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Personalized exercise programming enhances training responsiveness: a double-blind randomized controlled trial

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ABSTRACT

Aim: The purpose of this study was to examine the effectiveness of personalized exercise programming using the American Council on Exercise (ACE) Integrated Fitness Training (IFT) model at eliciting favorable comprehensive training responsiveness. **Methods:** Thirty-one nonsmoking men and women (18 to 64 yrs) were recruited. After the completion of baseline testing, participants were randomized to a non-exercise control group or one of two exercise training groups. Participants randomized to the exercise training groups performed 13wk of exercise training according to one of two programs: 1) the ACE IFT model, or 2) a standardized program according to current ACSM guidelines. **Results:** After 13wk, changes in body mass, waist circumference, body fat percentage, VO_2max, bench press 5RM, and leg press 5RM were significantly more desirable ($p<0.05$) in the standardized treatment group when compared with the control group. Similarly, changes from baseline to 13wk in body fat percentage were significantly more desirable ($p<0.05$) in the ACE IFT treatment group relative to the control group. Additionally, changes in body mass, waist circumference, body fat percentage, VO_2max, bench press 5RM, and leg press 5RM were significantly more favorable ($p<0.05$) in the ACE IFT treatment group when compared to the standardized treatment group and control group. In the standardized treatment group, 54.5% (6/11) of individuals experienced a favorable change in VO_2max ($\Delta > 5.9\%$) and were categorized as responders. In the ACE IFT treatment group, the prevalence of individuals who experienced a favorable change in VO_2max was significantly ($p<0.05$) greater when compared to the standardized treatment group. Indeed, exercise training in the ACE IFT treatment group elicited a positive improvement in VO_2max ($\Delta > 5.9\%$) in 90% (9/10) of the individuals. Muscle fitness training responsiveness was similar between groups; however, there was less variability in bench press and leg press changes in the IFT treatment group relative to the standardized treatment group. Additionally, the magnitude change in bench press and leg press in the IFT treatment group was ~1.5- to 2.0-fold greater when compared to the standardized treatment group. **Conclusions:** In the present study, a personalized exercise program using the ACE IFT model, which combined Cardiorespiratory Training in conjunction with Muscular Training elicited significantly greater improvements in VO_2max, muscular fitness, and various cardiometabolic outcomes (e.g., fasting blood glucose values) combined with diminished inter-individual variation in training responses when compared to standardized exercise training and a non-exercise control group. These findings provide insightful data on the effectiveness of personalized exercise programming.

KEYWORDS: Exercise Training, Prevention, Responders, Training Variability.

Introduction

In a small landmark randomized trial, Lance Dalleck and colleagues compared the effectiveness of two exercise training programs for improving cardiorespiratory fitness, muscular fitness, and cardiometabolic health[1]. Participants were randomized into one of two training programs: (1) an ACE IFT Model personalized training program, and (2) a standardized training program designed according to current American College of Sports Medicine[2] guidelines. Each training program was 13 weeks in length, with weeks 1 through 3 focused on cardiorespiratory training and weeks 4 through 13 including both cardiorespiratory training and resistance training.

The standardized training group performed cardiorespiratory exercise at an intensity based on a percentage of their heart-rate reserve (HRR), progressing from 40 to 45% HRR in weeks 1 to 60 to 65% HRR in weeks 9 through 13. Each participant in the ACE IFT Model group received a personalized exercise program based on heart rate (HR) at their unique ventilatory thresholds (VT1 and VT2), with exercise intensity progressing from HR <VT1 in week 1 to HR $\geq$VT2 in weeks 9 through 13. Both groups performed cardiorespiratory exercise three days per week, starting with 25 minutes per session in week 1 and progressing to 50 minutes per session in weeks 9 through 13. The muscular training program for the standardized training group was comprised of two sets of 12 repetitions on a resistance training machine circuit of traditional exercises performed three days per week. The ACE IFT Model group performed a muscular training circuit comprised of two sets of 12 repetitions of multijoint/multiplanar exercises using free weights and machine modalities that allowed for free motion during exercise.

Baseline and follow-up assessment results revealed that when compared to the standardized training group, the ACE IFT Model personalized group had significantly ($p<0.05$) greater beneficial changes in body-fat percentage, fat-free mass, VO_2max, systolic blood pressure, diastolic blood pressure, right and left leg stork-stand performance, bench press at five repetition maximum (5RM), and leg press five repetition maximum (5RM). Additionally, 100% of the individuals in the ACE IFT Model training group experienced positive improvements in VO_2max (i.e., all individuals were responders), which was significantly ($p<0.05$) greater than the 64.3% of individuals in the standardized training group who showed positive improvements in VO_2max. Interestingly, the remaining 35.7% of individuals in the standardized training group experienced undesirable changes in VO_2max and were categorized as non-responders to cardiorespiratory exercise training. The ACE IFT Model personalized training group also had significantly more individuals elicit favorable responses (i.e., responders) in anthropometric, cardiometabolic, muscular, and neuromotor outcome measurements when compared to the standardized training group.

This was the first study to show that personalized exercise prescription using the ACE IFT Model elicited significantly greater improvements in VO_2max, muscular fitness, and key cardiometabolic risk factors when compared to standardized exercise programming following 13 weeks of exercise training. In addition, the ACE IFT Model personalized training group had significantly increased training responsiveness compared to the standardized exercise training group. More recent work[3,4] has extended these preliminary findings and provided further evidence that personalized exercise programming to both enhance training efficacy and limit training unresponsiveness. The next logical step is execution of a large randomized, controlled trial to examine the effectiveness of personalized exercise programming using the ACE IFT Model at eliciting favorable comprehensive training responsiveness (e.g., cardiorespiratory fitness + muscle fitness + cardiometabolic health). It is anticipated that this three-year trial and its findings will provide robust evidence for the efficacy of personalized exercise programming using the ACE IFT Model.

The purpose of this study was to continue to examine the effectiveness of personalized exercise programming using the ACE IFT Model at eliciting favorable comprehensive training responsiveness (e.g., cardiorespiratory fitness + muscle fitness). It was hypothesized that personalized exercise programming using the ACE IFT Model would be more effective when compared to standardized exercise programming with respect to eliciting training responders across multiple outcomes, including cardiorespiratory and muscle fitness. This report presents findings from <u>year three</u> of a three-year randomized, controlled trial.

Methods

Participants

Thirty-one nonsmoking men and women (18 to 64 yrs) were recruited from the faculty population of a local university, as well as the surrounding community, via advertisement through the university website, local community newspaper, and word-of-mouth. Participants were eligible for inclusion into the study if they were physically inactive[2]. Participants were considered inactive if they reported not participating in at least 30 min of moderate intensity physical activity on at least three days of the week for at least three months[2]. Participants were also eligible for inclusion into the study if they verbally agreed to continue previous dietary habits and not perform additional exercise beyond that required for the present study. Exclusionary criteria included evidence of cardiovascular, pulmonary, and/or metabolic disease as determined by medical history questionnaire. This study was approved by the Human Research Committee at Western Colorado University. Each participant signed an informed consent form prior to participation.

Baseline and post-program experimental testing procedures

Measurements of all outcome variables were obtained both before and after the exercise training intervention. All measurements were obtained across two nonconsecutive days (testing day #1 and testing day #2) by following standardized procedures as outlined elsewhere[5,2]. Procedures for each measurement are also briefly described below. On testing day #1, prior to fasting blood lipid and blood glucose measurement, participants refrained from all food and drink other than water for 12 hours. On testing days #1 and #2 participants were also instructed to refrain from strenuous exertion 12 hours prior to testing. All post-program testing took place within 1 to 4 days of the last exercise training session.

Resting Heart Rate and Blood Pressure measurement

The procedures for assessment of resting heart rate and blood pressure (BP) outlined elsewhere were followed[2]. Briefly, participants were seated in a chair with a back support with feet on the floor and arm supported at heart level quietly for 5 minutes. Resting heart rate was obtained via manual palpation of radial artery in the left wrist and recording the number of beats for 60 seconds. The left arm brachial artery systolic and diastolic BP were measured using a sphygmomanometer in duplicate and separated by 1-minute. The mean of the two measurements was reported for baseline and post-program values.

Anthropometric measurements

Participants were weighed to the nearest 0.1 kg on a medical grade scale and measured for height to the nearest 0.5 cm using a stadiometer. Percent body fat was determined via skinfolds[2]. Skinfold thickness was measured to the nearest ± 0.5 mm using a Lange caliper (Cambridge Scientific Industries, Columbia, MD). All measurements were taken on the right side of the body using standardized anatomical sites (three-site) for men and women. These measurements were performed until two were within 10% of each other. Waist circumference measurements were obtained using a cloth tape measure with a spring-loaded handle (Creative Health Products, Ann Arbor, MI). A horizontal measurement was taken at the narrowest point of the torso (below the xiphoid process and above the umbilicus). These measurements were taken until two were within 0.5 mm of each other.

Fasting blood lipid and blood glucose measurement

All fasting lipid and blood glucose analyses were collected at room temperature. Participants' hands were washed with soap and rinsed thoroughly with water, then cleaned with alcohol swabs and allowed to dry. Skin was punctured using lancets and a fingerstick sample was collected into a heparin-coated 40 µl capillary tube. Blood was allowed to flow freely from the fingerstick into the capillary tube without milking the finger. Samples were then dispensed immediately onto commercially available test cassettes for analysis in a Cholestech LDX System (Alere Inc., Waltham, MA) according to strict standardized operating procedures. The LDX Cholestech measured total cholesterol, high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol, triglycerides, and blood glucose in fingerstick blood. A daily optics check was performed on the LDX Cholestech analyzer used for the study.

<u>Muscular fitness assessments</u>

The procedures for muscular fitness assessment outlined elsewhere were followed[5]. Participants performed five-repetition maximum (5RM) testing for the bench and leg press exercises to assess muscular fitness. The following protocol was used for 5RM testing:

1. 10 repetitions of a weight the participant felt comfortable lifting (40-60% of estimated 5RM) were performed to warm up muscles followed by a 1-minute rest period
2. 5 repetitions at weight of 60-80% estimated 5RM was performed as a further warm up and followed by a 2-minute rest period
3. First 5RM attempt at weight of 2.5-20kg greater than warm up
    - If first 5RM lift was deemed successful by the researcher (appropriate lifting form) weight was increased until maximum weight participant can lift was established with 3 minutes between each attempt.
    - If first 5RM lift deemed unsuccessful by the researcher, weight was decreased until participant successfully lifted the heaviest weight possible.

There were 3 minutes rest between 5RM attempts and a maximum of 3 x 5RM attempts. There were 5 minutes of rest between the 5RM testing of each resistance exercise.

<u>Maximal exercise testing</u>

Participants completed a modified-Balke, pseudo-ramp graded exercise test (GXT) on a motorized treadmill (Powerjog GX200, Maine, USA). Participants walked or jogged at a self-selected pace. The treadmill incline was increased by 1% every minute until the participant reached volitional fatigue. Participant HR was continuously recorded during the GXT via a chest strap and radio-telemetric receiver (Polar Electro, Woodbury, NY, USA). Expired air and gas exchange data was recorded continuously during the GXT using a metabolic analyzer (Parvo Medics TrueOne 2.0, Salt Lake City, UT, USA). Before each exercise test, the metabolic analyser was calibrated with gases of known concentrations (14.01 ± 0.07% O_2, 6.00 ± 0.03% CO_2) and with room air (20.93%O_2 and 0.03% CO_2) as per the instruction manual. Volume calibration of the pneumotachometer was done via a 3-Litre calibration syringe system (Hans-Rudolph, Kansas City, MO, USA). The last 15s of the GXT were averaged—this was considered the final data point. The closest neighbouring data point was calculated by averaging the data collected 15s immediately before the test's last 15s. The VO_2max was represented by the mean of the two processed data points. Maximal HR was considered to be the highest recorded HR in beats per minute (bpm) during the GXT. Participant heart rate reserve (HRR) was determined by taking the difference between maximal HR and resting HR.

Determination of ventilatory thresholds

Determination of both the first ventilatory threshold (VT1) and second ventilatory threshold (VT2) were made by visual inspection of graphs of time plotted against each relevant respiratory variable (according to 15s the time-averaging). The criteria for VT1 was an increase in VE/VO_2 with no concurrent increase in VE/VCO_2 and departure from the linearity of VE. The criteria for VT2 was a simultaneous increase in both VE/VO_2 and VE/VCO_2. All assessments were completed by two experienced exercise physiologists. In the event of conflicting results, the original assessments were reevaluated and collectively a consensus was agreed upon.

Randomization and exercise intervention

After the completion of baseline testing, participants were randomized to a non-exercise control group or one of two exercise training groups according to a computer-generated sequence of random numbers that was stratified by sex (Figure 1). This was a double-blind research design because participants were unaware of the group to which they had been assigned. Likewise, the researchers specifically responsible for the testing and supervision of exercise sessions were unaware of the group to which participants had been allocated. Participants randomized to the exercise training groups performed 13wk of exercise training according to one of two programs: 1) the ACE IFT model, or 2) a standardized program according to current ACSM guidelines. Each exercise training group performed a similar frequency and duration of exercise training. Overall, the exercise prescriptions for both groups were intended to fulfill the consensus recommendation of 150 min/wk.

Cardiorespiratory fitness exercise prescription

Cardiorespiratory fitness training was performed on various aerobic modalities: arm, cycle, and rowing ergometers; elliptical crosstrainer; and treadmill. The exercise intensity method for the cardiorespiratory fitness exercise prescription differed between treatment groups. The standardized training group was prescribed exercise intensity according to a percentage of HRR. Conversely, the ACE IFT model training group was prescribed exercise intensity according to ventilatory threshold. In both exercise training groups a target heart rate (HR) coinciding with either the prescribed HRR or prescribed VT (Figure 1) was used to establish a specific exercise training intensity for each exercise session.

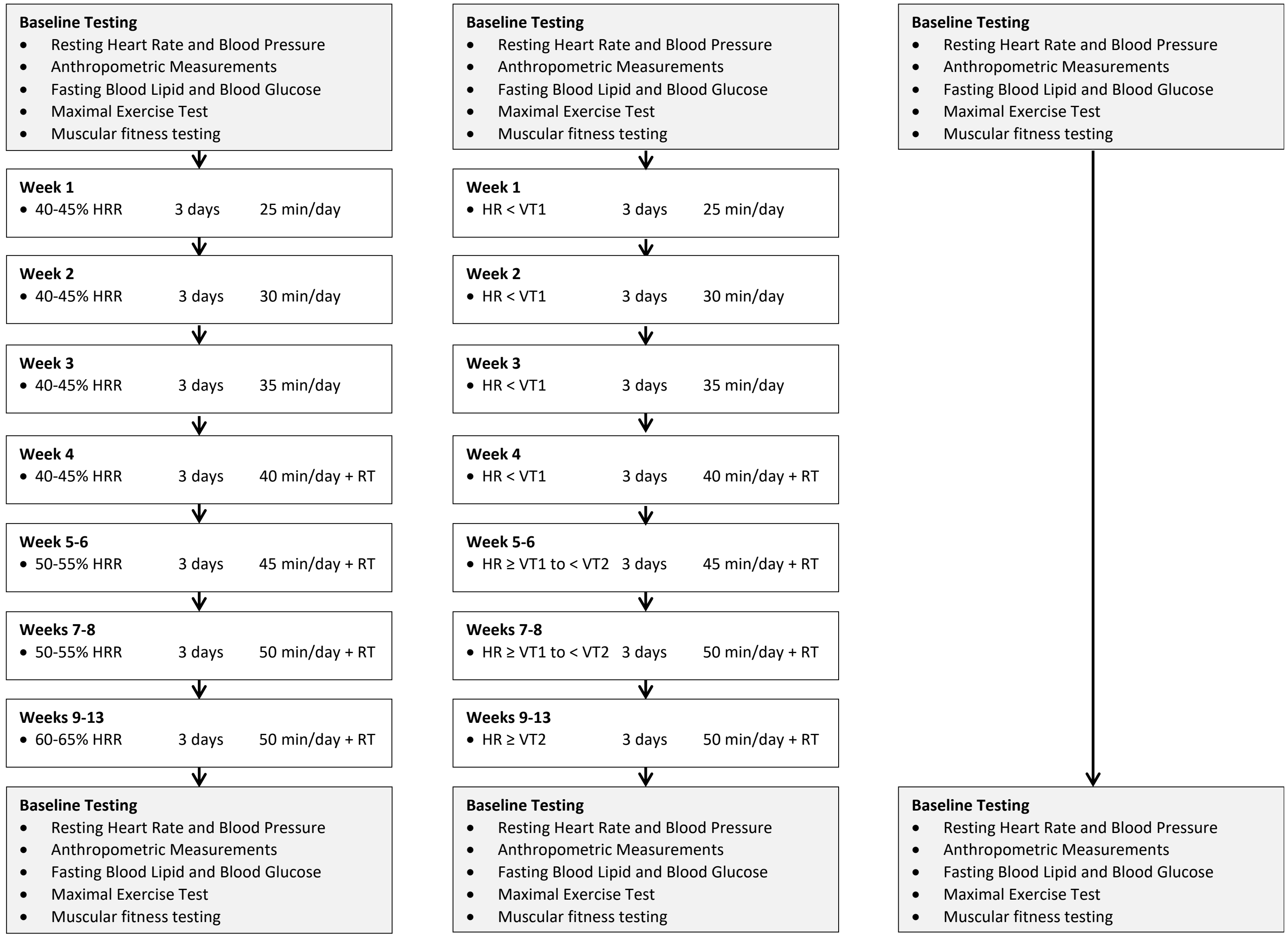

Figure 1. Flow chart of experimental procedures and exercise prescription for each of the two exercise training treatment groups. ACE IFT, American Council on Exercise Integrated Fitness Training, HR, heart rate; HRR, heart rate reserve; RT, resistance training; VT1, first ventilatory threshold; VT2, second ventilatory threshold.

In the ACE IFT model group target HR for each training zone (Figure 1) was established in the following manner:

- **Wk 1-4 (HR < VT1):** target HR = HR range of 10-15 bpm just below VT1.
- **Wk 5-8 (HR ≥ VT1 to < VT2):** target HR = HR range of 10-20 bpm above VT1 and below VT2.
- **Wk 9-13 (HR ≥ VT2):** target HR =HR range of 10-15 bpm at or just above VT2.

Exercise training was progressed according to recommendations made elsewhere by the ACE and ACSM. Polar HR monitors (Polar Electro Inc., Woodbury, NY, USA) were used to monitor HR during all exercise sessions. Researchers adjusted workloads on aerobic modalities accordingly during each exercise session to ensure actual HR responses aligned with target HR. Figure 1 presents all cardiorespiratory fitness exercise prescription details for each training group over the course of the 13wk training period.

Resistance exercise prescription

Resistance training commenced during week 4 of the overall study for both treatment groups and was subsequently completed 3 days a week for the remainder of the intervention. All sessions were supervised by researchers who closely monitored adherence to the prescribed program, ensured proper technique for each exercise, and provided specific information on progression. The details of the resistance exercise prescription are outlined below:

Standardized group

The resistance training program for the standardized treatment group was designed according ACSM guidelines and consisted of single and multi-joint exercises completed using machine modalities. The following traditional exercises were performed: bench press, shoulder press, lateral pulldown, seated row, bicep curl, tricep pushdown, seated leg press, seated leg extension, prone lying leg curl, and seated back extension/flexion. Two sets of 12 repetitions at a moderate intensity of 5–6 on the modified Borg rating of perceived exertion (RPE) scale[6] were completed for each lift and rated according to guidelines published by Sweet et al.[7]. Resistance was progressed every 2 weeks by ~3-5% of total weight lifted for the upper body and ~6-10% for lower-body exercises so that the session RPE of 5–6 was maintained across the training program.

ACE IFT group

The resistance training program for the ACE IFT treatment group was designed according to ACE guidelines and consisted of multijoint/multiplanar exercises completed using both free weights and machine modalities. The machine modalities that were used allowed for free motion during the exercise and therefore range of motion was not limited to a specific arc. The following exercises were performed in the ACE IFT treatment group: stability ball circuit (hip bridges, crunches, Russian twists, planks), lunge matrix, kneeling/standing wood chops, kneeling/standing hay bailers, dumbbell squat to 90-degree knee bend, standing one-arm cable row, step-ups with dumbbell onto 15cm step, modified (assisted) pull-ups, and dumbbell bench press. Two sets of 12 repetitions were completed for each exercise. Intensity of weighted exercises started at 50% 5RM and was progressed by 5% 5RM increments every 2 weeks. For exercises that did not include a weighted resistance (e.g. stability ball circuit, modified pull-ups), the volume of each exercise in the form of repetitions was increased by ~5-10% to maintain an RPE rating of 5–6.

Statistical analyses

All analyses were performed using SPSS Version 26.0 (Chicago, IL, USA) and GraphPad Prism 8.0. (San Diego, CA, USA). Measures of centrality and spread are presented as mean ± SD. All baseline-dependent variables were compared using general linear model (GLM) ANOVA and, where appropriate, Tukey post hoc tests. Within-group comparisons were made using paired t-tests. All between-group 13wk changes were analyzed using GLM-ANOVA and, where appropriate, Tukey post hoc tests. The assumption of normality was tested by examining normal plots of the residuals in ANOVA models. Residuals were regarded as normally distributed if Shapiro-Wilk tests were not significant. Delta values (Δ) were calculated (post-program minus baseline value divided by baseline value) for percent change in relative VO_2max (%) and participants were categorized as: ‘1’ = responders (% Δ > 5.9%) or ‘0’ = non-responders (Δ ≤ 5.9%) to exercise training using a day-to-day variability, within subject coefficient of variation (CV) criterion applied previously in the literature[1]. Chi-square (χ^2) tests were subsequently used to analyze the prevalence of responders and non-responders to exercise training separated by treatment group (i.e., standardized and ACE IFT model) between baseline and post-program. The probability of making a Type I error was set at $p<0.05$ for all statistical analyses.

Results

All analyses and data presented in the results are for those participants who completed the investigation. The exercise prescription in both treatment groups was well tolerated. Overall, there was excellent adherence to the total number of prescribed training sessions: standardized group – mean, 92.7% (range, 77.5-97%) and ACE IFT group – mean, 91.5% (range, 80.0-100%). The physical and physiological characteristics for participants are shown in Table 1.

All between-group and within-group changes from baseline to 13wk are presented in Table 1. After 13wk, changes in body mass, waist circumference, body fat percentage, VO_2max, bench press 5RM, and leg press 5RM were significantly more desirable ($p<0.05$) in the standardized treatment group when compared with the control group. Similarly, changes from baseline to 13wk in body fat percentage were significantly more desirable ($p<0.05$) in the ACE IFT treatment group relative to the control group.

Additionally, changes in body mass, waist circumference, body fat percentage, VO_2max, bench press 5RM, and leg press 5RM were significantly more favorable ($p<0.05$) in the ACE IFT treatment group when compared to the standardized treatment group and control group.

Table 1. Physical and physiological characteristics at baseline and 13wk for control, Standardized, and ACE IFT groups. (Values are mean ± SD).

Parameter	Control group (n=10; women = 6, men = 4)		Standardized group (n=11; women = 6, men = 5)		ACE IFT group (n=10; women = 5, men = 5)	
	Baseline	13wk	Baseline	13wk	Baseline	13wk
Age (yr)	43.6 ± 10.6	____	39.1 ± 9.4	____	40.8 ± 14.8	____
Height (cm)	168.3 ± 6.5	____	169.7 ± 9.5	____	170.2 ± 8.4	____
Body mass (kg)	68.6 ± 12.3	69.4 ± 11.8	70.7 ± 13.6	70.2 ± 13.2*†	71.8 ± 10.9	70.1 ± 10.1*‡
Waist circumference (cm)	78.7 ± 5.5	79.4 ± 4.6	84.0 ± 9.4	83.3 ± 9.2†	82.8 ± 7.2	80.7 ± 6.5*‡
Body fat (%)	26.4 ± 4.4	27.5 ± 4.9*	27.4 ± 6.2	25.6 ± 5.4*†	27.8 ± 7.3	23.6 ± 6.6*‡
Resting HR ($b \cdot min^{-1}$)	61.4 ± 5.8	63.2 ± 6.7	60.7 ± 10.7	60.4 ± 9.2	61.6 ± 7.4	63.4 ± 8.9
VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$)	32.6 ± 4.9	32.8 ± 4.6	32.9 ± 7.3	35.3 ± 8.7*†	34.0 ± 6.8	39.1 ± 6.7*‡
Systolic BP (mmHg)	108.8 ± 7.6	113.0 ± 5.2	112.0 ± 9.5	110.4 ± 9.9	119.4 ± 8.0	114.0 ± 7.2*†
Diastolic BP (mmHg)	75.8 ± 8.8	83.8 ± 9.4	83.1 ± 7.9	81.5 ± 7.3	84.2 ± 4.6	82.4 ± 7.5
Total cholesterol ($mg \cdot dL^{-1}$)	175.8 ± 27.3	177.3 ± 17.7	176.8 ± 25.5	179.4 ± 19.8	192.3 ± 28.3	188.8 ± 21.6
HDL cholesterol ($mg \cdot dL^{-1}$)	66.6 ± 16.0	65.1 ± 15.1	60.6 ± 13.0	62.7 ± 11.7	55.0 ± 10.9	60.4 ± 11.7*†
LDL cholesterol ($mg \cdot dL^{-1}$)	94.4 ± 5.4	88.0 ± 13.2	99.4 ± 30.2	100.3 ± 20.4	113.0 ± 34.1	111.1 ± 31.1
Triglycerides ($mg \cdot dL^{-1}$)	97.7 ± 41.9	102.3 ± 45.6	90.5 ± 37.9	86.1 ± 27.8	107.5 ± 39.2	91.9 ± 32.0*
Blood Glucose ($mg \cdot dL^{-1}$)	86.3 ± 4.6	88.1 ± 7.3	90.2 ± 7.3	88.3 ± 6.3	91.6 ± 6.7	87.1 ± 5.5*†
Bench press 5RM (lb)	99.0 ± 28.6	97.5 ± 28.2	93.2 ± 41.4	109.5 ± 41.7*†	97.5 ± 29.1	129.5 ± 30.8*‡
Leg press 5RM (lb)	298.5 ± 112.2	301.0 ± 96.7	262.7 ± 103.8	319.5 ± 102.2*†	286.5 ± 85.9	383.0 ± 76.0*‡

* Within-group change is significantly different from baseline, $p<0.05$; † Change from baseline is significantly different than control group, $p<0.05$; ‡ Change from baseline is significantly different than control and standardized groups, $p<0.05$.

Prevalence of VO_2max non-responders and responders

Figure 2 shows the prevalence of VO_2max responders and non-responders to exercise training in both the standardized and ACE IFT treatment groups. In the standardized treatment group, 54.5% (6/11) of individuals experienced a favorable change in VO_2max (Δ > 5.9%) and were categorized as responders (Figure 2A). Alternatively, 45.5% (5/11) of individuals in the standardized treatment group experienced an undesirable change in VO_2max ($\Delta \leq 5.9\%$) and were categorized as non-responders to exercise training (Figure 2A). There were no significant differences ($p<0.05$) between treatment groups in several potential influencing factors of responder/non-responder, including age, baseline VO_2max, exercise adherence, and sex. In the ACE IFT treatment group, the prevalence of individuals who experienced a favorable change in VO_2max was significantly ($p<0.05$) greater when compared to the standardized treatment group. Exercise training in the ACE IFT treatment group elicited a positive improvement in VO_2max ($\Delta > 5.9\%$) in 90% (9/10) of the individuals (Figure 2B).

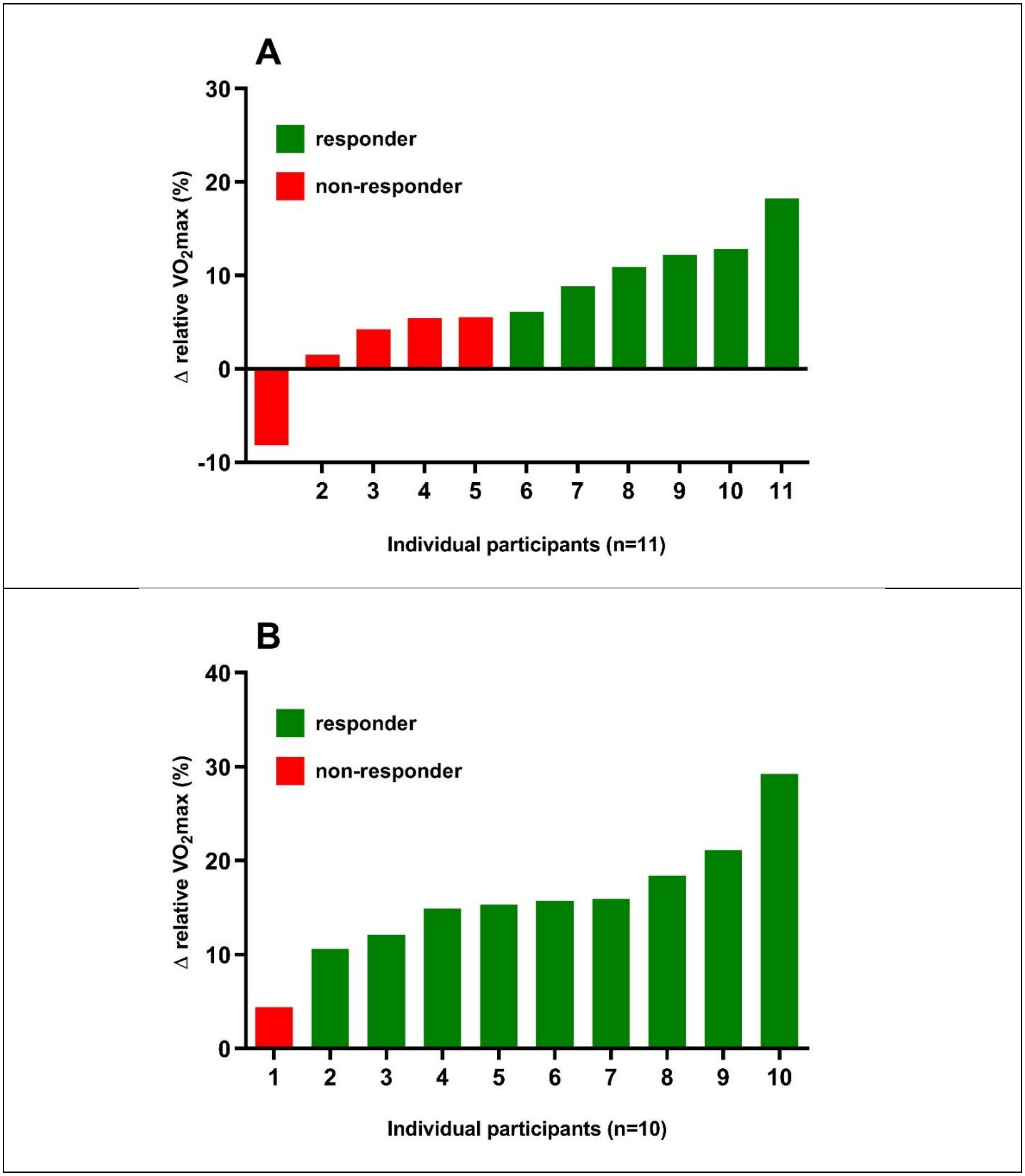

Figure 2. Individual variability in relative VO_2max response (% change) to exercise training in the Standardized (A) and ACE IFT (B) treatment groups.

Prevalence of muscle fitness non-responders and responders

Figure 3 shows the prevalence of muscle fitness responders and non-responders to exercise training in both the standardized and ACE IFT treatment groups. Training responsiveness was similar between groups; however, there was less variability in bench press and leg press changes in the IFT treatment group relative to the standardized treatment group. Additionally, the magnitude change in bench press and leg press in the IFT treatment group was ~1.5- to 2.0 times greater when compared to that of the standardized treatment group.

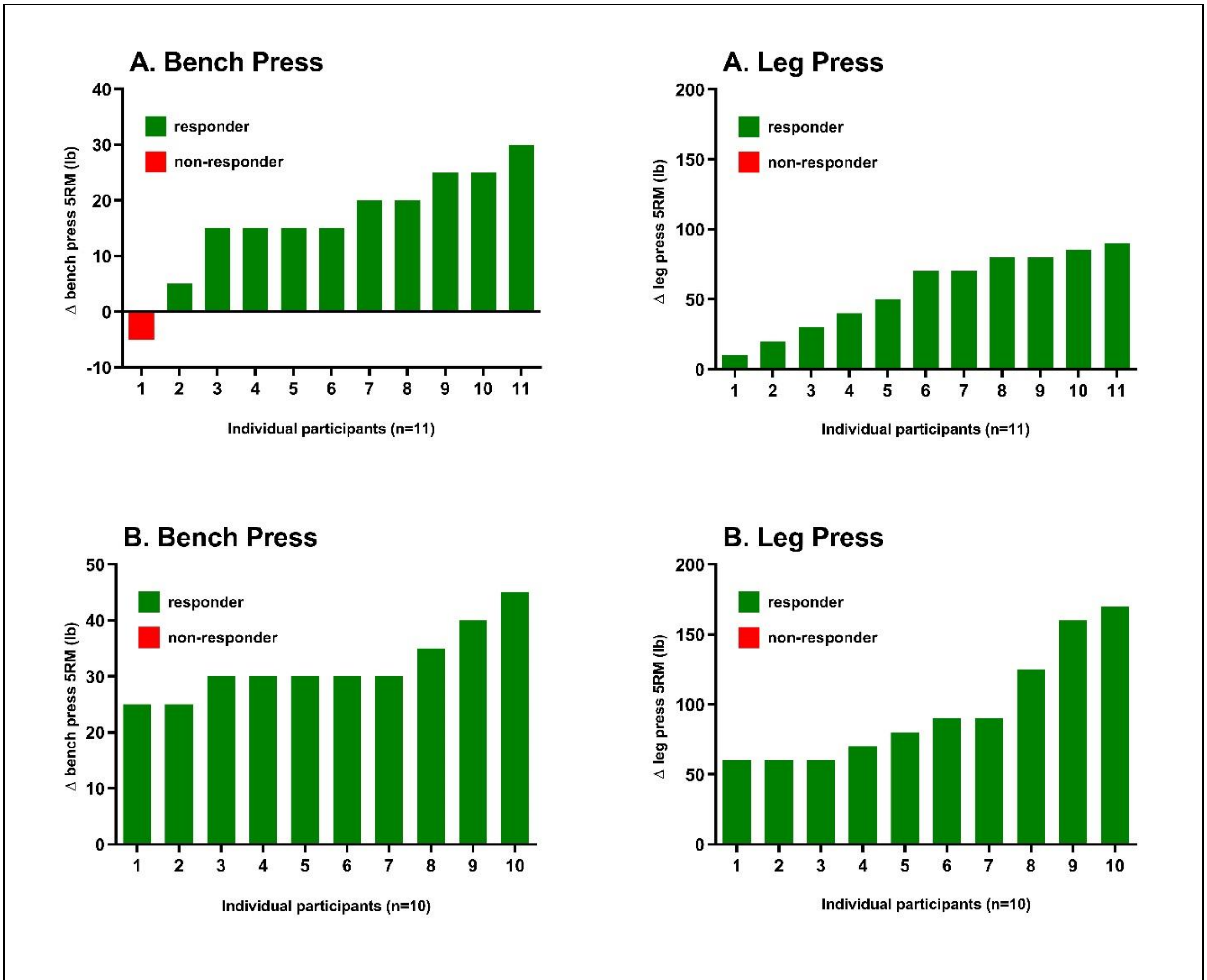

Figure 3. Individual variability in muscular fitness responses (Δ lbs) to exercise training in the Standardized (A – bench and leg press) and ACE IFT (B – bench and leg press) treatment groups.

Discussion

Recent preliminary evidence[1] demonstrated that the personalized approach of the ACE IFT Model augments training responsiveness. The next logical step is the execution of a large, randomized, controlled trial to examine the effectiveness of personalized exercise programming using the ACE IFT model at eliciting favorable comprehensive training responsiveness (e.g., cardiorespiratory fitness + muscle fitness + cardiometabolic health). This report presents findings from year three of a three-year randomized, controlled trial.

In the present study, a personalized exercise program using the ACE IFT model, which combined Cardiorespiratory Training in conjunction with Muscular Training elicited significantly greater improvements in VO_2max, muscular fitness, and various cardiometabolic outcomes (e.g., fasting blood glucose values) combined with diminished inter-individual variations in training responses when compared to standardized exercise training and a non-exercise control group. These findings continue to be encouraging and provide insightful data on the effectiveness of personalized exercise programming.

How meaningful are these findings to overall health?

In the past few decades both low cardiorespiratory and muscular fitness have garnered considerable attention as independent and powerful predictors of CVD risk and premature mortality. For instance, it has been reported that increased muscular fitness is associated with a reduced risk of all-cause mortality[8]. Likewise, Williams[9] showed in a meta-analysis that there was a marked decrease in relative risk for CVD when individuals moved out of the lowest quartile of cardiorespiratory fitness. More recently, Blair[10] estimated that low cardiorespiratory fitness accounted for more overall deaths when compared to deaths which could be attributed to traditional CVD risk factors such as obesity, smoking, hypertension, high cholesterol, and diabetes. Accordingly, the changes in cardiorespiratory (i.e., ↑ VO_2max) and muscular fitness (i.e., ↑ 5RM bench press and leg press scores) in the current study have novel clinical and public health relevance, a large number of adults fall into clinically defined low cardiorespiratory and muscular fitness categories and therefore demonstrate increased CVD risk[11]. Overall, VO_2max was improved on average by ~1.5 METs following 13wk of exercise training in the ACE IFT group. These improvements likely have important long-term prevention implications as a recent study reported a 1 MET increase in VO_2max was associated with an 18% reduction in deaths due to CVD[12].

The Importance of personalized exercise for muscular fitness

In the past decade, low muscular fitness has garnered considerable attention as an independent and powerful predictor of chronic disease risk and premature mortality. It has been reported that increased muscular fitness is associated with a reduced risk of all-cause mortality[8]. Additionally, various muscular fitness parameters (strength, endurance, and power) have been found to be associated with common cardiometabolic risk factors including body mass index, waist circumference, blood lipids, and blood pressure[13]). It also has been demonstrated that that there is a strong association between muscular strength and mortality from all causes in various clinical populations, including those with CVD, cancer, and arthritis[14]. More recently, elevated levels of both upper and lower body muscular strength have been linked to lower risk of mortality[15]. Additionally, it has been shown that a moderate level of muscular strength is associated with a 32% lower risk of developing type 2 diabetes[16]. Taken together, this body of scientific literature highlights the critical long-term role of muscular fitness for overall client health. In the present report, it was demonstrated that a personalized exercise prescription enhanced training efficacy and limited training unresponsiveness with respect to muscular fitness (i.e., 5RM bench press and leg press). These muscular fitness findings are novel. As Figure 3 presents , the individual changes in 5RM bench press and 5RM leg press are consistently 1.5- to 2-fold greater across all IFT group participants when compared to their standardized group counterparts. These muscular fitness responsiveness findings highlight the importance of personalizing the exercise program, which is accomplished best with the ACE IFT model.

What mechanisms underpin the different prevalence of responders between groups?

Although not completely understood, various factors are known to mediate the heterogeneity in training responses including the parameters of the exercise training program itself. For instance, it has previously been demonstrated that one of the most important predictors of a positive VO_2max response to exercise training is a greater volume of exercise[17]. More recently, it has been suggested that the method of exercise intensity prescription may underpin the inter-individual variation in VO_2max response to exercise training[18,1]. Those previous studies[19,20,21] that have reported wide variability in the individual VO_2max response to exercise training have used one of several relative exercise intensity methods including %HRmax, %HRR, or %VO_2max. However, it has been demonstrated that these "one size fits all" relative exercise intensity prescription methods elicit large inter-individual variations in the metabolic responses to exercise training[18,22]. On this basis, it has been postulated that the individual variation in metabolic response will subsequently lead to differences in the overall homeostatic stress from each training session, which will ultimately result in heterogeneity in the exercise training response. Alternatively, it has been suggested that use of a threshold-based method for establishing exercise intensity might better normalize the metabolic stimulus for individuals with varying fitness levels[5,22]. Findings from the present report continue to support this paradigm and extend our previous findings[1]. It was demonstrated that a threshold-based exercise intensity prescription, as employed in the ACE IFT treatment group, elicited significantly more desirable training adaptations in VO_2max. Moreover, a threshold-based approach to exercise training elicited greater training responsiveness as evidenced by the significantly higher prevalence of responders in the ACE IFT treatment group when compared to the standardized group.

Conclusion

There is a wealth of previous research reporting that regular exercise training confers positive effects on fitness (cardiorespiratory and muscular) and numerous other cardiometabolic outcomes related to cardiovascular morbidity and mortality. Nonetheless, it has also been highlighted that considerable heterogeneity exists with respect to the individual responses to chronic exercise training. In the present report, it was demonstrated that a personalized exercise prescription enhanced training efficacy and limited training unresponsiveness with respect to cardiorespiratory fitness (i.e., VO_2max). Our ongoing findings continue to be encouraging and provide robust data for exercise physiologists, fitness professionals, and others who design exercise training programs in the adult/older adult populations.

Competing interests

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