ACTIVATION AND CONTRIBUTION OF TRUNK AND LEG MUSCULATURE TO FORCE PRODUCTION DURING ON-WATER SPRINT KAYAK PERFORMANCE.

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Velocity production during sprint kayaking has been shown to be dependent on the magnitude of forces produced during the stroke cycle. However, while the importance of the upper body in force production has been promoted by previous research, the importance of the trunk and lower body are yet to be established. Eight international level paddlers completed 5 on-water sprint trials during which paddle force and trunk and leg muscle activations were recorded. Significant correlations ($p<0.05$) were identified between peak force and peak contralateral rectus abdominus activation, while the left external oblique demonstrated significant correlations ($p<0.05$) with peak and mean force during both left and right paddle strokes. Results indentify that the lower trunk plays an important role in force production and therefore sprint performance.

KEYWORDS: Electromyography, Kayaking, Force production

INTRODUCTION: Propulsion during sprint kayaking is dependent on the magnitude of the force that can be developed during the paddle stroke (Mononen *et al*., 1994; Mononen and Viitasalo, 1995). Petrone *et al*. (2006) recorded peak force values ranging between 253 N and 465 N, while other researchers have commonly recorded peak force values above 200 N (Mononen *et al*., 1994; Mononen and Viitasalo, 1995). Despite the clear importance of force, the majority of previous technique research has focused upon the positioning and motions of the upper limbs and as such suggested these to be key in kayak propulsion. However, the magnitude of the forces required during a single paddle stroke and the high stroke rates exhibited (60-70 spm) would result in extreme demands being placed upon the small muscles of the upper limbs. Therefore investigations of other muscles with possible contributions to propulsion are required. Furthermore, Lovell and Lauder (2001) identified, through maximal on-ergometer testing, that bilateral strength imbalances are prevalent in kayakers, predisposing athletes to injury. Whilst Aitken and Neal (1992) and Mononen and Viitasalo (1995) further identified bilateral asymmetry in force production during on-water paddling.

Asymmetries although well established within the arena of force production are yet to be established in the activation levels of muscles during kayaking. Previous work has clearly overlooked this factor with the only on-water study measuring muscular activation being collected from the musculature on a single side athlete (Fleming *et al*. 2007). A bilateral analysis has been conducted on-ergometer (Logan and Holt, 1985). However, only basic sequencing data has been presented, with theories put forward sugg*esting* that the role of the upper limbs is to ensure correct orientation of the paddle whilst large unspecified muscles provide the majority of the propulsive work. Consequently, the lack of empirical findings limits the validity of these claims until such research is conducted to corroborate such propositions. Resultantly, this paper will investigate the activations of the large muscles of the legs and trunk, in accordance with the teachings of Kemecsey (1986) and the on-ergometer findings of Logan and Holt (1985), focusing on their contributions to force production. Furthermore, this analysis will be deconstructed into left and right paddle strokes in accordance with the asymmetrical findings of previous research.

METHOD: Eight male (n=6) and female (n=2) international level paddlers participated after completing informed consent and health questionnaires. Subjects were prepared with Blue Sensor passive surface electrodes over the muscle belly of the latissimus dorsi (LD), rectus abdominus (RA), external oblique (EXO), rectus femoris (RF), biceps femoris (BF) and gastrocnemius (G) on both left (L) and right (R) sides. Each subject used their own paddle with bespoke strain gauges (Sperlich and Sperlich, Germany) mounted perpendicular to the blade. Prior to testing, maximal voluntary contractions (MVC) and force calibration were conducted to normalise all data. Each subject completed 5 trials over a 75m distance, comprising of a 50m acceleration sector, 5m calibrated volume and 20m run off. Data was analysed using Myodat v6.47 and Sportlogger software, from which peak RMS EMG for each muscle, and peak and mean force were calculated for each stroke within the 5m calibrated volume. Paired samples t-tests were conducted to compare peak and mean values during left and right strokes, while correlations and linear regressions between peak activation and force were used to determine relationships between propulsive force and muscle activation.

RESULTS: Comparison of force production identified a significantly higher mean force (MF) during the left stroke (Left: 239.9 N; Right: 208.3 N, $p<0.05$), while peak force (PF) and loading rate (LR) displayed no difference (Table 1).

Table 1. Intra stroke performance descriptives of paddle force.

	Left Stroke	Right Stroke
Mean Force (N)	239.9±13.6*	208.3±17.4*
Peak Force (N)	365.1±24.7	343.6±43.1
Loading Rate ($N.s^{-1}$)	2062.3±369.7	1880.3±347.5

*** denotes significant difference (p<0.05) between left and right strokes.**

Significant differences in peak activation between left and right stroke were identified in the left and right latissimus dorsi alone (Figure 1). Peak left (r = 0.680) and right (r = 0.855) rectus abdominus activation during the left stroke exhibited significant positive relationships with mean force (p<0.05). The right rectus abdominus also displayed a significant predictive relationship with mean force (R^2 = 0.731, $p<0.05$) and a significant positive relationship (r = 0.651, $p<0.05$) with peak force production during the left stroke. The left external oblique displayed significant positive relationships with both mean (r = 0.801, $p<0.05$) and peak (r = 0.798, $p<0.05$) force during the left paddle stroke. The right stroke was characterised by significant positive relationships between mean and peak force and the left external oblique (MF: r = 0.663, PF: r = 0.643, $p<0.05$) and rectus abdominus (MF: r = 0.944; PF: r = 0.955, $p<0.05$) (Table 2).

DISCUSSION: The significant difference identified between left and right paddle strokes within mean force corroborates the findings of previous researchers (Aitken and Neal, 1992; Mononen and Viitasalo, 1995; and Lovell and Lauder, 2001).Thus, indicating a clear dependence on the left stroke in this group of subjects; this raises the question of handedness, although this data was not recorded. However, as a propulsive mechanism this would only affect lateral motion of the kayak if the positioning of the blade does not apply the force in the appropriate direction. Furthermore, the clear activation of the rectus abdominus and rectus femoris holding the lower trunk and ipsilateral leg in a braced position would aid in ensuring that the force be directed longitudinally down the kayak in the intended direction of travel. As such, the variation between sides although significant is not necessarily detrimental to performance; this imbalance may, however, predispose athletes to injury (Lovell and Lauder, 2001).

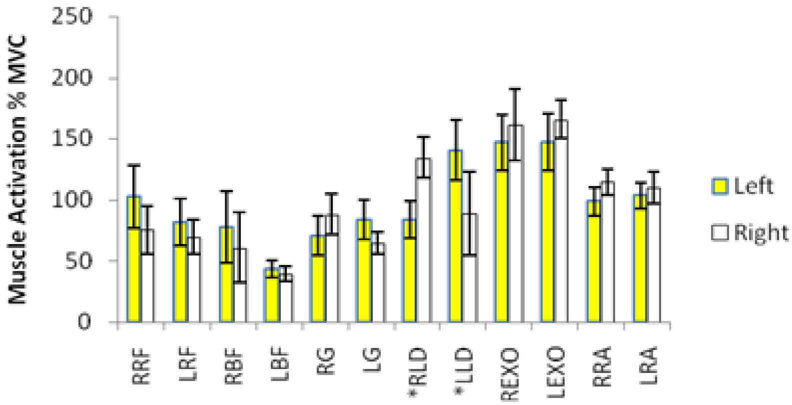

Figure 1. Comparison of peak muscle activation during the left and right paddle strokes. * depicts significant difference between left and right stroke.

The significant difference in peak activation of the latissimus dorsi during left and right strokes was characterised by higher activation in the ipsilateral muscle. This indicates the clear importance of the ipsilateral latissimus dorsi within the stroke, reinforcing the findings of Logan and Holt (1985). Correlation analysis did not, however, support this finding, indicating that the muscles of the lower abdomen were more important in the production of force. The contralateral rectus abdominus displayed significant predictive relationships with mean force during both strokes and peak force during the right stroke. Thus indicating an isometric role within the lower trunk as a stable platform against which propulsive force is developed, in what is a largely instable competitive environment.

Table 2. Correlation Results between muscular activations and force production during the left and right paddle strokes.

Muscle	Left Stroke		Right Stroke	
	Mean Force	Peak Force	Mean Force	Peak Force
Right Rectus Femoris	0.570	0.516	0.228	0.352
Left Rectus Femoris	0.323	0.431	0.719*	0.806*
Right Biceps Femoris	-0.397	-0.489	-0.384	-0.178
Left Biceps Femoris	0.042	0.390	-0.376	-0.394
Right Gastrocnemius	0.698*	0.477	0.196	0.289
Left Gastrocnemius	-0.580	-0.812*	0.270	0.197
Right Latissimus Dorsi	0.396	0.564	0.589	0.576
Left Latissimus Dorsi	0.429	0.408	-0.452	-0.346
Right External Oblique	0.249	0.143	0.439	0.442
Left External Oblique	0.801*	0.798*	0.663*	0.643*
Right Rectus Abdominus	0.855*	0.651*	0.242	0.214
Left Rectus Abdominus	0.680*	0.471	0.944*	0.955*

*** denotes significant correlation ($p<0.05$)**

The strong significant relationships displayed by the left external oblique with mean and peak force during left stroke (Table 2) would indicate a rotatory contribution from the muscle. Thus allowing the paddle to spend a greater duration of the stroke in contact with the water and providing greater opportunity for production of propulsive force. However, further significant relationships during the right stroke indicate a similar role to that of the rectus abdominus during the contralateral paddle stroke. This would, therefore, suggest an important role throughout the entire paddle stroke for the external oblique. However, the right external oblique displayed no significant relationships during either stroke or with either peak or mean force; although correlations were higher during the ipslateral paddle stroke (MF: 0.439, PF: 0.442, $p>0.05$). Therefore, the role of the external oblique during paddling appears to be

increasing the duration that the paddle is in contact with the water, whilst having a lesser emphasis on the production of propulsive force.
Finally, significant positive correlations were exhibited between the left rectus femoris and peak and mean force during the right paddle stroke, suggesting that the contralateral leg has an important role in force production as the hip and knee flex. Despite this relationship and the high level of ipsilateral rectus femoris activation (>80% MVC) suggesting that the lower limbs would also contribute to providing this stable base for force production, the contribution of the thigh musculature to propulsive force production during the kayak stroke has no statistical support and as such cannot be ascertained without further investigation.

CONCLUSION: Findings indicate that the musculature of the trunk and legs demonstrate clear activation throughout the paddling cycle. However, it is the muscles of the lower abdomen, namely the contralateral rectus abdominus, that have exhibited clear relationships with force output and as such are fundamental in the production of propulsive force. Furthermore, the activation of the ipsilateral latissimus dorsi has been shown to be significantly higher than the contralateral latissimus dorsi; although regression analysis displayed no significant relationship with force production. Therefore in addition to the traditional on-land resistance training, emphasis should also be placed upon recreating the instable conditions experienced on-water, to improve isometric strength of the lower abdomen in preparation for competitive performance.

REFERENCES:

Aitken, D.A., and Neal, R.J. (1992) An on-water analysis system for Quantifying Stroke Force Characteristics During Kayak Events. *International Journal of Sport Biomechanics*, 8, 165-173.

Fleming, N., Donne, B., and Mahony, N. (2007). Electromyographic and kinesiological analysis of the kayak stroke: comparison of on-water and on-ergometer data across exercise intensity. In J. Kallio, P.V. Komi, J. Komulainen, J. Avela (Eds.), *Proceedings of the 12th Annual Congress of the European College of Sports Sciences,* (pp. 177). Jyvaskyla: Otavan Kirjapaino Oy, Keuruu, Finland.

Kemecsey, I. (1986) Theory and Methodology of Kayaking, Unpublished Manuscript. Personal communication from British Canoe Union, Holme Pierrepont, Nottingham, UK.

Logan, S.M., and Holt, L.E. (1985). The flatwater kayak stroke. *National Strength and Conditioning Association journal*, 7(5), 4-11.

Lovell, G., and Lauder, M. (2001). Bilateral Strength Comparisons Among Injured and Noninjured Competitive Flatwater Kayakers. *Journal of Sports Rehabilitations,* 10, 3-10.

Mononen, H.V., Kolehmainen, E., Salonen, M., and Viitasalo, J.T. (1994). Paddle Force Characteristics During 200m Kayaking. *International Congress on Applied Research in Sport*, 151-155.

Mononen, H.V. and Viitasalo, J.T. (1995). Stroke Parameters and Kayak Speed During 200m Kayaking. *Congress of the International Society of Biomechanics*, 632-633.

Petrone, N., Isotti, A., and Guerrini, G. (2006). Biomechanical Analysis of Olympic Kayak Athletes During Indoor Paddling. *International Conference on the Engineering of Sport*. 9(2), 413-418.