ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

ON WATER PERFORMANCE RELATED BIOMECHANICAL MESURMENTS FOR FLAT WATER KAYAKING.

[1]Julia Fisher, [1]David Karpul, [1]Nicholas Tam, [1]Ross Tucker and [1]Timothy Noakes
[1]UCT/MRC Research Unit for Exercise Science and Sports Medicine, Department of Human Biology, Faculty of Health Sciences, University of Cape Town, email: Julia.thomas@myuct.ac.za

SUMMARY
Traditionally performance testing for flat water kayaking has been performed off the water, on a kayak ergometer under laboratory conditions. This situation does not take into consideration the athlete, paddle, and boat's interaction with the water. The unstable environment on the water creates a complex task where co ordination of muscle recruitment, weight distribution and movement is required to maintain balance, while optimizing blade force through the water. This study used novel biomechanical measurements and calculations on the water to measure performance of flat water kayaking.

INTRODUCTION
In flat water kayaking athletes use a paddle with a blade on each end, in an alternate cyclic motion, to repeatedly apply force to the water, resulting in forward movement of the athlete and boat through the water [6]. When there is no paddle in the water, the boat is slowed by aerodynamic and hydrodynamic drag [6, 1].

The forces that contribute to the resultant movement of the kayak are gravitational, buoyancy, total resistance (aero and hydrodynamics drag) and paddle force [1]. In order to improve performance in kayaking, a kayaker needs to maximise his/her mean velocity, either by decreasing the deceleration of the kayak or by increasing acceleration in the direction of the kayak's movement.

Performance testing of a kayaker is commonly performed in a laboratory on a kayak ergometer. There have been studies that validate ergometer performances to be similar to the water using performance times and cadiovasular measurements [4] however, many another study shows biomechanical differences using electromyography [5]. The literature does state that boats react to paddle stokes with movement in three planes [6, 2], however no one has objectively been able to relate this to performance.

The purpose of this study was to analyse kayak performance on the water using accessible, reliable, objective, multi planar biomechanical measures.

METHODS
Eight flat water kayakers consisting of national level marathon paddlers (n = 6) and club level paddlers (n=2) performed maximal time trials in the same boat over the same stretch of water, approximately 180 meters long. All trials were performed in similar environmental conditions; wind speed, air temperature, humidity and water depth were all recorded. An accelerometer Minimax B4 (Catapult, Australia) was placed in a standardised position in the center of the back deck of the boat and a custom instrumented paddle, with a strain gauges at each end of the paddle shaft, was used. The paddle length and feather was self selected. The accelerometer measured the forward acceleration, the degree of the boats' side dips (roll) and the degree the nose lifts out and sinks into the water (pitch, each of these were measured per stroke.

The strain gauges on the paddle shaft were normalized to known weights, and has been reported as units of torque (N.m). The time integral of paddle force per pull was used for all calculations and is depicted in Figure 1 below as the shaded area.

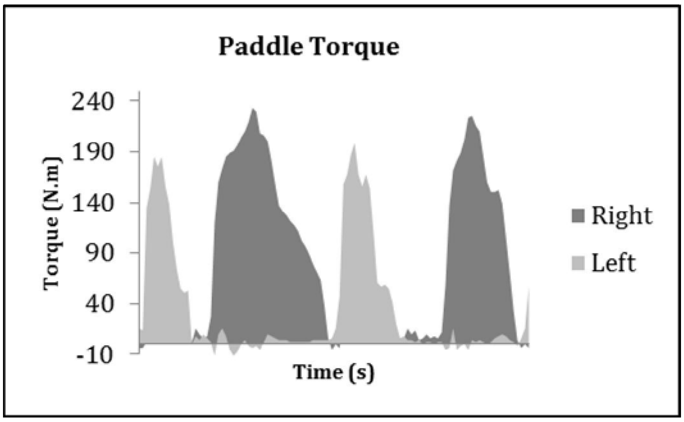

Figure 1: Four consecutive strokes showing the magnitude of the torque measured by the strain gauges on the instrumented paddle. The shaded area per stroke represents a summary variable for the amount of force applied by the paddler.

The acceleration was also reported on as an integral and is graphically shown in Figure 2 as the shaded area. The pitch and roll were reported as absolute values so as not to distinguish between left and right. The average pitch and roll were used for all calculations.

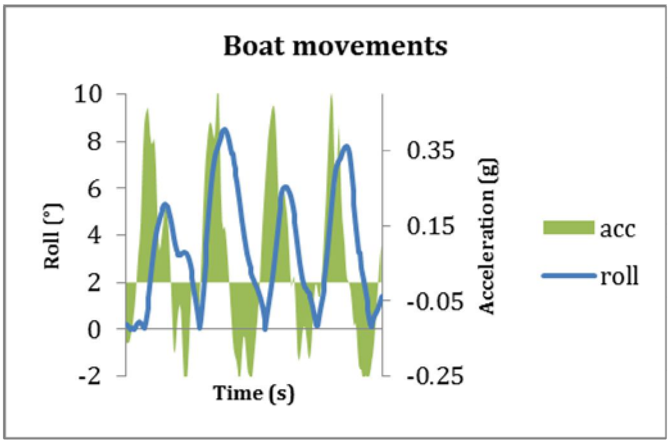

Figure 2: Four consecutive stokes showing the boat's forward acceleration and absolute roll.

Efficiency was defined for each trial as the ratio of the integral acceleration to the integral torque. While this is not the strict definition of mechanical efficiency, it is an indication of how effort on the paddle translates into net boat movement. Linear regressions between measured and calculated variables were used to determine relationships.

RESULTS AND DISCUSSION

There were significant negative relationships found between performance with both the paddle torque and the boat acceleration ($P < 0.01$, $r^2 = 0.76$ and $P = 0.02$, $r^2 = 0.64$, respectively). Since performance is regarded as a reduction in total time, a negative correlation implies a contribution to improved performance. Performance time also had significant negative relationships with the boats' pitch and roll ($P = 0.03$, $r^2 = 0.56$ and $P = 0.05$, $r^2 = 0.51$, respectively).

The subjects with faster performance times were paddling with greater paddle torque and forward acceleration per stroke, while their boats' accessory movements were also larger. The increased boat movements could suggest greater pedalling motion of the legs and trunk rotation, which has previously been found to increase paddling performance [1, 3]. However Brown et al. [1] also noted that international sprint kayakers, who require maximal efficiency, had less boat accessory movements compared to national and club level paddlers.

The calculated efficiency had a significant negative relationship with performance time ($P = 0.02$, $r^2 = 0.61$).

Paddle torque and forward acceleration were found to have strong significant relationships with efficiency ($P < 0.01$, $r^2 = 0.85$ and $P < 0.01$, $r^2 = 0.93$, respectively).

When pitch and roll were analysed against efficiency, the relationships were not found to be significant for this group of athletes ($P = 0.08$, $r^2 = 0.41$ and $P = 0.14$, $r^2 = 0.32$, respectively), although the pitch did tend towards significance. A larger sample size is needed to establish these relationships with more certainty, and whether these relationships are linear.

CONCLUSIONS

Kayak performance was found to be significantly related to paddle torque, boat forward acceleration, boat roll and pitch as well as efficiency.

Novel multi planar measurements of the kayak coupled with paddle torque data allows for greater in-depth performance analysis of kayaking. This gives advantages over the laboratory setting as the complex co ordination of the athlete with the boat and paddle in the water can better be understood and monitored. It opens possibilities for greater athlete and coach education on technique that is objective and performance orientated.

REFERENCES

1. Begon M, et al., *A method of providing accurate velocity feedback of performance on an instrumented kayak ergometer.* Sports Engineering, **11**, 57-65, 2009.
2. Begon M, et al., *Lower limb contributionin kayaking performance: modeling, simulation and analysis.* Mulitbody Systems Dynamics, **23**, 387- 400, 2010.
3. Brown M, et al., *Notational analysis of sprint kayaking: Differentiating between ability levels.* International Journal of Performance Analysis in Sport, **11(1)**, 171-183, 2011.
4. De Campos M, et al., *Energy systems contributions in 2000m race simulation*, European Journal of Applied Physiology, **107**, 615 – 619, 2009.
5. Fleming N, et al., *A biomechanical assessment of ergometer task specificity in elite flat water kayakers.* Journal of Sports Science and Medicine, **11**, 16 – 25, 2012.
6. Mann, R. & Kearney, J., *A biomechanical analysis of the Olympic-style flawater kayak stroke.* Medicine and Science in Sports and Exercise, **12(3)**, 183-188, 1980.