Introduction

Sprint kayaking has been an Olympic sport since 1936, with athletes competing over race distances of 500 m (both men and women) and 1,000 m (men only). In 2009, changes were made to the Olympic program, resulting in the introduction of the 200 m (K1 for women, K1 and K2 for men). This addition resulted in the loss of the men’s K1 and K2 500 m events. The shortest competitive Sprint Kayak race for men is the K2 200 m (~3 min 30 s) and the longest the K1 1,000 m (~31 s to complete). The shortest competitive women’s race is the K1 200 m (~40 s to complete) and the longest is the K1 500 m (~1 min 50 s).

The differences in the physiological demands of the 500 m and 1,000 m events are considered to be subtle (Fry and Moreton 1991; Tesch et al. 1976), clearly demonstrated by athletes successfully competing over both distances. At the 2008 Beijing Olympic Games the men’s K1 1,000 m gold medalist won the bronze medal in the K1 500 m and the K1 500 m gold medalist won bronze in the K1 1,000 m. Furthermore, variations to the type of training undertaken by athletes for each of these competition distances are minimal. It is well established that the 500 m and 1,000 m events are predominately aerobic (62% and 82%, respectively) in nature (Byrnes and Kearney 1997); however, a recent review concluded that successful kayakers over 500 m and 1,000 m require not only a high level of aerobic power but also a high anaerobic energy yield and great upper-body muscle strength (Michael et al. 2008).

In contrast to the 500 m and 1,000 m events, the shorter duration of the 200 m is expected to impose different physiological demands on the paddler, resulting in training programs with a bigger emphasis on speed, speed-endurance, and acceleration. As such, there is likely to be a shift in the focus toward enhancing the power to weight ratio of 200 m kayak athletes. Research suggests that a superior capacity of the anaerobic energy pathway may be essential for successful 200 m racing (Van Someren and Palmer 2003). However, the aerobic contribution for the 200 m is approximately 37% (Byrnes and Kearney 1997), which suggests that the aerobic energy contribution to the 200 m cannot be ignored. As a result, both the aerobic and anaerobic energy systems should be targeted in the 200 m paddler’s training plan.
Regardless of the distance of the event in which an elite kayak athlete competes, it is essential that the progression of the athlete’s training program be monitored via regular physiological monitoring throughout the annual training plan. Monitoring is not meant to be the only indicator of on-water performance, because many other factors are involved with performance and cannot be measured from individual tests. The best measure of performance is the race itself; however, this does not provide a clear insight into the physiological capacities that contribute to performance.

To this end, the physiological monitoring of kayakers has the following aims:
- To assess the characteristics believed to be directly related to elite kayaking performance
- To compare an athlete’s current physiological capabilities with prior monitoring at the same time of year and identify progression and deficiencies
- To provide meaningful data that can be used to design an effective training program
- To provide data that may indicate an athlete’s adaptation to a prescribed training program, which may include training-induced changes in:
  - sub-maximal capabilities, and
  - maximal performance parameters.

The normative data given in this chapter are from male 1,000 m paddlers and female 500 m paddlers. To date, not enough information had been collected to present normative data for 200 m paddlers.

**Athlete Preparation**

Prior to monitoring, a standardised pretest preparation is recommended to allow for reliable and valid physiological data to be obtained. Refer to the *AIS Pretest Preparation* document for specific information relating to athlete and laboratory preparation. Athletes should be injury free and well hydrated, should have consumed adequate prior nutrition, and should not have undertaken any intensive training sessions in the afternoon prior to monitoring.

On the day preceding monitoring, any training sessions that are completed should consist of no more than 12 km for senior athletes and no more than 5 km for junior athletes on the water and should be of low intensity. The athlete should undertake no heavy weight training or exercise to which they are not accustomed. Where possible the athlete should replicate (as closely as possible) similar training loads in the 24 h prior to each monitoring session attended.

With regards to strength monitoring, no unaccustomed exercise should be performed 72 hours prior to strength monitoring that may result in sarcomere damage and/or decreased activation of motor units. Unaccustomed exercise includes: a change in resistance exercise selection; increases in training volume (number of sets, exercises or resistance sessions) or the performance of high volume eccentric contractions [Nosaka 2001; Byrne, 2001].

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To ensure task familiarisation, the strength measures (e.g. bench press) should be incorporated into the usual training routine prior to monitoring. An equivalent volume of training should be performed prior to all sessions. At least three days prior to monitoring, a decrease in strength training volume of up to 50% should occur with training intensity remaining the same.

### Environments

#### Laboratory

The Dansprint Pro kayak ergometer (Dansprint ApS, Hvidovre, Denmark) or the Kayak Pro (Kayak Pro, England) are currently used for kayak ergometer laboratory monitoring in Australia; however, other ergometers can be used. Dynamic calibration of the ergometer should occur at least every 12 months or ideally immediately before each block of athlete monitoring (refer to AIS *Determination of Maximal Oxygen Consumption* document).

Calibration data against a first-principles torque meter indicate that it is necessary to establish a calibration regression or correction that takes into account the total true load exerted by the paddler. The power output displayed by the Dansprint ergometer is approximately 22% higher than the output on the calibration rig and the Kayak Pro 27-30% than the calibration rig, and that it is likely there will be minor variations between ergometers with regard to flywheel characteristics and resistance to flywheel rotation (Tom Stanef, South Australian Sports Institute, unpublished findings 2007-2011). Therefore, all protocols performed on a particular athlete during a competitive season should be conducted on the same well-maintained ergometer.

Prior to monitoring, the ergometer resistance should be standardised on the ergometer digital display. The flywheel resistance should then be adjusted as per the settings outlined in tables 1.0 and 1.1. As indicated by elite Australian Kayakers and the Kayak Pro manufactures these settings are associated with a resistance generated on the ergometer that simulates those experienced on water.

<table>
<thead>
<tr>
<th>Category</th>
<th>Drag Resistance Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior Female</td>
<td>30</td>
</tr>
<tr>
<td>Senior Female</td>
<td>30</td>
</tr>
<tr>
<td>Junior Male</td>
<td>35</td>
</tr>
<tr>
<td>Senior Male</td>
<td>40</td>
</tr>
</tbody>
</table>
Table 1.1: Kayak Ergometer flywheel settings for laboratory monitoring

<table>
<thead>
<tr>
<th>Category</th>
<th>Drag Resistance Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior Female</td>
<td>65</td>
</tr>
<tr>
<td>Senior Female</td>
<td>65</td>
</tr>
<tr>
<td>Junior Male</td>
<td>65</td>
</tr>
<tr>
<td>Senior Male</td>
<td>65</td>
</tr>
</tbody>
</table>

To standardise the paddle tension, the bungee cord used to retract the rope drive system via the ergometers paddle shaft must be calibrated. It is important that the load factor of this bungee cord is standardised using a digital scale (e.g., Kern hanging scales) to a tension value of $1.5 \pm 0.2 \text{ g}$ for Dansprints (see figure below) or to what has been recommended in the calibration reports for the Kayak Pro’s. Tension adjustments are made when the drive ropes are extended at a length of 210 cm (figure below), which is representative of the extension achieved in typical use. Adjustment of the tension is done by resetting the length of the bungee using the locking device and simple knots. It is recommended that the drive ropes on Dansprint and the Kayak Pro ergometers be replaced regularly to avoid any wearing that may influence test results. Following the replacement of the drive ropes the ergometer should always be recalibrated.

In addition to the flywheel resistance and bungee tension, the tester should ensure that the paddler’s body mass on the day of monitoring is entered into the ergometer digital display. The manufacturer’s software analysis of the distance travelled during each monitoring stage is influenced by the body mass of the athlete.

*Using a digital scale to adjust the bungee cord tension*
Drive rope setup (extension) for adjusting the bungee tension on the Dansprint (red line indicates 210 cm)

The following factors are also important for the standardisation of monitoring:

- The seat height and type (swivel vs. flat), the footrest position and the paddle-shaft length are consistent between sets of the same athlete;
- The footrest position and the paddle-shaft length are consistent between protocols of the same athlete;
- The thermal environment of the laboratory is kept between 18-23°C, and a relative humidity <70% during testing;
- The gas analysers are turned on at least 45 min before the scheduled start of the protocol;
- The gas analysers are calibrated against reference standards shortly before the commencement of testing, and again at the completion of the protocol, to account for any analyser drift;
- The ergometer is set up no closer than 1 m to the closest wall or barrier for safety reasons;
- For the Dansprint the back of the seat base is positioned 19 cm from the end of the kayak ergometer frame to keep the calibration consistent;
- For the Kayak Pro, if using a variable shaft then the length must be kept consistent across protocols for that athlete.

On-Water
Non-Flowing, minimal wind (<3.5km.h⁻¹) conditions are required to gather the most accurate information, particularly for the 750 m on-water protocol.
It is suggested that a two week window is allowed to conduct all the monitoring. Where possible, anthropometric and laboratory monitoring should be completed on the same day. For sprinters, the all-out ergometer protocol should be performed within a few days of the laboratory protocol. If possible, on-water monitoring should be conducted within a week of the laboratory protocols. The recommended test order is as follows:

<table>
<thead>
<tr>
<th>DAY</th>
<th>TESTS</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anthropometry</td>
<td>Undertaken prior to kayak laboratory monitoring</td>
</tr>
<tr>
<td>2</td>
<td>Laboratory testing - Endurance</td>
<td>Following anthropometry</td>
</tr>
<tr>
<td>3</td>
<td>Laboratory Testing - Sprinters</td>
<td>Within a couple of days of the 7 x 4 min laboratory profiling</td>
</tr>
<tr>
<td>4</td>
<td>On-water MONITORING</td>
<td>Optional, but doing the laboratory profiling and on-water monitoring in the same week enables a cross-check of prescribed training zones</td>
</tr>
<tr>
<td>5</td>
<td>Strength Monitoring</td>
<td>Undertaken a few days post laboratory testing</td>
</tr>
</tbody>
</table>
Equipment Checklist

Anthropometry:
[ ] Stadiometer (wall mounted)
[ ] Reference scales (accurate to +/- 0.05 kg)
[ ] Anthropometry box
[ ] Skinfold calipers (Harpenden skinfold caliper)
[ ] Marker pen
[ ] Anthropometric measuring tape
[ ] Recording sheet
[ ] Pen

7 x 4 minute Incremental and Accumulated Oxygen Deficit Protocols:
[ ] Kayak ergometer
[ ] Ergometer calibration sheets
[ ] Heart rate monitoring system
[ ] Metabolic cart
[ ] Rating of Perceived Exertion Scale (e.g. 6-20 Borg scale)
[ ] Reference scales (accurate to +/- 0.05 kg)
[ ] Lactate analyser (and consumables as required)
[ ] Sterile alcohol swabs
[ ] Lancets and sharps container
[ ] Biohazard Bag
[ ] Tissues
[ ] Disposable rubber gloves
[ ] Recording sheet
[ ] Pen

Speed Endurance Protocol:
[ ] Kayak Pro Hi-Res ergometer
[ ] Rating of Perceived Exertion Scale (e.g. 6-20 Borg scale)
[ ] Reference scales (accurate to +/- 0.05 kg)
[ ] Recording sheet
[ ] Pen
On-Water Monitoring Sets:
[ ] Lactate analyser (and consumables as required)
[ ] Sterile alcohol swabs
[ ] Lancets and sharps container
[ ] Biohazard Bag
[ ] Tissues
[ ] Disposable rubber gloves
[ ] Heart rate monitoring system
[ ] 10Hz GPS system (preferable) or GPS system
[ ] Testing scales (accurate to +/- 0.05 kg)
[ ] Stroke rate watch
[ ] Recording sheet
[ ] Pen
[ ] Environmental monitor

On-Water Incremental Protocol:
[ ] Lactate analyser (and consumables as required)
[ ] Sterile alcohol swabs
[ ] Lancets and sharps container
[ ] Biohazard Bag
[ ] Tissues
[ ] Disposable rubber gloves
[ ] Heart rate monitoring system
[ ] Rating of Perceived Exertion Scale (e.g. 6-20 Borg scale)
[ ] Testing scales (accurate to +/- 0.05 kg)
[ ] GPS system that measures speed or pace
[ ] Stroke rate watch
[ ] Recording sheet
[ ] Pen
ANTHROPOMETRY
Protocol – Anthropometry

Rationale -
Tracking an athlete’s body composition over time allows the sport scientist to understand the interaction of diet, training status, and other lifestyle factors that can affect body composition. To date, few investigations have shown a positive relationship between anthropometry and kayak performance. Although Sitkowski (2002) and van Someren and Howatson (2008) demonstrated that anthropometric parameters were not associated with 1,000 m performance, it was also shown that chest circumference and humeral breadth correlated strongly with successful 500 m and 200 m performances. Additionally, Ackland and colleagues (2003) showed that Olympic-level sprint kayak athletes have a lean body composition, with a proportionally large upper-body girth and narrow hips (for males). Such characteristics are unique and are not commonly observed in the general population. From a state-level perspective, team-selected athletes have been shown to be taller and heavier than non-selected paddlers (Fry and Moreton 1991). Furthermore, bicep and forearm girths of the state team members were significantly greater than those nonselected athletes, suggesting that a high degree of musculature may be a prerequisite for success at a higher level (Fry and Moreton 1991). Despite these confounding outcomes, it is likely that the long-term tracking of body composition may indicate the current training status of an athlete and where they are positioned relative to previous peak performances.

Procedure -
Measurement of height, body mass, and skinfolds should be carried out prior to ergometer monitoring. Skinfolds are measured over seven sites (triceps, biceps, subscapular, supraspinale, abdominal, front thigh, and medial calf) and in accordance with the standards of the International Society for the Advancement of Kinanthropometry (ISAK). The individual skinfold measures as well as the sum of the seven sites should be reported. More advanced anthropometric assessment including muscle girths, bone breadths, and limb lengths can be conducted if required.

Although the description of skinfold measurement procedures seems simple, a high degree of technical skill is essential for consistent results. It is therefore important that these measurements be taken by an experienced tester who has been trained and accredited in these techniques. It is also important that the same tester conduct each retest using the same calibrated equipment to ensure reliability.

Data Analysis -
An anthropometric assessment gives a detailed overview of an athlete’s body composition. Changes in body composition targeted through specific training can be tracked through repeated anthropometric measures. This allows an evaluation of the training effect on the athlete’s body composition. Depending on the training goal, the focus is typically on changes in lean muscle mass or skinfolds rather than purely on total body mass gains or losses. All data should be entered into the Athlete Management System (AMS).
Normative Data -
Table 2.0 presents anthropometric normative data for female and male national senior team kayak athletes.

Table 2.0: Anthropometric data for female and male National senior team kayak athletes
(mean ± SD; range)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Height (cm)</th>
<th>Body Mass (kg)</th>
<th>(\sum^7) Skinfolds (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEMALE</td>
<td>170.6 ± 6.2</td>
<td>67.4 ± 6.4</td>
<td>65.5 ± 13.4 (45.6-82.1)</td>
</tr>
<tr>
<td>MALE</td>
<td>185.1 ± 4.5</td>
<td>87.3 ± 5.7</td>
<td>42.6 ± 6.7 (31.8-59.9)</td>
</tr>
</tbody>
</table>

Typical error: Height 1.0 cm; Body Mass 1 kg; \(\sum^7\) Skinfolds ~ 1.5 mm

Source: National Senior Team during International Competition; female n=9; male n=15.
LABORATORY MONITORING PROTOCOLS
Protocol – 7 x 4 min Incremental

Rationale -
The 7 x 4 min incremental protocol is designed to provide reliable information regarding the athlete’s sub-maximal and peak physiological capabilities. The incremental protocol provides a good indication of the physiological efficacy of the on-water training program in athletes over the different mesocycles within a periodised training program. By using standardized workloads and amounts of work done prior to the final step, one can compare both efficiency and maximal performance improvements among junior, developing, and senior elite athletes during a season and over an Olympic cycle. These results then allow the coach or sport scientist to set benchmarks to ascertain the minimal standards each gender and age group should achieve.

Procedure -
The first six stages of the 7 x 4 min incremental protocol are sub-maximal and should be performed at fixed intensities depending on the gender, age, and performance ability of the athlete. These workloads are outlined in table 3.0. Each workload is followed by a 60 s rest to allow for the collection of a blood lactate sample and the recording of average power, average stroke rate, distance covered and ratings of perceived of exertion (RPE).

Table 3.0: Sub-maximal workloads for the 7 x 4 min step protocol and AOD protocol

<table>
<thead>
<tr>
<th>Step</th>
<th>MALE</th>
<th></th>
<th>FEMALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>World Class</td>
<td>Elite</td>
<td>Senior</td>
</tr>
<tr>
<td></td>
<td>K1 Senior</td>
<td>Senior</td>
<td>Junior</td>
</tr>
<tr>
<td>1</td>
<td>150</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>175</td>
<td>125</td>
<td>120</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>150</td>
<td>140</td>
</tr>
<tr>
<td>4</td>
<td>225</td>
<td>175</td>
<td>160</td>
</tr>
<tr>
<td>5</td>
<td>250</td>
<td>200</td>
<td>180</td>
</tr>
<tr>
<td>6</td>
<td>275</td>
<td>225</td>
<td>200</td>
</tr>
<tr>
<td>7</td>
<td>Max</td>
<td>Max</td>
<td>Max</td>
</tr>
</tbody>
</table>

Sub-Maximal Workloads:
When the athlete arrives at the laboratory, the tester should ensure that the guidelines for athlete preparation have been met and that all pretest consent forms have been signed. The protocol is designed such that the initial two workloads act as a warm-up. Therefore, no pre-monitoring warm-up needs to be conducted prior to monitoring, because this could influence the subsequent heart rate and blood lactate readings recorded during the early stages of the protocol.

Because the starting workload and subsequent work increment will vary depending on the athlete’s gender, age, and performance level, it is suggested that for all monitoring sessions completed throughout a given competition year, the athlete’s starting workload and the
subsequent work increments during the first six stages be kept consistent. This will help to ensure that a similar workload is completed between sessions during the sub-maximal stages. Unless there has been a big performance change, only in the subsequent competitive season should a coach or sport scientist move the athlete up to a new category, which will influence the starting workload.

The designated workloads and stage increments of the 7 x 4 min incremental protocol have been designed so that the sixth step produces a blood lactate value in the range of 4 to 6 mmol.L⁻¹. This range of blood lactate concentration ([La⁻]) is often seen at training intensities of anaerobic threshold and slightly above. These values will vary depending on the time of year and the athlete’s current training status.

Once the equipment has been set up and calibrated, the protocol proceeds as follows:

- Collect all necessary details for the athlete to be monitored and enter them into the software associated to the equipment required. These details might include such variables as stature, body mass and sum of skinfolds.
- Attach heart rate (HR) monitoring chest transmitter to the athlete and ensure that the device is synchronised to its associated data receiver.
- Ask the athlete to be seated on the kayak ergometer. If necessary, adjust the position of the ergometer foot rest according to the athlete’s preference and record for future reference.
- Position the metabolic cart apparatus (respiratory valve etc.) appropriately and ensure that the athlete is comfortable. Have the athlete take several light paddle strokes and make any necessary adjustment to the respiratory hoses or other apparatus, ensuring that the paddle shaft is not impeded at any stage during the stroke.
- Program the ergometer for 4 min workloads. It is suggested that the recovery period is not programmed so that delays that may be encountered in the recovery period do not impact on the workload time.
- If the athlete is using a mouth piece, place a small piece of tape on the athlete’s nose and secure the nose clip. Alternatively, a face mask may be used.
- Ensure that the athlete’s feet are secured in position on the foot rest, and ask that they prepare the paddle shaft in anticipation of the protocol commencement.
- Activate the metabolic cart for protocol commencement and instruct the athlete when to begin paddling the first workload of the protocol.
- As the athlete works through the protocol, provide continual information from the calibration sheets produced for the specific ergometer concerning target power outputs. It is recommended the tester count the athlete into each step with a “ready, set, go” to ensure synchronisation of the work effort to acquisition of oxygen consumption data.
- Stroke ratings and heart rates should be recorded during the last 30 s of each workload. At the end of each workload record average PO, then correct to the true power output (PO) using the calibration regression equation generated from the first principles calibration of the ergometer.
- On completion of each workload, request an RPE from the athlete. An earlobe blood sample should be collected and analysed for [La⁻] as soon as possible.

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During the rest period between each workload, permit the athlete to remove the gas collection apparatus in order to have a drink. However, it is important to ensure that the breathing apparatus is back in position well before the start of the next work bout (approximately 10-15 s).

**Maximal Step Component:**
The final (usually seventh) 4 min step of the protocol is a maximal effort and is completed after 60 s recovery from step 6. This stage requires the athlete to perform at a perceived time trial intensity. The results of this time trial can be compared with previous maximal efforts from the same monitoring protocol. This final stage will also provide the sport scientist with information about an athlete’s ability to perform at their maximal intensity and will differentiate performance between athletes who have completed the same sub-maximal steps. Several factors are important during this seventh stage:

- The athletes are informed that they must complete as much work as possible over the 4 min period.
- Most athletes tend to over-pace rather than under-pace the maximal stage, and variations in pacing can have a substantial effect on the result. Therefore, it is recommended that the athletes adopt an even pacing strategy during this 4 min time-trial period. This can be aided by limiting the start phase to 10s and then providing a guideline on what power output to hold for the first half of the protocol based off of their previous results. The power output attained by the athlete during the final 2 min is then optional.
- On completion of the final step, immediately record average power, average stroke rate, rating of perceived exertion (RPE) and 4 min post-completion collect a blood lactate sample.

**Limitations -**
The limitations of the 7 x 4 min incremental protocol may include, but are not limited to, the following. A substantial learning effect can be present between sessions, particularly with athletes who are not familiar with the ergometer or protocols. Therefore, new athletes should be monitored in duplicate fashion to minimize these learning effects. Most athletes will be able to technically use the ergometer at sub-maximal intensities; however, some athletes may experience technical difficulties during the final maximal stage.

**Data Analysis -**
The following points should be considered when interpreting oxygen consumption and blood lactate results from the 7 x 4 min incremental protocol:

- Sub-maximal oxygen uptakes should be reported as the average value for the final 1 min of each 4 min submaximal stage (L·min⁻¹ and ml·kg⁻¹·min⁻¹).
- Maximal oxygen consumption (VO₂ max) is reported as the highest value attained over a period of one full minute or sum of the two highest consecutive 30 s values (L·min⁻¹ and ml·kg⁻¹·min⁻¹).
- Sub-maximal heart rates are the values for the final 30 s of each sub-maximal workload.
- Maximal heart rate is the highest value recorded over a 5 s sampling period during the entire protocol. This will generally be achieved during the final stages of the maximal 4 min effort.

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• Data from the maximal 4 min effort are included as the final workload values of the protocol, and are used in combination with values from the sub-maximal workloads for the calculation of blood lactate thresholds and related measures (refer to the AIS Blood lactate thresholds: concepts, controversies and applications document). Guidelines for sprint kayak training zones are presented below in Table 4.0.

• The tester should report power, VO₂ and HR data for the first and second lactate thresholds (i.e. LT1 and LT2) with the option of using the fixed points of 2, 4 and 6 mmol·L⁻¹ of lactate.

• Power to weight of an athletes can be measured using the average power output from the maximal stage.

• When comparing Dansprint and Kayak Pro ergometer results, the Kayak Pro’s average power output in the final stage is 3.6% higher than the Dansprint so an adjustment factors needs to be added and noted in the results interpretation

• All data should be entered into the AMS
Table 4.0: Guidelines for sprint kayak training zones

<table>
<thead>
<tr>
<th>Training Zone</th>
<th>Description</th>
<th>Blood Lactate Threshold Relationship</th>
<th>Blood Lactate (mmol-L⁻¹)</th>
<th>Percent HR_{max} (%)</th>
<th>Percent VO_{2max} (%)</th>
<th>Kayak Stroke Rate (s.min⁻¹)</th>
<th>RPE Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T1</strong></td>
<td>Light Aerobic</td>
<td>&lt; LT1</td>
<td>&lt; 2.0</td>
<td>60-75</td>
<td>&lt; 60</td>
<td>&lt; 60</td>
<td>Very Low</td>
</tr>
<tr>
<td><strong>T2</strong></td>
<td>Moderate Aerobic</td>
<td>Lower half b/w LT1 &amp; LT2</td>
<td>1.0-3.0</td>
<td>75-84</td>
<td>60-75</td>
<td>56-72</td>
<td>Light</td>
</tr>
<tr>
<td><strong>T3</strong></td>
<td>Heavy Aerobic</td>
<td>Upper half b/w LT1 &amp; LT2</td>
<td>2.0-4.0</td>
<td>82-89</td>
<td>75-85</td>
<td>70-82</td>
<td>Some</td>
</tr>
<tr>
<td><strong>T4</strong></td>
<td>Threshold</td>
<td>LT2</td>
<td>3.0-6.0</td>
<td>88-93</td>
<td>85-90</td>
<td>75-92</td>
<td>Hard</td>
</tr>
<tr>
<td><strong>T5</strong></td>
<td>Maximal Aerobic (1000-m race pace)</td>
<td>&gt; LT2</td>
<td>&gt; 5.0</td>
<td>92-100</td>
<td>90-100</td>
<td>88-110</td>
<td>Very High</td>
</tr>
<tr>
<td><strong>T6</strong></td>
<td>500-m race pace</td>
<td>&gt; LT2</td>
<td>&gt; 8.0</td>
<td>100</td>
<td>n/a</td>
<td>106-120</td>
<td>Very, Maxi</td>
</tr>
<tr>
<td><strong>T7</strong></td>
<td>200-m race pace</td>
<td>&gt; LT2</td>
<td>&gt; 6.0</td>
<td>n/a</td>
<td>n/a</td>
<td>115-140</td>
<td>Almost Maxi</td>
</tr>
<tr>
<td><strong>T8</strong></td>
<td>Sprints</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>&gt; 130</td>
<td>Maxi</td>
</tr>
</tbody>
</table>

* These are guidelines only for training zones. n/a = not applicable

*Stroke rates will vary throughout the year with athlete’s aerobic fitness

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Normative Data -
Normative data for aerobic power parameters for female and male national senior team kayak athletes from the Dansprint ergometer are presented Table 5.0 and 5.1. Lactate transition threshold data is also presented.

Table 5.0: Aerobic power data from 7 x 4 min Incremental Protocol for female and male National senior team kayak athletes on the Dansprint Ergometer (mean ± SD; range)

<table>
<thead>
<tr>
<th></th>
<th>FEMALE</th>
<th>MALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Mass (kg)</td>
<td>66.2 ± 3.8</td>
<td>89.6 ± 6.1</td>
</tr>
<tr>
<td></td>
<td>(61.5-71.7)</td>
<td>(80.7-100.4)</td>
</tr>
<tr>
<td>VO2max (L.min⁻¹)</td>
<td>3.69 ± 0.24</td>
<td>5.17 ± 0.12</td>
</tr>
<tr>
<td></td>
<td>(3.50-3.96)</td>
<td>(5.00-5.30)</td>
</tr>
<tr>
<td>VO2max (ml.kg⁻¹.min⁻¹)</td>
<td>56.1 ± 0.9</td>
<td>56.5 ± 3.3</td>
</tr>
<tr>
<td></td>
<td>(55.3-57.1)</td>
<td>(52.0-62.3)</td>
</tr>
<tr>
<td>PO @ VO2max (W)</td>
<td>205.4 ± 8.4</td>
<td>313.6 ± 23.9</td>
</tr>
<tr>
<td></td>
<td>(193-215)</td>
<td>(291-357)</td>
</tr>
<tr>
<td>PO@VO2max (W.kg⁻¹)</td>
<td>3.1 ± 0.2</td>
<td>3.6 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>(2.9-3.4)</td>
<td>(3.1-4.1)</td>
</tr>
<tr>
<td>HRmax (bpm)</td>
<td>174.2 ± 10.8</td>
<td>180.1 ± 4.0</td>
</tr>
<tr>
<td></td>
<td>(157-186)</td>
<td>(175-187)</td>
</tr>
<tr>
<td>Blood Lactate (mmol.L⁻¹)</td>
<td>9.3 ± 1.6</td>
<td>10.2 ± 2.3</td>
</tr>
<tr>
<td></td>
<td>(7.1-11.6)</td>
<td>(6.2-14.0)</td>
</tr>
</tbody>
</table>

Typical Error: \( \dot{V}O_2_{max} \pm 0.06 \text{ L.min}^{-1}, \pm 1.0 \text{ m.kg}^{-1}\text{.min}^{-1}; \text{Power output at } \dot{V}O_2_{max} \pm 3.0 \text{ W}; \text{Heart rate max} \pm 1.7 \text{ bpm}; \text{Blood lactate} \pm 0.6 \text{ mmol.L}^{-1} (n=9)

Source: National Senior Team during Domestic Competition; female n=5; male n=9.
Table 5.1: Lactate transition data from 7 x 4 min Incremental Protocol for female and male National senior team kayak athletes on the Dansprint Ergometer (mean ± SD; range)

<table>
<thead>
<tr>
<th></th>
<th>FEMALE</th>
<th></th>
<th>MALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LT1</td>
<td>LT2</td>
<td></td>
</tr>
<tr>
<td>(\dot{V}O_2)max (L.min(^{-1}))</td>
<td>2.46 ± 0.07 (2.38-2.51)</td>
<td>3.24 ± 0.18 (3.12-3.45)</td>
<td>3.25 ± 0.23 (2.90-3.6)</td>
</tr>
<tr>
<td>%(\dot{V}O_2)max</td>
<td>69.3 ± 2.9 (66-71)</td>
<td>91.6 ± 5.5 (88-98)</td>
<td>63.8 ± 6.6 (56-75)</td>
</tr>
<tr>
<td>PO (W)</td>
<td>112.6 ± 11.5 (100-122)</td>
<td>158.0 ± 12.5 (148-174)</td>
<td>159.5 ± 19.6 (135-200)</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>143.0 ± 11.8 (132-160)</td>
<td>166.2 ± 11.9 (148-180)</td>
<td>138.5 ± 5.7 (129-146)</td>
</tr>
<tr>
<td>% HR(_{max})</td>
<td>82.0 ± 3.7 (76-86)</td>
<td>95.2 ± 1.8 (93-97)</td>
<td>76.9 ± 3.3 (72-80)</td>
</tr>
<tr>
<td>Blood Lactate (mmol·L(^{-1}))</td>
<td>1.2 ± 0.1 (1.1-1.4)</td>
<td>3.7 ± 0.7 (2.8-4.5)</td>
<td>1.2 ± 0.4 (0.8-1.9)</td>
</tr>
</tbody>
</table>

Typical Error: \(\dot{V}O_2\) 0.15 L.min\(^{-1}\); %\(\dot{V}O_2\)max 2.2%; Power output 4.3 W; Heart rate 5 bpm; % Heart rate \(_{max}\) 2.1%; Blood lactate 0.4 mmol·L\(^{-1}\) (n=9)

Source: National Senior Team during Domestic Competition; female n=5; male n=9.
Protocol – Kayak Accumulated Oxygen Deficit

**Rationale -**
The kayak accumulated oxygen deficit protocol (AOD) allows the sport scientist to determine an athlete’s submaximal workload (LT1 and LT2) and maximal oxygen consumption and to estimate anaerobic capacity (i.e., accumulated oxygen deficit). This protocol requires the athlete to paddle at progressively ramped sub-maximal 4 min work increments, each separated by a 1 min recovery period. The submaximal component is completed when the athlete produces a lactate 4 mmol.L\(^{-1}\) or greater. Following the completion of the sub-maximal work stages, the athlete is given a 20 min break before performing a maximal 4 min effort.

**Procedure -**
The sub-maximal stages of the AOD protocol are the same as the 7 x 4 min incremental protocol. However, athletes are only required to complete as many 4 min sub-maximal workloads as required to elicit a blood lactate concentration of 4 mmol.L\(^{-1}\) or greater. Once this has been achieved, the submaximal component of the protocol is stopped to avoid fatiguing the athlete prior to the ensuing maximal 4 min time-trial effort.

**The 20 Minute Rest Interval:**
On completion of the last submaximal workload, a 20 min active recovery period is allowed to prepare the athlete for the maximal 4-min. During this recovery period, the following should occur:

- The athlete should be provided the opportunity to drink and actively recover as they see fit during this period. The active recovery component should incorporate at least 10 min of work at an intensity corresponding to LT1 in order to help clear any lactate accumulated during the submaximal component of the protocol. This active period can be performed using an exercise modality of the athletes’ choice (e.g. cycling, rowing, jogging etc.).
- Calibration of the gas analysers should be checked and verified.
- A countdown to the commencement of the maximal 4 min ergometer protocol should be provided regularly to the athlete throughout the recovery period.
- If AOD is to be determined, ensure the collection period for your metabolic cart is set to 30s. Ergometer data will also need to be collected by an external computer so that average power for each 30 s of the 4 min maximal effort can be determined.
- At an elapsed recovery time of 17 min, the athlete should return to the ergometer to prepare for commencement of the maximal 4 min effort.
**The Maximal 4-minute Effort:**
This final component of the AOD monitoring protocol is treated the same as the 7 x 4 min maximal component. At the 18 min mark of the active recovery period, ask the athlete to be seated on the kayak ergometer. Position the gas collection apparatus appropriately and ensure that the athlete’s feet are secured in position on the footrest. At the 20 min mark of the recovery period, provide a 10 s count-in for the athlete to commence the 4 min maximal effort.

**Data Analysis -**
The blood lactate data collected from both the submaximal and 4 min time trial efforts during the AOD protocol can be analyzed in the same manner as that indicated in the 7 x 4 min incremental protocol.

A measure of anaerobic capacity as calculated by the AOD method first described by Medbo et al., (1988) can be determined from the 4 min time trial effort of the AOD protocol. The AOD is calculated by extrapolation from the linear relationship between submaximal work intensity (power output or meters per minute) and oxygen consumption. This relationship can be determined from data obtained during the submaximal component of the protocol. Once the relationship has been established, work intensities (power output) can be quantified in terms of their oxygen consumption equivalents for each 30 s period of the maximal 4 min performance protocol. Measured oxygen consumption is subtracted from the estimated oxygen requirement to give the oxygen deficit for each 30 s. The oxygen deficits over the entire period of the protocol (up to the end of the 30 s collection period preceding protocol completion) are then summed to obtain the AOD. Please refer to the AIS Determination of Anaerobic Capacity in Athletes document for a comprehensive description of this method.

An alternative to the AOD full protocol is to collect data using the 7 x 4 min incremental protocol, before following up 1 or 2 days later with a maximal 4 min effort (following a standardized warm-up), as mentioned previously. If one method is chosen over another, then the tester cannot compare data between the different protocols because different amounts of work prior to the AOD test will have been performed.

**Normative Data -**
Table 6.0 below presents normative data for the AOD test.
Table 6.0: Accumulated oxygen deficit (AOD) protocol results from a 4 min maximal effort for female and male state institute athletes on the Dansprint Ergometer (mean ± SD; range)

<table>
<thead>
<tr>
<th></th>
<th>FEMALE</th>
<th>MALE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Mass (kg)</strong></td>
<td>69.7 ± 3.6</td>
<td>81.6 ± 11.1</td>
</tr>
<tr>
<td></td>
<td>(66.3-73.4)</td>
<td>(73.5-94.3)</td>
</tr>
<tr>
<td><strong>4 min Average Power (W)</strong></td>
<td>195.5 ± 3.7</td>
<td>296.3 ± 53.9</td>
</tr>
<tr>
<td></td>
<td>(193-200)</td>
<td>(263-359)</td>
</tr>
<tr>
<td><strong>4 min Distance (m)</strong></td>
<td>853 ± 8</td>
<td>997 ± 71</td>
</tr>
<tr>
<td></td>
<td>(845-861)</td>
<td>(954-1079)</td>
</tr>
<tr>
<td><strong>HR\textsubscript{max} (bpm)</strong></td>
<td>175 ± 15</td>
<td>184 ± 8</td>
</tr>
<tr>
<td></td>
<td>(157-186)</td>
<td>(176-192)</td>
</tr>
<tr>
<td><strong>\dot{V}O_2\textsubscript{max} (L.min\textsuperscript{-1})</strong></td>
<td>3.8 ± 0.2</td>
<td>5.3 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>(3.5-3.9)</td>
<td>(5.1-5.6)</td>
</tr>
<tr>
<td><strong>\dot{V}O_2\textsubscript{max} (ml.kg\textsuperscript{-1}.min\textsuperscript{-1})</strong></td>
<td>54.0 ± 6.2</td>
<td>62.3 ± 7.7</td>
</tr>
<tr>
<td></td>
<td>(47.3-59.6)</td>
<td>(56.8-71.1)</td>
</tr>
<tr>
<td><strong>Anaerobic O2 capacity (L)</strong></td>
<td>2.3 ± 1.0</td>
<td>2.4 ± 1.0</td>
</tr>
<tr>
<td></td>
<td>(1.2-2.9)</td>
<td>(1.3-3.3)</td>
</tr>
<tr>
<td><strong>Total \dot{V}O_2 (L)</strong></td>
<td>13.0 ± 0.8</td>
<td>18.9 ± 0.9</td>
</tr>
<tr>
<td></td>
<td>(12.1-13.7)</td>
<td>(18.2-19.9)</td>
</tr>
<tr>
<td><strong>Aerobic Potential (%)</strong></td>
<td>86.5 ± 0.8</td>
<td>89.2 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>(85.6-87.0)</td>
<td>(89.0-89.4)</td>
</tr>
<tr>
<td><strong>Aerobic Contribution (%)</strong></td>
<td>85.4 ± 5.1</td>
<td>89.1 ± 3.7</td>
</tr>
<tr>
<td></td>
<td>(82.2-91.3)</td>
<td>(86.0-93.2)</td>
</tr>
<tr>
<td><strong>Anaerobic Contribution (%)</strong></td>
<td>14.6 ± 5.1</td>
<td>10.9 ± 3.7</td>
</tr>
<tr>
<td></td>
<td>(8.7-17.8)</td>
<td>(6.8-14.0)</td>
</tr>
<tr>
<td><strong>Peak Blood Lactate (mmol.L\textsuperscript{-1})</strong></td>
<td>10.1 ± 2.9</td>
<td>10.7 ± 1.3</td>
</tr>
<tr>
<td></td>
<td>(7.1-12.9)</td>
<td>(9.4-11.9)</td>
</tr>
</tbody>
</table>

**Source:** State Institute Athletes during Domestic Competition; female n=3; male n=3.
Protocol – Speed Endurance Ergometer (Sprinters only)

Rationale -
The 30 s and 45 s Speed Endurance protocol is designed to test the supra-maximal capabilities of the 200m Sprint Kayak athlete. The protocol requires the athlete to cover as much distance as possible over a 30 s period following a standardized individual warm-up. The protocol is then repeated over 45 s following a 30 minute break.

Procedure -
This protocol should be conducted on the Kayak Pro Hi-Res machine only.

- Ask the athlete to be seated on the kayak ergometer. If necessary, adjust the position of the ergometer footrest according to the athlete’s preference and record for future reference.
- Set the Kayak Pro calibration factor to 65 for men and 55 for women before entering the body mass of the athlete.
- Program the ergometer for a 30 s workload. It is suggested that the recovery period is not programmed and then reprogram the ergometer for a 45 s workload
- Ensure that the athlete’s feet are secured in position on the foot rest, and ask that they prepare the paddle shaft in anticipation of the protocol commencement.
- The athlete should undertake their standard race warm-up either on the kayak ergometer or on-water and it is suggested that a 10 minute period elapses between finishing the warm-up and the start of the protocol to simulate regatta conditions.
- The athlete should be reminded it is a protocol to cover as much distance as possible during each effort and the aim is to get up to race stroke rate as quickly as possible while minimising the decline towards the back end of the effort.
- Once the athlete is comfortable the tester will start the athletes using the international standards of “ready, set, go”. The athlete should follow standard race starting procedures where the shaft mimics the angles of the paddle in an on-water start.
- Record distance covered for each 15 s period. This can be recorded from the display screen or alternatively, can be collected by connecting the computer to the Kayak Pro.
- Average stroke rate and total distance covered should be recorded at the end of the 30 s and 45 s.
- On completion of the efforts request an RPE from the athlete.
**Data Analysis -**

Distance covered at 15 s, 30 s and 45 s, athlete body mass and average stroke rating should be recorded for each effort. The best overall time and average of the two efforts should also be recorded to check the consistency of the athlete over the two efforts. Each 15 s period can be recorded as an interval in an attempt to understand how and where an athlete is gaining or losing time across the season. All data should be entered into the AMS.

**Normative Data -**

Table 6.0 presents normative data for the all out 30 s.

<table>
<thead>
<tr>
<th></th>
<th>MALE SENIOR</th>
<th>MALE U23</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Mass (kg)</strong></td>
<td>84.6 ± 4.6</td>
<td>81.1 ± 3.8</td>
</tr>
<tr>
<td></td>
<td>(78.9-91.8)</td>
<td>(74.3-84.2)</td>
</tr>
<tr>
<td><strong>Distance Covered (m)</strong></td>
<td>162.4 ± 5.3</td>
<td>158.6 ± 3.5</td>
</tr>
<tr>
<td></td>
<td>(154-167)</td>
<td>(153-162)</td>
</tr>
</tbody>
</table>

**Typical Error:**

Source: National
ON-WATER MONITORING
Protocol – 4 x 2000 m (Men) 4 x 1500 m (Women)

Rationale -
The 4 x 2000 m and 4 x 1500 m sets are efforts around the athletes’ critical speed (higher than Level 4 anaerobic threshold but lower than Level 5 VO\textsubscript{2max}).

Procedure -
All efforts are undertaken from a rolling start and where possible as evenly paced as possible.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total Number of Efforts</th>
<th>Stroke Rate Men</th>
<th>Stroke Rate Women</th>
<th>Base Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seniors</td>
<td>4</td>
<td>78-88</td>
<td>75-83</td>
<td>15 mins</td>
</tr>
<tr>
<td>U23</td>
<td>4</td>
<td>75-85</td>
<td>72-80</td>
<td>15 mins</td>
</tr>
<tr>
<td>U18</td>
<td>4</td>
<td>70-85</td>
<td>67-75</td>
<td>15 mins</td>
</tr>
</tbody>
</table>

- At the end of each effort an earlobe blood sample should be collected and analysed for [La\textsubscript{−}] as soon as possible.
- Total time for each effort as well as average heart rate (if available) and average stoke rate should be recorded.
- Environmental conditions including air temperature (°C), humidity (%), water temperature taken at elbow depth (°C), wind velocity (km.h\textsuperscript{−1}) and wind direction (head, tail, cross etc) should be recorded.
- Data should be entered into the AMS.
Protocol – 10 x 1000 m (Men)/ 8 x 500 m (Women)

Rationale -
This is a demanding threshold training set that requires the athlete to hold a specific pace for a set number of efforts, perform two maximal efforts with pre-fatigue and back-up following the maximal efforts. The sub-maximal pace should be done as indicated below which approximates T4/LT2 pace.

Procedure -
Depending on the competition age group of the athletes the total number of efforts undertaken, the threshold pace and the maximal effort set number will vary as per the table below.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total Number of Efforts</th>
<th>Target Pace/1000m</th>
<th>Max Efforts</th>
<th>Stroke Rate</th>
<th>Base Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seniors</td>
<td>10</td>
<td>4:00</td>
<td>4 &amp; 8</td>
<td>75-85</td>
<td>7 mins</td>
</tr>
<tr>
<td>U23</td>
<td>10</td>
<td>4:10</td>
<td>4 &amp; 8</td>
<td>75-85</td>
<td>7 mins</td>
</tr>
<tr>
<td>U18</td>
<td>8</td>
<td>4:20</td>
<td>3 &amp; 6</td>
<td>70-80</td>
<td>7 mins</td>
</tr>
<tr>
<td>WOMEN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seniors</td>
<td>8</td>
<td>2:05</td>
<td>3 &amp; 7</td>
<td>88-98</td>
<td>7 mins</td>
</tr>
<tr>
<td>U23</td>
<td>6-8</td>
<td>2:10</td>
<td>3 &amp; 5/7</td>
<td>85-95</td>
<td>7 mins</td>
</tr>
<tr>
<td>U18</td>
<td>6</td>
<td>2:15</td>
<td>3 &amp; 5</td>
<td>80-90</td>
<td>7 mins</td>
</tr>
</tbody>
</table>

- Where possible a buoyed course should be used.
- Environmental conditions including air temperature (°C), humidity (%), water temperature taken at elbow depth (°C), wind velocity (km.h⁻¹) and wind direction (head, tail, cross etc.) should be recorded.
- Threshold efforts should be undertaken from a rolling start with final time and average stroke rate recorded for each (these are also available from the MinimaX).
- Maximal efforts should be recorded with a MinimaX and commence from a standing start using the command ‘ready, set, go’.
- Immediately post each maximal effort an earlobe blood sample should be collected and analysed for [La⁻] as soon as possible. In addition, RPE and Heart rate are also recorded
- Data should be entered into the Australian Canoeing AMS.
Protocol – 2 x 6 x 300m

Rationale -
This set is a test of lactate tolerance which is important for the back end of the 1000 m (men) or 500 m (women). All efforts are performed with a rolling start.

Procedure –
Depending on the competition age group of the athlete’s stroke rate will vary. The recovery time between sets is 10 minutes (or 12 minutes if you include the recovery time from the last effort)

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total Number of Efforts</th>
<th>Stroke Rate Men</th>
<th>Stroke Rate Women</th>
<th>Base Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seniors/U23</td>
<td>12</td>
<td>95-110</td>
<td>95-105</td>
<td>3 mins</td>
</tr>
<tr>
<td>U18</td>
<td>12</td>
<td>90-105</td>
<td>90-100</td>
<td>3 mins</td>
</tr>
</tbody>
</table>

- Where possible a buoyed course should be used.
- Environmental conditions including air temperature (°C), humidity (%), water temperature taken at elbow depth (°C), wind velocity (km.h⁻¹) and wind direction (head, tail, cross etc.) should be recorded.
- Immediately post set an earlobe blood sample should be collected and analysed for [La⁻] as soon as possible.
- For each effort, final time and average stroke rate should be recorded.
- Data should be entered into the Australian Canoeing AMS.
Protocol – 4 x 300 m + 2 x 100 m (Men) 2 x 300 m + 2 x 200 m + 2 x 100 m (Women)

Rationale -
These sets are a test of speed endurance and speed capabilities with pre-fatigue. All efforts are performed with full or near full recovery so the athletes can perform a maximal effort.

Procedure –
Depending on the competition age group of the athletes the total number of efforts undertaken and the start technique will vary as per the tables below.

Men:

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total Number of Efforts</th>
<th>Standing/Rolling Start</th>
<th>Base</th>
</tr>
</thead>
</table>
| Seniors/U23 | 3 x 300 m  
2 x 100 m  
1 x 300m | 1 Rolling, 2+3 Standing  
All Standing  
Standing | 10 min  
7 min |
| U18 | 3 x 300 m  
2 x 100 m  
1 x 300m | 1+3 Rolling, 2 Standing  
All Standing  
Standing | 10 min  
7 min |

Women:

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total Number of Efforts</th>
<th>Standing/Rolling Start</th>
<th>Base</th>
</tr>
</thead>
</table>
| Seniors/U23 | 2 x 300 m  
2x 200 m  
2 x 100 m | 1st effort over each distance rolling 2nd effort standing | 8 min  
7 min  
6 min |
| U18 | 2 x 300 m  
2x 200 m  
2 x 100 m | All Rolling | 8 min  
7 min  
6 min |

- Where possible a buoyed course should be used.
- Environmental conditions including air temperature (°C), humidity (%), water temperature taken at elbow depth (°C), wind velocity (km.h⁻¹) and wind direction (head, tail, cross etc.) should be recorded.
- Immediately post set each maximal effort an earlobe blood sample should be collected and analysed for [La⁻] as soon as possible.
- For each effort, final time and average stroke rate should be recorded.
- Data should be entered into the Australian Canoeing AMS.
Protocol – Flying and Standing 50 m (Women and Sprinters)

Rationale -
The flying 50 m is a test of top end speed which is an important measure of 200 m sprint kayak performance and closely related to the 25-50 m component of the 200 m race. Standing starts are crucial as the ability of the athlete to accelerate the boat as quickly as possible to maximum speed is also critical to performance in the 200m race. The starting 50 m not only involves a big physical component but is also very reliant on technique.

Procedure -
All efforts should be undertaken in still water where possible and on a buoyed course.
- For Sprinters 4 efforts are done off a 10 min base with the first two efforts always being flying 50 m efforts and the last two standing 50 m efforts.
- For Women 6 efforts are done off a 10 min base with all six being flying 50 m efforts
- A full competition warm-up should be undertaken prior to the start of this session.
- For flying 50m efforts, the athlete starts ~ 50m back from the starting buoy of the measured 50 m effort (2nd buoy at 50 m to mark finish line). The athlete should gradually build up speed so that they are at maximal speed when they reach the first timing buoy. The aim to is complete the 50 m in as short as time as possible.
- It is recommended a 3rd buoy is placed ~ 1m past the finish buoy and that all athletes are encouraged to paddle to this buoy to ensure they do not slow down before completion of the full the 50 m effort.
- The standing starts where possible should be conducted in starting gates.
- The standing start is called by the coach using international starting procedures of ‘ready, set, go’.
- As per flying 50m efforts, it is recommended that a 3rd buoy is placed ~ 1m past the finish buoy and that all athletes are encouraged to paddle to this buoy to ensure they do not slow down before completion of the full the 50m effort.
- All efforts should be conducted in the same direction and where possible with a tail-wind.
- Where possible MinimaX units or 10Hz GPS units should be used on boats to record race profiles during all efforts.

Data Analysis -
- For both the flying 50 m and standing 50 m efforts, time, maximum and average speed as well as maximum and average stroke rate for each effort as well as 25 m intervals should be recorded from MinimaX units. In the AMS record the fastest effort as well as the average for the two efforts.
Protocol – Speed Endurance 50 m on 50m off 100 m On (Women and Sprinters)

Rationale -
This set monitors speed endurance which is important for the back end (100-200 m) of a 200 m and 500 m race. In this, the last 100 m is the main variable of interest as the athlete has pre-fatigue from the first 50 m and it is the ability of the athlete to maintain the back 100m.

Procedure -
All efforts should be undertaken in still water where possible and on a buoyed course.
- All 4 efforts are done off a 15 minute base for sprinters and 10 minute base for women.
- A full competition warm-up should be undertaken prior to the start of this session.
- The athlete starts the first maximal 50 m effort from a standing start which is called by the coach using the international starting procedure of ‘ready, set, go’.
- During the 50 m ‘off’ the athlete continues to paddle and at ~ 25 m into the 50 m ‘off’ the athlete should start to build the pace so that they hit the 100m mark at maximum pace.
- The aim of the final maximal 100 m effort is for the athlete to complete this segment as fast as possible.
- It is recommended a 3rd buoy is placed ~ 1m past the finish buoy and that all athletes are encouraged to paddle to this buoy to ensure they do not slow down before completion of the full the 100m effort.
- Where possible MinimaX units or 10Hz GPS units should be used on boats to record results

Data Analysis -
- Report the average flying 100 m time as well as the fastest 100 m time as well as the 50 m splits
- Report the maximum and average stroke rate for 50 m and 100 m efforts.
- Data should be entered into the AMS
Protocol – On-Water Incremental 750m

Rationale -
On-Water incremental monitoring is designed to provide reliable information regarding the athlete’s sub-maximal and peak physiological capabilities. The incremental test provides the best indication of the physiological efficacy of the on-water training program in athletes. By using standardized stroke rates and amounts of work done prior to the final step, one can compare both efficiency and maximal performance improvements among junior, developing, and senior elite athletes during a season and over an Olympic cycle. On-Water testing differs to lab testing as it takes into account both the physiological aspects of an athlete as well the efficiency of an athlete as the technique interacts with the physiology in their ‘real environment’ which should provide the most accurate training zone information to the athletes and coaches.

Procedure -
The on-water steps entails the completion of an incremental protocol performed on a buoyed or marked course with no flowing water. If weather permits (i.e., wind velocity is <1.0 m/s and therefore is not affecting boat speed), a straight 750 m buoyed course should be used, with the athletes paddling up and back on subsequent steps.

The athletes are required to complete 4 x 750 m sub-maximal efforts on a 10 minute cycle (men) and women 4 x 750 m sub-maximal efforts on a 12 minute cycle (women).

Administration of the protocol should proceed as follows:

- Record all necessary details for the athlete being tested (e.g., body mass) and environmental conditions (e.g., location, ambient temperature, relative humidity, water temperature, water depth, water currents, wind speed and direction).
- Attach the HR monitoring chest strap to the athlete and ensure that the device is synchronized to its associated data logger.
- Ensure that a global positioning system (GPS) watch is attached to the boat so the athlete can view the elapsed time and speed.
- Line the athlete up on the start of the buoyed course, ensuring that they know the stroke rate of the ensuing effort.
- Ask the athlete to start the GPS watch.
- The athletes can either paddle solo allowing a 2 min gap between athletes or as a group with the emphasis on keeping the required SR
- As the athlete works through the protocol, the coach should provide continual information concerning stroke rates
- During each workload, record time to complete the effort average stroke ratings over the entire period and heart rate over the final 15 s.
- At the completion of each of the sub-maximal efforts, an earlobe blood sample should be collected and analyzed for [La⁻].
- An RPE should also be collected when the lactate sample is being collected

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During the remaining rest period prior to commencement of the next 750 m effort, the athlete should paddle back to the start line as all efforts should be undertaken in the same direction.

<table>
<thead>
<tr>
<th>Effort</th>
<th>750 m</th>
<th>750 m (max effort 500 m)</th>
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<tbody>
<tr>
<td></td>
<td>Men’s Effort Start Time</td>
<td>Men’s Stroke Rate</td>
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<tr>
<td>1</td>
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<tr>
<td>2</td>
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<td>3</td>
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<tr>
<td>4</td>
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<td>100</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>Max</td>
</tr>
</tbody>
</table>

The Maximal Effort (750 m Effort for Men and 500 m Effort for Women):
The final stage can provide the sport scientist with information about an athlete’s ability to perform at maximal intensity and can differentiate performance between athletes who have completed the same submaximal steps. Several factors are important during the maximal effort:

- Athletes should be informed that they must complete the 750/500 m as fast as possible and without the aid of a GPS giving time or velocity feedback during the effort.
- Athletes should be encouraged to adopt an even pacing strategy during the final trial.
- On completion of the maximal step, a RPE should be collected immediately and blood lactate sample should be collected 4 min posttest.

Data Analysis -
The following points should be considered when interpreting the On-Water Step protocol:

- Total time for each effort and average stroke rate should be taken from the MinimaX
- The tester should report final time, average stroke rate, 1000 m pace (500m pace for women), and effective work for the efforts.
- ADAPT2 and LTmod method should be used to report heart rate and SR for the first and second lactate thresholds (i.e. LT1 and LT2). Stroke rate for fixed points of 4 and 6 mmol·L⁻¹ of lactate should also be reported.
- Lactate values for LT1 and LT2 should be calculated using only the data from the first four submaximal efforts
- Heart rate at LT1 and LT2 should be calculated using data from all five efforts including the maximal stage.
- Training Zones should be given back to the athletes and coaches which should provide lactate, heart rate and stroke rate.
- Lactate and HR values for training zones should be based off values for LT2 as calculated above, stroke rate values for training zones should be calculated from SR at 4 mmol·L⁻¹.
- Data should be entered into the AMS
- The report is automatically generated in the AMS

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Limitations -
One consideration of the on-water incremental kayak protocol is the ambient temperature in which the set is conducted. High ambient temperatures (~30 °C) have been shown to increase blood lactate concentrations (Chen et al. 2006), heart rate and RPE (Marino et. al. 2001), and lactate threshold (Flore et al. 1992) compared with similar workloads in normothermic temperatures (10-15 °C). Such findings are potentially of major importance when taking blood lactate measures in the field and should be considered when interpreting the results. The water temperature, water depth, and direction of current will also affect boat speed and should be recorded during the session for future reference.

Laboratory vs. On-Water Monitoring -

Advantage of laboratory-based protocols:
• Performed in a controlled, stable environment.
• Physiological data are easier to gather.
• Provide greater accuracy in the control of workloads.

Disadvantages of laboratory-based protocols:
• Specific paddling technique may be questionable due to ergometer design.
• Maybe affected by the ability of the ergometer to cope with high stroke rates.
• Because of equipment limitations, generally only one athlete can be monitored at a time.

Advantages of field-based protocols:
• Extremely specific to actual athletic performance.
• Perceived as more practically significant to the athlete and coach.
• Enable the scientific staff to assess more than one athlete at a time.

Disadvantages of field-based protocols:
• Effected by environmental conditions (e.g., ambient and water temperature, wind speed and direction, water surface conditions).
• Limited by the equipment the athlete can use.
• Limited number of physiological parameters that can be measured and monitored.
STRENGTH MONITORING
Strength / Power:
Maximum strength is the peak external load that can be moved in a specific dynamic task without reference to time. It is considered to be the basic quality that influences power [Schmidtbleicher, 1992]. Strength can be measured/expressed as a given number of repetitions (1 RM, 3 RM, 6 RM), where 1 RM is the maximum load an athlete can lift for one repetition. Three RM and six RM are the heaviest loads an athlete can lift in a given exercise with good technique and no external assistance three or six times, respectively. Strength and power assessment protocols included in this manual include variations of multiple RM protocols.

The benefits of a multiple RM test compared to a maximal 1 RM test are:
• Most athletes are not accustomed to using 1RM in training therefore multiple repetitions provide greater familiarity to training sets
• Multiple repetitions allow for assessment of technique during performance of test and allow for the early detection of technique deterioration
• Multiple repetitions can provide for greater reliability in the assessment of strength and power.

Strength endurance (SE) is measured as the maximum number of continuous repetitions completed at a designated load. Strength Endurance can be classified as either absolute or relative to maximum strength [Young, 1995]. Relative SE relates to the muscles ability to work at a given percentage of maximum strength (i.e. 75% of 3RM). Absolute SE is the muscles ability to work at a predetermined load, irrespective of maximum strength (i.e. 50 kg or 100 kg).

All of the following recommendations must be supervised by an accredited strength and conditioning coach/scientist. All exercises are to be performed in a controlled manner. Any noted technical violations will result in the trial being invalid and a 2nd attempt at the same weight will be provided. All results should be entered into the Athlete Monitoring System (AMS).

The following general guidelines must be adhered to for all exercises:

• Record the athlete’s body mass (kg) on calibrated scales.
• Ensure that the athlete has performed an appropriate warm-up. As a minimum, all athletes are required to perform a trial at ~ 90% of their specified repetition maximum for each exercise. In the first test, the athlete should perform an initial trial at ~ 90% of weight lifted in training for the specified number of repetitions.
• Lowering and lifting actions must be performed in a continuous manner. A single rest of no more than 3 s is allowed between repetitions.
• A minimum of 2 mins recovery between trials should be required.
• A maximum of 5 mins recovery between trials is allowed.

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• Recovery should ideally be passive rest and stretching should be avoided unless required for medical reasons.
• Minimum weight increments should be guided by the ease of each trial. However, it is important to note that increments less than the TE for that exercise may not necessarily reflect a true biological change.
• Ideally, specified RM sets should be completed within four trials (not including the warm-up).
• If the athlete is unable to complete tests as per protocol then this should be noted on monitoring results information, and values should not be included in any mathematical calculations (e.g. average, TE).
• It is recommended that a spotter, other than supervising coach/assessor, should be used where possible.
• If the athlete is unable to adequately complete one rep within a set, then set/test should be recorded as a fail. If the tester is unsure as to the successful completion of a test set, or an athlete believes that they can complete the set successfully, allow the athlete a 2nd attempt within 2-3 min of initial trial.
• An athlete’s body mass for each monitoring session should be recorded as the body mass including clothes and shoes if these are lifted against gravity, e.g., in chins.
• Relative strength scores, i.e., load lifted divided by body mass, should be calculated using the body mass without excess clothes and shoes.
• Relative strength scores may also be calculated as a function of lean or fat-free body mass.
Protocol – Bench Press 3 RM

**Preparation** -
- Athletes may choose the width of grip that they prefer initially, but this should remain consistent over consecutive attempts and monitoring sets.
- The Olympic barbell should weigh 20 kg with no weights loaded.
- Foot position: both feet on the floor with thighs horizontal to the floor. (Blocks may be used to attain correct foot position. Ensure repeatability is achieved).
- The athlete’s buttocks should be on the bench.
- Record RM result in the AMS.
- Recommended assessor position ~ 45° to the front of the athlete, level with hips to facilitate observation of feet, shoulders and buttocks and bar contacting chest or pad.

**Technique** -
- A valid repetition is one in which the athlete lowers the bar to a 90° elbow flexion in a controlled movement prior to completing the lift to full elbow extension.
- A pad on the athlete’s chest may be used to provide the tester with a clear sign of whether the athlete has reached the pre-determined depth.
- The thickness of the pad should be chosen such that the bar contacts the pad when the athlete’s elbows reach 90° of flexion in the descent.
- Thickness of pad must be recorded and consistent within each test.

**Technical Violations** -
The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:
- Failing to make contact with or excessively bouncing the bar off the chest or pad;
- Lifting the shoulders or buttocks off the bench;
- Raising either foot off the bench/ground so that it breaks contact with the floor;
- An uneven bar during the lift (shoulder elevation or uneven extension of arms during lift);
- Having greater than 3 s rest between repetitions.

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Protocol – Bench Pull 3 RM

Preparation -
- Set bench height so that the athlete can comfortably take the desired grip whilst the weight is on the ground. If required, blocks can be used to raise the height of the barbell starting position
- Start position: athletes must start all lifts from a stationary position with the bar supported as described above.
- The Olympic barbell should weigh 20 kg with no weights loaded
- Athletes may choose the width of grip that they prefer initially, but this should remain consistent over consecutive attempts and monitoring sets.
- Some part of the head should be on the bench at all times.
- The height of the knee platform should be adjusted so that the athlete’s hips are flat on the upper bench; the athlete’s femurs are parallel to the rear support and the knees rest comfortably on the knee platform.
- The height setting of the knee platform should be recorded and maintained at the same setting throughout the test session and in subsequent tests unless the athlete undergoes significant changes in leg length
- The knees should remain on the bench at all times and at no point should the legs be secured to a wall
- Record RM result in the AMS.
- Recommended assessor position - 45° to front of athlete level with hips to facilitate observation of feet, knees, shoulders and head and bar contacting underside of bench.

Technique -
- A valid repetition is one in which the athlete raises the bar to a 90° elbow flexion and the bar is dropped in a controlled manner to the floor.
- Feet should remain off the ground throughout the lift and in the same position throughout lifts.

Technical Violations -
The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:
- Movement of the head and/or legs from chosen start position (i.e. athlete can start with head down or to the side but it must remain in this position and in contact with the bench at all times);
- Movement of trunk away from bench, and/or any hip flexion/extension;
- Failing to reach 90° elbow flexion or greater than 3 s rest between repetitions;
- Excessive deviation of bar from ‘normal’ position observed in warm-up (i.e. maintain abducted or adducted position);
- An uneven bar during the lift (shoulder depression, uneven flexion of elbows during lift);

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Protocol – Weighted Chin Ups

This test requires a high level of technical proficiency and is recommended for athletes with a solid training base. A qualified and experienced strength coach/scientist must supervise this test.

**Preparation -**
- Chin ups should be performed with a medium width, pronated grip. Athletes may choose the width of grip within limits, but this must remain consistent over consecutive attempts and longitudinally.
- A straight bar should be used for testing chin ups.
- Record RM result on the AMS. Results should be recorded as body mass + external mass lifted (in kgs)
- Recommended assessor position – side on to the athlete at eye level with bar.

**Technique -**
- Starting from a fully extended elbow position (hang position with a set scapula) the athlete is required to pull body up in one smooth action so that at the top of the lift, the top of the hands are level with the nose with the athlete facing horizontally ahead, i.e., the head is not tilted backward.
- Legs can be held in semi-flexed position or extended, however they must not be moved in a way that increases upward momentum in the pulling phase of the lift, i.e., no kicking.
- Athletes should be encouraged to complete the lift with minimal head movement.

**Technical Violations -**
The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:
- Not achieving correct height (bar is below the level of the nose);
- Breaking of the hips and/or knees from start position during the lift;
- Body swing during lift;
- Not going to full elbow extension between repetitions;
- Having greater than 3 s rest between repetitions.
Protocol – Deadlifts 3 RM

This test requires a high level of technical proficiency and is recommended for athletes with a solid training base. A qualified and experienced strength coach/scientist must supervise this test.

**Preparation** -
- 20kg Olympic bar should be used and placed in front of the individual on the floor.
- Starting position requires a comfortable neutral position with feet shoulder width apart, chest should be elevated, shoulder blades back and knees bent. Experienced lifters will tend to adopt a consistent stance that suits their particular individual anatomical characteristics.
- Grip should be slightly wider than legs with arms straight to create some tension on the bar.
- Blocks may be used to raise the bar off the ground in order to attain correct starting position due to individual anatomical positions. These block heights must be measured and maintained longitudinally.

**Technique** -
- A valid repetition is one in which the bar is lifted in one continuous motion to a point at which the body reaches a fully upright position with the knee and hip joints extended to a ‘neutral’ position (i.e. the back in line with the rest of the fully upright body).
- For the lift the individual should not initially lead with the hips but rather maintain the starting position until the bar is at knee height before allowing the hips to drive forward to meet the bar at the apex of the lift. Bar is required to move in a straight line and as close to the individuals legs as possible.
- The hips should swing through and meet the bar at the apex of the lift.
- Finish position - the body should be in an upright position with the bar held with fully extended arms.
- During the movement little or no change in back position should be noted until the final extension of the hips occurs, bringing the back into line with the rest of the fully upright body.
- The chest should stay up and the back must not bend or show excessive flexion during the lift.
- Repetitions should be completed as soon as possible after each other, however a single rest of no more than 5 s is allowed to re-position hands.
- The bar should be dropped to the floor between repetitions.
- Record RM result on the AMS.
Technical Violations
The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Failing to have the correct set-up, and lifting techniques;
- Failing to lift the bar in one continuous motion;
- Collapsing the back position during the lift;
- Having greater than 5 seconds rest between repetitions.

Protocol – Single Leg Squats

This exercise requires a high level of technical proficiency and is recommended for athletes with a solid training base. A qualified and experienced strength coach/scientist must supervise this.

Preparation

- The safety bars should be set at the highest possible point without affecting the athlete’s range of motion.
- Heel blocks should not be used unless anatomical structures limit the athlete’s range of motion or prevent the exercise from being performed with correct technique. Use of heel blocks should be consistent longitudinally.
- Athlete should assume a natural stance with feet approximately shoulder width apart.
- A bench or box should be placed behind the athlete. This bench or box should be adjusted to the approximate height of the athlete’s tibial tuberosity with the leg vertical or lower. The height must be recorded and maintained longitudinally.
- The Bar should be held in a ‘high’ bar position on the trapezius during the exercise. Hands should be held in a comfortable position as close to shoulders as possible.
- The athlete should lift the bar from the rack then step backwards to a comfortable, natural stance.
- One foot, the rear foot, should be lifted backwards and placed on the box/bench with the dorsal surface of the rear foot on the top of the bench/box and still about shoulder width apart laterally from the front foot, despite being separated by a large distance antero-posteriorly.
- Majority of body weight must be placed on the front foot not on the back foot.
- The front foot should be positioned such that at the bottom the squat, the front lower leg is close to vertical and the front knee tracks forward over the front foot but does not project excessively beyond the toes of the front foot.

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**Technique** -

- A valid repetition is one in which the weight is lowered to required depth and then extended to full leg extension with trunk as upright as possible.
- The rear knee will drop directly towards the floor and may touch the floor at the bottom of the range.
- During the lowering action the knee should travel forward over toes. The heel must remain in contact with the floor at all times during the set.
- Athletes are required to lower to 90° at the knee.
- The set should be repeated on both sides with a short rest, 30 s – 1 min between each leg.
- The legs should be tested independently, so a different 3RM may be achieved on each leg.
- Record RM result on recording sheet.
- Recommended assessor position – side on to athlete to facilitate observation of hip/knee angle, back posture and depth.

**Technical Violations** -
The following technical violations will result in the trial being invalid and a 2nd trial at the same weight provided:

- Excessive forward or sideways movement during test;
- Loss of controlled spinal position;
- Lifting of heels off the floor;
- Not lowering to required depth;
- Raising of hips prior to shoulder elevation;
## Traceability Information

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<th>Date</th>
<th>Protocol / Code</th>
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<td>NP_Kayak_v1.0_2007</td>
<td>Kayaking “2 in 1” test (6 x 5min submaximal steps with 1 min recovery; 20 min break followed by maximal 4 min effort)</td>
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<td>Feb 2011</td>
<td>NP_Sprint Kayak_v2.0_2012</td>
<td>Sprint kayak chapter prepared for 2\textsuperscript{nd} edition of Physiological Tests for Elite Athletes; April 2010 - “2 in 1” test replaced by 7 x 4 min step test (6 submaximal steps + 1 maximal step); Feb 2011 - Kayak AOD test added; Revised normative data included</td>
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<tr>
<td>2015</td>
<td>NP_Sprint Kayak_v3.0_2015</td>
<td>Protocol document formatted for National use; New AIS logo included. On-Water Step test changed to reflect adoption of stroke rate to dictate pace rather than velocity and 500m now performed as the max effort for women. Interpretation of the on-water test now added. 2 x 6 x 300m protocol added. All wind conditions are now monitored in km.h rather than m.s. Strength and Conditioning National Protocols added to document following the S&amp;C Performance Support meeting and agreement on monitoring protocols (Craig Colduck, SASI; Geoff White, NSWIS; Greg Morgan, WAIS; Glen Workman and Deb Savage, AIS October 2014)</td>
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References


