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Technical Note

Metabolic and Cardiovascular Responses on a Novel, Whole Body Exercise Device Compared to a Cycle Ergometer

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ABSTRACT

International Journal of Exercise Science 12(2): 1206-1215, 2019. The purpose of this study was to compare the metabolic effects during a similar bout of exercise on a novel, whole body exercise device (Fish and Kangaroo Machine; FKM) and a cycle ergometer. Recreationally active men and women (*n* =13) completed two exercise sessions. The exercise protocol included intervals alternating between exercise (3-min) and rest (3-min) for a total duration of 39-min. The exercise intensity between the two modes was matched based on heart rate response. Heart rate, cardiac output, and stroke volume were measured using a wireless telemetry technique (Physioflow Enduro). Oxygen consumption (VO_2) was measured via breath-by-breath automated analysis of expired respiratory gas (MGC Diagnostics Ultima). Capillary blood lactate was measured using a handheld meter (LactatePlus). While maintaining the heartrate response, stroke volume presented at a higher-level during rest periods, although not significant. There was also higher cardiac output at the end of the exercise bout with the FKM. VO2 was lower at the same heart rate and peak lactate was higher during FKM exercise. Cardiovascular recovery was improved following FKM exercise compared to cycling. The observed responses demonstrated that for a similar heart rate response, the FKM has an enhanced anaerobic metabolic component compared to cycling. These findings demonstrate the FKM may represent a novel exercise device comparable to cycling with unique anaerobic training potential.

KEY WORDS: Whole body exercise, anaerobic exercise, blood lactate, cardiac output

INTRODUCTION

Different modes of exercise elicit varying degrees of physiological stress on the body (1, 8, 9). Many factors affect the exercise stress response including intensity, duration, and the amount of muscle mass that is active to name a few (9). As novel exercise devices appear in the commercial marketplace (4, 14), it is important to validate their role as an exercise training tool. Our laboratory previously reported the potential for a novel whole-body exercise device (10). That initial study generated data that resulted in an improved device, which was the focus of the present investigation. The purpose of this technical note was to compare the metabolic responses of exercise on a novel whole-body device to a cycle ergometer when matched based on heart rate response.

METHODS

Participants

The protocols and procedures for this study were reviewed and approved by the University of North Texas Institutional Review Board for the use with human subjects in accordance with the *Declaration of Helsinki*. Each subject was given an oral explanation of the study and gave written and verbal informed consent before participating. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (7). Thirteen recreationally active individuals participated in this study. Subjects were screened for contraindications to exercise using a brief medical history form, a whole-body dual-energy X-ray absorptiometry (DXA) scan (GE Lunar Prodigy, Piscataway, NJ, USA) and a graded exercise test (Medical Graphics Ultima Metabolic Cart, St. Paul, MN, USA). Subject characteristics are shown in Table 1.

Table 1. Characteristics of the participants.

Variable	*n* = 13
Gender (#Males)	6
Age (Y)	20±1
Height (M)	1.66±0.09
Weight (kg)	62.4±11.4
BMI	22.7±3.5
%Body Fat	26.4±9.7

Values represent the mean ± SD.

Protocol

Subjects were required to participate in two exercise trials, one on the FKM and one on a cycle ergometer. Subjects completed a brief familiarization protocol to acclimate to each device in order to minimize learning effects. The FKM was completed first to establish the heart rate response that would be mirrored on the cycle ergometer. Exercise sessions were completed on separate days separated by seven days between sessions. The exercise protocol consisted of alternating intervals of exercise (3-min) with intervals of rest (3-min) for a total duration of 39-min. Resistance on the FKM was applied using elastic tubing (Theraband; Akron, OH) that was selected to create moderate resistance on the legs (2 yellow, 1 red band) and low resistance on the arms (1 red band) (Table 2). During FKM exercise subjects lay in a prone position over the FKM with feet strapped into the foot pedals, hands holding onto the hand levers and their chest supported by a small stand. Foot pedals and hand levers were moved using an alternating motion (i.e. when left hand is up and right foot is up) for the duration of the exercise interval (Figure 1). These actions are similar to the motion of a stair climber and an elliptical machine combined. During rest intervals, the participant moved to a seated position.

The same exercise intervals were used for the cycle ergometer (Table 3). Resistance was set to match the individual heart rate response observed during the FKM exercise bout. In all cases the participant initially rode at a moderate resistance (100W) and as the heartrate was recorded, the resistance would be adjusted to match closely the heartrate response of the FKM workout. Care was taken to ensure heart rate reached the steady state between adjustments. Average cycle resistance was 125 ± 50 W.

Table 2. Example of Exercise Trial.

	FKM Trial												
Stage	1	2	3	4	5	6	7	8	9	10	11	12	13
Condition	E	R	E	R	E	R	E	R	E	R	E	R	R
Resistance (Bands)	1-YA 1-YL		1-YA 2-YL		2-YA 1-RL		2-YA 1-RL		1-RA 2-RL		1-RA 2-RL		
Avg. Resistance Arms (lb)	3		3		6		6		3.7		3.7		
Avg. Resistance Legs (lb)	3		6		3.7		3.7		7.4		7.4		
Heart Rate (BPM)	76	104	77	108	75	110	83	113	76	119	85	123	74

Resistance band colors had a representative weight when elongated to 100%. The yellow (Y) was equal to 3 lbs. red (R) was equal to 3.7 lbs. The number next to each resistance band type was the number of bands on each respective component (i.e. hand levers (A) and the leg peddles (L)). The conditions were exercise (E) and rest (R). Measurements taken at the start of each phase.

Table 3. Example of Exercise Trial.

	Cycle Trial												
Stage	1	2	3	4	5	6	7	8	9	10	11	12	13
Condition	E	R	E	R	E	R	E	R	E	R	E	R	R
Resistance (W)	75		100		110-105		105		115-120		140		
Avg. Resistance (W)	75		100		107.5		105		117.5		140		
Heart Rate (BPM)	78	101	81	108	82	112	90	112	96	117	90	124	77

The conditions were exercise (E) and rest (R). Measurements taken at the start of each phase.

During exercise, hemodynamics were measured via wireless telemetry technique using six electrodes places on the subject per the manufacturer's instructions (Manatec PhysioFlow Enduro; Petit Ebersviller; Folschviller, France). This system allowed for the non-invasive measurement of heart rate, stroke volume, and cardiac output.

Oxygen consumption (VO_2) was measured via breath-by-breath analysis of expired respiratory gas using a neoprene facemask with a pneumotach attached to an umbilical tubing connected to the metabolic cart (Medgraphics Ultima; St. Paul, MN). This system allowed for the measurement of VO_2 and other common metabolic parameters.

Figure 1. Fish and Kangaroo Machine.

Capillary (fingertip) blood lactate was measured prior to exercise, at the beginning of each rest interval, and 6-min after the final exercise interval. Lactate was measured using a handheld meter (Nova Biomedical Lactate Plus lactate meter, Waltham, MA, USA).

Statistical Analysis

Data was analyzed for significance using SPSS v. 25 (Chicago, IL). Data were specifically compared using a gender (2) x exercise mode (2) x exercise trial time (13) ANOVA with repeated measures on the 2^{nd} and 3^{rd} factors. Significance was set at $p < 0.05$ and location of significant effects was determined using individual t-tests with a Bonferroni adjustment for multiple comparisons.

RESULTS

Due to no statistical significance between gender responses in all areas of measurement, we have combined the genders in the results reported.

Table 4. Results of Measured Variables.

	Heart Rate (BPM)		Stroke Volume (ml/min)		Cardiac Output (L/min)		VO_2 (ml/min)		Lactate (mmol/L)	
	FKM	Cycle	FKM	Cycle	FKM	Cycle	FKM	Cycle	FKM	Cycle
E1	80±4	83±4	69.3±5.5	61.1±4.2	5.8±0.5	5.1±0.5	280±92	396±147	3.1±0.4	2.8±0.4
R1	116±6	114±5	72.3±4.4	71.6±5.4	8.7±0.5	8.3±0.8	1199±161	1247±96		
E2	87±5	89±5	77.1±5.7	66.0±6.0	7.0±0.5	5.9±0.6	447±91	463±145	4.3±0.5	3.9±0.6
R2	129±8	127±7	74.3±4.1	69.1±5.4	9.3±0.8	8.7±0.9	1261±154	1670±208		
E3	89±5	94±7	73.4±5.3	63.7±4.0	7.3±0.8	6.1±0.5	390±59	620±174	3.7±0.6	4.3±0.8
R3	129±7	130±7	78.0±5.4	70.7±5.1	9.3±1.0	9.3±0.9	1395±164	1820±272		
E4	91±5	101±6	77.1±6.0	61.7±3.6	7.5±0.9	6.3±0.5	476±94	566±160	4.2±0.7	4.8±1.2
R4	134±7	137±7	76.2±4.3	71.6±5.9	10.1±0.7	9.8±1.0	1322±144	1987±257		
E5	91±4	104±7	80.6±10.8	64.5±4.4	6.6±0.6	6.8±0.6	516±99	587±170	4.4±0.7	5.0±0.8
R5	135±6	137±6	76.5±5.1	75.9±5.3	10.9±0.8	10.4±1.1	1303±139	1787±176		
E6	92±5	105±7	68.8±6.4	66.8±4.9	7.4±0.7	7.0±0.8	550±108	569±159	6.9±1.2	5.4±0.9
R6	142±6	143±6	82.3±4.8	78.0±5.1	11.1±1.0	11.2±1.0	1550±198	2018±163		
R7	76±3	83±4	71.7±6.5	62.2±4.7	5.8±0.6	10.6±5.5	289±42	341±53	3.7±0.6	3.9±0.7

These values represent mean ± SEM

There was no statistical difference for heart rate response between the FKM and cycle (p = 0.308; Observed Power = 0.454). This finding was not unexpected since we designed the study to match heart rate response between conditions (Figure 2) (Table 4).

FKM exercise resulted in no significant difference in stroke volume compared to cycling (p = 0.076; Observed Power = 0.752). Stroke volume was maintained at an elevated level during rest intervals with FKM but not cycling, but this difference did not reach statistical significance and thus may not be meaningful (Figure 3) (Table 4).

Cardiac output on the FKM did not differ significantly from cycle (p =0.509; Observed Power = 0.121). The only notable difference was that cardiac output returned to pre-exercise values more rapidly following the last exercise interval with the FKM; however, this effect did not reach statistical significance (Figure 4) (Table 4).

At the same heart rate response, exercise on the FKM resulted in lower oxygen consumption compared to cycling, although not significant (p = 0.786; Observed Power = 0.094) (Figure 5) (Table 4).

Peak blood lactate response was greater with FKM compared to cycling in the final exercise stage, although not significant (p = 0.463; Observed Power = 0.114). No other differences were observed during the exercise session (Figure 6) (Table 4).

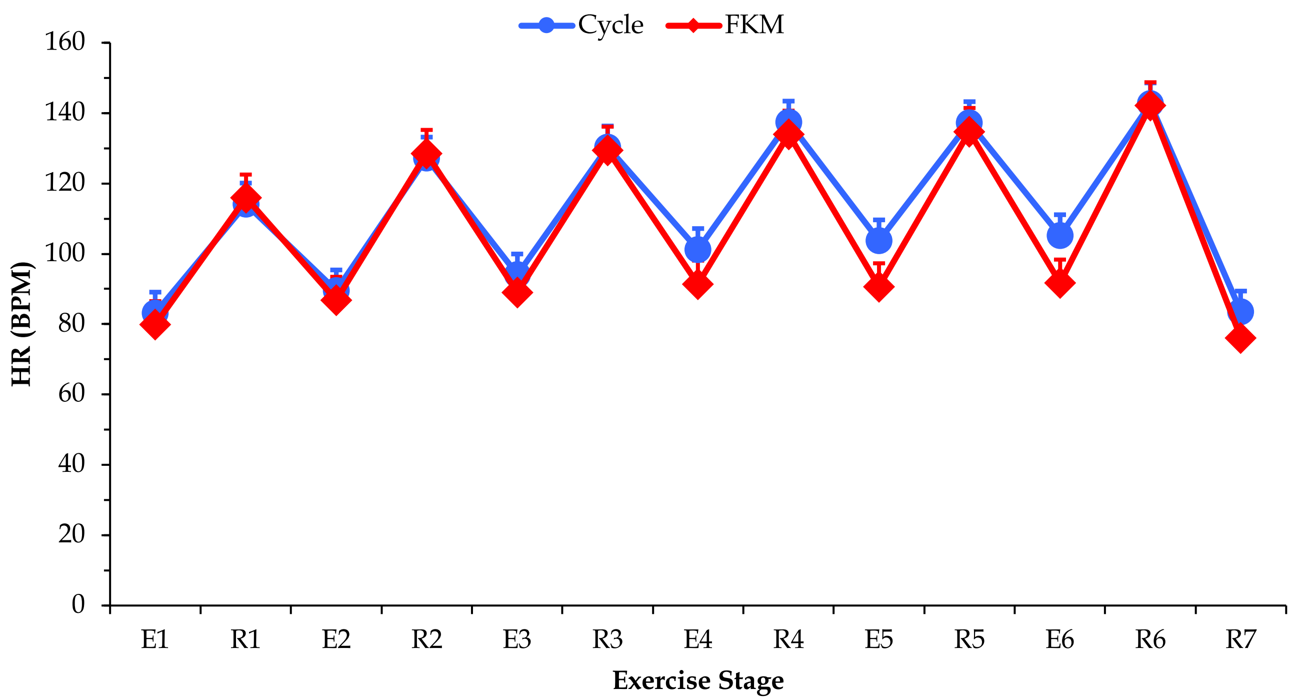

Figure 2. Heart rate response values show peak heart beats per minute at each stage of exercise and rest. These results represent values in Table 3. ($p < 0.05$)

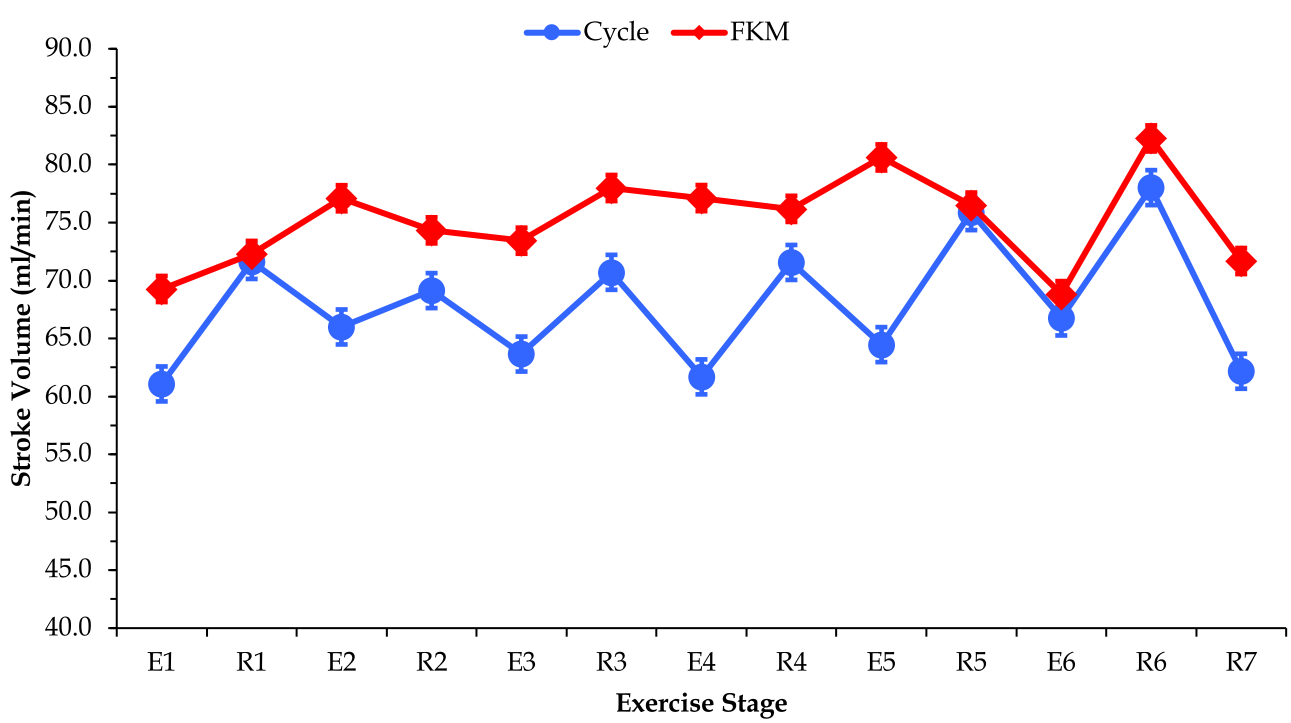

Figure 3. Peak stroke volume measured in ml/min at each exercise stage. These results represent values in Table 3. ($p < 0.05$)

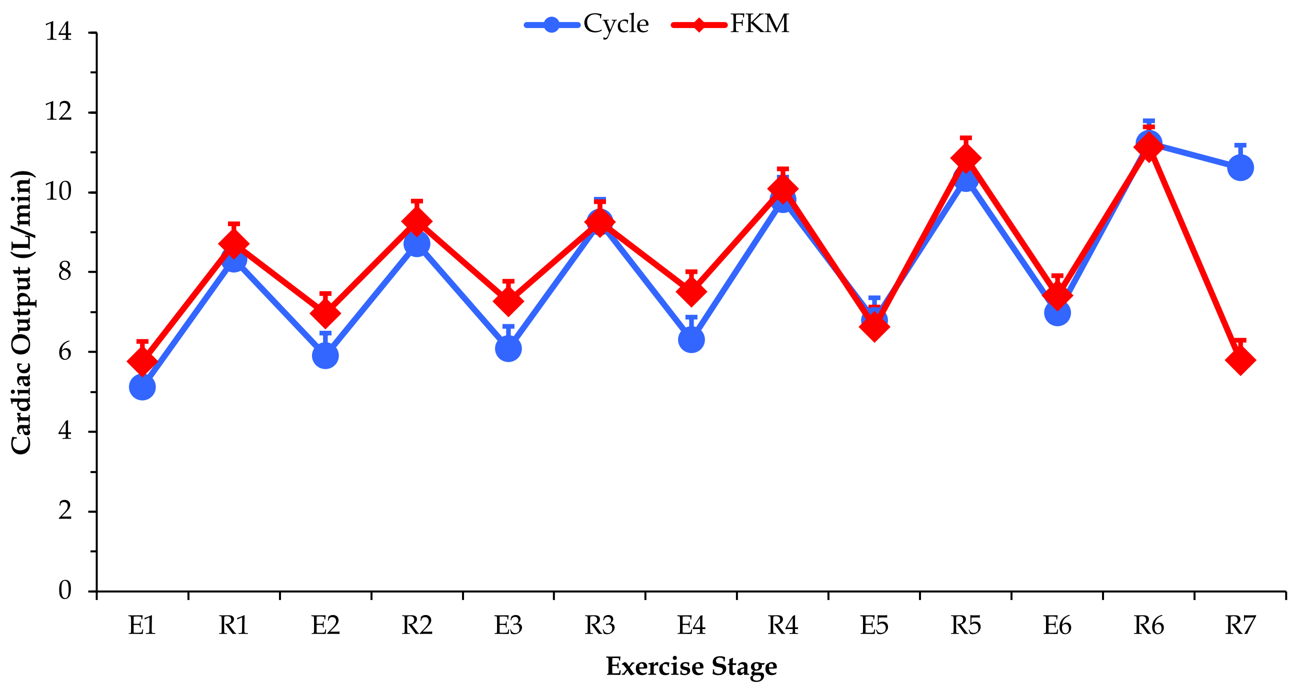

Figure 4. Peak cardiac output in L/min at each exercise and rest stage. These results represent values in Table 3. ($p < 0.05$)

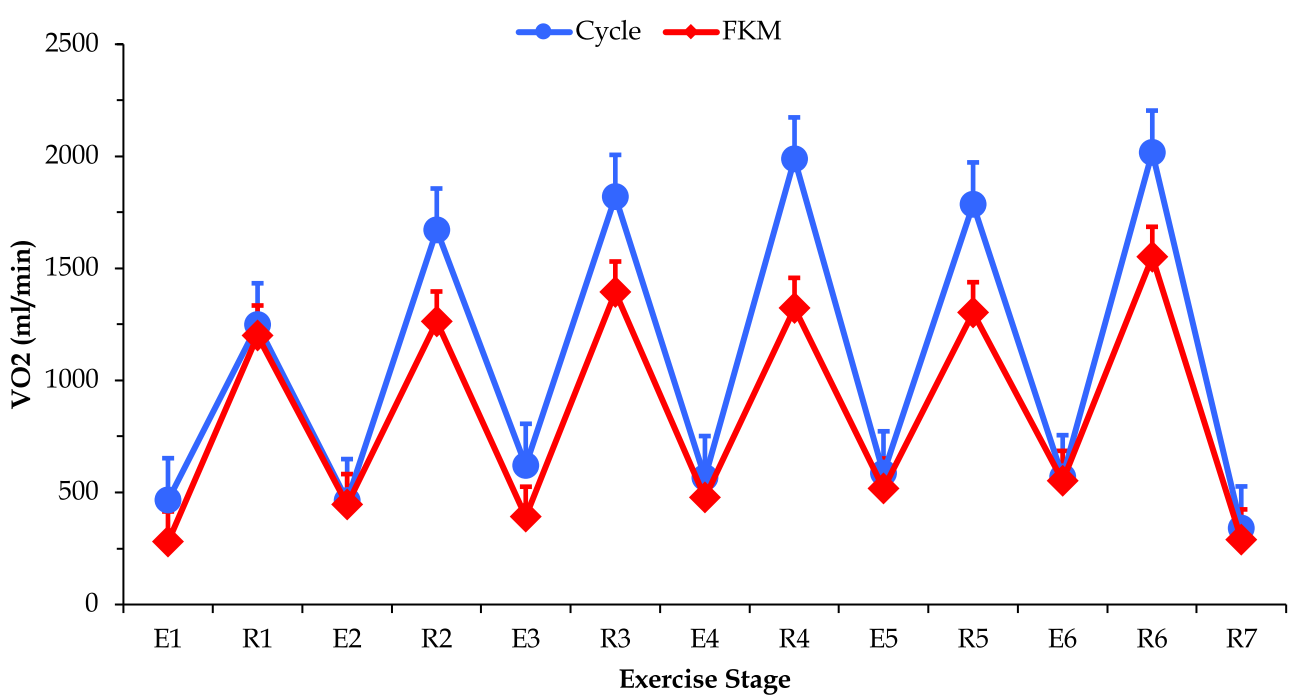

Figure 5. Peak VO_2 in ml/min at each exercise and rest stage. These results represent values in Table 3. ($p < 0.05$)

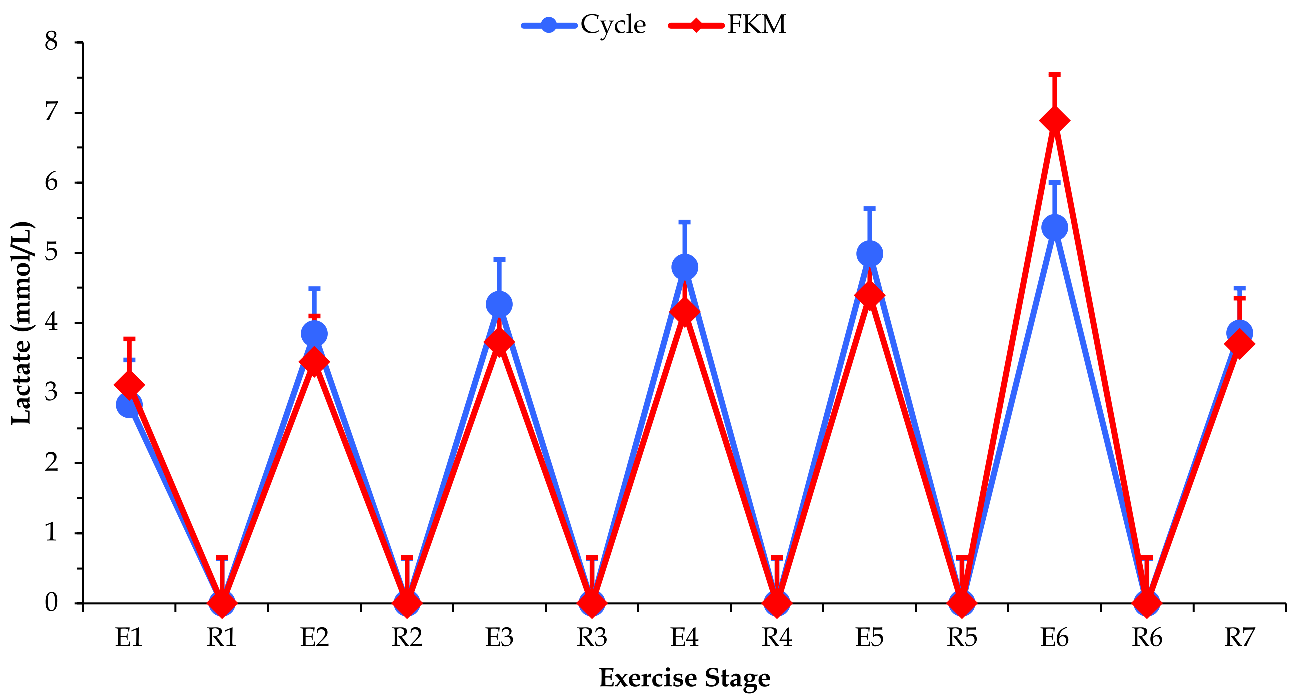

Figure 6. Peak blood lactate in mmol/L at each exercise and rest stage. These results represent values in Table 3. ($p < 0.05$)

DISCUSSION

The key objective of the present investigation was to report the metabolic and cardiovascular effects of exercise on a novel, whole-body exercise device compared to a cycle ergometer (2, 12). We observed greater stroke volume response during FKM but it was not statistically significant; however, this did not appear to significantly alter cardiac output. Since heart rate is one of the primary factors effecting cardiac output during exercise, this response was expected (6, 16). We also observed a response of lower oxygen consumption and a greater lactate response during FKM exercise. This validates previous research involving mechanical work during resistance training verifying anaerobic response (3). Increased neuromuscular activity and muscle recruitment due to the body positioning during the exercise on the FKM could explain the differences as compared to the cycle ergometer (11, 13). Further interpretation of these findings indicates that the FKM device may be better suited for anaerobic rather than aerobic exercise training (5, 15).

As this study was only preliminary and a technical note, our primary limitation is the sample size. Future studies might seek to enroll a larger study cohort. While we didn't find significant differences in the metabolic responses between the FKM and cycling, this is not necessarily a negative finding. In fact, both devices yielded similar outputs and thus the FKM might be a good cross-training alternative to cycling. Since the present investigation was acute in nature, more research is needed to understand how the FKM could be used as a training stimulus during chronic exercise training.

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REFERENCES

1. Bonacci J, Vleck V, Saunders PU, Blanch P, Vicenzino B. Rating of perceived exertion during cycling is associated with subsequent running economy in triathletes. J Sci Med Sport 16(1): 49-53, 2013.

2. Boudreaux BD, Hebert EP, Hollander DB, Williams BM, Cormier CL, Naquin MR, Gillan WW, Gusew EE, Kraemer RR. Validity of wearable activity monitors during cycling and resistance exercise. Med Sci Sports Exerc 50(3): 624-633, 2018.

3. Buitrago S, Wirtz N, Yue Z, Kleinoder H, Mester J. Mechanical load and physiological responses of four different resistance training methods in bench press exercise. J Strength Cond Res 27(4): 1091-1100, 2013.

4. Buskard AN, Oh J, Eltoukhy M, Brounstein S, Signorile JF. A novel method to determine optimal load in elastic-based power training. J Strength Cond Res 32(9): 2401-2408, 2018.

5. Conceicao MS, Gaspari AF, Ramkrapes APB, Junior EMM, Bertuzzi R, Cavaglieri CR, Chacon-Mikahil MPT. Anaerobic metabolism induces greater total energy expenditure during exercise with blood flow restriction. PLoS One 13(3): e0194776, 2018.

6. Duschek S, Hoffmann A, Reyes Del Paso GA, Ettinger U. Autonomic cardiovascular control and executive function in chronic hypotension. Ann Behav Med 51(3): 442-453, 2017.

7. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exer Sci 12(1): 1-8, 2019.

8. Maciejewski H, Bourdin M, Feasson L, Dubouchaud H, Denis C, Freund H, Messonnier LA. Muscle mct4 content is correlated with the lactate removal ability during recovery following all-out supramaximal exercise in highly-trained rowers. Front Physiol 7: 223, 2016.

9. MacInnis MJ, Gibala MJ. Physiological adaptations to interval training and the role of exercise intensity. J Physiol 595(9): 2915-2930, 2017.

10. Melling E and McFarlin BK**.** Prototype Whole Body Exercise Device May Be Useful for Anaerobic Exercise Training. J Sport Hum Perform 2(1): 2014.

11. Mier CM, Feito Y. Metabolic cost of stride rate, resistance, and combined use of arms and legs on the elliptical trainer. Res Q Exerc Sport 77(4): 507-513, 2006.

12. Riegler M, Stotz G, Fitzgerald K, Munoz CK, Lewis J, Ring S, Astorino TA. Acute responses to the 7-minute workout. J Strength Cond Res 31(9): 2572-2578, 2017.

13. Saeterbakken AH, Fimland MS. Effects of body position and loading modality on muscle activity and strength in shoulder presses. J Strength Cond Res 27(7): 1824-1831, 2013.

14. Swaine IL, Hunter AM, Carlton KJ, Wiles JD, Coleman D. Reproducibility of limb power outputs and cardiopulmonary responses to exercise using a novel swimming training machine. Int J Sports Med 31(12): 854-859, 2010.

15. Thomas HJ, Scott BR, Peiffer JJ. Acute physiological responses to low-intensity blood flow restriction cycling. J Sci Med Sport 21(9): 969-974, 2018.

16. Vincent JL. Understanding cardiac output. Crit Care 12(4): 174, 2008.