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Physiological and Biomechanical Assessment of the Rockboard Scooter

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Overview

This physiological and biomechanical assessment was done in an effort to provide valuable and marketable feedback to M.Y. Products, LLC regarding the energy demand and resulting potential fitness benefits that children would see as riders of the Rockboard Scooter. The assessment compares the oxygen consumption (i.e. energy demand) required to ride the Scooter with the oxygen consumption of other activities that children may take part in. Assessments were performed on the Rockboard using multiple modes of physical testing. Specifically, energy demand, muscle activity, and joint motion data were collected. Energy demand was measured at three different speeds on the Rockboard using a computerized metabolic cart that determines the body's oxygen consumption level during activity. Electromyography (EMG) analysis of the calf, hamstring, quadriceps and gluteus muscles was acquired using surface electrodes and National Instruments LabVIEW 8.5 software. Two-dimensional video analysis was used to determine joint movements of the hip, knee, and ankle.

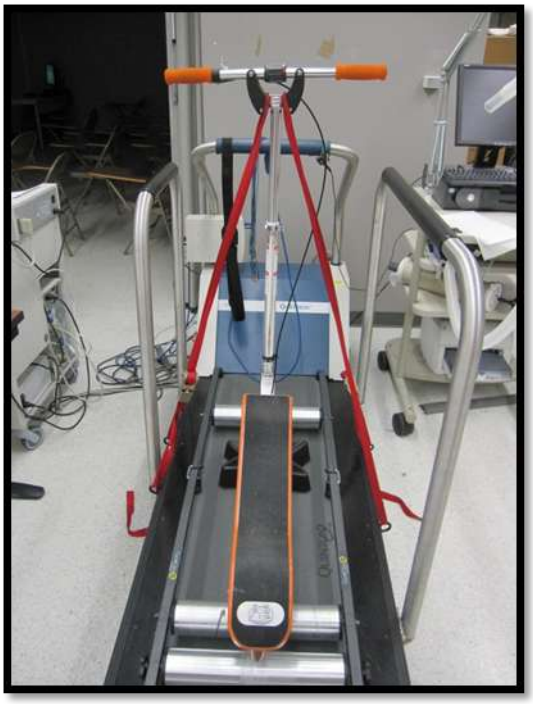
Methods

Subjects:

In order to get a better representation of the physical demands of the Rockboard scooter, three subjects were used in each of the testing modes and the values were then averaged. The subjects included one female, age 22, and two males, ages 25 and 27. All subjects are college undergraduate students at Indiana University-Purdue University Indianapolis. All subjects were apparently healthy, with no existing medical conditions.

Protocol:

Before testing, the Rockboard scooter was rigged into a stationary position using a Cycleops Aluminum bicycle roller frame, a wheel block, and two ratchet straps (see Picture #1). The subjects familiarized themselves with the Rockboard scooter by participating in several warm up runs consisting of four to five minutes of use during the weeks leading up to the actual data collection. It was during the familiarization sessions that the speeds used during actual data collection were determined. The three speeds chosen were categorized as slow, cruising, and fast (i.e. 6, 8, and 10 mph, respectively). Different speeds were utilized in order to better understand the range of fitness benefits that a child could see while riding the Rockboard scooter.



Picture #1

For example, the 6 mph speed was estimated by the subjects to be one of the slowest speeds that might be used when riding the scooter. The 8 mph speed seemed to be the most comfortable riding speed and thus was chosen as the "cruising" speed. The 10 mph speed was estimated to be close to the fastest speed that an individual would maintain while riding the scooter for an extended period of time. Certainly, it is possible that a child may in fact be able to ride the Rockboard at faster speeds (i.e. >10 mph) and see greater oxygen consumption values, but for this assessment, we wanted to perform the physiological and biomechanical assessments using speeds that would be more representative of typical use.

Oxygen consumption (abbreviated as VO_2) was measured using a computer-controlled, metabolic cart with included headgear and measurement software (see Picture #2). The metabolic cart literally measures the amount of oxygen consumed (i.e. liters of oxygen or milliliters of oxygen per body weight) by the body to make the energy necessary to perform the activity. As a result, the oxygen consumption values collected during activity are directly related to the number of calories burned for that specific activity. Oxygen consumption values can also be converted into metabolic equivalents (i.e. METs). One MET is equivalent to the energy an individual expends at rest. Thus for any activity, the energy demand required can be expressed as a multiple of resting energy expenditure. In other words, an activity that requires an oxygen consumption that is equivalent to 3 METS, demands 3 times as much energy than when at rest.

Picture #2

The EMG data was collected on a Noraxon eight channel electromyographic (EMG) system using surface electrodes that identify and measure the electrical activity within muscles (see Pictures #3, #4, and #5). EMG data was collected for each muscle group under two conditions: a maximal voluntary contraction (MVC) and during the Rockboard ride. The MVC measurements were used to establish a maximal electrical activity level for each muscle. The subsequent EMG measurements collected while using the Rockboard were then compared to the maximal levels of muscle activity. The comparison between MVC and Rockboard measures, enabled us to determine how active the various muscles were when riding the Rockboard.

Picture #3

Picture #4

Picture #5

The two-dimensional, biomechanical joint analysis involved using a high-speed, digital video camcorder recording the subjects riding on the Rockboard. The camera was set up at 90 degrees to the direction of travel thus providing a lateral view of the subject on the scooter. After recording, video data was then downloaded into a portable computer and Maxtrack software was used to digitize joint movements on a frame by frame basis.

Testing:

During data collection, each subject rode with the right leg forward on the scooter (see Picture #6). Data collection began at the slow speed of six mph. The subject maintained this speed for four minutes in order to establish a steady-state rate of oxygen consumption. Once the subject finished the four-minute test, oxygen consumption and heart rate values were documented. The subjects then rested for 5 minutes to return their oxygen consumption and heart rate levels back to resting state. After the rest period, the test was performed again, this time at the cruising speed of 8 mph. This procedure was repeated once more to collect data at the fast speed of 10 mph.

Picture #6

EMG activity was recorded during all three speeds. However, the biomechanical joint movement analysis was completed only during the cruising speed test. The reason was because of the technical complexity and time consuming nature of digitizing the video data. Because a high-speed video camera was required, one second of video data for each subject consisted of 200 frames or pictures, each of which required the hip, knee and ankle to be identified and marked. Additionally, it was felt that this would most likely be the most representative speed at which children would ride the Rockboard. Picture #6 shows one of the subjects on the Rockboard during testing.

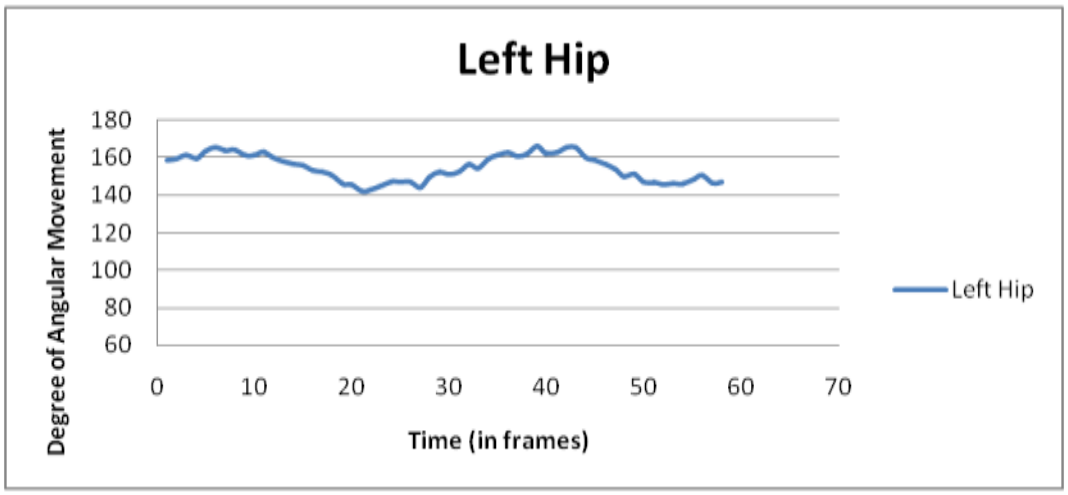
Results

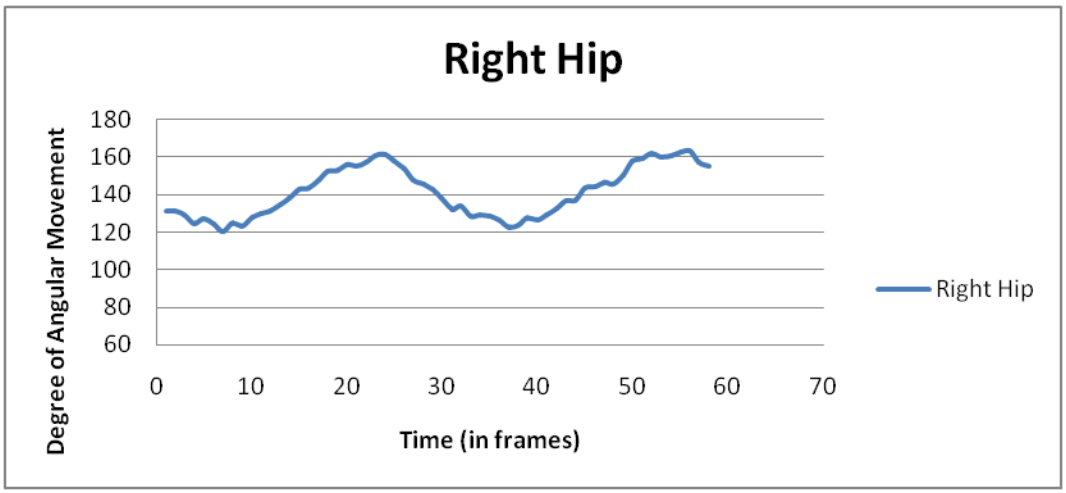
- The average of the obtained oxygen consumption values for each speed on the Rockboard are found in Table 1 below.

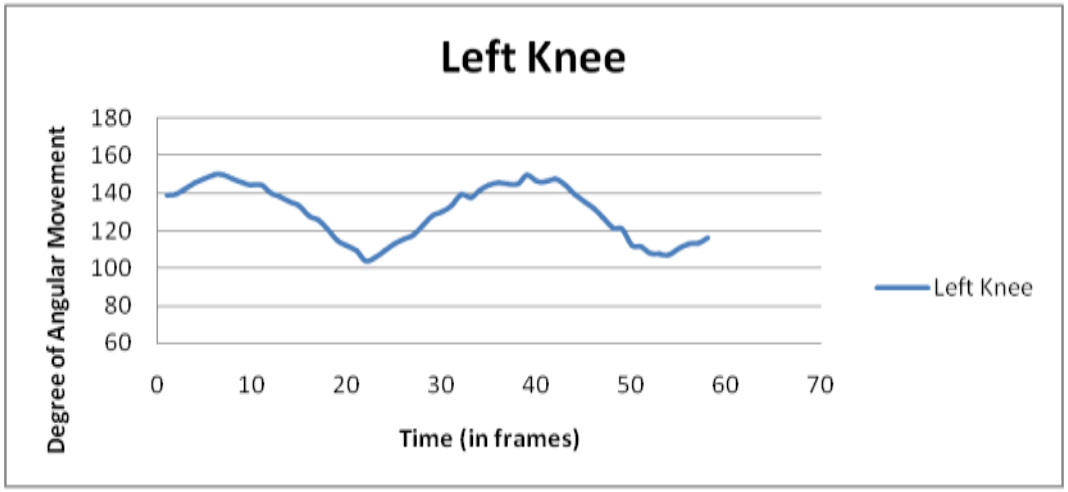
Table 1:

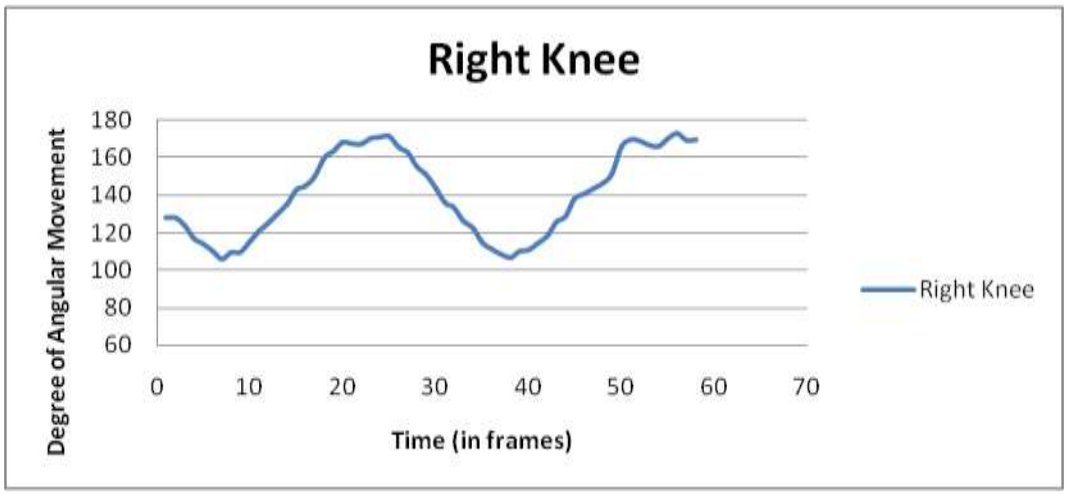
Speed (mph)	VO_2 (L/min)	VO_2 (ml/kg/min)	Heart Rate (bpm)	Calories Burned (kcal/min)	% Maximum Heart Rate	Exercise Intensity (METS)
6	1.64	24.13	93	8.18	49	6.9
8	1.94	28.52	103	9.70	54	8.1
10	2.46	35.64	116	12.18	61	10.2

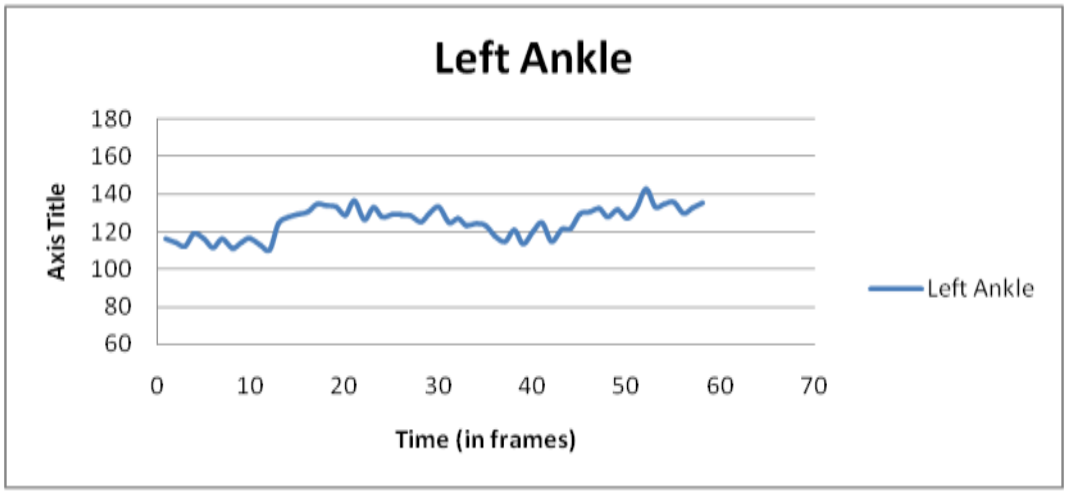
- The data from the biomechanical analysis of the right and left hip, knee, and ankle joints while riding the Rockboard are displayed in the charts below.

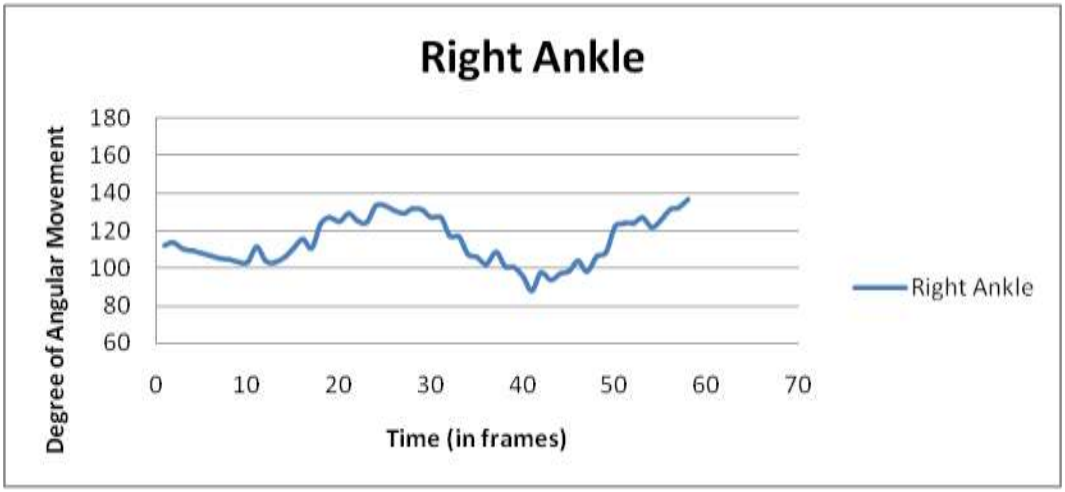





Left Knee
Degree of Angular Movement
180
160
140
120
100
80
60
0
10
20
30
40
50
60
70
Time (in frames)
Left Knee


Right Knee
Degree of Angular Movement
180
160
140
120
100
80
60
0
10
20
30
40
50
60
70
Time (in frames)
Right Knee


Left Ankle
Axis Title
180
160
140
120
100
80
60
0
10
20
30
40
50
60
70
Time (in frames)
Left Ankle



- EMG activity was tested in seven muscles of the lower body. The charts below display muscular activity while riding the Rockboard compared to each muscle's MVC.

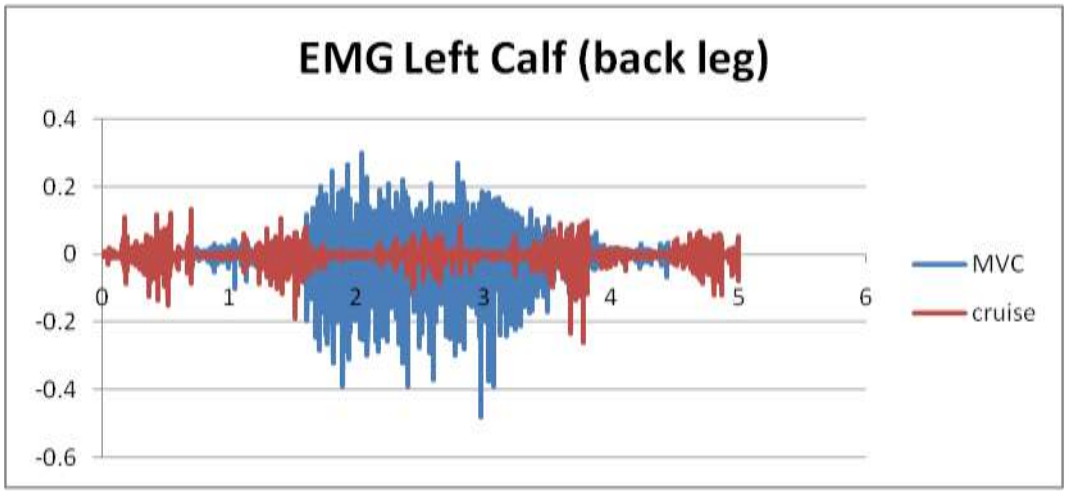


Fig 1.1

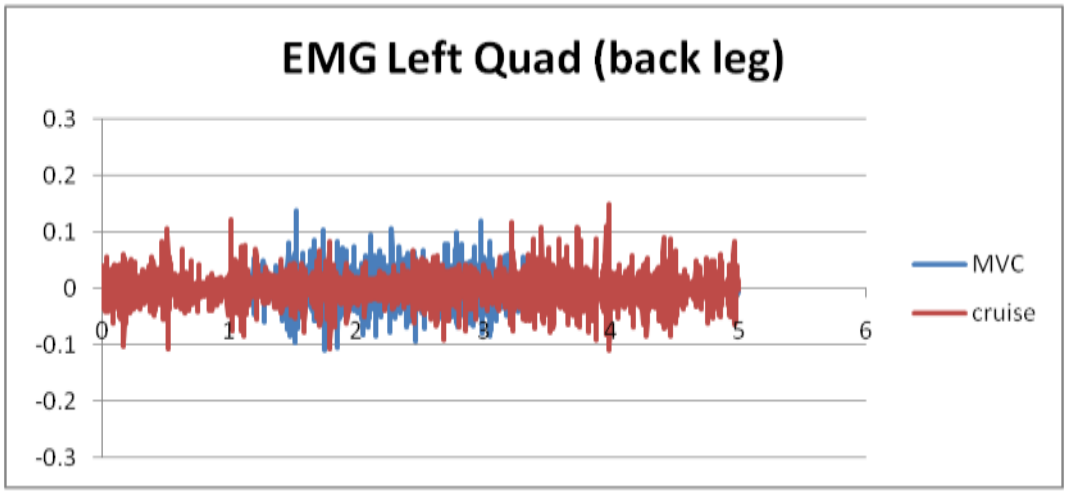


Fig 1.2

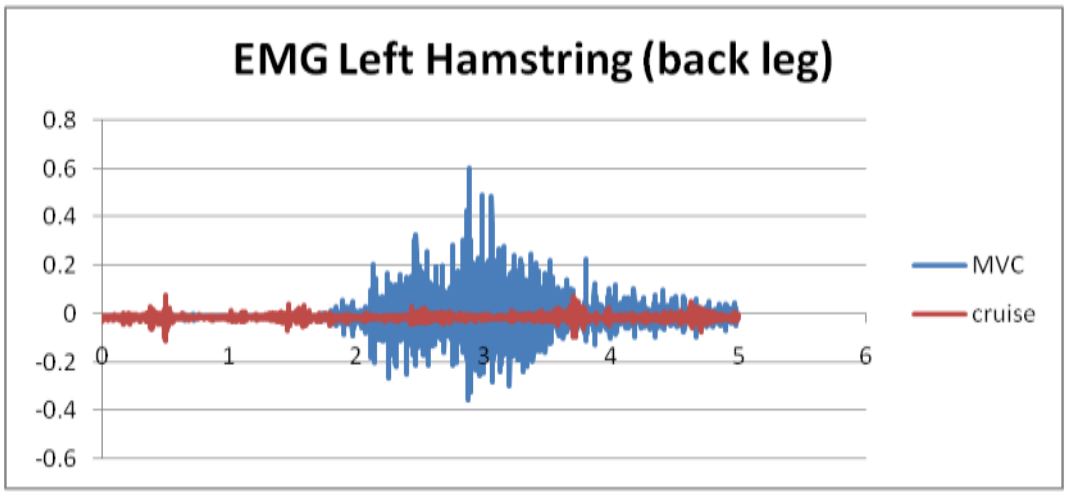


Fig 1.3

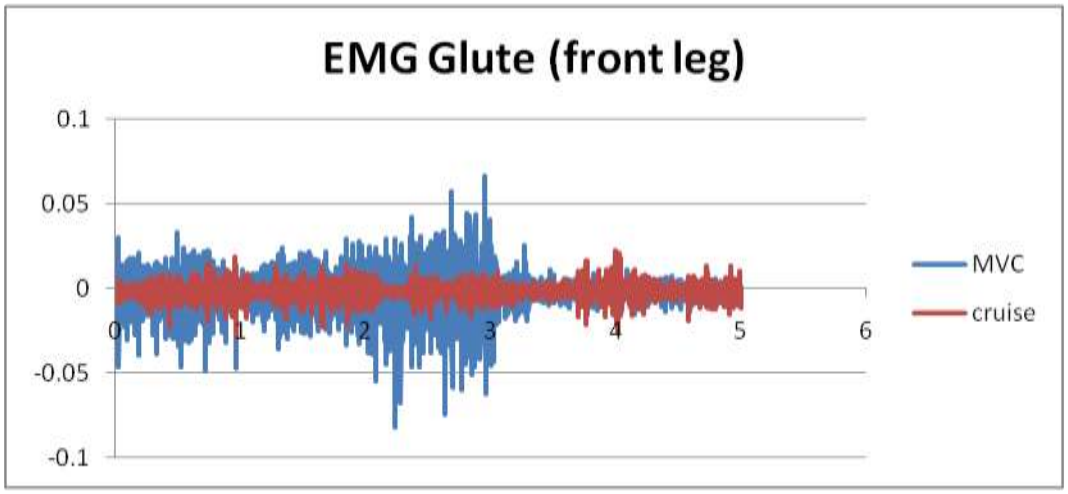


Fig 2.1

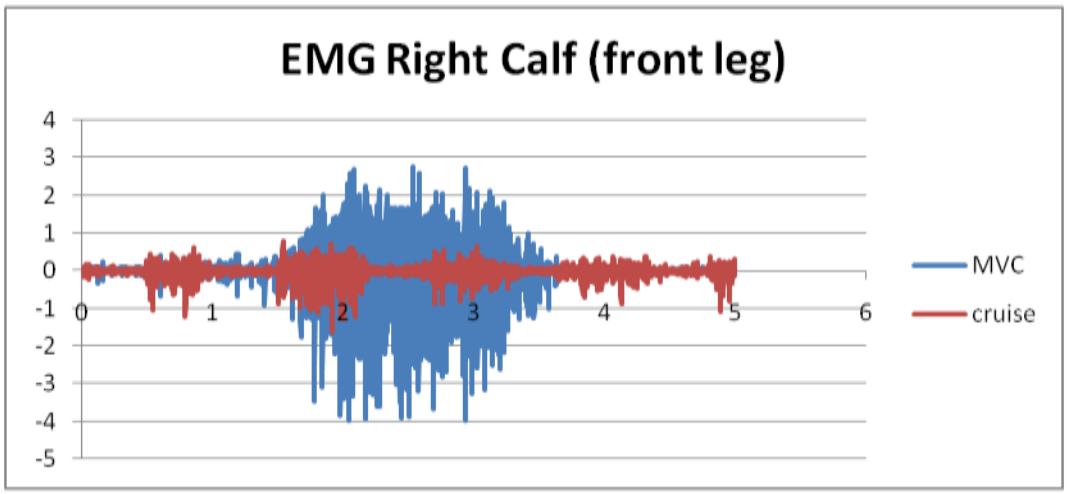


Fig 2.2

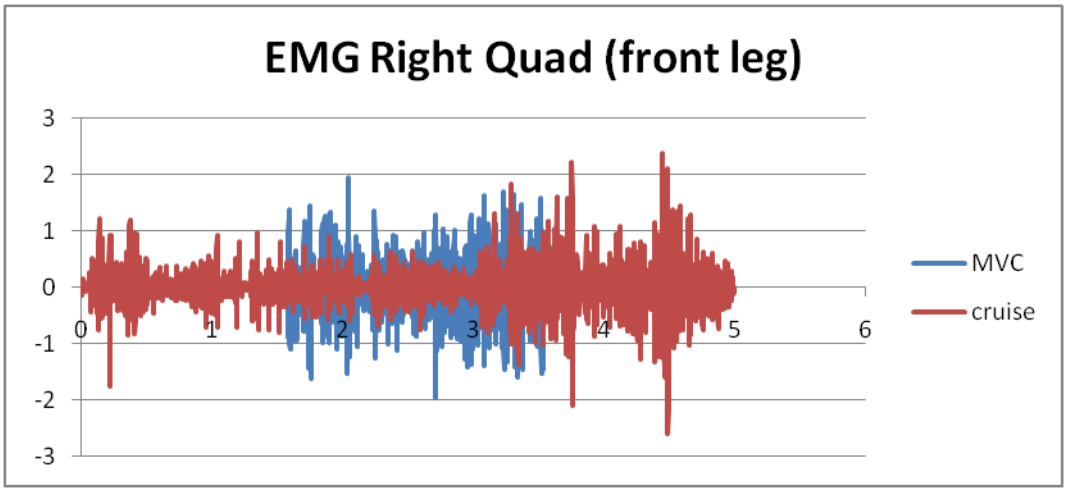


Fig 2.3

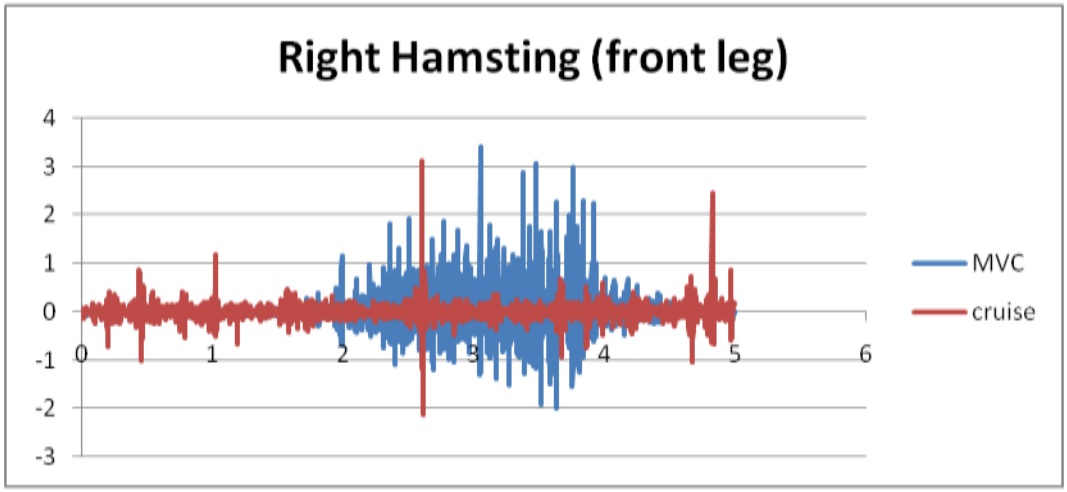


Fig 2.4

- The following charts display EMG/muscular activity of the front leg quadriceps (i.e. the right leg) when propelling the Rockboard at the three different speeds. The quadriceps muscle of the front leg was chosen because it was the most actively used muscle when powering the Rockboard.

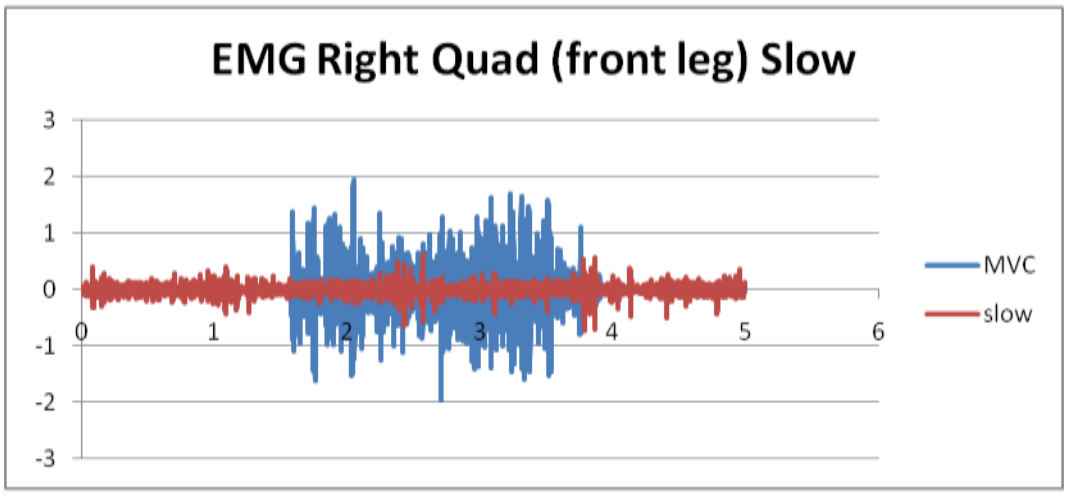


Fig 3.1

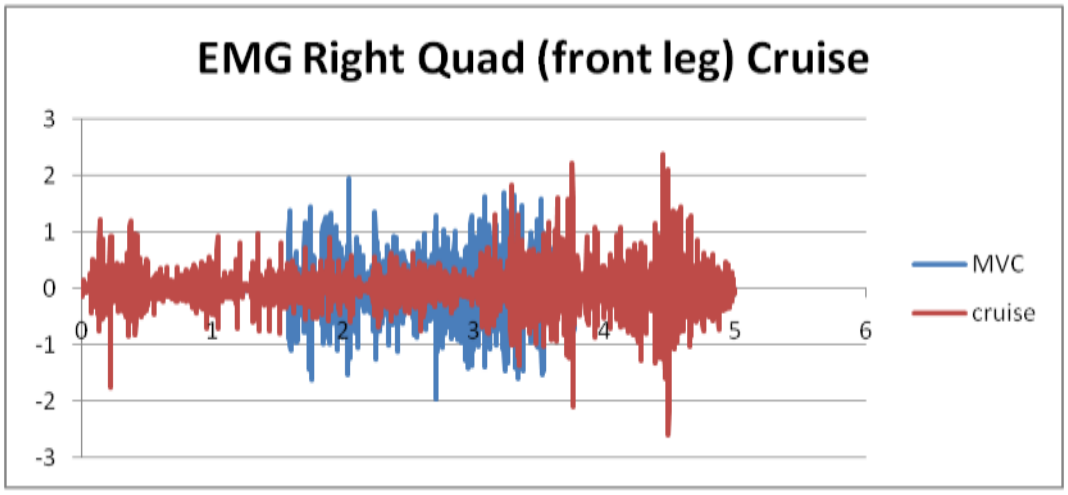


Fig 3.2

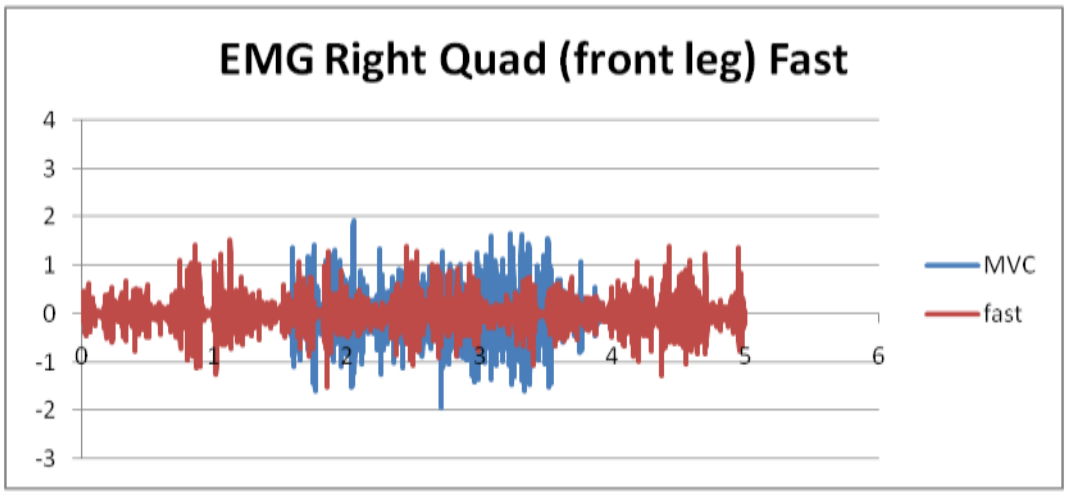


Fig 3.3

Discussion

The oxygen consumption values that were obtained from testing show that the energy expended while powering the Rockboard is comparable to many recreational and exercise activities. As discussed earlier in the methods section, using METs is an acceptable way to categorize exercise intensity of various activities. Activities requiring less than 3 METs are considered light exercise while activities requiring from 3 to 5.9 METs are considered to be moderately taxing. Vigorous exercise typically requires greater than 6 METs, with 6 to 7.4 METs defining low vigorous activity and anything greater than 7.5 being considered highly vigorous. Recall that the METs for each speed on the Rockboard were 6.9 METs at 6 MPH, 8.1 METs at 8 MPH, and 10.2 METs at 10 MPH. These values correspond to vigorous levels of activity and are comparable to performing some of the common activities listed below:

Kickball – 7.0 METs	Volleyball – 8.0 METs
Tennis – 7.0 METs	Running, 5mph (12min/mile) – 8.0 METs
Soccer – 7.0 METs	Ultimate Frisbee – 8.0 METs
Swimming laps – 7.0 METs	Racquetball – 10.0 METs
Bicycling – 8.0 METs	Rope Jumping (moderate) – 10.0 METs
Basketball – 8.0 METs	Running, 6mph (10min/mile) – 10.0 METs

Based on the MET values, powering the Rockboard scooter is an excellent way for children to expend energy and be physically active. Additionally, **if done on a regular basis, the activity levels achieved while powering the Rockboard are high enough to confer fitness benefits.**

Cardiovascular fitness is a concern for not only adults but children, particularly in light of the growing number of children who are sedentary and overweight in today's society. To achieve improvements in cardiovascular fitness, a physical activity should be challenging enough to increase the heart rate to 50% or more of its maximum. **Powering the Rockboard scooter in our subjects increased their heart rates to about 54% of maximal heart rate at the moderate cruising speed of 8 mph.** This indicates that regular use of the Rockboard could confer cardiovascular fitness benefits if ridden on a regular basis (i.e. at least 3 times per week) for at least 30 minutes.

Based on the EMG data, **the quadriceps and calf muscles of the legs are the prime movers used when propelling the Rockboard**. Looking at Figures 1.1-1.3, we can see that the left leg, which was the rear-positioned leg, had significant EMG activity in the calf and quadriceps muscles, but showed little activity in the hamstrings. Figures 2.1-2.4 show the muscle activities for the forward-positioned leg. Similar to in the rear leg, there was significant activity in the quadriceps and calf muscles, with lesser activity in the glute and hamstrings. Based on the EMG data, **the primary movers are the calf and quadriceps muscles. Additionally, when we compare the calf and quad muscle activity from both legs, the right leg (i.e. the front leg) shows a greater amount of EMG activity than the left leg.**

The joint movement analysis based on the video data indicates that the greatest range of motion when powering the Rockboard occurs at the knee, particularly of the forward leg (i.e in this case the right knee). The forward knee moved through a 65-degree range of motion while the knee of the back

leg (i.e. the left knee) moved through a 45-degree range. The 41-degree range of motion of the hip joint for the forward leg was greater than the 25-degree range of motion for the hip of the back leg. Similar to the findings from the hip and knee, the ankle motion of the front leg was greater than the ankle of the rear leg (i.e. 44 degrees versus 26 degrees, respectively). These results coincide well with the EMG data in that the greatest amount of muscular activity was seen in front leg, particularly in the quadriceps, which is the muscle group responsible of extending (i.e. straightening out) the knee. Based on this information, a suggestion would be to have riders switch lead legs on a regular basis to balance any potential training effects from regular use of the Rockboard scooter.

Summary

The energy demands for powering the Rockboard scooter at slow (6 mph) to faster (10 mph) speeds range from 6.9 to 10.2 METs. The quadriceps femoris muscle group appears to be the most important prime mover when riding the scooter and is responsible for extending the knee which helps to press the foot board on the scooter in the downward direction for forward propulsion. There is also muscle activity in the calves and glutes but to a lesser extent than in the quads. Hamstring engagement is minimal. The findings from the biomechanical analysis support the EMG findings in that the greatest movement when powering the Rockboard occurs at the knee, particularly of the front leg. **In conclusion, these results indicate that powering the scooter requires significant muscle activity that can be classified as moderate to intense and is capable of eliciting fitness benefits if done on a regular basis.**

According to the American College of Sports Medicine (ACSM), it is recommended that children engage in at least 60 minutes of physical activity everyday of the week. If fat loss is a goal, then the number of calories expended during that physical activity should exceed 300 calories. Riding the Rockboard could certainly be a fun and effective option for helping to meet the ACSM's physical activity recommendation. In addition, the moderate to intense energy demands required to power the Rockboard certainly could exceed suggested 300 calories of physical exertion (e.g. only 30 minutes of continuously riding the scooter can burn anywhere from 245 calories at 6mph to 365 calories at 10mph). In conclusion, data support the use of the Rockboard scooter in helping children meet and/or exceed the ACSM recommendations for physical activity and weight loss in children.