Muscle oxygen saturation dynamics during upper body resistance exercise

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Introduction

Wireless near-infrared spectroscopy (NIRS) has emerged as a low-cost, non-invasive technology for real-time observation of muscle oxygenation-deoxygenation dynamics. Yet, information describing the changes in muscle oxygen saturation during dynamic resistance exercises across multiple sets of resistance exercise is limited. Additionally, the impact of control over relevant participant characteristics has been left unexplored.

Purpose

The purpose of this study was to describe the physiological response of muscle oxygenation parameters during upper-body resistance exercise. Additionally, we examined the differential effects of relevant participant characteristics on resistance training performance and muscle oxygen saturation dynamics.

Methods

Sixty-one recreationally resistance-trained men (n=44; 21.8 ± 2.6 years, 179 ± 6 cm, 89.3 ± 15.7 kg) and women (n=17; 20.2 ± 1.8 years, 166 ± 9 cm; 70.3 ± 14.8 kg) volunteered to participate in this study. Participants completed 5 repetition-maximum sets of barbell bench press at a load equal to 75% 1-RM with a 2-minute rest interval. Muscle oxygen saturation (SmO_2) dynamics within the anterior deltoid were monitored for changes across all repetitions using a portable NIRS sensor (Moxy, Fortiori Design, LLC). The percent change in SmO_2 ($\Delta\%SmO_2$) from the start to the end of each set was recorded. Additionally, the muscle oxygen re-saturation rate (SmO_2RecSlope) was measured as the slope of SmO_2 values for 30 seconds immediately following the final repetition of each bench press set. Two-way (sex [men, women] x time [sets 1-5]) repeated measures analyses of variance (ANOVA) were performed on repetitions completed and muscle saturation variables. To examine the effect of relevant controlling variables, separate analyses of covariance (ANCOVA) with repeated measures were also performed on repetitions completed and muscle saturation variables.

Main Findings

No sex differences and only a few set differences in muscle oxygenation saturation dynamics were observed during 5 repetition-maximum sets of barbell bench press (75% 1RM)

Body mass, diastolic blood pressure, and mean arterial pressure were identified as factors that could influence observed responses.

Table 1. Performance and muscle oxygenation across five sets of bench press (mean ± SD).

	Set 1	Set 2	Set 3	Set 4	Set 5	Mean Estimate ± SE
Repetitions						
Men	13.4 ± 2.7	7.8 ± 2.2	5.2 ± 1.9	4.6 ± 1.5	4.3 ± 1.6	7.0 ± 0.2
Women	13.4 ± 3.1	9.2 ± 1.6	6.8 ± 1.2	5.9 ± 1.7	4.9 ± 1.4	8.0 ± 0.4*
All	13.4 ± 2.8	8.2 ± 2.1#	5.7 ± 1.9#	5.0 ± 1.6#	4.4 ± 1.5#	7.5 ± 2.1
Volume Load (kg)						
Men	1061 ± 230	617 ± 179#	419 ± 175#	363 ± 124#	339 ± 129	560 ± 19
Women	497 ± 133*	346 ± 96*#	259 ± 83*#	224 ± 81*	187 ± 73*	303 ± 30
All	904 ± 328	541 ± 201	375 ± 171	324 ± 129	297 ± 135	431 ± 18
$\Delta\%SmO_2$ (%)						
Men	74.7 ± 16.1	74.3 ± 18.5	69.7 ± 19.7	70.5 ± 19.6	74.2 ± 18.2	72.7 ± 2.3
Women	65.8 ± 18.1	68.1 ± 14.4	70.5 ± 17.6	67.7 ± 13	66.3 ± 13.3	67.7 ± 3.6
All	72.3 ± 17	72.6 ± 17.5	69.9 ± 19	69.8 ± 17.9	72.0 ± 17.3	70.2 ± 2.1
SmO_2RecSlope						
Men	1.12 ± 0.54	1.12 ± 0.57	0.98 ± 0.50	0.92 ± 0.53	0.80 ± 0.57	0.99 ± 0.08
Women	1.00 ± 0.69	0.82 ± 0.52	0.75 ± 0.53	0.74 ± 0.50	0.77 ± 0.55	0.82 ± 0.11
All	1.08 ± 0.59	1.02 ± 0.57	0.91 ± 0.51	0.86 ± 0.52#	0.79 ± 0.56#	0.90 ± 0.07
SmO_2Peak						
Men	80.7 ± 12.1	79.9 ± 11.9	79.3 ± 12.1	80.8 ± 9.4	77.7 ± 12.3	79.7 ± 1.9
Women	81.3 ± 11.8	80.8 ± 10.9	80.8 ± 11.8	79.4 ± 11.8	76.3 ± 14.1	79.7 ± 2.7
All	80.9 ± 11.9	80.2 ± 11.5	79.8 ± 11.9	80.3 ± 10.2	77.2 ± 12.8#	79.7 ± 1.7

Note: * = Significant ($p < 0.05$) difference between men and women; # = Significant ($p < 0.05$) difference from previous set

Results

Repeated measures ANOVA revealed main effects for sex (F=5.3, p=0.025, η^2_p=0.08) and sets (F=289.7, p<0.001, η^2_p=0.83) with repetitions completed. Women typically completed more repetitions than men, and less repetitions were completed on each successive set compared to its previous set. According to repeated measures ANOVA, main effects for sets occurred for SmO_2RecSlope (F=5.0, p=0.001, η^2_p=0.09) whereby a decline was noted on sets 4 and 5 compared to set 1. No differences were seen with $\Delta\%SmO_2$ across sets. Moreover, body mass (p = 0.013), diastolic blood pressure (p = 0.044), and mean arterial pressure (p = 0.033) for $\Delta\%SmO_2$ were the only significant covariates noted amongst the muscle oxygenation variables.

Conclusion

No sex differences and only a few set differences in muscle oxygen saturation dynamics were seen without employing any covariates. However, a sex difference appeared when controlling for body mass and the previously observed set differences in SmO_2RecSlope disappeared with each covariate.

Summary and Practical Applications

Body mass, diastolic blood pressure, and mean arterial pressure were identified as factors that could influence observed responses. These findings demonstrate the importance of strict study controls for relevant participant characteristics when examining muscle oxygenation dynamics surrounding resistance exercise.