ISB 2013 BRAZIL
24th CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS

MUSCLE SYNERGIES DURING 6 MINUTES MAXIMAL ROWING

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SUMMARY
Rowing is a physiologically intense sport which requires consistent and economically efficient strokes. Therefore, the muscles synergy is crucial to determine success in rowing either on ergometer or water. However, there is no studies have been done comparing the muscle synergy during rowing with and without slides system. Thus, the purpose of this study is to evaluate the muscle synergies during 6 minutes all out rowing with and without the slides. Nine physically active non-rower males participated in the study. Surface electromyography activity and kinematics patterns were recorded. Average power output, heart rate, stroke length and stroke rate were collected to evaluate the rowing performance. Electromyographic data were processed as recommended by seniam and time interpolated into rowing cycle. Principal component analysis with varimax rotation was applied to eight electromyographic patterns to identify muscle synergies. Results were compared between two conditions: rowing with the slides attached to the ergometer and without the slides. Three muscle synergies were sufficient to explain the majority of variance in both conditions. Rowing with slides emphasized on bi-articular muscles which explain significantly greater (p value < 0.05) rowing performance, indicated by increase in maximal heart rate, stroke rate, average power output, total distance covered and reduce stroke length compared to rowing without the slides. Rowing without slides relied heavily on trunk and upper limb muscles which caused early fatigue. The results proved the flexibility of muscle synergies to adapt to physiologically efficient technique in regards of mechanical constraint.

INTRODUCTION
Rowing is a unique power-endurance sport that involves whole body muscles. Rowing ergometers provide a viable alternative for training, evaluation and team selection in a controlled environment. It is also an extremely useful tool for the investigation of rowing physiology.

Concept II is the most used ergometer [1]. Besides, it has a close simulation of on-water rowing due to the air resistance system which generates the resistance increase proportionally to the increase of power input [2]. The resemblance was further enhanced by the slide system which allowing the ergometer to move in opposite direction of the rower as if displacing the boat [3].

There were only two studies that compare the effect of slides system on rowing physiology. They [3, 4] both used Concept II ergometer and observed increase of power output and stroke rates when rowing with slides. There were no other significant differences in physiological variables such as maximal heart rate, peak lactate concentration and peak VO_2 in both conditions.

It is well known that rowing is a physiologically demanding sport however another key aspect of rowing is strokes skill [5]. Thus, this is where muscle synergy plays an important role. In rowing, muscle synergy reduce the dimensionality at musculoskeletal level hence improve efficiency of rowing strokes as illustrated by [6]. They showed that the elite rowers adapt to bio compensation strategy to combat the effect of fatigue in 6 minutes all out rowing test. This strategy provides enough time for the fatiguing muscles to restore their energy while other muscles took over to maintain the same power output

Thus, the purpose of this study is to evaluate the muscle synergies during 6 minutes maximal intensity of rowing with and without the slides. We hypothesize that the number of synergies will be the same in both conditions due to robustness of neuromuscular control but with different loading coefficients on particular muscles.

METHODS
Nine physically active non-rower males were recruited (age: 26.8 ± 2 years, weight: 80.6 ± 11.5 kg, height: 1.8 ± 0.1 m). Each participant signed a written informed consent. All tests complied with the ethical code from University of Delaware IRB.

Each participant performed an identical protocol around the same time of day on a Concept II model D stationary and slide ergometer, separated by at least one week interval. Testing included: i) 5 min self-warm up and familiarization with the ergometer, ii) 6 min all-out test at self-pace, iii) 5 min self-cool down. The resistance of the ergometer was applied only during 6 min all-out test.

The muscle activity was recorded using wireless Noraxon Telemyo DTS. Eight rowing specific muscles were evaluated: gastrocnemius lateralis (GL), biceps femoris (BF), rectus femoris (RF), erector spinae (ES), lattisimus

dorsi (LD), brachioradialis (BR), triceps lateralis (Tri) and deltoid medius (DM). Electrode placement and preparation followed seniam recommendation. EMG signal were synchronized to kinematic data and processed following method by [7]. Then, Principal Component Analysis (PCA) was applied to extract the muscle synergies as following technique described by [8]. All significance value were set at $\alpha = 0.05$. All statistical tests were carried out in SPSS 20.

RESULTS AND DISCUSSION

Rowing performance during all out test was summarized in Table 1. High maximal heart rate, increase power output and stroke rate was observed while rowing on slides. However, stroke length was significantly less compared to rowing on stationary ergometer. The slide system improves the ergometer to glide which further shortened the recovery phase. The participants were able to achieve high power output at significantly high heart rate. This proves that rowing with slides is less fatiguing than rowing on stationary ergometer.

Inspection of muscle synergies revealed that the participants adapted to different strategy when rowing in two different mechanisms. For rowing with slides the synergies are consist of (Figure 1):
-Synergy 1: bi-articular muscles (RF, BF. GL)
-Synergy 2: upper limbs muscles (BR, Tri, DM)
-Synergy 3: trunk muscles (LD, ES)

Meanwhile, rowing without the slides used different synergies (Figure 2):
-Synergy 1: trunk and limbs muscles (GL, Tri, LD, ES)
-Synergy 2: upper limbs muscles (Br, DM)
-Synergy 3: thigh muscles (RF, BF)

Synergies were ranked with regards to their loadings which means synergy 1 contributed most than the other two synergies. It is physiologically efficient to emphasize on bi-articular muscles in order to maintain high power output during rowing.

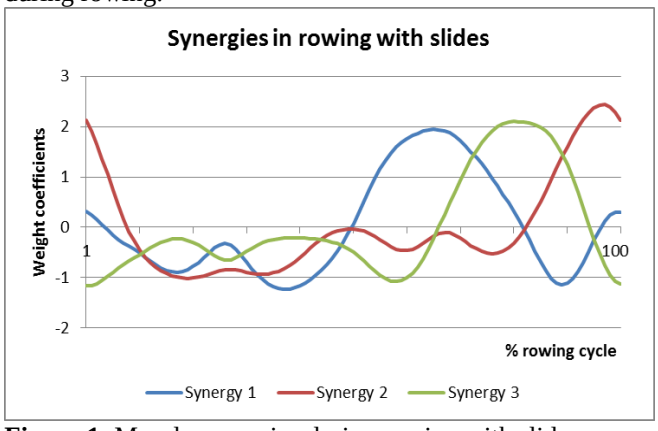

Figure 1: Muscle synergies during rowing with slides.

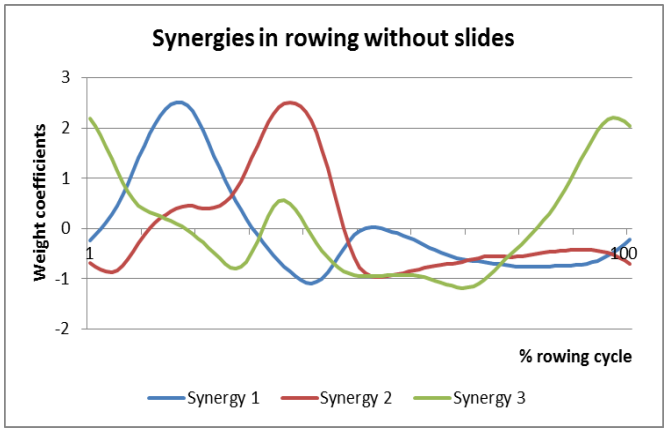

Figure 2: Rowing synergies during rowing without slides.

CONCLUSIONS

As a conclusion, rowing with slides utilized different synergies compared to rowing on stationary ergometer. By emphasizing on bi-articular muscles, participants were better adapted to high intensity of rowing.

ACKNOWLEDGEMENTS

The first author was funded by Ministry of Higher Education, Malaysia and University of Science, Malaysia.

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Table 1: Rowing performance on Concept II ergometer with and without slides attachment. (N = 9, *p* value < 0.05)

	Rowing with slides	Rowing without slides	*p* value
Maximal heart rate (bpm)	177 ± (8.1)	172 ± (6.5)	0.045
Stroke rate (strokes/ min)	38 ± (5.9)	30 ± (4.3)	0.001
Stroke length (meter/ strokes)	7 ± (1.7)	8 ± (1.6)	0.001
Power (Watt/ weight)	50 ± (13.6)	41 ± (11.3)	0.001