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Greater Reliance on Carbohydrates during Single Leg Versus Double Leg Cycling

Research Brief

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Introduction: Small muscle mass exercises, such as single leg cycling, allow for greater muscle specific workload which should result in greater reliance on carbohydrate oxidation (CarbOx). However, the metabolic consequences to smaller muscle mass exercise have not been fully elucidated.
Purpose: To determine differences in CarbOx and fat oxidation (FatOx) between single-leg (SL) and double-leg (DL) cycling when performed at similar VO2.
Methods: Ten healthy college students completed two separate 30-minute bouts of SL and DL cycling at 45% of VO2peak. Oxygen consumption, respiratory exchange ratio (RER), CarbOx, FatOx, HR and power were recorded throughout the exercise. Paired samples t-tests were utilized to identify differences in all dependent variables between cycling conditions.
Results: Matching oxygen consumption required a slightly lower power output for the SL condition (86±25 W) compared to DL (94±30 W). Despite similar kcal expenditure between the two cycling modalities, participants had 7% greater RER (0.92±0.03 versus 0.86±0.05; $p=0.001$), 45% greater CarbOx ($p<0.001$) and 37% reduced FatOx ($p<0.001$) during SL compared to DL cycling.
Conclusion: Thus, inclusion of smaller muscle mass activities into exercise training may enhance skeletal muscle glucose uptake kinetics, which would benefit athletes, and help with blood glucose control for those with diabetes.

Key Words: Exercise, metabolism, skeletal muscle.

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Introduction

Single leg cycling allows for greater muscle specific blood flow and tissue perfusion[1]. This increase in oxygen delivery allows individuals to tolerate a greater limb specific workload [1–6] which potentially would result in greater reliance on carbohydrate oxidation. However, the metabolic consequences of manipulating active muscle mass at any given level of oxygen consumption is not fully understood. Thus, the purpose of this study was to determine the difference in carbohydrate and fat oxidation between single-leg and double-leg cycling at the same rate of whole body oxygen consumption.

Methods

Participants

Healthy college aged men (n=5, 24.6 ± 2.7 years of age, 183 ± 3.5 cm, 83.6 ± 12.04 kg) and women (n=5, 23.6 ± 4.3 years of age, 163 ± 6.7 cm, 61.3 ± 6.7 kg) participated in this study. Inclusion criteria included normal fasting blood glucose levels (<100 mg/dL^{-1}), free of cardiovascular, pulmonary or metabolic disease, and moderately active based on the American College of Sports Medicine guidelines. The institutional review board at Kent State University approved this study and participants completed an informed consent prior to participation.

Protocol

During visit one, participants completed a submaximal cycling protocol on a Velotron cycle ergometer (Spearfish, South Dakota) that consisted of 4 x 4 min stages of increasing intensity (60, 80, 120, 160W).

Following 10-minute recovery participants completed a maximal cycle test. This protocol started at 80W for 2 minutes and increased by 25W every minute thereafter until volitional fatigue. VO2 was measured throughout both protocols via metabolic cart (Parvo Medics TrueOne 2400, Sandy, Utah) to determine the individuals VO2-power relationship and VO2peak. These results were utilized to determine power output required to elicit 45% VO2 peak during the subsequent cycling protocols.

Session two and three required participants to report to the lab following an eight hour fast. During each visit subjects completed a thirty-minute bout of either single leg or double leg cycling at 45% of their predetermined VO_2 peak. Single leg cycling was performed using the dominant leg with 10Kg mass added to the unoccupied crank arm to simulate normal cycling dynamics[1,2]. Oxygen consumption (VO_2), respiratory exchange ratio (RER), kilocalories (kcal), CarbOx, FatOx, HR (Polar H10 Heart Rate Sensor, New Hyde Park, New York) and cycling power were recorded throughout the entire bout of exercise.

Statistical Analysis
Paired samples t-tests were performed to find differences between all dependent variables (VO_2, RER, CarbOx, FatOx, kcal, HR and power) across both conditions (single leg cycling and double leg cycling). All analysis were performed with $\alpha=0.05$. All values are reported as mean ± standard deviation.

Results
Matching for oxygen consumption (1.60±0.39 versus 1.58±0.38 L/min) (figure 1A) required slightly lower power (t=3.08, p=0.015) in SL (86±25 W) than DL (94±30 W). In addition to VO_2 there were no differences in total kcal expenditure (SL: 239.38±75.64 kcal versus DL: 232.19±74.65 kcal; p=0.07) However, participants had a greater rate of carbohydrate oxidation (t=7.61, p=<0.001) during SL (1.46±0.45 g/min) compared to DL (1.01±0.49 g/min) and reduced FatOx in SL (t=5.47, p=<0.001; 0.22±0.06 g/min) compared to DL (0.36±0.09 g/min) (figure 1B and C). These metabolic differences are further realized with significantly greater RER values (t=5.28, p=0.001) in SL (0.92±0.03) compared to DL (0.86±0.05) (figure 1D). HR was slightly higher for the SL (147±16 bpm) compared to DL (139±13 bpm) (p=0.009).

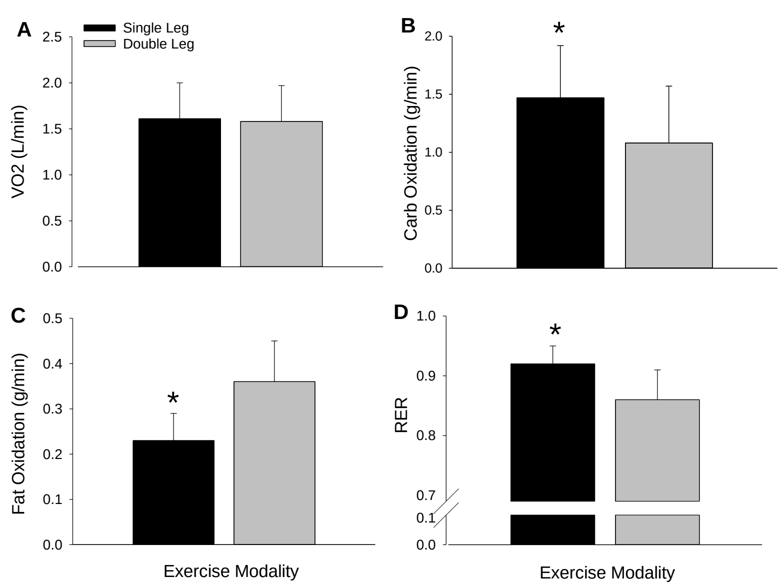

Figure 1. Oxygen consumption (A), carbohydrate oxidation (B), fat oxidation (C), and respiratory exchange ratio (D) between single leg and double leg cycling conditions. Values are means ± standard deviation. *$p < 0.05$

Discussion

The current investigation found a shift in metabolic demand between single leg and double leg cycling while maintaining the same oxygen consumption and energy expenditure for both conditions. During double leg cycling, participants' legs shared the workload, allowing for lower metabolic demand per leg. Results indicate that performing the same workload on one leg increased the reliance on carbohydrates by 45% while decreasing the fat oxidation by 37% which ultimately resulted in a greater respiratory exchange ratio. These results agree with Burns et al[1] who also reported a significant increase in RER with single leg cycling, compared to double leg during shorter 4 minute stages of cycling. However, Burns controlled for power, not VO2, which may have confounded the results. The data from this investigation help clarify the changes in fuel utilization with changes in active muscle mass for any given VO2.

The differences in the muscle specific exercise intensity and fuel utilization between these two modalities during acute exercise would suggest a more dramatic physiological adaptations to chronic small muscle mass exercise. Specifically, skeletal muscle contractions are known to be an insulin independent way to increase glucose uptake into the muscle cell through an increase in activated protein kinase and AMP/ATP ratio. This stimulates greater intracellular GLUT-4 translocation to the cell membrane for greater influx of glucose into the cell[7]. In addition to glucose transport, higher metabolic demand per muscle mass during single leg cycling creates greater mitochondrial oxidative capacity[2]. In fact, Abbiss et al[2] investigated adaptations to 6 bouts of single leg versus double leg cycle training in elite cyclists and reported that the increased muscle specific intensity during single leg cycling resulted in an increase in GLUT-4 translocation and mitochondrial oxidative capacity. If single leg cycling can improve these two parameters in highly trained cyclists, it is likely that these adaptations would be even greater in sedentary individuals. Thus, single leg cycling may serve as an exercise modality that could increase glucose uptake kinetics for athletes and help control blood glucose levels for those with diabetes.

In addition to those with metabolic syndrome, previous reports indicate that single leg cycling is very beneficial for those with pulmonary limitations. For example, Dolmage and Goldstein[4], investigated single leg cycling for those with chronic obstructive pulmonary disease (COPD). Their results indicated that applying greater workload to smaller muscle mass (via single leg cycling) resulted in lower ventilation rates. This allowed participants to tolerate exercise for a longer duration while performing greater total work. The same premise might hold true for those with central cardiac limitations[8]. Single leg cycling can serve as a way to maximize skeletal muscle adaptations without excessive central cardiovascular stress.

Conclusion

For the same levels of oxygen consumption and kcal expenditure, the greater muscle specific workload during single leg cycling results in greater carbohydrate oxidation rates when compared to standard double leg cycling. Future investigations should focus on the long-term metabolic adaptations to single leg cycling for those with diabetes.

Media-Friendly Summary

Ten college aged students performed 30 minutes of single leg cycling and 30-minutes of double leg cycling at the same exercise intensity. Results indicated that there was a shift to greater carbohydrate utilization during single leg cycling than double leg cycling. This is likely due to the greater work performed in the single leg muscle mass versus sharing the workload between both legs.

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