The cumulative effects of training at different weekly energy expenditures on cardiorespiratory fitness and markers of metabolic syndrome

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ABSTRACT

PURPOSE To determine the cumulative effects of vigorous intensity aerobic training at different weekly exercise energy expenditures (ExEE) but similar total overall volume on markers of cardiorespiratory fitness (CRF) and metabolic syndrome (MetS).

METHODS Following completion of the initial 9-mo STRRIDE trial, 22 participants underwent an additional 6- to 24-mo of exercise training in one of two groups: 1) Low-Amount/Vigorous-Intensity (LAVI; n=14): 14 kcal ExEE/kg/week (KKW) at 65-80% peak VO_2; 2) High-Amount/Vigorous-Intensity (HAVI; n=8): 23 KKW at 65-80% peak VO_2. Absolute peak VO_2 (AVO_2; L/min) and relative peak VO_2 (RVO_2; mL/kg/min) were measured via gas exchange during graded maximal exercise testing. Metabolic measures included body fat percentage, waist circumference, HDL-C, triglycerides, fasting glucose, and insulin sensitivity index (S_I). A modified MetS *z*-score was calculated using waist circumference, HDL-C, triglycerides, and fasting glucose to allow for a continuous assessment of metabolic fitness. Comparisons between groups were performed via two-tailed, two-sample t-tests (α=0.05) at equivalent time points and time points of nearly equivalent cumulative ExEEs (LAVI 15-mo vs HAVI 9-mo; LAVI 21-mo vs HAVI 15-mo; and LAVI 33-mo vs HAVI 21-mo). Linear mixed models for repeated measures were also constructed while controlling for baseline outcome measures, age, and sex.

RESULTS At equivalent time points, mean change scores in all outcomes did not significantly differ between groups. For cumulative ExEE comparisons, the mean change in S_I was significantly greater in HAVI compared to LAVI at the LAVI 21-mo/HAVI 15-mo contrast (mean difference ± SD: 2.13±0.68 mU/L/min, p=0.008) in a univariate analysis. In a linear mixed model for repeated measures, there was a significant main effect for group (p=0.048) for AVO_2 that was attenuated to borderline significance (p=0.052) after adjusting for age and sex. The mean changes in both AVO_2 and RVO_2 were significantly greater in HAVI compared to LAVI at the LAVI 21-mo/HAVI 15-mo contrast: model contrast estimate (standard error) = 0.21 (0.01, 0.40) L/min, p=0.038 and 3.05 (0.14, 5.96) mL/kg/min, p=0.041, respectively; and the LAVI 33-month/HAVI 21-month contrast: 0.25 (0.04, 0.45) L/min, p=0.022 and 3.21 (0.10, 6.32) mL/kg/min, p=0.044, respectively. The contrasts in AVO_2, but not RVO_2, remained significant after adjusting for age and sex. Nonsignificant, similar trends were identified for all other outcomes at these same contrast time points. Adherence decreased over time in both groups.

CONCLUSION In an exploratory analysis of the cumulative effects of vigorous intensity aerobic training, LAVI participants did not experience as robust of improvements in certain measures of aerobic and metabolic fitness as HAVI participants at time points of prescribed equivalent cumulative relative ExEE.

BACKGROUND

- Modifying effects for both exercise intensity and exercise volume have been identified for cardiorespiratory fitness (CRF) and markers of metabolic syndrome (MetS), though their exact relationships remain unclear.
- In the original Studies of a Targeted Risk Reduction Intervention through Defined Exercise (STRRIDE) randomized controlled trial (RCT), matched for vigorous intensity, exercising at a higher volume (23 KKW vs 14 KKW) resulted in greater improvements in MetS burden, lipid profiles, insulin sensitivity, body composition, absolute peak VO_2 (AVO_2), and relative peak VO_2 (RVO_2).[1-5]
- Recent studies have investigated whether individuals who exercise in several shorter bouts throughout the day or week can achieve similar health benefits as individuals who exercise in longer, continuous bouts. Evidence suggests the principle of equivalency between "accumulated bouts" and "continuous bouts" with equivalent *total daily* (or equivalent *total weekly*) amounts appears to hold true for many outcomes, including CRF, blood pressure, glycemic control, and most lipid and body composition measures.
- A large gap remains in the literature as to whether *variations* in *total weekly* exercise amounts can result in similar health benefits once the total program amount is equivalent over the long term (*e.g.,* months to years). Furthermore, few studies of this nature have controlled for exercise energy expenditure (ExEE) – a crucial parameter to consider when assessing the impact of exercise amount on these outcomes.
- The purpose of this study was to explore the longitudinal effects of varying weekly amounts of vigorous intensity aerobic exercise on CRF and markers of MetS. We hypothesized that at time points of roughly equivalent *cumulative* relative ExEEs (*i.e.,* ExEE relative to body weight), exercise groups would have achieved similar health benefits and would not significantly differ on measures of CRF and MetS improvements.

METHODS

- STRRIDE-Extension: 6- to 24-month extension phase of STRRIDE, a 9-month RCT examining the modulating effects of exercise amount and intensity on measures of aerobic fitness and MetS.
- Participants in two groups of the original STRRIDE protocol were given the opportunity to continue the intervention for an additional 6 to 24 months:
  - Low-Amount/Vigorous-Intensity (LAVI): 14 KKW at 65-80% VO_{2peak} for 2 to 3 days/week
  - High-Amount/Vigorous-Intensity (HAVI): 23 KKW at 65-80% VO_{2peak} for 3 to 4 days/week
- AVO_2, RVO_2, body fat percentage, waist circumference, HDL-C, triglycerides, fasting glucose, insulin sensitivity index (S_I), and MetS *z*-score were measured at baseline, 9-mo, 15-mo, 21-mo, and 33-mo (lipid and MetS *z*-Score measures unavailable at 33-mo).
  - MetS *z*-score = gender-specific continuous score of the 4 available MetS components, calculated using the revised ATPIII criteria and group baseline standard deviations.

Objectives:

1. Describe baseline outcome and associated change scores at each time point by exercise group.
2. Compare exercise groups at differential time points of roughly equivalent cumulative relative ExEEs (*e.g.,* LAVI 15-mo vs HAVI 9-mo; LAVI 21-mo vs HAVI 15-mo; and LAVI 33-mo vs HAVI 21-mo) using both univariate change score contrasts and contrasts within a linear mixed model for repeated measures.

RESULTS

TABLE 1. Group characteristics

	LAVI	HAVI
Age (years)	51.6 ± 7.2	48.0 ± 6.5
Sex (% Female)	42.9	25.0
Race (% Caucasian)	85.7	100.0
Weight (kg)	85.4 ± 13.7	94.4 ± 15.0
Adherence (%)		
0 to 9 months	96.4 ± 0.1 (n=14)	96.0 ± 0.1 (n=8)
9 to 15 months	89.6 ± 0.1 (n=14)	93.5 ± 0.1 (n=8)
15 to 21 months	85.9 ± 0.1 (n=13)	90.3 ± 0.1 (n=6)
21 to 33 months	81.4 ± 0.1 (n=7)	62.8 ± 0.3 (n=4)

Continuous values presented as mean ± SD.

TABLE 2. Baseline values and change score contrasts between exercise groups at differential time points of equivalent cumulative ExEE

	LAVI Baseline	HAVI Baseline	HAVI 9-mo – LAVI 15-mo	HAVI 15-mo – LAVI 21-mo	HAVI 21-mo – LAVI 33-mo
AVO_2 (L/min)	2.58 ± 0.75	2.90 ± 0.76	0.14 ± 0.09	**0.22 ± 0.11***	**0.18 ± 0.12***
RVO_2 (mL/kg/min)	29.64 ± 5.83	30.05 ± 4.65	0.75 ± 1.27	**2.99 ± 1.85***	**3.03 ± 2.17***
Waist circumference (cm)	104.01 ± 9.75	107.19 ± 7.28	1.30 ± 2.36	-1.19 ± 2.70	-2.66 ± 1.99
HDL-C (mg/dL)	53.64 ± 16.00	50.75 ± 15.79	3.58 ± 2.42	5.55 ± 3.07	-
Triglycerides (mg/dL)	140.93 ± 60.36	154.88 ± 52.74	-21.80 ± 20.81	-10.55 ± 18.17	-
Fasting glucose (mg/dL)	96.85 ± 10.60	94.60 ± 10.77	3.21 ± 2.98	-3.06 ± 4.10	-5.33 ± 7.55
S_I (mU/L/min)	3.95 ± 2.32	2.94 ± 1.52	-0.14 ± 0.62	**2.13 ± 0.68**	2.21 ± 1.88
Body fat (%)	32.87 ± 5.69	34.35 ± 4.67	0.55 ± 1.36	-0.91 ± 1.86	-1.94 ± 1.53
MetS *z*-score	-0.16 ± 1.88	-0.20 ± 1.92	0.02 ± 0.54	-0.86 ± 0.67	-

Values presented as mean or mean difference ± SD. Bolded text indicates significance at the 0.05 alpha level with a two-tailed two-sample t-test. Bolded text with asterisk (*) indicates significance at the 0.05 alpha level in a linear mixed model for repeated measures.

RESULTS

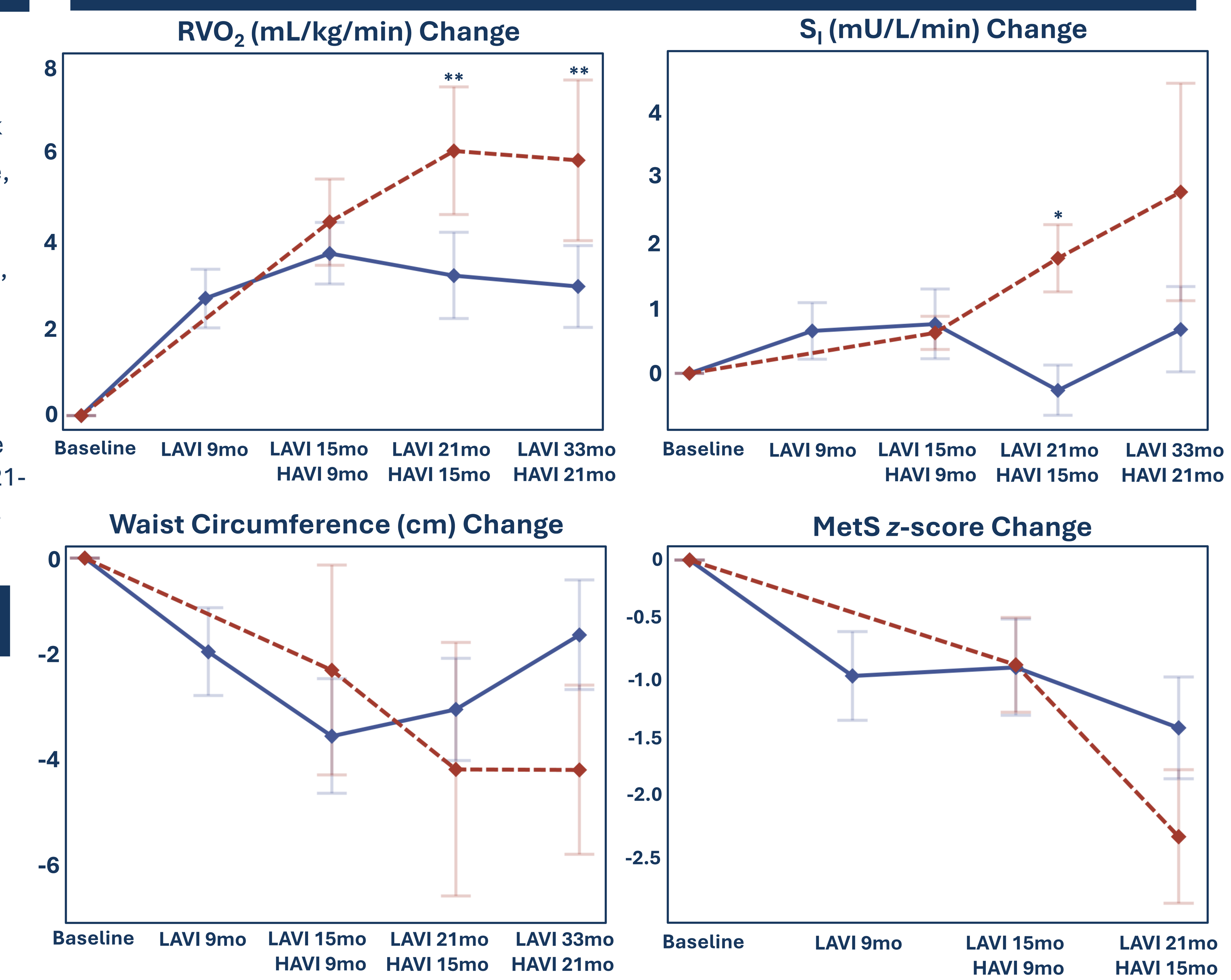

Figure 1. Changes in markers of aerobic and metabolic fitness at equivalent cumulative ExEE timepoints by group

*Indicates significant contrast at the 0.05 alpha level in a univariate analysis.
**Indicates significant contrast at the 0.05 alpha level in a linear mixed model for repeated measures. Adjusting for age and sex removed the significant RVO_2 contrasts but not the AVO_2 contrasts (not shown). There was a significant main effect for group for AVO_2 that was attenuated to borderline significance after adjusting for age and sex.

CONCLUSIONS

- In an exploratory analysis of STRRIDE-Extension, we detected no significant differences among all outcomes at the LAVI 15-mo/HAVI 9-mo time point of roughly equivalent cumulative relative ExEE. As adherence and sample size decreased over time, there were significant differences identified for AVO_2, RVO_2, and S_I at the LAVI 21-mo/HAVI 15-mo and LAVI 33-mo/HAVI 21-mo time points, showing greater improvements in HAVI compared to LAVI. Nonsignificant, similar trends were observed for all other outcomes at the LAVI 21-mo/HAVI 15-mo and LAVI 33-mo/HAVI 21-mo time points.
  - This finding suggests that the principle of volumetric equivalency, controlling for relative ExEE at a vigorous intensity, may not hold across metabolic outcomes and CRF over long periods of time (months to years).
- Additional, larger scale RCTs should be conducted and powered to test for equivalency between groups exercising at different weekly relative ExEEs at time points of similar cumulative relative ExEEs.

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