# THE EFFECT OF BUNGEE TENSION ON POWER PROFILING IN KAYAK ERGOMETRY

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In water sports, where accurate biomechanical measurement in situ is difficult, ergometers are frequently used to test athletes. Many kayak ergometer designs involve a bungee to assist in returning the athlete/paddle to the correct position for the next stroke. The study's aim was to investigate the effect of bungee tension on the ergometer-measured maximal power-velocity profile of three experienced male kayak athletes. Bungee tension influenced the power-velocity profile, reducing peak power measured by up to 328.4 W from optimal to least optimal tension. Athlete's anecdotally preferred feel tensions may be optimal, thus these tensions should be considered in investigating power-related factors.

**KEYWORDS**: Power-Velocity, Force Measurement.

**INTRODUCTION**: Ergometers are used frequently in water-based sports, when environmental conditions might preclude on-water activity for training, rehabilitation or scientific analysis. They enable the quantification of variables which would be difficult to measure on water and therefore are a valuable tool for improving our understanding of kayaking, improving performance and reducing injury risk.

All commercially available kayak ergometers have some form of elastic bungee, used to return either the paddle and rope or trolley system to the original position during recovery. In training environments, this is typically set according to the athlete's wishes, based on how the stroke "feels". Too low a tension and the rope will not retract sufficiently, causing the rope to be lax and therefore the power applied at the beginning of the stroke will act to first extend the rope and will not be quantified through flywheel measurement. If the tension is too high, however, the bungee force will increase according to its spring characteristics before the end of the stroke, meaning much of the athlete's applied power is absorbed in stretching the bungee rather than rotating the flywheel. In the majority of previous kayak ergometry research, bungee tension has not been mentioned, even where power is one of the reported variables (e.g. van Someren et al., 2000; Bishop et al., 2001). Where force and power are quantified based on strain gauges on the paddle shaft, or between the paddle and flywheel, this is not an issue as power applied to the paddle, rather than flywheel, is measured. However, ergometers which measure flywheel speed with a known resistance to calculate power, disregard the force which is stretching the bungee, and are used frequently by coaches, athletes and researchers. When using these ergometers it is therefore important to ensure as much of the stroke as possible rotates the flywheel, without compromising the athlete's natural stroke characteristics.

Physiologically, ergometers have been found to provide a good replication of on-water kayaking (van Someren et al., 2000). Begon et al. (2008) found kinematics to be largely the same between an ergometer and on-water kayaking when paddling at a steady stroke rate of 84 strokes per minute (spm), with the exception of the shoulders. In agreement with this, Fleming et al. (2012a) conducted a comparison of EMG and kinematic parameters on an ergometer to on-water kayaking and found differences in the EMG activity of muscle groups around the shoulder which they attributed to the recoil of the ergometer. In a separate study by the same authors (2012b), bungee recoil tension was varied and the effect of different chord lengths on the muscle activity of the shoulders was investigated. They found increasing tension led to an increase in anterior deltoid activity and an anterior shift in the upper limb kinematics. The authors controlled stroke rate and power output, meaning the impact of tension changes on these parameters remains untested.

Due to the importance of power and ballistic movements to overall performance in many sporting activities, power-velocity and force-velocity profiles have been used in various sports to try and increase understanding of optimising performance (e.g. cycling: Dorel et al., 2005; track sprinting: Morin et al., 2012). Recent research has shown an individual's force-velocity and power-velocity profiles can be used to modify training and enhance improvements (Morin et al., 2016). These measures are also used as monitoring tools and can even be used in selection events. In kayaking, differences in power-velocity curves have been found between 200m and 1000m athletes at elite level (Schofield, 2015). The aim of this study was to compare the power-velocity profiles produced on an ergometer at four different bungee tensions.

**METHODS**: *Ergometer*: A kayak ergometer (Dansprint, Denmark) was modified by replacing the flywheel with a single disc weight of 5 kg with reflective markings (Figure 1; Schofield, 2015). The inertia of this disc is the sole resistive force for the athlete to overcome. The angular velocity of this weighted flywheel was measured using a photodiode and microprocessor. Combined with the known inertial characteristics, power applied to the flywheel was calculated from angular acceleration. Bungee tension was set by attaching a digital strain gauge in series with the elastic and extending the bungee until it reached the required value of 2.5, 3, 3.2 or 3.5 kg (24.5, 29.4, 31.4 and 34.3 N). These values were chosen to compare against previous research and to test extremes.

**Table 1: Participant characteristics**

| | Athlete A | Athlete B | Athlete C |
|---|---|---|---|
| Mass (kg) | 86.4 | 77.0 | 84.1 |
| K1 200 m time 2016 (s) | 37.64 | 39.17 | 40.59 |
| Bench Pull (kg) | 130 | 102 | 105 |
| Bench Press (kg) | 140 | 92 | 105 |
| Weighted Chin up | 75 | 50 | 60 |

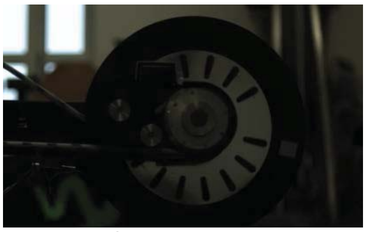

**Figure 1: flywheel on adapted ergometer**

*Experimental design*: Three experienced male kayakers participated in the study (Table 1). Each participant took part in a familiarisation and then two testing sessions on consecutive days. Each testing session consisted of three trials at each of two bungee tensions, with two minutes between trials, and a six minute rest between the two tensions. Tensions were tested in random order. A trial consisted of 14 maximal strokes with verbal encouragement throughout. For each tension, athletes provided anecdotal feedback as to whether they felt they were able to paddle as normal. *Analysis:* Using Excel (Microsoft), angular velocity, torque and power were calculated from the position-time data of the flywheel. Force and paddle tip velocity were then calculated from the drive sprocket radius. Power was normalised for mass and the peak power values and associated paddle tip velocity from each stroke were identified. *Statistical analysis:* Mean values from the three trials at each tension were calculated. A second order polynomial regression curve was fitted, with velocity on the x axis and power on the y, and coefficient of determination calculated.

**RESULTS**: Measured power-velocity profiles differed between bungee tensions for all three athletes (Figure 2), with greatest peak power achieved with a bungee tension of 3 kg. The reduction in measured peak power at other tensions differed between athletes, with athlete B showing the largest differences (Table 2). Raw peak power was found to be 174.5, 328.4 and 131.8 W higher with optimum tension when compared to least optimal tension for athletes A, B and C respectively. In practical kayaking settings, these peak power differences are considerable, and similarly meaningful differences were found in the velocity at peak power (Table 2).

**DISCUSSION**: Bungee tension had a clear effect on power-velocity profiling on a kayak ergometer; for all athletes in the range of resistance from 2.5 to 3.5 kg, 3 kg resulted in the highest peak power. The magnitude of the decrease in power either side of this peak was different between participants, potentially due to differences in strength (Table 1).

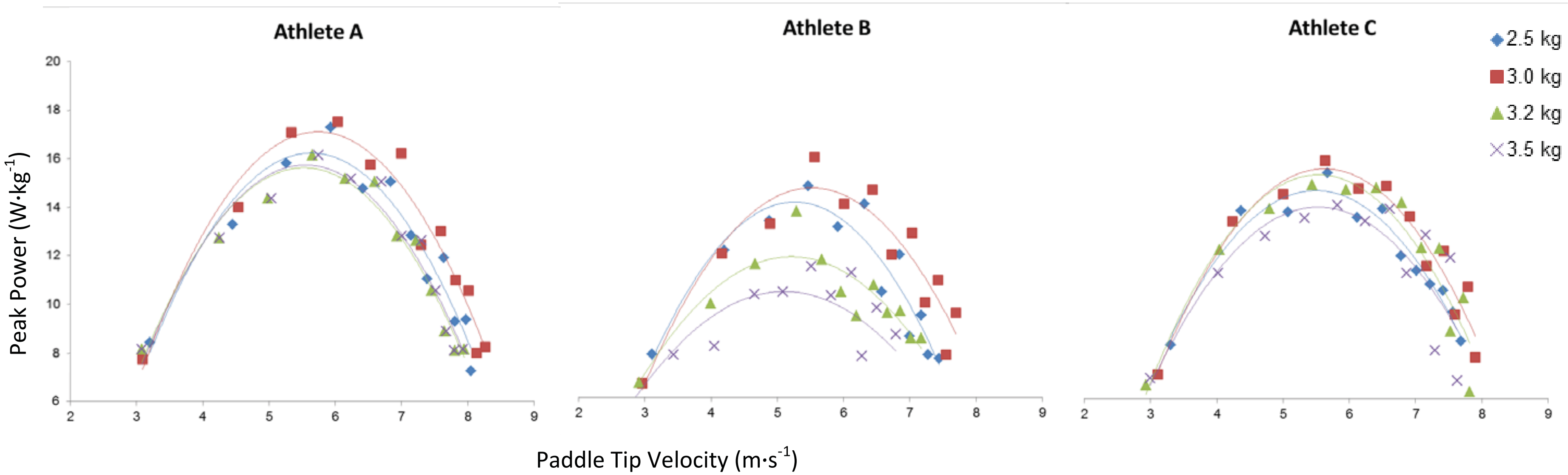


**Figure 2: Peak power-velocity data for each stroke, with regression curves included for different bungee tensions for 3 athletes.**

**Table 2: Maximum power from power-velocity regression curves, fit of regression to data, and the velocity at which maximum power was attained.**

| Bungee tension (kg) | | 2.5 | 3 | 3.2 | 3.5 |
|---|---|---|---|---|---|
| Max power from regression (W/kg) | Athlete A | 16.2 | 17.1 | 15.1 | 15.7 |
| | Athlete B | 13.4 | 14.6 | 11.8 | 10.4 |
| | Athlete C | 14.5 | 15.4 | 15.2 | 13.9 |
| | **Average** | **14.7** | **15.7** | **14.0** | **13.3** |
| | **SD** | **1.4** | **1.3** | **1.9** | **2.7** |
| Fit of regression ($R^2$) | Athlete A | 0.93 | 0.95 | 0.96 | 0.94 |
| | Athlete B | 0.82 | 0.87 | 0.80 | 0.68 |
| | Athlete C | 0.94 | 0.94 | 0.90 | 0.72 |
| | **Average** | **0.90** | **0.92** | **0.89** | **0.78** |
| | **SD** | **0.07** | **0.04** | **0.08** | **0.14** |
| Velocity at max power ($m \cdot s^{-1}$) | Athlete A | 5.71 | 5.76 | 5.68 | 5.55 |
| | Athlete B | 5.31 | 5.52 | 5.2 | 5.15 |
| | Athlete C | 5.52 | 5.63 | 5.54 | 5.53 |
| | **Average** | **5.51** | **5.64** | **5.47** | **5.41** |
| | **SD** | **0.20** | **0.12** | **0.25** | **0.23** |

Athlete comfort is an important aspect to training and it is therefore worth noting that the 3 kg resistance was the tension at which the athletes felt most comfortable. Indeed, none of the other resistances allowed them to feel like they were paddling as they would on water. While this provides anecdotal support for previous research which has allowed athletes to choose their own set-up tension, there is inevitably going to be some unquantified loss in measured power, which is exacerbated if tension is increased or decreased away from optimal, particularly in athletes who are lighter or less strong. The belief of the kayakers that the changing of tensions was altering their movement pattern is not reflected by kinematic results of a study with similar changes (Fleming et al., 2012b) which concluded that kayakers "maintained normal upper limb kinematics".

Fleming et al. (2012b) investigated the effect of bungee tension on EMG and kinematics. They changed tension by "shortening" the chord by 0, 10, 20 and 30%, reporting stationary recoil forces of 20, 29, 37 and 45 N- equivalent to 2.04, 2.96, 3.77 and 4.59 kg. As power output and stroke rate were controlled at those corresponding to 85% of VO2 max, the results cannot be directly compared to the current study. The authors reported that the lowest tension level available on the ergometer was most reflective of on-water paddling. While this can be seen logically, as there would be no pulling force on the opposite blade during on-water paddling, is it limited to low stroke rates only as otherwise the delay in retraction would alter paddling stroke.

While the current study gives insight into the influence of changing bungee tension on power measurement, it does not investigate the change in tension through the stroke. In order to ascertain the influence of bungee tension throughout the stroke, tension must be measured through instrumentation of the bungee in future research.

**CONCLUSION**: Bungee tension can have a large influence on parameters measured during kayak ergometry. Within the small sample measured, changing only bungee tension was found to change peak power recorded by as much as 328.4 W. Anecdotally, the most comfortable level of resistance was found to be the one at which highest power was achieved. Researchers need to be aware of the influence of bungee tension on power values when conducting ergometer based kayak research.

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