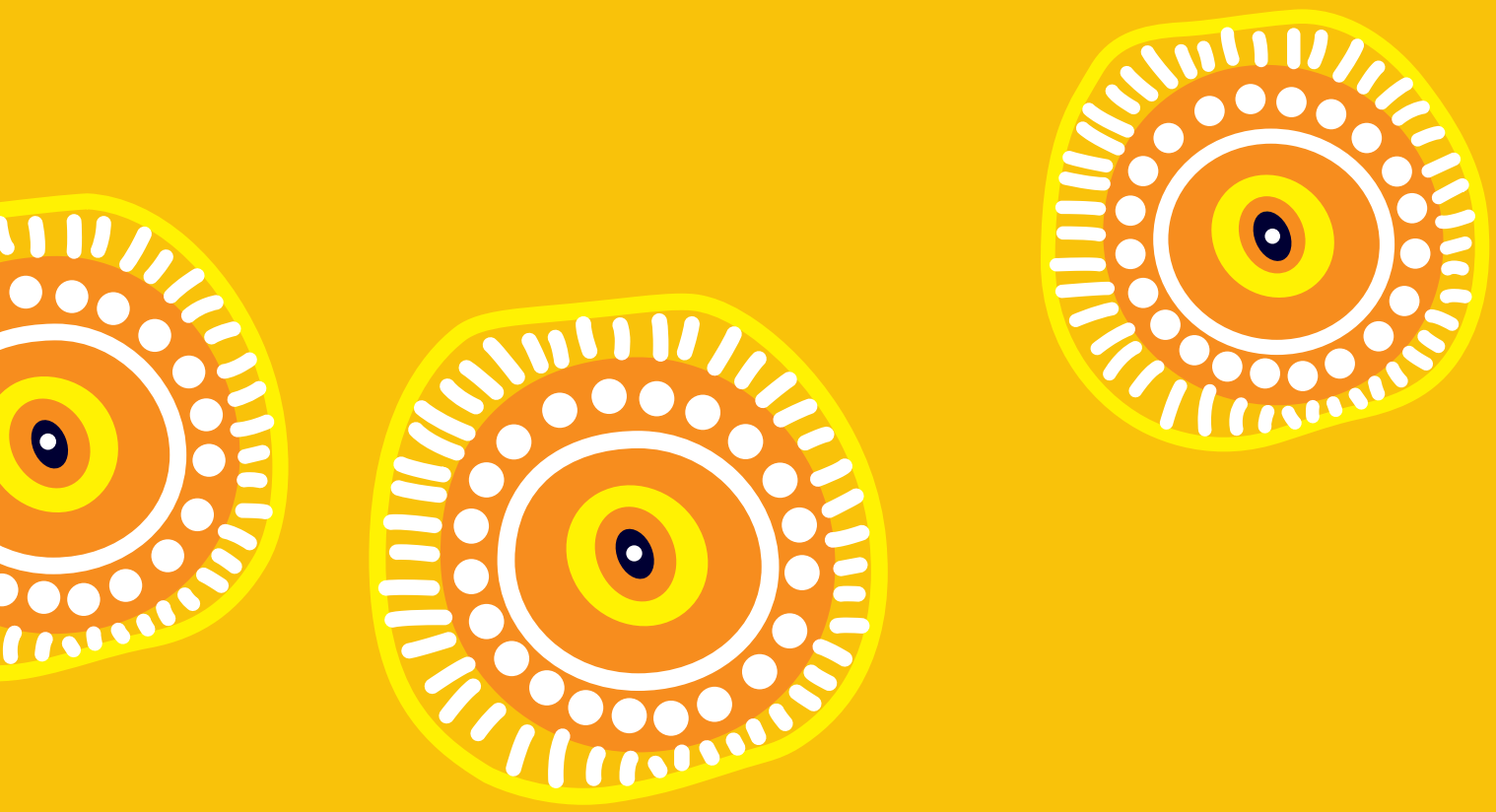
AIS

RESTING METABOLIC RATE MEASUREMENT

National Testing Protocol



Australian Sports Commission Acknowledgement of Country

The Australian Sports Commission (ASC) acknowledges the Traditional Custodians of the lands where its offices are located, the Ngunnawal people and recognise any other people or families with connection to the lands of the ACT and region, the Wurundjeri Woi-wurrung people of the Kulin Nation, the people of the Yugambeh Nation and the Gadigal people of the Eora Nation.

The ASC extends this acknowledgment to all the Traditional Custodians of the lands and First Nations Peoples throughout Australia and would like to pay its respects to all Elders past, present and future.

The ASC recognises the outstanding contribution that Aboriginal and Torres Strait Islander peoples make to society and sport in Australia and celebrates the power of sport to promote reconciliation and reduce inequality.

CONTENTS

1. INTRODUCTION

Basal metabolic rate (BMR), also known as basal energy expenditure, represents the minimal energy cost of living (1) and makes up one of the components of total daily energy requirements alongside the thermic effect of food, exercise activity thermogenesis, and non-exercise activity thermogenesis (2). BMR is measured in the morning, in a fasted state, with the individual staying overnight in the laboratory (3). When metabolic rate is measured in an outpatient setting such that the individual sleeps outside of the laboratory and commutes to the laboratory for testing, this is known as Resting Metabolic Rate (RMR) (3). Measurements of RMR are typically higher than BMR, but similar results are seen when there is an adequate period of rest prior to the RMR measurement (4, 5). As measurements of metabolic rate within the Australian High Performance Sport System occur under outpatient conditions, the terminology of RMR will be used throughout the remainder of this report.

The reference standard for measuring RMR is direct calorimetry, which measures total heat loss from the body by placing an individual in a thermically isolated chamber from which heat dissipation can be quantified (6). However, facilities needed for these assessment methods are incredibly rare, and instead, indirect calorimetry is more commonly used (7). Methods of indirect calorimetry include open circuit calorimeters (metabolic cart and Douglas Bag method), open circuit diluted flow calorimeters (metabolic cart with hood) and respiratory chambers. (8). Indirect calorimetry assesses the amount of heat generated indirectly according to substrate use and by-product production, by measuring the amount of oxygen consumed (VO_2) and carbon dioxide (VCO_2) produced through respiratory gases (9).

Total energy expenditure can then be calculated using the modified Weir equation as follows:

$$\mathbf{[3.94 \times VO_2] + [1.11 \times VCO_2]}\ (10)$$

Knowledge of an athlete's RMR has many practical applications. This includes providing information on an athlete's energy requirements, which can help guide dietary planning. A more novel use of RMR is as a potential clinical indicator for low energy availability (LEA) (11). LEA is the underlying cause of Relative Energy Deficiency in Sport (REDs), a syndrome of impaired physiological function that may result in impaired health and performance consequences, making early identification of an athlete with LEA critical (12). A proposed physiological outcome of LEA within the REDs model is impaired energy metabolism resulting in a suppressed RMR (12). The suppression of RMR is typically assessed by determining the ratio of an athlete's laboratory-measured RMR via indirect calorimetry to their estimated RMR using a prediction equation, and/or relative to fat free mass (FFM) (13, 14). If the corresponding value falls below a threshold, this has been used to indicate LEA risk (13, 14). However, the use of RMR measurements as a clinical indicator of REDs is still emerging and not considered formal diagnostic criteria due to specificity and sensitivity concerns (15).

A uniform approach is needed when measuring RMR across the Australian High Performance Sport System to reduce technical and biological variability in RMR measurements that is contributing to specificity and sensitivity concerns. In 2024 an Insight Report was undertaken by the Australian Institute of Sport (AIS) and Australian Catholic University (ACU) to capture the current practice for measuring RMR across the Australian High Performance Sport System. Interviews were conducted with technicians measuring RMR at National Institute Networks (NIN), National Sport Organisations (NSO), and Sporting Codes. This information was then used to update the Best Practice Protocol for measuring RMR. An insight report, which includes detailed information on these interviews can be obtained by emailing QualityAssurance@ausport.gov.au. The rationale for the RMR measurement protocols recommended can be found in Appendix A.

Beyond one NIN and one NSO using the Douglas Bag method to measure RMR, all remaining technicians reported using the ParvoMedics TrueOne metabolic cart with a mouthpiece and nose clip. Therefore, this protocol is specific to RMR data collection using the ParvoMedics TrueOne metabolic measuring system.

To obtain a copy of the Douglas Bag method please email QualityAssurance@ausport.gov.au

1.1 Reasons for referral and contraindications

Possible indications for a RMR measurement referral include the following:

- Athlete with suspected or known LEA as per the REDs Clinical Assessment Tool Version 2 (REDs CAT2) Severity/Risk Assessment Tool.
- As part of athlete health monitoring, such as monitoring the impact of a dietary and/or training intervention.
- To assist in determining an athlete's energy requirements for dietary assessment and/or planning purposes.
- As part of a research study i.e. where RMR measurements are being used to assess for LEA, in response to an intervention, and/or to help determine energy needs.

If RMR measurements are being used for LEA screening and/or assessment purposes, the following should be considered as reasons that a RMR measurement **may not** be appropriate:

- **Athletes with disordered eating, an eating disorder, or body image concerns** where an assessment of body composition may be contraindicated, given RMR data interpretation requires concurrent capture of fat free mass (FFM) mass. Please refer to the Disordered Eating Position Statement here: Disordered eating in high performance sport | ASC for more information.
- When other indicators of LEA are not being measured (As outlined in Section 1.2: Additional measurements)

Further potential contraindications for RMR measurement are:

- An athlete is unable to follow the requirements of testing (unable to lay on back for an hour, present in a fasted state etc.)
- Absence of appropriate equipment and trained technician for testing.
- There is no clear rationale for a RMR measurement.
- Consent cannot be obtained from the athlete.
- RMR on <18 years is not recommended due to potential growth. Seek guidance from support services team before proceeding and obtain guardian consent.
- Referring technician is unable to schedule individual feedback on RMR measurement results.
- Time frame between measurements is insufficient to observe any likely true change.
- Other relevant measures important to interpretation of data can't be captured concurrently.

1.2 Additional measurements

When RMR measurements are being used to screen for LEA or to monitor the effectiveness of a nutrition intervention to resolve LEA, **the following must also be measured concurrently to help interpret findings** in accordance with the REDs CAT2:

- Biochemical indicators of LEA: triiodothyronine (T3), total cholesterol, low density lipoprotein (LDL) cholesterol, and testosterone levels (males only)
- Bone mineral density (BMD) Z-score of lumbar spine, total hip, and femoral neck (unless BMD scan within the last 12 months with findings of a normal BMD)
- Bone stress injury (BSI) history in the previous 2 years
- Menstrual status in female athletes
- Global score on the Eating Disorder Examination Questionnaire (EDE-Q)
- Body composition via DXA scan to quantify relative RMR and RMR ratios

If risk of REDs has already been assessed, then remeasuring the LEA indicators above may not be necessary. It is the responsibility of the practitioner referring for a RMR measurement to also ensure that the above LEA indicators are also captured.

1.3 Technician training

Technicians must be offered structured training on RMR measurement procedures (16). Education on the following must be provided:

- Rationale for RMR measurement referral and contraindications
- Informed consent
- Athlete pre-measurement standardisation requirements
- Testing room requirements including athlete's privacy
- Infection control and hygiene practices
- Equipment preparation and set-up
- RMR measurement protocol
- Post-measurement analysis and clean-up
- Data management and AMS

In addition to providing education on the above, technicians should have the opportunity to shadow and perform a RMR measurement alongside a trained technician until they are competent and confident to perform the measurement without supervision. It is recommended they attend a minimum of three competency-based training sessions in short succession prior to administering a test unsupervised. These include a theory session, a shadow session and finally a session where they lead with the assessor shadowing to make corrections if required and deem competency.

2. PRE-TEST PREPARATION

2.1 Informed consent

All athletes (and parents or guardians if athlete <18 years) must be fully informed of the RMR measurement procedures and rationale for testing plus complete an informed consent form (see Appendix B for example informed consent). Written informed consent must occur prior to the morning of testing as athletes will need to stay in a rested state for the RMR measurement with testing commencing as soon as the athlete arrives on testing morning (see more below under athlete preparation). The RMR technician should ask the athlete the following questions and obtain verbal consent on the day:

- Are you aware of what testing you are having done today and why?
- Do you consent to us completing this testing today?

A briefing before testing is required to give all the required information, allow time for questions, and for informed consent. Athletes must be given the opportunity to ask questions about RMR measurements and be made aware that they are able to withdraw their consent at any time prior to and during the RMR measurement.

2.2 Athlete preparation

Athletes must present to RMR testing in a standardised state. Athletes must be made aware of the following instructions in advance of the day of RMR measurement:

- Must be overnight fasted.
- Normal training the day prior to a RMR measurement with no novel training and avoiding excessive intensive training.
- No training and minimal activity on the morning of testing. If possible, RMR testing should occur as close as possible to an athlete's natural wake time. This should be discussed in advance with the athlete when planning timing of the testing. For example, for a morning of multiple tests, plan a staggered start so early risers are scheduled first with those who prefer to sleep in booked for later timeslots.
- Park or get dropped off as close as possible to where the RMR measurement will be conducted, and walk there slowly.
- Wear clothing that is comfortable to rest in.
- Minimise screen time and interactions prior to testing.
- No brushing of teeth or showering prior to testing.
- If athlete is on any medication that could affect results e.g., ADHD, then this should be consistent across testing and documented accordingly.

Athletes should be made aware that the technician will minimise talking and engagement on the day of testing until after the RMR measurement is complete. Therefore, the test should be fully explained to athletes prior to the morning of testing. Please see Appendix C for an athlete preparation handout. The RMR technician should check if athlete has ticked any of the boxes in the informed consent that would suggest testing should not proceed. Each sports institute should determine if it is the role of the referring practitioner or the technician to inform the athlete of RMR testing instructions.

2.3 Testing room

The testing room used for RMR measurements should be set-up in accordance with the unique environment of the sports institute. The testing room where RMR measurements occur must prioritise the following:

- **Darkness:** If windows are present in testing room, black-out blinds must be hung to minimise light.
- **Quietness:** There should be no noise coming from the surrounding area. Maintain two-way communications with other lab users in advance, such as others who may schedule activities nearby e.g., VO_2 Max tests, or facilities management with fire drills, on testing mornings. Consider hanging quiet signs to notify those in the area that quietness is needed for testing.
- **Comfort:** The room should be set up to maximise athlete comfort. If possible, a room specific for RMR measurements should be set up that minimises the feel of a clinical environment that may cause anxiety in some athletes. A comfortable bed should be available to athletes with blankets and pillows, and if possible, the room should be maintained at 20-24°C.
- **Airflow:** For small enclosed RMR rooms, a fan may be required to circulate air at the back of the analyser to minimise O_2 and CO_2 anomalies.

2.4 Equipment checklist

- [ ] **ParvoMedics TrueOne metabolic cart (referred to in the document as the metabolic cart)**
- [ ] **Clear and completely dry 6 ft tubing for expirate**
- [ ] **Mouthpiece and Hans Rudolph valve assembly (2-way non-rebreathing T-shape valve with saliva collector, 35mm OD) - 1 per athlete**
    - If adult (model 2700) and paediatric (model 2600) size mouthpiece is available for the first RMR measurement, both sizes should be presented to the athlete to select the more comfortable one used during the measurement. This should be noted on the test results, and the same size mouthpiece should be used for successive measures.
- [ ] **Nose clip – 1 per athlete**
- [ ] **RMR data collection sheet (see Appendix D)**
- [ ] **Stopwatch**
- [ ] **Bed, blanket, and pillow**
- [ ] **Towels – 3 per athlete**
- [ ] **Blackout blinds (if windows in testing room)**
- [ ] **Torch**

3. RMR TEST PROTOCOL - PARVOMEDICS

The following protocol is for RMR measurement using the ParvoMedics TrueOne metabolic cart with a mouthpiece and nose clip.

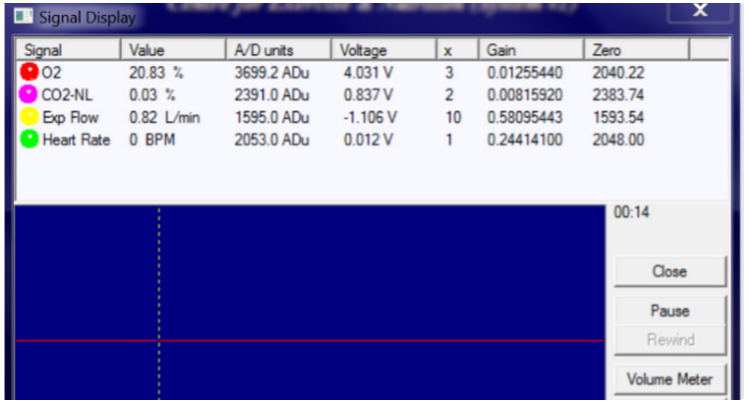
There are alternative gas collection methods that can be used with the ParvoMedics TrueOne metabolic cart, such as a ventilated hood. However, **a different protocol is needed if not using the mouthpiece and nose clip**.

As different gas collection methods may provide different results, a standardised gas collection method is recommended to be used across the Australian High Performance Sport System and when repeating an athlete's RMR measurement. At the time of writing this protocol, all technicians measuring RMR reported the use of the mouthpiece and nose clip, therefore this approach has been written into the national protocol. The Australian Institute of Sport reported the use of the First Principles Douglas Bag method to measure RMR, and a copy of the protocol for this measurement method can be obtained by emailing QualityAssurance@ausport.gov.au

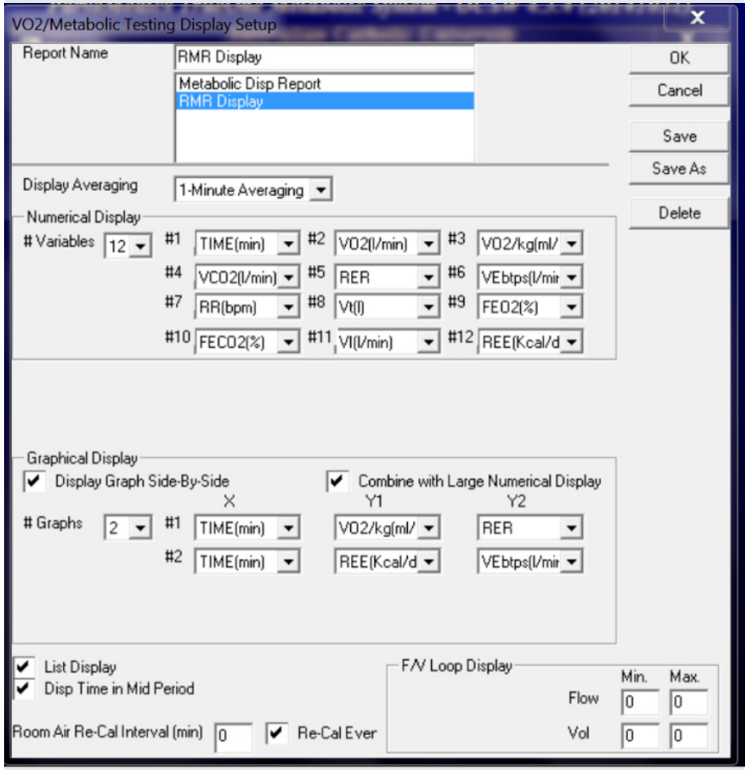
3.1 Test preparation

3.1.1 ParvoMedics TrueOne quality check

The following ParvoMedics TrueOne quality check should be completed on the day prior to testing.

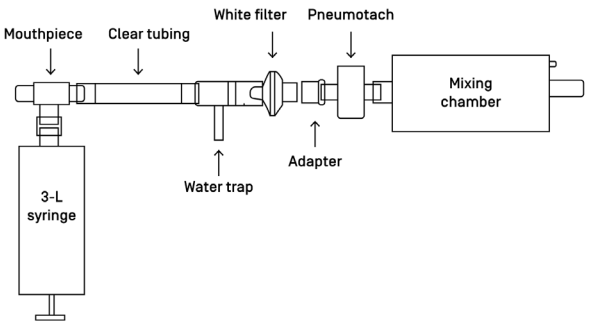
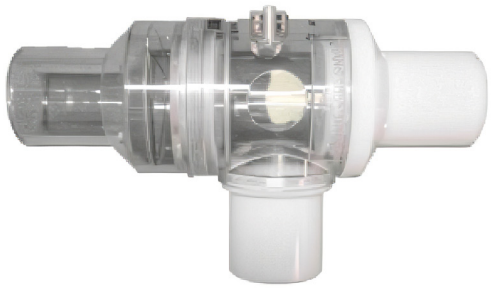
1	Turn on the metabolic cart and allow it to warmup for 30 minutes.	
2	Check that the O2 voltage and CO2 voltage is within the acceptable range: 1. Open the TrueOne Exercise program and open "Signal Display". 2. Check the O2 voltage is around ~4-4.2 V for sea level and around ~3.8 V for Canberra. 3. The CO2 voltage should be around ~0-1 V. 4. Ideally, the voltages should be checked on the day prior to planned testing to allow time to correct If required. 5. If the CO2/O2 voltages are not within the required ranges, a coarse or fine zero reset must be done.	
3	Ensure PermaPure drying lines have been replaced within the last 3 months.	
4	Check flow meter ball for correct location: Must be between 0.2-0.4 L/min.	
5	Check the regulator on the calibration gas cylinder for correct flow pressure 3 psi.	

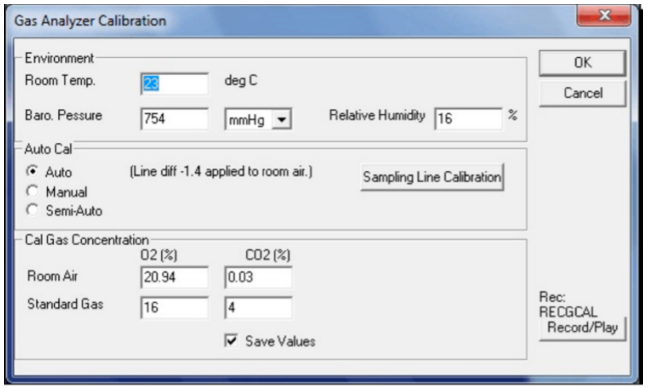
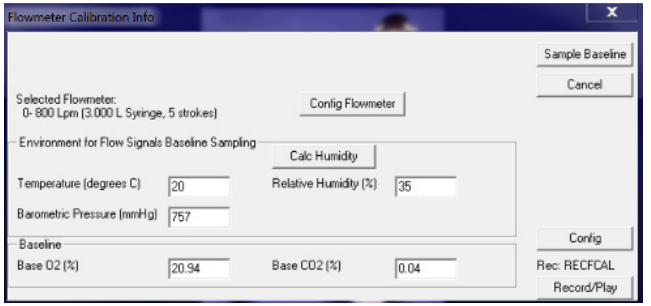
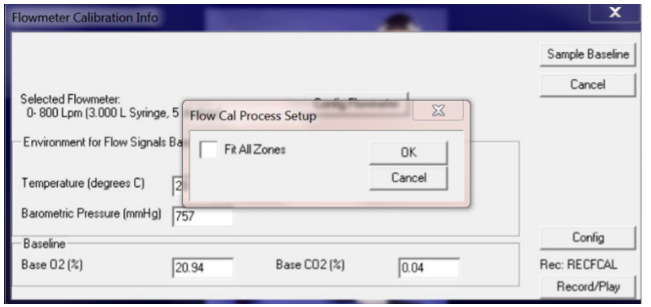
3.1.2 Setting up ParvoMedics TrueOne to measure RMR

1	1. Open “Utilities” and then “Procedure Configuration”. 2. Ensure "Breathe in room air" is ticked. 3. Ensure the temperature is "1/2 room to body".	
2	1. Open “Utilities” and then “VO2/Metabolic Test Display” and setup: Report Name: RMR Display; RMR Text Report Display Averaging: 1 minute averaging # Variables: 12. #1: Time (min) #2: VO2 (L/min)as #3: VO2/kg (ml/min) #4: VCO2 (L/min) #5: RER #6: Vebtps (L/min) RR (bpm) #7: Vt (l) #8: FEO2 (%) #9: FECO2 (%) #10: Vi (l/min) REE (kcal/day) The above headings will avoid calculation error if using AMS to store data. Graphical Display #Graphs: 2. This is up to you, but a suggested display is as follows: #1: Time (min) × VO2/kg (ml/min) × RER #2: Time (min) × VEbtps (L/min) × REE	

3.2 Day of RMR measurement

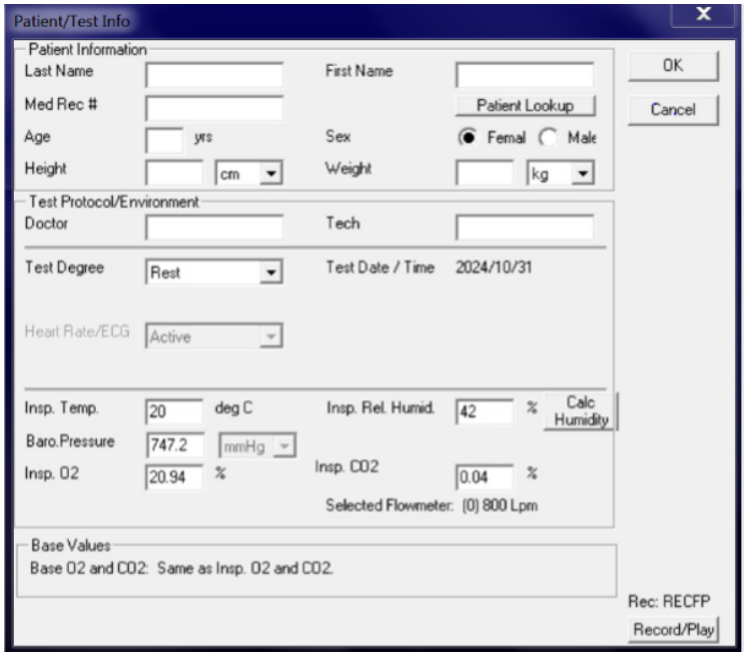
3.2.1 Setting up the metabolic cart (~60 min)

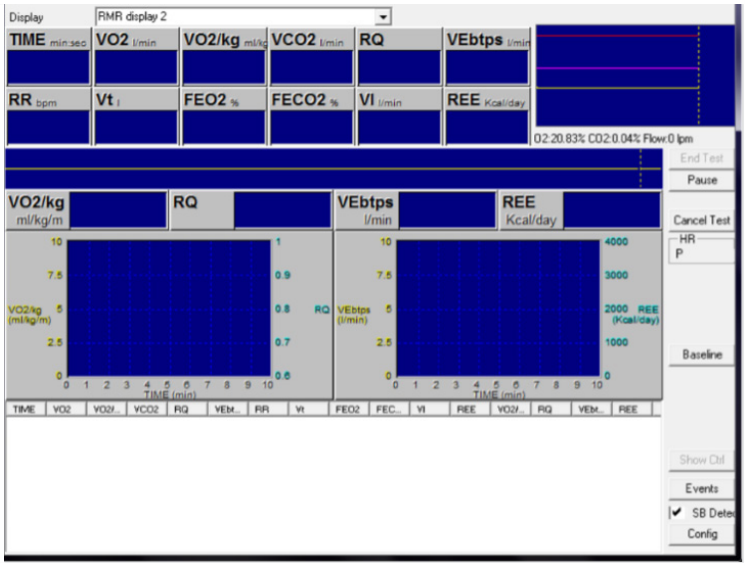
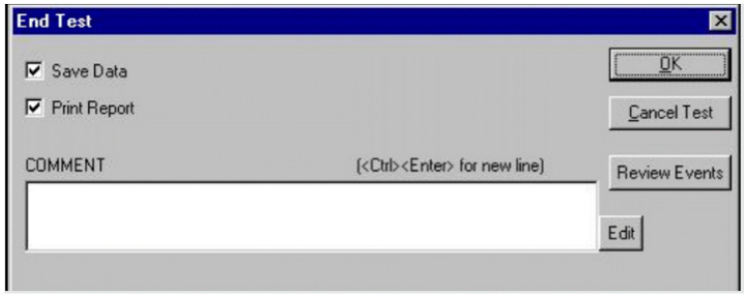
1	Turn on metabolic cart pump and heater <u>at least 30 minutes</u> prior to calibration.	
2	Connect equipment as follows: **Hans Rudolph mouthpiece** ▸ **Clear tubing** approx. 6 ft in length to minimise dead space ▸ **Water trap assembly** ▸ **Filter** ▸ **Pneumotach** ▸ **Mixing chamber**	
3	Assemble 2-way breathing valve without spit trap as per image and attach regular or paediatric mouthpiece according to best fit.	
4	Open the TrueOne Exercise Program. <u>Do not use the TrueOne RMR program as this is only appropriate to use when using the ventilated hood to measure RMR.</u>	
5	Sample line calibration – this doesn't need to be performed every test, but at the start of a testing battery, if the machine is moved from position, or new sample lines are being used.	

6	1. Open “Gas Calibration.” Enter environmental and auto Cal Gas calibration. 2. Ensure exercise gas is used (approximately 16% O_2, 4% CO_2). 3. Save. 4. Repeat to ensure difference is <1%.	
7	1. Open “Flowmeter Calibration”. 2. Click on “Config” and uncheck the "fit all zones" box. 3. Perform low flowmeter calibration × 2 so that strokes at 10-60 lbm. 4. Only need slight twist of rod clockwise for first 10cm, then straight. 5. Save. 6. Repeat until difference is <1%.	 
8	Dim light screen on computer and turn the screen away from computer to minimise brightness in room and so that athletes are not monitoring their data during the test.	

3.2.2 Measuring RMR (~60 min)

1	Upon athlete's arrival, obtain body mass and age. Blinded body mass should be considered to address possible sensitivities an athlete may have with this measure. Ask athlete to leave phone, watch, and other distractions outside testing room.	
2	1. Athlete should then lie down on testing bed. 2. Ensure athlete is warm and comfortable. 3. Remind athletes that they should remain still, relaxed, and try not to fall asleep, and that you will remain in the room during the measurement. 4. Once athlete is comfortable, start the stopwatch for 10-minute rest period.	
3	After 10 minutes of rest, give athlete a Hans Rudolph mouthpiece (without nose clip) that is attached with tubing to the mixing chamber. Towels should be resting under the athlete's chin and around neck for support, so mouthpiece is not pulling. Rest with mouthpiece in for a further 15 minutes as familiarisation.	

4	1. After 15 minutes of familiarisation, click “V02/metabolic testing”. 2. Enter the athlete’s details and change the test degree to “Rest”. 3. Give athlete a nose clip. 4. Press OK.	
5	1. At “Ready to start testing” window, check tubing connections to filter, pneumotach and mixing chamber, ensuring no leaks. 2. Wait ~1-2 minutes minute for gases and flow to stabilise – CO2 >3% or no longer increasing. 3. Once stabilised, press OK.	

6	System will begin recording data. After approximately 5-6 minutes, or when you are satisfied that the system is stabilised (graphs should be trending close together) begin recording the start and finish time for a 20-minute collection period. Technicians should stay in the room during testing in order to monitor the measurement and take notes of any events that may create an artefact in the measurement (i.e. athlete coughing, unexpected noise etc) and the time this occurred.	
7	1. Upon completion of the collection period, click “End Test”. 2. Ensure that “Save Data” and “print report” are checked then click OK. 3. Remove the athlete’s mouthpiece and nose clip. 4. Click on “reports” and select appropriate report. 5. Select “Excel Export.” This data will be entered into AMS as outlined below.	
8	Ask athletes post-test questions on the data collection form as this information will help interpret findings, and ensure all data points have been collected as per the RMR data collection sheet.	

4. DATA ANALYSIS, INTERPRETATION AND REPORTING

Data should be entered from the Excel export into the AMS for automatic calculation of an athlete's RMR when using the ParvoMedics to measure RMR.

- All of the ParvoMedics data should be entered into the AMS form.
- The first 5 minutes of entered data will be automatically excluded.
- RMR will automatically be calculated from the mean of steady state during the testing window.
- Steady state is defined as >5 minutes with <10% coefficient of variation (CV) in VO_2 and VCO_2.
- The modified Weir equation will then be used to calculate the average RMR over the period of steady state. If steady state was not achieved during the RMR measurement, then the test should be considered inaccurate and repeated.

When RMR is being used as an LEA screening tool, an athlete's measured RMR can then be divided by an athlete's FFM (relative RMR) and/or by predicted RMR (RMR ratio). The following are typically used as thresholds to indicate a suppressed RMR indicative of LEA:

LEA Threshold	Equation
<30 kcal/kg FFM/day	**Relative RMR =** Measured RMR ÷ FFM
<0.90	**RMR ratio with Harris Benedict (Men) =** Measured RMR ÷ [66.47 + 13.75(BM) + 5(Ht) – 6.76(Age)]
<0.90	**RMR ratio with Harris Benedict (Women) =** Measured RMR ÷ [655.1 + 9.56(BM) + 1.85(Ht) – 4.68(Age)]
<0.90	**RMR ratio with Cunningham 1980 =** Measured RMR ÷ [500 + 22(LBM)]
<0.92	**RMR ratio with Cunningham 1991 =** Measured RMR ÷ [370 + 21.6(FFM)]

BM= body mass; FFM= fat free mass; Ht= height; LBM= lean body mass.

AMS will automatically flag RMR results that fall below the thresholds indicative of a suppressed RMR. However, the thresholds above may change with various biological factors, such as age, sex, or ethnicity and should be used with caution. Particularly, caution should be taken when using a relative RMR <30 kcal/kg FFM/day for athletes with a high quantity of FFM as this ratio is reduced with increased FFM due to an increased proportion of FFM as low metabolic rate tissue. Athletes with a RMR measurement that falls below the thresholds above does not necessarily have a suppressed RMR indicative of LEA. Similarly, athletes with a RMR measurement above the thresholds could still have LEA. Primary and secondary indicators of LEA must be used to help interpret RMR measurements and RMR measured longitudinally to assess changes over time.

Referring practitioners should schedule a follow-up consultation with the athlete to provide feedback on results.

5. ACKNOWLEDGEMENT

We gratefully acknowledge Australian Catholic University (ACU) for its significant scientific expertise, technical guidance, and collaborative contribution to the development of the Resting Metabolic Rate (RMR) National Testing Protocol.

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APPENDIX A:
COMMENTARY ON RATIONALE

COMMENTARY ON RATIONALE

During the development of the Resting Metabolic Rate Measurement National Test Protocol, some aspects of the test set up, and measurement were undertaken differently across different sites, and there was no definitive or strong evidence base to determine the point of truth. To achieve the benefits of a nationally standardised approach to the measurement of Resting Metabolic Rate across Australian High Performance Sport, discussion with subject matter experts was used to determine a standardised approach, and the rationale for inclusion has been described below.

To ensure continuous improvement towards best practice, as further evidence is gathered through research, the national protocol will be updated and communicated accordingly. Practitioners play a critical role in continuous improvement and are encouraged to provide feedback on this document.

Exercise restriction

Rationale: Purposeful exercise is restricted prior to the RMR measurement as metabolic rate remains elevated following exercise cessation, which is known as excess post-exercise oxygen consumption (EPOC) (17). This increased metabolic rate is greatest immediately following exercise and then progressively declines (18). It is important that there is a sufficient period between the last bout of exercise and a RMR measurement, so that RMR measurements are not artificially inflated due to residual EPOC. There was no impact of 210 minutes of cycling at 55-60% of VO_2 max on RMR measurements that occurred 12-hours post-exercise (19), This suggests that athletes can engage in exercise to which they are accustomed the day prior to a RMR measurement. However, the time for metabolic rate to return to baseline depends on both exercise intensity and duration (20, 21).

As such, higher intensity exercise, resistance exercise, and/or matches/competitions may have an impact on next day RMR measurements due to residual EPOC. Realistically, most high calibre athletes will be unable to adjust their training the day prior to a RMR measurement. The training that athletes completed the day prior to a RMR measurement should be noted within the AMS and used to help interpret findings. The need to restrict higher intensity exercise, resistance exercise and/or matches/competitions will be revisited pending further research.

Food and beverage restriction

Rationale: There is an increased metabolic rate postprandial due to the digestion, absorption and metabolism of dietary nutrients known as the thermic effect of food (TEF) (22). While TEF peaks between ~60-180 minutes post-prandial (23), there are various factors that will influence the magnitude of TEF, such as the macronutrient composition of the meal (22). In order to avoid an artificially elevated RMR due to residual TEF, RMR measurements occur in an overnight fasted state. There is little evidence to suggest that large variations in energy intake will create artifacts in next day RMR measurements (19). As such, energy intake does not need to be standardised the day prior to an RMR measurement as an overnight fasted state is sufficient to eliminate residual TEF.

Length of tubing

Rationale: Different lengths of tubing are available to connect the mouthpiece to the metabolic cart. The length of tubing must balance being of sufficient length to reach the athlete while also minimising dead space. Additionally, tubes of 9 feet length were reported by practitioners to cause a rattling noise during testing, which may create an artefact in the measurement. The recommendation of using tubing that is 6 feet long was based on consensus agreement. The use of a different length of tubing may be revisited pending feedback from those measuring RMR across the Australian High-Performance Sport System.

Use of mouthpiece plus nose clip

Rationale: There is evidence to suggest that the gas collection device (i.e. ventilated hood vs. mouthpiece plus nose clip vs. facemask) used when measuring RMR will introduce variability in RMR measurements (24, 25). As such, a singular gas collection device should be used across the Australian High-Performance Sport System. Given that the majority of those interviewed used a mouthpiece plus nose clip, it was decided to use this gas collection device. The use of a different gas collection device will be revisited pending further research and feedback from those measuring RMR across the Australian High-Performance Sport System.

Paediatric and adult size mouthpiece

Rationale: Discomfort with the mouthpiece was noted by interviewed practitioners. Based on consensus agreement, it was decided that offering a paediatric size mouthpiece may reduce the discomfort associated with the larger mouthpiece.

10-minute rest period

Rationale: A period of rest is recommended when measuring RMR in an outpatient setting to allow any elevations in metabolic rate due to commuting into the testing site to subside. Studies which have compared outpatient and inpatient protocols of RMR assessment have reported similar RMR measurements when a ~25-30-minute rest period is implemented prior to RMR being measured in an outpatient setting (4, 5). Additionally, ~20 minutes appears to be sufficient to return RMR to baseline values following a 300 m walk (26). A 10-minute rest period plus 15-minute familiarisation with mouthpiece in-situ results in 25 minutes of rest prior to commencing the RMR measurement. In the situation that the familiarisation period was reduced, then the rest period would need to be altered accordingly to result in a cumulative rest period of 25 minutes prior to commencing the measurement.

5-minute familiarisation period

Rationale: Familiarisation with RMR measurement equipment prior to commencing the test may reduce error. A 5-minute familiarisation with the mouthpiece plus nose clip reduced RMR by ~9.5% compared to when no familiarisation period was used (27). However, a familiarisation period must be balanced with the possibility of discomfort caused by prolonged use of the mouthpiece plus nose clip that may introduce error in measurements. For instance, a study comparing gas collection devices found that the mouthpiece plus nose clip became less reliable over a 50-minute measurement whereas the other gas collection devices became more reliable (28). We are not aware of the origin of a familiarisation period that is 15 minutes in duration, but based on consensus agreement, we decided to continue with this length of familiarisation. However, this recommendation will be revisited pending further research and feedback from those measuring RMR across the Australian High Performance Sport System.

Discarding first 5 minutes of collected data

Rationale: The first 5 minutes of collected data is discarded to exclude artefacts as this data is elevated compared to subsequent data collected (28, 29).

Use of steady state data to calculate RMR

Rationale: There are various methods of gas exchange data selection that can be used to calculate RMR. This includes:

- Steady state: Time period with <10% CV in VO_2 and VCO_2
- Time interval approach: Values averaged over a pre-defined time interval (i.e. minutes 5-25 of the measurement)
- Filtering method: Thresholds are set and depending on the mean RMR value obtained data is discarded (i.e. discarding values <85% or >115% of average RMR)

As the majority of research supports the use of steady state to calculate RMR [29–31], this method should be used. However, it is recognised that not everyone will reach steady state during RMR measurements [30, 32]. In this situation, a repeat RMR measurement is warranted. We are unsure of the number of athletes that this will impact, and it may mean that a significant number of athletes will need to have RMR measurements re-measured. A different gas exchange data selection may be needed pending feedback from practitioners across the Australian High Performance Sport System.

Technician staying in room during measurement

Rationale: We are unaware of any research demonstrating if a technician's absence or presence in the testing room introduces variability or error in measurement. However, we felt that it was the duty of the technician to be in the room during testing in order to monitor the athlete to ensure that there were no concerns during the test or situations that may create artefacts in the measurement [i.e. athlete coughing, noise in surrounding area etc.]

Collecting primary and secondary indicators of LEA alongside RMR measurements

Rationale: RMR measurements have been listed as potential indicators within the REDs CAT2 and as such, are not currently used to support risk assessment of REDs [15]. Given this, primary and secondary indicators of LEA should be collected to help interpret RMR data.

Not using RMR ratio and relative RMR thresholds

Rationale: The RMR ratio thresholds were validated in a group of women exercising ≥2 hrs/week [14]. Different thresholds may be needed for men, and/or athletes of higher calibre that will engage in more exercise. These thresholds may also change with other biological factors, such as age or race, or when a different protocol is used to measure RMR.

The origin of the relative RMR threshold is unknown. There are further concerns that this threshold may not be appropriate for athletes with a large quantity of FFM as there is a decreased proportion of this FFM is made up of high metabolic rate organs [i.e. liver, kidney, heart] resulting in a lower relative RMR [33, 34].

Document Quality Assurance

Version	Title	Authors	Approved	Date	Comments
V1.0	Resting Metabolic Rate Measurement *National Testing Protocol*	Megan Kuikman Gary Slater Aimee Morabito Nicole Townsend Kylie Andrew Ava Farley Nikki Jeacocke Nikolay Pichshev	AIS Quality Assurance Lead	May 2026	Document created

APPENDIX B:
RMR INFORMED CONSENT FORM

RMR INFORMED CONSENT FORM

The

[insert name of sporting organisation]

is providing testing services to you.

The welfare of athletes is important to the

[insert name of sporting organisation]

and we only seek to undertake activities that minimises any potential harm to participants and respects their rights and integrity.

Your participation in this activity is voluntary and you may withdraw your consent freely at any time before, or during the assessment. If you become uncomfortable with any aspect of the assessment, please advise our staff who will cease all activities.

The

[insert name of sporting organisation]

will respect your rights to restrict your information and provide you with the opportunity to ask questions and be fully informed about all aspects of the assessment.

If you are happy to continue, please read and sign the form below.

What is a RMR measurement?

Resting metabolic rate (RMR) is the energy needs of the body at complete rest. RMR can be measured using indirect calorimetry. Indirect calorimetry involves measuring the amount of oxygen consumed and carbon dioxide produced through respiratory gases.

RMR measurements can occur for various reasons. One reason is to help with nutrition planning as knowledge of an athlete's RMR can assist in determining daily energy needs. RMR measurements may also be used to screen for low energy availability (LEA). LEA occurs when there is not enough dietary energy remaining for the body to function after accounting for the energy expended through exercise. LEA is the underlying cause of Relative Energy Deficiency in Sport (REDs), a syndrome of impaired physiological function that may result in various health and performance consequences. LEA may lead to an impaired energy metabolism resulting in a suppressed RMR. A suppressed RMR means that measured RMR is lower than expected.

RMR measurements take ~60 minutes and should occur as close to your natural wake time as possible. This measurement must occur in an overnight fasted and rested state. This means no exercise or food on the morning prior to the RMR measurement. Your referring technician will provide all necessary information on how to prepare for this measurement in advance to the test.

Are RMR measurements safe?

There are no risks associated with a RMR measurement. However, there may be some discomfort during the test due to mouthpiece and nose clip, and the requirement to lay still for 60 minutes in an overnight fasted state.

RMR measurements should NOT be undertaken if:

Under some circumstances, it may be inappropriate for a RMR measurement. Please check if any of the below relate to you and be sure to inform your referring practitioner or RMR technician in advance of your RMR measurement:

- ☐ **A clear rationale for the RMR measurement has not been provided**
- ☐ **You or your guardian (if you are <18 yrs) are unable to provide consent**
- ☐ **You are unable to lay comfortably on your back for 1 hour**
- ☐ **You are unable to comply with the guidelines on appropriate preparation for the RMR measurement**
- ☐ **You are unable to schedule individual feedback with your referring practitioner**
- ☐ **RMR measurements are occurring for LEA screening, and you are unable to undergo a DXA scan**
- ☐ **RMR measurements are occurring for LEA screening, and you are unable to have other LEA indicators measured**
- ☐ **RMR measurements are occurring for LEA screening, and you are unable to have a repeat RMR measurement**
- ☐ **RMR measurements are occurring for LEA screening, and you are still growing (<18 years)**

When will I get the results?

The technician measuring your RMR will not provide you with results on the day of testing. Instead, follow up with your referring practitioner for detailed feedback on your RMR measurement results and what it means for you. Results will be stored securely on the Athlete Management System (AMS). It may be appropriate to share your test results with relevant members of your Performance Support Team, including your coach. However, your consent will be sought separately from your referring practitioner before any data is shared with others.

Retention of records

The [insert name of sporting organisation]

is required to apply the Archives Act 1983 (Cth) to maintain the security and retention of its records over time.

This legally requires the

[insert name of sporting organisation]

to keep athlete health records (including RMR measurements) and to manage them appropriately for periods up to 100 years.

Your rights

You have a right to physical privacy and respect. Please advise the RMR technician conducting the testing of any considerations concerning bodily integrity, gender or the presence of other persons in the testing environment.

If you have questions or concerns, please feel free to reach out to your referring practitioner to seek clarification. Remember, no testing is compulsory. If you are uncomfortable or encounter a negative experience before, during, or after your assessment, please raise this with someone you feel comfortable with. This may be the RMR technician, your referring practitioner, or another person in your Performance Support team. There are also independent avenues for you to seek support such as the AIS Mental Health Referral Network.

If you are not satisfied that your rights have been upheld, you may make a confidential complaint to the Australian Sports Commission Complaints Team (complaints@ausport.gov.au) or through the complaints page of the ASC website.

Statement of Consent

i. I [print name] acknowledge and agree that:

a) I have been provided with information relating to the use of RMR measurements, which clearly described what is involved. I have read and understood the contents of that document;

b) Relevant staff have explained to me in detail the nature, safety procedures and discomforts associated with RMR measurements, and I understood their explanation; and

c) I have been given an opportunity to ask questions, and have received a satisfactory response about the nature, safety procedures and discomforts associated with RMR measurements.

ii. I agree that I will:

a) Present myself for the RMR measurement in an appropriate condition, having abided by pre-measurement requirements, including diet and physical activity guidance; and

b) Advise relevant staff conducting the RMR measurement any reason why I should **NOT** undertake a RMR measurement (see checkboxes under "**RMR measurements should NOT be undertaken if...**")

iii. I understand that my participation in the RMR measurement is voluntary and that I may withdraw my consent freely and without prejudice (i.e. without limiting further assessment opportunities) at any time before or during the measurement.

iv. I understand that the information obtained during the RMR measurement will be treated confidentially, respecting my rights of privacy. If it is deemed appropriate that the results be shared with members of the broader performance health support team, my specific and separate consent must be sought before the data can be shared

v. The [Insert name of sporting organisation]
May use broad themes, learnings and insights from RMR measurement to enhance our programs and practices and to improve athlete health and performance both internally and within Australian sport. Any insights created or released from RMR measurements will not contain the personal information of any individual participants

Athlete signature: _____ Date:

Parent/Guardian signature: _____ Date:

I, the undersigned, explained to the athlete the nature of the RMR measurement and to my best knowledge and belief they understood the safety procedures and discomforts associated with the procedure

Practitioner name: _____

Practitioner signature: _____ Date:

APPENDIX C:
ATHLETE RMR TESTING HANDOUT

ATHLETE RMR TESTING HANDOUT

What to expect

Resting metabolic rate (RMR) testing is used to measure the calorie needs of the body at complete rest. For this test to be accurate, you must be overnight fasted and in a rested state during the measurement. This means no food or exercise on the morning of testing until after the RMR measurement is complete.

RMR measurements take about 1 hour. Upon your arrival, the technician will confirm that you are rested and fasted and ask that you do not bring your mobile phone, watch, or any other technology into the testing room. You will then be brought into a testing room, which will have a bed for you to rest on. The technician will stay in the room during the RMR measurement. If you have any concerns or discomfort during the test, you can let the technician know. The aim is for you to be as comfortable and relaxed as possible, without falling back asleep. The RMR measurement will have 3 phases:

Rest 1	Familiarisation 2	Measurement 3
The test will start with a 10-minute rest period in a dark and quiet room.	The technician will give you a mouthpiece to place in your mouth for 15 minutes.	The technician will give you a nose clip. This is when the measurement begins, which will last 20-25 minutes

To make this test as accurate as possible, you will need to be as rested and relaxed as possible. As a result, the technician conducting your measurement will ask you minimal questions prior to testing. Following the RMR measurement, the technician will ask questions to help interpret results.

Day before

- ✓ Eat normal
- ✓ Follow normal training plan with no novel training and/or excessive intensive training

Day of

- ✓ Wake as close as possible to the time of the RMR measurement
- ✓ Do not eat or drink any fluids prior to the test (if you are not undergoing a DXA scan after your RMR measurement, you can drink water)
- ✓ Do not brush your teeth or shower prior to the RMR measurement
- ✓ Do not engage in any exercise. Drive or take public transport to the testing site, and walk slowly into testing site
- ✓ Minimise screen time, and social interactions
- ✓ Wear comfortable clothing
- ✓ Leave mobile phone, watch and other technology outside the testing room

During

- ✓ Get comfortable and relaxed!
- ✓ Try not to fall asleep *(but let us know if you do)*

APPENDIX D:
RMR DATA COLLECTION SHEET

RMR DATA COLLECTION SHEET

Pre-measurement check list

- ☐ Written Informed consent received from the athlete
- ☐ Verbal informed consent obtained from the athlete on the morning of testing
- ☐ Athlete informed of pre-measurement guidelines and RMR procedures
- ☐ If being used for LEA screening, primary and secondary indicators of LEA have been measured, or a referral has been made for these measures

Technician name: _____

Athlete details:

Name:	Date of birth:
Sport:	
Height:	Weight:	Sex:

Measurement details:

Date of test:	Time of test:

Gas collection device:

☐ Mouthpiece ☐ Hood ☐ Face mask

Mouthpiece size:

☐ Adult ☐ Paediatric ☐ Not used

Date of DXA: _____ ☐ No referral

Post measurement questions

How did you find that test?

Did you fall sleep?

Did you cough or sneeze while wearing the mouthpiece and nose clip?

Did you feel comfortable during that test?

Anything else that I should know about?

How did you sleep last night? What time did you fall asleep? What time did you wake up?

What training did you do yesterday?

What time was your last meal or snack?

Did you eat your usual diet yesterday? If not, what was different?

FEMALES ONLY

What was the date of the start of your most recent menstrual cycle? And how long is your typical cycle?

If unsure or unknown, can you estimate how long ago it was?

- [ ] 0-6 days
- [ ] Within last month
- [ ] 2-3 months ago
- [ ] 4-5 months ago
- [ ] 6 months or more
- [ ] Pregnant
- [ ] Never menstruated

Australian Government

Australian Sports Commission

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ASC38128 – June 2026