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KINEMATICS AND PHYSIOLOGICAL EFFECT OF A SYNCHRONIZED BIPEDAL "RISE-SIT-GO" CYCLING EXERCISE

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This study demonstrated the kinematics and physiological effect of a synchronized bipedal cycling exercise. Fifteen male subjects performed a 30-minutes exercise on a synchronized bipedal stationary bike and a conventional stationary bike at same cycling speed. The performance was evaluated by a metabolic testing system, a subjective rating of perceived exertion, an electromyography system and a motion analysis system, and was compared by paired t-tests. Results showed significant increases in oxygen uptake, energy expenditure, rating of perceived exertion, muscle activity in triceps, biceps, rectus abdominis, left gluteus maximus, left medial gastrocnemius, right tibialis anterior and left tibialis anterior, and range of motion of left hip, left and right knees, shoulders, elbows and wrists. The synchronized bipedal cycling exercise was more physically demanding.

KEY WORDS: Biking, sports equipment, sports medicine, rehabilitation exercise

INTRODUCTION: Risigo, abbreviation for "Rise, Sit and Go" is a product invented by a Hong Kong entrepreneur (Hung, 1984). In this design, the cyclist pedals simultaneously with both feet. As the pedals rotate to the bottom, the seat will "rise" accordingly. The cyclist then "sits" and pushes the pedals down and back to the starting position, and the bike "goes" and the cycle continues. Figure 1 demonstrates this form of cycling exercise, which is symmetrical in the frontal plane. In sports medicine and rehabilitation, the exercise on stationary bike could be a safe option for amputated patients for rehabilitation exercise, as they usually could hardly pedal backwards with the amputated limb (Childers et al, 2009).

Figure 1: Demonstration of the synchronized bipedal cycling exercise.

There were many studies in the field regarding the biomechanical and physiological effect of conventional cycling, but none existed for the synchronized bipedal cycling method. This study investigated the effect of the synchronized bipedal cycling exercise on total energy expenditure, muscle activity as reflected by electromyography (EMG), and range of motion of the upper and lower limb joints. We hypothesized that the synchronized bipedal cycling method is more physically demanding than conventional cycling method, and substantial increases in the measured parameters would be found.

METHODS: Fifteen male recreational cyclists (age = 20.9 ± 1.0 years, height = 1.74 ± 0.06 m, body weight = 65.4 ± 8.5 kg) were recruited for this study. Each subject completed a

30-minutes exercise (Garber et al, 2011) on the synchronized bipedal stationary bike (Risigo MAG 1500U, Hong Kong) and a conventional stationary bike (Monark Ergomedic 874E, Sweden), as shown in Figure 2. Subjects were asked to maintain their speed at 60 revolutions per minute (Ansley & Cangley, 2009, Moseley et al, 2004) and were given visual feedback from the display on the stationary bikes in order to do so. Prior to the test, a warm up section was given to familiarize with the pedalling techniques and every subject would sign a written consent. This test was approved by the university ethics committee.

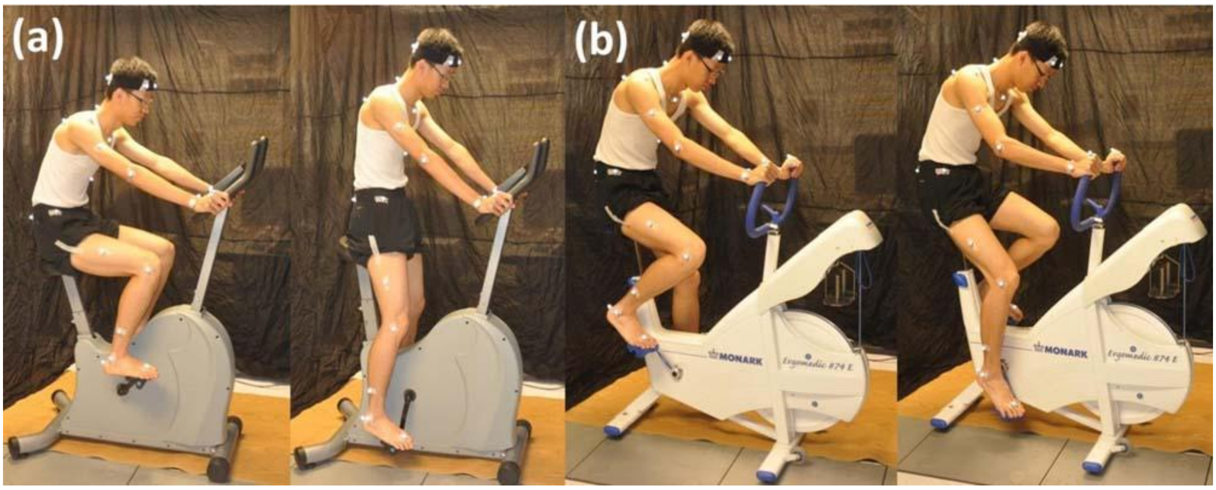

Figure 2: A subject performing the exercise on the (a) synchronized bipedal Risigo stationary bike, and (b) conventional stationary bike.

The volume of oxygen uptake (VO_2) was measured pulse-by-pulse using a metabolic testing system (Medgraphic Cardiorespiratory Diagnostics Ultima^{TM} CardiO_2, US). The energy expenditure was calculated using the following formula: Energy Expenditure (kcal/min) = 15.913 + [(5.207 x RER) x VO_2 (L/min)] / 4.186 (Brooks et al, 2005). The respiratory exchange ratio (RER) was calculated using the following equation: RER = VCO_2 / VO_2. A subjective measurement, Rating of Perceived Exertion (RPE), about the exercise intensity was recorded alongside the energy expenditure.

Wireless EMG (Noraxon TeleMyo^{TM} 2400T, Germany) was used to record the muscle activity of the sixteen selected muscles at a sampling rate of 1500 Hz. After the area for electrodes attachment was rubbed and cleaned with alcohol, a pair of electrodes was placed on both the left and right side of gluteus maximus, semitendinosus, vastus medialis, rectus femoris, medial gastrocnemius and tibialis anterior. Electrodes were placed on the right side only for triceps, biceps, erector spinae and rectus abdominis due to the limitation of channels available (16 in total). The collected EMG data was full-wave rectified, smoothed, integrated and normalized with the data from submaximal isometric contractions (Fong et al, 2008).

The range of motion of the upper and lower limb joints during the two cycling methods was determined through the use of a motion capture system (Vicon T040, UK). 37 reflective markers were placed according to the Plug-in-Gait full body model. The range of motion for the shoulders, elbows, wrists, hips, knees and the ankles on the left and right side (12 in total) in the sagittal plane (flexion and extension) were analyzed.

Paired t-tests were performed to investigate any significant difference between the two cycling methods. The significance level was set at $p < 0.05$.

RESULTS: Significantly higher oxygen intake, energy expenditure and rating of perceived exertion were found (Table 1). Significant increase in muscle activity was found in 7 muscles, including triceps, biceps, rectus abdominis, left gluteus maximus, left medial gastrocnemius, right tibialis anterior and left tibialis anterior (Figure 3). Significant increase was found in the range of motion for the left hip, left and right knees, shoulders, elbows and wrists (Figure 4).

Table 1: Average VO_2, energy expenditure and rating of perceived exertion during the exercise on the conventional bike (Bicycle) and the synchronized bipedal bike (Risigo)

	Bicycle	Risigo	% Difference	p-value
Average VO_2 (L/min)	0.961 (0.160)	1.239 (0.258)	+28.9%	**0.002***
Total Energy Expenditure (kcal)	515.9 (6.7)	529.9 (11.6)	+2.7%	**<0.001***
Rating of Perceived Exertion	11.0 (1.4)	13.9 (1.5)	+26.4%	**<0.001***

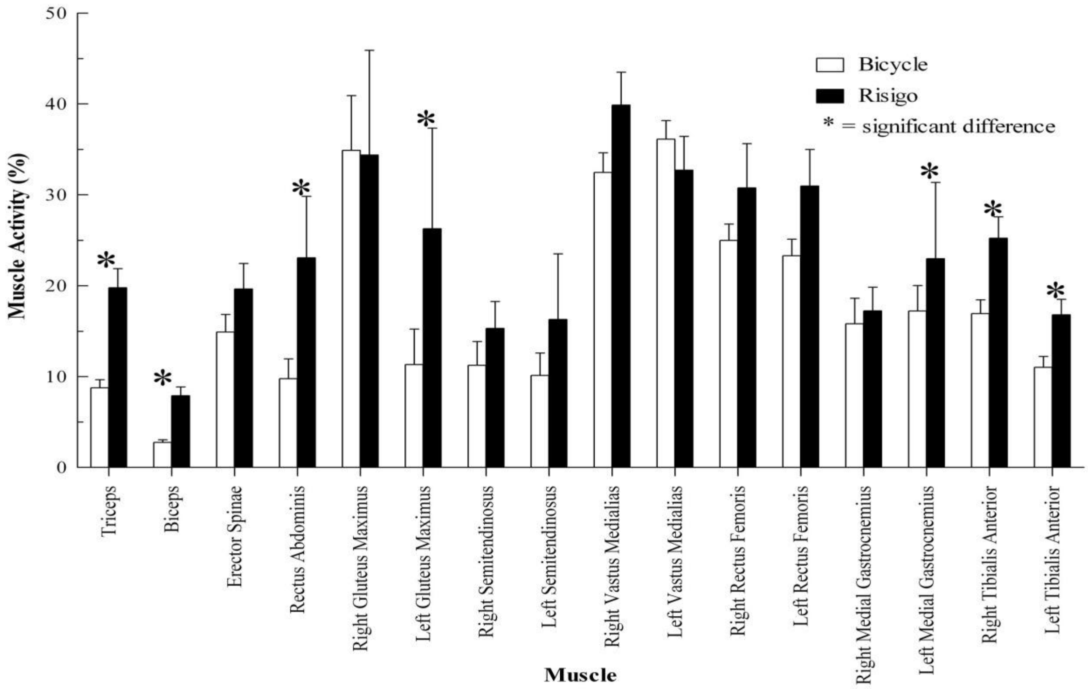

Figure 3: Muscle activity of the 16 muscles during the exercise on the conventional bike (Bicycle) and the synchronized bipedal bike (Risigo)

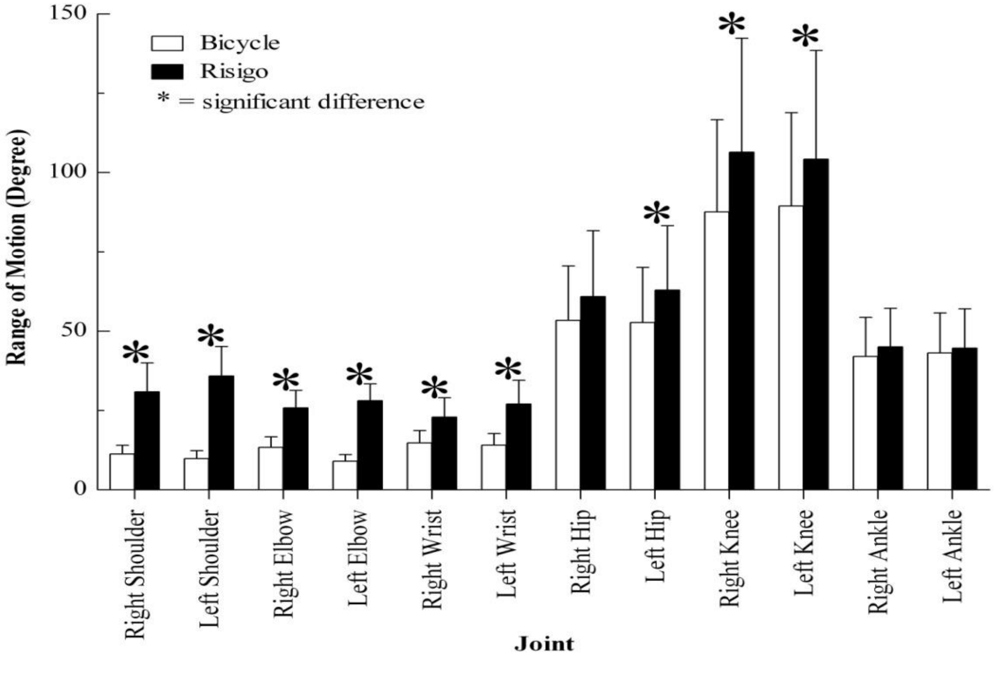

Figure 4: Range of motion for the 12 joints during the exercise on the conventional bike (Bicycle) and the synchronized bipedal bike (Risigo)

DISCUSSION: Triceps and biceps, the flexor and extensor of the upper limb, along with rectus abdominis were used extensively to maintain body balance and to facilitate a smooth pedalling motion while cycling on the synchronized bipedal stationary bike. The increased activity was expected since these muscle groups were inactive while cycling on the conventional stationary bike. Medial gastrocnemius, responsible for plantar flexion, is the antagonistic pair of tibialis anterior, responsible for dorsiflexion. These muscle groups were used extensively due to the design limitation of the synchronized bipedal stationary bike. The pedalling method was slightly different and an additional force was needed at the following positions: First when the pedals were in the highest position, the rider would be in a squatting position. Dorsiflexion was required to push the pedal slightly in order to start a new pedalling cycle. Since this motion was required in every cycle, a significant increase was shown on both left and right tibialis anterior. On the other hand, when the pedals were at its lowest position, the leg would be in a fully extended position due to the elevation of the seat. Slight plantar flexion was also necessary for a smooth pedalling cycle. Therefore there was a significant increase in left medial gastrocnemius.

The physiology data – oxygen uptake, energy expenditure and the rating of perceived exertion – all showed a significant increase. These parameters suggested it is physically more demanding to complete the 30-minutes exercise, with a constant speed, on the synchronized bipedal exercise bike than on a conventional exercise bike.

Finally, there was a significant increase in the sagittal plane range of motion for all the upper limb joints, the knee joints and the left hip joints. During the conventional stationary bike exercise, the centre of mass of the subjects was relatively stable. However, in the synchronized bipedal stationary bike exercise, the user initiated a lot of up and down body motions. As a result, the upper limb joints showed an increase ranging from 54.7% to 262.6%.

CONCLUSION: The synchronized bipedal cycling exercise is more physically demanding than the conventional cycling method as reflected by the demonstrated biomechanical and physiological parameters. Sports medicine and rehabilitation specialists are encouraged to prescribe this form of exercise to suitable patients or subjects.

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