

Separate Effects of Intensity and Amount of Exercise on Interindividual Cardiorespiratory Fitness Response

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Abstract

Objective: To determine the separate effects of exercise intensity and amount on interindividual cardiorespiratory fitness (CRF) response.

Participants and Methods: Participants were 121 (75 females, 62%) sedentary, middle-aged (mean [SD] age, 53.2 [7.5] years), abdominally obese adults who completed at least 90% of 5 weekly exercise sessions prescribed over a 24-week intervention. Participants were randomly assigned to (1) low-amount, low-intensity exercise (LALI) (180 and 300 kcal per session for women and men, respectively, at 50% of CRF [$\dot{V}O_{2peak}$]; n=39), (2) high-amount, low-intensity exercise (HALI) (360 and 600 kcal per session for women and men, respectively, at 50% of CRF; n=51), or high-amount, high-intensity exercise (HAHI) (360 and 600 kcal per session for women and men, respectively, at 75% of CRF; n=31). Cardiorespiratory fitness was measured using a treadmill test at 4, 8, 16, and 24 weeks. The study duration was September 1, 2009, through May 31, 2013.

Results: Cardiorespiratory fitness increased within all 3 groups at 24 weeks ($P<.001$). At 24 weeks, 38.5% (15 of 39), 17.6% (9 of 51), and 0% (0 of 31) of the participants within the LALI, HALI, and HAHI groups, respectively, were CRF nonresponders. At a fixed exercise intensity, increasing exercise amount reduced the rate of nonresponse by 50% ($P=.02$). At a fixed amount of exercise, increasing the exercise intensity eliminated nonresponse ($P=.001$). Exposure to exercise decreased the number of CRF nonresponders between 4 and 8 weeks for LALI and by 16 weeks for HALI but plateaued thereafter. For HAHI, the number of CRF nonresponders decreased continually over the 24 weeks.

Conclusion: For a fixed amount of exercise, increasing exercise intensity consistent with consensus recommendations eliminated CRF nonresponse. Low-intensity exercise may not be sufficient to improve CRF for a substantial proportion of sedentary obese adults.

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Cardiorespiratory fitness (CRF) is an established independent predictor of cardiovascular disease (CVD) and all-cause mortality,¹⁻³ and the addition of CRF to established algorithms improves CVD risk classification.⁴ Although it is known that increasing physical activity is associated with improvements in CRF at the group level,⁵ there is a growing body of evidence confirming that the association between physical activity and CRF may not apply to each member of that group. Bouchard and Rankinen⁶ were the first to carefully document the enormous heterogeneity in CRF response with variability in improvement to a standardized dose of exercise ranging from 0 (nonresponse) to 1 L of oxygen, a finding later confirmed by others.^{7,8} Of importance is the observation that

in all studies, a substantive proportion of the participants were considered CRF nonresponders. Given that exercise-induced improvement in CRF is associated with corresponding reductions in CVD risk,^{9,10} CRF nonresponse to exercise is a clinically relevant concern.

The mechanistic underpinnings responsible for the heterogeneity in response to a standard dose of exercise are unclear. Sisson et al⁸ considered whether varying the amount of exercise performed influenced the rate of CRF nonresponse in postmenopausal women. The authors reported that the amount (energy expenditure) of exercise performed at a fixed intensity significantly influenced CRF response—participants exercising for approximately 120 min/wk were



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55% more likely to improve CRF than those exercising for 60 min/wk.

We⁵ and others¹¹ have found that for a fixed amount of exercise, intensity is positively associated with greater improvements in CRF compared with lower-intensity exercise at the group level. To our knowledge, there are no randomized studies that have simultaneously investigated the separate and combined effects of exercise intensity and amount on interindividual CRF response. Thus, questions with important practical and clinical implications remain unanswered: For a fixed amount of exercise, does increasing intensity influence the rate of CRF nonresponse? Does the combination of higher amount and intensity of exercise influence the rate of CRF nonresponse more than increasing intensity or amount of exercise alone? Is exposure to exercise associated with CRF nonresponse independent of exercise amount or intensity? Answers to these questions are important and would help practitioners who seek to add precision to exercise-based strategies designed to improve CRF and consequently decrease CVD risk.

In this ancillary study, we sought to determine the separate and combined effects of exercise intensity and amount on the heterogeneity of CRF response during a 24-week, rigorously controlled exercise trial among abdominally obese adults. We measured CRF at multiple time points during the trial to examine the effect of exercise exposure on CRF. To help isolate the effects of exercise on CRF response, we accounted for physical activity performed outside the exercise prescribed through multiple objective measures of unstructured daily physical activity.

PARTICIPANTS AND METHODS

Study Setting and Participants

Details of the trial design and methods¹² and findings from the primary analysis⁵ have been published elsewhere. Briefly, we conducted a 24-week, single-center, randomized controlled trial with a parallel group design between September 1, 2009, and May 31, 2013. The primary objective of the original investigation was to determine the separate effects of exercise intensity and amount on waist circumference (WC) and glucose tolerance among 300 sedentary, abdominally obese adults. Potential participants were

excluded if they reported a history of heart disease, stroke, or any condition that would prevent them from engaging in exercise, if they were already engaging in 2 or more planned exercise sessions per week, and if they were diabetic. All participants provided informed consent before participation, and the study was originally approved by the Queen's University Health Sciences Research Ethics Board.

The purpose of the current analysis was to examine the separate effects of exercise intensity and amount on interindividual CRF response and nonresponse. Therefore, of the 300 participants originally randomized, participants were excluded from the final data set if they were in the nonexercise control group ($n=75$), did not complete the study and/or did not have follow-up CRF data ($n=74$), or had an exercise adherence (number of exercise sessions attended) of less than 90% ($n=30$). This resulted in a study sample of 121 participants (mean [SD] age, 53.2 [7.5] years; 75 females, 62%).

Exercise Intervention

Participants were randomly assigned to (1) low-amount, low-intensity exercise (LALI; $n=39$), (2) high-amount, low-intensity exercise (HALI; $n=51$), or (3) high-amount, high-intensity exercise (HAHI, $n=31$). All participants performed primarily walking exercise on a treadmill for the time required to achieve the desired energy expenditure (kcal per session) 5 times per week at the required intensity (relative to CRF [$\dot{V}O_{2peak}$]) for 24 weeks. Using the heart rate and oxygen consumption data obtained from the baseline exercise test, the heart rate associated with an oxygen consumption of approximately 50% (LALI and HALI) and approximately 75% (HAHI) were prescribed for each participant. At these exercise intensities, the energy expenditure targets (exercise amount) for women and men were 180 and 300 kcals, respectively, for LALI and 360 and 600 kcals for both HALI and HAHI. Heart rate was monitored continuously for all exercise participants at every session to help ensure adherence to the prescribed exercise intensity. All exercise sessions were performed under supervision by specially trained personnel with undergraduate degrees in kinesiology.

Accelerometry

Physical activity performed outside the supervised exercise sessions was monitored using

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