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INVESTIGATION OF ELECTROMYOGRAPHY OF MAJOR MUSCLE GROUPS WHILE HIKING OUT DURING SAILING ON BOTH LAND AND WATER

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The purpose of this study is to compare the Electromyographic (EMG) readings of muscle activation while hiking out on both land and water. This preliminary study aims to determine if there is a significant difference between EMG readings conducted in laboratory conditions as well as on water when the subject is hiking out while sailing. Muscle groups tested in this study were the *Rectus Femoris, Vastus Laterialis* and the *Tibialis Anterior*. EMG readings were taken and expressed as a percentage of the maximal voluntary contraction (MVC) baseline from the subject. The preliminary results of this study show that the RF muscles contribute more to hiking out than the VL muscles in the laboratory and at sea.

KEY WORDS: Laser sailing, EMG, hiking.

INTRODUCTION: Sailing is a dynamic sport that requires dynamic repeated movement of the body (Cunningham et al., 2007). This is achieved by hiking out, a process in which the upper half body of the sailor is outside and perpendicular to the deck of the sailboat. Hiking out is an essential part of sailing to balance the sailboat as well as to counteract the heeling forces generated by the sails (Tan et al., 2006). Poor hiking technique and inadequate leg strength are thought to predispose the knee to injury (Neville et al., 2009). Measurement of hiking technique is done in the lab with the help of a hiking bench or hiking simulator that replicates the dimensions of the deck of a Laser sailboat. This preliminary study aims to determine if there is a significant difference between Electromyography (EMG) readings conducted in laboratory conditions as well as on water when the subject is hiking out while sailing. This would allow us to determine if simulated hiking techniques on land are reflective of muscle activity of a sailor who is sailing out at sea.
Muscle groups tested in this study were the *Rectus Femoris, Vastus Laterialis* and the *Tibialis Anterior* (Vogiatzis et al., 1996). During hiking out on water, the lower half body of the sailor is used (Spurway N.C. et al 2007).

METHODS: A wireless EMG system (Trigno Wireless System, Delsys Inc., USA) with built-in motion artefact suppression connected to a laptop was used for both laboratory trials and water trials. The subject's skin was swabbed with alcohol wipes. Electrode placement on the muscles was according to Lin et al. (2008) and also according to the SENIAM Project (Knutson et al. 1994). EMG measurements were taken at 2000 Hertz, the default setting for the wireless EMG system. The subject is a 25-year-old male who has been sailing for 5 years and is physically fit. Prior to taking EMG readings, the purpose and methods of the work were explained to the subject.
Hiking posture in the laboratory is set at 140^0 for the quadricep muscles and 110^0 between the hip and the lower spine (Boyas et al., 2009). The subject was informed to adopt the same hiking posture while hiking out at sea. The subject was made to hike out for 180 seconds in the laboratory with verbal encouragement given by the investigators. Before hiking out, a maximal voluntary contraction test was carried out on the subject for both land and water trials for normalization purposes. There is a danger of misinterpreting the signal if the process is not carried out (Burden et al., 2010).
In other to waterproof the equipment for the water trials, Tegaderm Film 10 cm x 12 cm (3M Inc, USA) was used to secure the EMG electrodes to the subject's skin. The Tegaderm film

was then held by waterproof duct tape to the subject's body. To measure the motions of the boat, accelerometers were wrapped in re-sealable bags and secured with duct tape to various positions on the Laser sailboat. Accelerometers were placed on the bow, stern, starboard, and port side of the Laser sailboat as well as on the point of centre of gravity (60 cm from the daggerboard) of the Laser sailboat.
EMG muscle activity on water was determined by adopting methodology of Castagna et al. (2007). Subject was asked to sail upwind while hiking out and tests were carried out when wind speed did not vary by more than 20% to ensure accuracy. In between hiking tests, subject was given a break of 30 seconds for tacking maneuvers. Since a typical regatta lasts for 30 – 45 minutes, as such, we asked the subject to do successive hiking and tacking maneuvers for 30 minutes. The investigator followed closely behind the Laser sailboat together with the Wireless EMG system to ensure data can be captured properly. Instructions were communicated to the subject via a loud hailer on water to ensure he adhered to the experiment protocols.
The EMG readings for both land and water were acquired using EMG Works 3.7 Acquisition (Delsys Inc, USA) and processed by EMG Works Analysis 3.7 (Delsys Inc, USA) by first applying Butterworth high pass filter at a frequency of 20Hz for both MVC and normalization of experimental trials to reduce artefact noise (De Luca et al., 2010). The EMG readings were then processed by using the Root Mean Square function in order to compare EMG activity. In order to reduce measurement errors, Intrasubject coefficients of variation (ICV) was computed for each trial to determine reproducibility and precision of the experiment according to Knutson et al. (1994).

RESULTS AND DISCUSSION: The results from Table 1 shows the averaged MVC readings of the Quadriceps muscles done in the laboratory before the start of the static hiking test on the hiking bench. EMG readings were recorded in Volts and the first 3 seconds of an 8 second MVC test were omitted to ensure accuracy and consistency. For each test, the maximum EMG reading from the muscle group was taken and an average of the 3 tests were computed to obtain the final MVC. All usage of terms left and right are with reference to the anatomical left and anatomical right of the subject's body.

Table 1
Averaged MVC Readings from the subject's Rectus Femoris (RF) and Vastus Lateralis (VL) muscles in Volts

	Averaged MVC of Quadriceps (10^{-4} Volts)			
	Left RF	Left VL	Right RF	Right VL
EMG Reading	1.5271	4.591	2.311	3.027

Table 2 shows the percentage of MVC of muscles exerted by the subject on the static hiking bench. The average % MVC values of the subject in static hiking position are 23.29% MVC and 3.02% MVC for Left RF and Left VL and 6.89% MVC and 0.59% MVC for the Right RF and Right VL respectively. All values have been rounded to 4 significant figures.
We presume that the VL muscles play a small role during hiking out as compared to the RF muscles on a hiking bench as they produce lower percentage maximal voluntary contraction as shown in Table 2.
Data from our first water trials also confirmed the above observation. The EMG readings from the water trials shows that the Left RF and Left VL displayed 15.35% and 1.03% MVC respectively while the Right RF and Right VL displayed 5.05% and 0.78% MVC respectively. For ease of comparison, we have presented the results in Figure 1.
We can see from Figure 1 that except for the Right VL muscle group, muscle activation in the Left RF, Left VL and Right RF appears to be higher on land as compared to water trials. We propose that the lower water trial % MVC might be due to fatigue from the muscle as the data was averaged out across the 6 bouts of 180 seconds of tacking and hiking out

conducted at sea. Also, temperature might also play a part in muscle activation, as the laboratory was air-conditioned whereas the temperature out at sea was around 28-30 Degrees Celsius. However, this might not provide a full picture as accelerometer data from the water trials are still being analysed.

Table 2
Percentage of maximal voluntary contraction of various muscle groups during sustained static hiking out on hiking bench for 180 seconds

	Average EMG (10^{-4} Volts)	% MVC
Trial 1		
Left RF	0.3360	22.00%
Left VL	0.1615	3.52%
Right RF	0.1449	6.27%
Right VL	0.0201	0.66%
Trial 2		
Left RF	0.3754	24.58%
Left VL	0.1157	2.52%
Right RF	0.1733	7.50%
Right VL	0.0156	0.51%

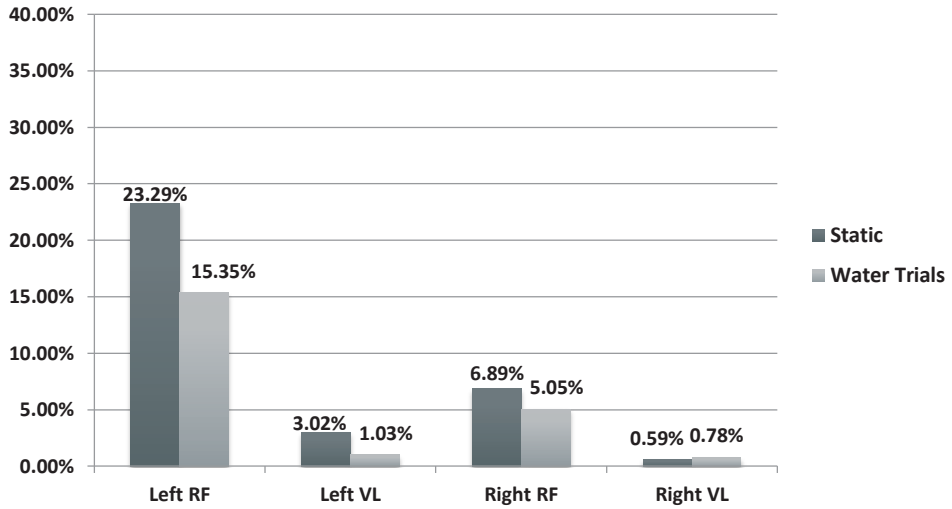

Figure 1: Comparison of %MVC for both on the static hiking bench and water trials.

Our water trials faced many difficulties such as the subject was unable to hike out continuously for 180 seconds due to the gusty winds in the Straits of Singapore. Average wind speeds were between 9-11 knots from Northeast. Also, due to the monsoon season, we experienced varying weather conditions that hampered data collection.

CONCLUSIONS: The EMG data was collected from both dynamic hiking on-water and static hiking in the laboratory. The preliminary results of this study show that the RF muscles contribute more to hiking out than the VL muscles in the laboratory. However, out at sea, both muscle groups seem to have an equal effect on the success of keeping the sailboat level. Also, muscle activation depends on which side of the boat the sailor is hiking out from, either the starboard side or port side of the boat. The data analysis is still on-going, more analysis results will be published after the analysis is completed.

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