LEVELS OF MUSCLE ACTIVATION IN STRENGTH AND CONDITIONING EXERCISES AND DYNAMOMETER HIKING IN JUNIOR SAILORS

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This study recruited 29 (17 male and 12 female) high-level Byte class sailors aged 14-16 years to examine the average levels of muscle activation in lower limb and trunk muscles in four selected strength and conditioning exercises (leg extension, back squat and back extension exercises, a 30-second hiking hold) and a maximal three-minute hiking test (HM_{180}). Results revealed that between-phase differences existed in the exercises examined. The level of muscle activation for the vastus lateralis for the leg extension exercise was shown to be comparable to that recorded during the back squat. Further, these exercises produced greater amounts of muscle activation when compared to those recorded during the HM_{180} test. Finally, the hiking hold produced greater levels of rectus abdominus activation when compared to the HM_{180} test.

KEYWORDS: sailing, strength and conditioning, EMG

INTRODUCTION: Olympic sailing is typically of an hour's duration and involves sailing 7-11 legs around marker buoys. Due to the unique physical demands of the sport, Olympic sailors are known to have well-developed levels of strength and strength endurance (Larsson et al., 1996). This may also be the case for the "Byte" class which has been selected as the single-handed class for the 2010 Youth Olympic Games. One of the reasons that strength and strength-endurance is well developed in Olympic sailors is due to a manoeuvre called "hiking". Hiking is considered as the most demanding aspect of Olympic class sailing (Larsson et al., 1996). Two hiking positions are typically adopted in Olympic sailing and these include; the short hiking position, where the trunk is kept rigid whilst the knees and hips are flexed and the long hiking position, where the trunk, hips and knees are relatively extended. These postures can be performed either statically or dynamically. The purpose of the sailor adopting a hiking position is to keep the sailing dinghy upright. This is done by counterbalancing the forces generated by the wind on the sail (termed the heeling force) through developing a "righting moment". Important muscles/muscle groups in hiking are thought to include: the medial quadriceps, hamstrings, paraspinal muscles and the abdominals (eg. Larsson et al., 1996; Tan et al., 2006).

It is of importance for sailors to keep themselves injury free whilst maximizing performance. This is especially important for juniors who form the competitive base of the sport and who have the potential to be the next generation of elite athletes. Therefore, more should be understood about the training practices in sailors. For instance, further information could be made available on the demands of hiking in relation to the strength and conditioning exercises that are commonly prescribed in this sport. Collecting biomechanical data in an aquatic and windswept environment is challenging, therefore collection of sport-specific data in a controlled laboratory environment can be justified. To this end, hiking performance has been assessed using a customised hiking dynamometer (Tan et al., 2006). These authors found that maximal hiking performance measured over a three-minute period (the so-called HM_{180} test), was associated with better results in a race.

The purpose of this study was to examine the levels of muscle activation in lower limb and trunk muscles in four selected strength and conditioning exercises and the HM_{180} test. This study was undertaken in 14-16 year old high-level Byte class sailors from Singapore.

METHODS: A total of 29 high-level Byte class sailors aged 14-16 years were recruited from the Singapore National Byte Class Training Squad (n=12, 8 males, 4 females) and the Singapore Byte Class High Participation Group (n=17, 9 males, 8 females). Males were of age 14.1 ± 0.7 years, height 167.8 ± 4.5 cms and mass 55.5 ± 7.7 kg and females were of age 14.3 ± 1.0 years, height 158.6 ± 6.8 cms and mass 51.1 ± 10.0 kg. Ethical approval was obtained from the relevant Institutional Human Research Ethics Committees to conduct the study.

This study involved two testing sessions separated by at least 72 hours. In the first session, participants underwent a six repetition maximum (6RM) strength test for two exercises (back squats and leg extension). The purpose of this session was to set the exercise intensity for these exercises in the second session. Participants from the National Byte Class Training Squad had a minimum of six months resistance training experience, whilst the Byte Class High Participation Group had no structured resistance training experience prior to participation in this study. However, prior to strength testing, the latter group were provided with sufficient familiarisation to both these exercises. Average (± SD) 6RM values were 59.1 ± 17.3 kg and 40.8 ± 13.1 kg for leg extension, and 47.5 ± 15.7 kg and 32.3 ± 12.6 kg for the back squat for males and females participants respectively.

The second testing session involved collecting electromyography (EMG) signals from selected lower limb and trunk muscles whilst participants performed four strength and conditioning exercises used to train junior sailors (leg extension, back squat, back extension, 30 second isometric hiking hold-long hiking position). The mass lifted during the leg extension and back squat exercises was the value recorded for the 6RM strength test. Three sets of each exercise were performed with three repetitions (except the hiking hold as it is a long duration isometric exercise). All relevant exercises and were carried out with a 2-1-2 tempo. These sets were completed in a randomized order to prevent any ordering effect and a three minute rest period was provided between sets to minimise the effect of fatigue. Participants then performed the HM_{180} test (Tan et al., 2006). In this test, participants were requested to hike maximally for the duration of the test on a hiking bench customised to the Byte class. Participants were allowed to adopt long or short hiking postures, jerk, crouch, or alternate their body weight on either leg however, during 30-second analysis periods (see below) long hiking postures were adopted (see below for further details). Whilst performing the abovementioned tasks, EMG signals were collected bilaterally from four muscles (rectus abdominus, superficial lumbar multifidus, vastus lateralis, and biceps femoris) using a portable ME3000 P8 data logger (Mega Electronics®, Kuopio, Finland) operating at 1000 Hz. To identify eccentric and concentric phases (where necessary) during data collection, participants were also filmed using a standard video camera. From this footage and the use of a triggered LED, the timing of the eccentric and concentric phases was determined. For the purpose of EMG data normalisation, participants also performed a series of maximum voluntary isometric contractions (MVICs). Participants performed three, five-second efforts for rectus abdominus and superficial lumbar mulifidus (Dankaerts et al., 2004), vastus lateralis (Lin et al., 2008) and biceps femoris (Mohr et al., 1998).

The muscles of interest for EMG analysis included; back extension (biceps femoris, lumbar multifidus), back squat (bicep femoris lumbar multifidus, vastus lateralis), leg extension (vastus lateralis), isometric hold (rectus abdominus) and the HM_{180} test (rectus abdominus and vastus lateralis). To quantify the level of muscle activation, raw EMG data were demeaned, full-wave rectified and low pass filtered at 4 Hz using a second order Butterworth filter to produce a linear envelope. The MVIC value for each muscle was considered as the greatest mean value recorded for a 200 msec window of the linear envelope measured in any of the three MVIC trials for each muscle. EMG data for the concentric and eccentric phases were then time normalized (0-100%) using cubic spline interpolation and the ensemble average of the three repetitions was calculated. The mean level of muscle activation was then calculated for each muscle of interest for each exercise. For the hiking hold, the mean level of muscle activation was calculated between the 10-15 second period for the hiking hold whilst for the HM_{180} test, the mean level of muscle activation was

calculated between 30-60 seconds, 90-120 seconds and 150-180 second periods. Analyses were conducted with customised software.
To determine between-set reliability for the level of muscle activation, intra-class correlation coefficients (ICC's) were calculated. Three-way ANOVA's with repeated measures with two between-group variables (muscle side, gender) and one repeated measures variable (exercise – which included when appropriate; the strength and conditioning exercises, the concentric/eccentric phases of these exercises and the three periods of the HM_{180} test) were performed for each muscle. Post-hoc analysis with particular emphasis on between-phase differences and between-exercise differences were performed using Least Significant Differences approach. Statistical analysis was performed using SPSS V17.0 for Windows (SPSS Inc, Seattle, WA, USA) with the alpha level set at 0.05.

RESULTS AND DISCUSSION: As all variables showed excellent reliability (ICC values>0.750), data from three sets were averaged for subsequent analysis. Levels of muscle activation for each muscle for the four strength and conditioning exercises and the three HM_{180} test periods are presented in Tables 1 and 2 respectively. Data in these tables have been pooled as there were no between-side or between-gender differences. Significant effects were found for all repeated measures conditions for each muscle ($p<0.001$).

Table 1. Mean (SD) level of muscle of activation (%MVIC) for muscles of interest. Data are presented for eccentric (ECC) and concentric (CON) phases where appropriate. The hiking hold exercise was isometric (ISO) in nature. Relevant post-hoc analysis results are included.

	Leg Extension		**Back Squat**		**Back Extension**		**Hiking Hold**
	ECC	CON	ECC	CON	ECC	CON	ISO
Biceps Femoris.			31.0* (11.2)	15.2 (5.7)	21.7* (8.4)	34.1 (10.8)	
Lumbar Multifidus			37.7* (11.2)	51.4 (14.6)	24.6* (7.8)	46.1 (16.0)	
Vastus Lateralis	38.9* (12.4)	58.8 (19.5)	37.7* (11.5)	54.0 (17.0)			16.7** (7.1)
Rectus Abdominus							45.3 (22.5)

*Indicates the ECC phase of the exercise was significantly different ($p<0.05$) to the CON phase.
**Indicates significantly different ($p<0.05$) when compared to all conditions for this muscle in this table.

Table 2. Mean (SD) level of muscle of activation (%MVIC) for muscles of interest during the three, 30-second periods during the HM_{180} test.

	30-60 sec	**90-120 sec**	**150-180 sec**
Lumbar Multifidus	7.2^,+ (5.3)	7.1^,+ (5.8)	15.6^ (13.0)
Vastus Lateralis	26.5^ (10.3)	22.8^,+,# (9.1)	26.4^ (10.0)
Rectus Abdominus	32.4^ (26.8)	25.2^,# (19.3)	29.3^ (19.5)

^Indicates significantly different ($p<0.05$) when compared to all conditions in Table 1 for this muscle.
+Indicates significantly different ($p<0.05$) when compared to the 150-180 sec condition.
# Indicates significantly different ($p<0.05$) when compared to the 30-60 sec condition.

With an increasing focus being placed on evidence-based practice in exercise and sport science, the quantification of muscle activation in training activities (such as strength and conditioning exercises) and target skills (such as the HM_{180}) test is warranted. In this study there were a number of findings that have practical application.

Firstly, there were numerous significant differences evident between the three periods analysed during the HM_{180} test and the strength and conditioning exercises. These differences in the level of muscle activation clearly showed that the strength and conditioning exercises examined in this study clearly overload the HM_{180} test. There were also several significant findings between the concentric and eccentric phases of each strength and conditioning exercise which was to be expected.

Secondly, whilst not evaluated via statistical analysis, one surprising finding of the study was that the superficial lumbar multifidus showed comparable levels of activation to those reported for the vastus lateralis in the back squat. Also, there were comparable levels of muscle activation in the concentric phase of the back squat and the back extension exercises for this muscle. This may suggest a possible technique problem. The back squat is an exercise that is used to primarily strengthen the quadriceps and the gluteals. Whilst the angle of the trunk was not determined in this study, the superficial lumbar multifidus may have been required to activate more than necessary as the trunk may have displayed excessive flexion in the back squat. In junior athletes, whilst performance can be improved through resistance training, this should not be at the expense of exercise technique. Faulty squatting technique has the potential to expose the athlete's passive structures of the lumbar spine to excessive load.

Thirdly, the vastus lateralis showed similar levels of muscle activation in the leg extension exercise as the back squat, and this may indicate that leg extensions can be used to strengthen the quadriceps whilst squatting technique is developed.

Limitations of this study included; hiking performance was measured on a hiking bench rather than on-water therefore, this study has reduced ecological validity. Further, muscle activation is dependent upon the weight lifted therefore, generalisation of activation levels to lower weight - higher repetition work have different repercussions.

CONCLUSIONS: Leg extension may be an appropriate exercise to increase quadriceps strength in the early phase of strength development whilst squatting technique is refined. Both the leg extension and back squat are capable of providing an overload stimulus for the HM_{180} test. Likewise, the hiking hold can overload the rectus abdominus in the HM_{180} test.

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