BASES PHYSIOLOGICAL TESTING
GUIDELINES: THE DISABLED
ATHLETE

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Following the continued rising standards of Paralympic athletes, there has been a marked influx of sport scientists seeking to develop their physiological knowledge of disabled participants. However, those working in this area face a complex challenge when they implement physiological testing procedures. Paralympic athletes display many different types of disability and within a particular sport there are varying classifications e.g. cerebral palsy or spinal cord injuries (SCI). To implement safe and effective testing procedures for the disabled athlete, the physiologist must develop a basic understanding of the disability and then assess the exercise implications. Because disabled participants span an array of classifications, it is beyond the scope of this chapter to cover all disabilities. Therefore, this chapter will focus primarily on SCI wheelchair participants.

PRE-TEST CONSIDERATIONS FOR
PARTICIPANTS WITH SCI

- Cancel the testing session if the participant has conditions such as bladder infection, pressure ulcer, influenza, unusual spasticity or autonomic dysreflexia;
- The participant should empty their bladder or leg bag prior to exercise testing to avoid dysreflexia (with hypertension) in persons with paraplegia above T6 or with quadriplegia;
- Obtain all medication details taken by the participant, and be aware of medications that induce hypotension;
If a standardised chair is used (arm cranking Chapter X) avoid using hard testing surfaces and allow the participant to sit on a cushion to prevent pressure sores;

Be careful when the participant transfers into the testing environment (either from their wheelchair or onto test equipment). These with SCI have an increased risk for fractures secondary to osteoporosis.

ANTHROPOMETRY

Testing

Measurement of body mass to the nearest 0.1 kg should be obtained in minimal clothing using a seated beam balance scale. It is recommended that skinfold measurements are taken at the biceps, triceps, subscapular and supra-iliac following the procedures described in Chapter X. The sum of either three (excluding the supra-iliac) or four sites is the preferred method for disabled populations. Because SCI groups vary considerably with the degree and level of injury it is difficult to provide normative data. Therefore, the most appropriate evaluation of an individual’s body fat is a comparison with their previous results. In this instance, care must be taken to ensure test and re-test variability is minimised. While it has been demonstrated that SCI populations can be successfully underwater weighed, it may be more desirable to employ dual energy X-ray absorptiometry if assessments of percentage of body fat is required.

EXERCISE TESTING CONSIDERATIONS FOR PARTICIPANTS WITH SCI

During upper body exercise (Chapter X) ensure that sufficient strapping is used for trunk stability. For wheelchair exercise allow the participant to introduce strapping or change wheelchair configurations in order to perform the test. Always record chair-configuration details and strapping used with test results;

Velcro hand straps might be required to grip the arm crank. Similarly, suitable gloves can prevent blisters occurring during prolonged wheelchair exercise;

Overuse injuries are common to wheelchair users, so always cease exercise that aggravates chronic shoulder joint pain;

The majority of participants with SCI have impaired thermoregulatory capacity. Ensure that the physiology laboratory has air-conditioning and that testing is conducted in a thermally neutral environment.
THE DISABLED ATHLETE

TESTING MODALITY – EQUIPMENT

A variety of exercise testing modes can be used for the physiological assessment of the disabled athlete:

- Arm crank ergometry (equipment and procedures outlined in Chapter X);
- Stationary rowing ergometry;
- Wheelchair propulsion/hand-cycling on a treadmill;
- Wheelchair ergometry (WERG);
- Electrical stimulation-induced ergometry.

The physiologist should adapt equipment as needed based on the above testing considerations, e.g. securing the hands on crank handles. The main advantage of wheelchair exercise is its specificity for wheelchair users, especially if the athlete’s sporting wheelchair is used. However, a main disadvantage of wheelchair ergometry is that mechanical efficiency is lower, because of increased energy expenditure arising from isometric muscle activity required to stabilise the trunk during the application of force to the hand-rim.

WHEELCHAIR TREADMILL

Wheelchair exercise testing dates back to the late 1960s and early 1970s. However, this was not evident in the UK until the 1980s when Lakomy and co-workers (1987) were the first to develop a system that allowed wheelchair athletes to perform exercise on a treadmill. This system enabled athletes to be tested in their own racing wheelchairs on a treadmill. Moreover, restricting devices prevented lateral movements of the chair and provided a safety backstop. Similar devices are currently in use in the UK by leading universities and the English Institute of Sport.

A protocol using only increments of speed might be unsatisfactory for some athletes to elicit peak responses, as their propulsion speeds may exceed the top speed of the treadmill. It is recommended that a combination of 0.5–1% gradient with speed increments is suitable for eliciting high relative exercise intensities (Goosey et al., 1995). Depending on the objectives of the physiology assessment and financial constraints the following need to be considered:

- Treadmills suitable for accommodating a wheelchair are more costly than WERGs;
- Some athletes can exceed the top speed of the treadmill (e.g. Woodway ELG2; speed range 0–7 m.s\(^{-1}\));
- Facilities for athletes to mount and dismount the treadmill or lack of laboratory space to accommodate a treadmill with a suitable ramp system;
- Sports wheelchairs with marked camber may be greater than the width of the treadmill belt;
• Fluctuations in rolling resistance in treadmill exercise. The use of a WERG allows wheelchair testing under conditions of near constant intensity of exercise.

Athletes tend to enjoy pushing on a motorised treadmill and report the validity of how the wheelchair responds to movements of the trunk. However, a WERG allows greater flexibility for conducting a battery of tests as it includes these of maximal intensity and time trials.

WHEELCHAIR ERGOMETER (WERG)

A WERG has been developed and distributed in the UK by the combined efforts of Kingcycle and Bromakin. Unfortunately, to accommodate different chair-configurations changes in the WERG have resulted in the single roller increasing in length. Furthermore, WERG devices used by research groups in the Netherlands, USA and France all differ in the braking force employed. The information presented hence will be based on the Bromakin WERG, which allows the athlete’s own sporting wheelchair chair to be secured to an adjustable pillar. This is used to adjust the rolling resistance of the rear wheels on an air-braked flywheel. The braking force is provided principally by the weight of the participant and their wheelchair.

SUB-MAXIMAL INCREMENTAL WHEELCHAIR EXERCISE TEST

Rationale

This test is designed to assess propulsion speed, heart rate (HR) and blood lactate corresponding to the blood lactate transitions. It also allows pushing economy (\(\dot{V}O_2\) at a given propulsion speed; L min\(^{-1}\)) to be calculated.

Test Procedure

On the athlete’s arrival explain the testing procedures and ensure that the participant has completed the pre-test questionnaire. It is important that they specify the nature of their disability (type, onset, degree and level). From this information adherence to the pre-test and exercise considerations discussed earlier must occur. Administration of the test should then proceed as follows:

1. Before the test, the participant should attach an HR monitor chest-piece and ensure that the monitor is functioning correctly. Set the HR monitor to record mode using 5 s intervals. The participant’s sports wheelchair should be securely attached to either the treadmill or WERG. Each participant should then complete a standardised warm-up;
2. After the warm-up, take a pre-exercise blood sample for the determination of blood lactate concentration. The preferred site for a blood sample within this population is the ear lobe;
3. Have the participant hold the safety rail. Start the treadmill; when it is at the desired speed (guidance follows), instruct the participant to commence pushing. Start the stop clock;
4. It is important that you indicate to the participant the time remaining and check with them their ability to complete the set intensity;
5. During the last minute of each stage, collect an expired air sample;
6. Instruct the participant to put their hands on the safety rail and once they have stopped pushing collect a small capillary blood sample. This can be analysed for blood lactate concentration as described in Chapter X. Record the participants rating of perceived exertion (RPE) using the Borg chart;
7. During the rest period increase the treadmill/WERG to the required speed/gradient. After one minute participant recommences pushing;
8. Proceed as outlined above, with the participant completing at least five stages;
9. Download the HR monitor and analyse the data accordingly.

GUIDANCE FOR TREADMILL SPEED RANGES (UK ATHLETES)

- Female racers (T53/54) – 5.0 to 7.25 m.s\(^{-1}\) (0.5 m.s\(^{-1}\) increments);
- Male racers (T53/54) – 5.5 to 8.5 m.s\(^{-1}\) (0.5 m.s\(^{-1}\) increments);
- Male basketball – 2.2 to 3.9 m.s\(^{-1}\) (0.28 m.s\(^{-1}\) increments).

GUIDANCE FOR WERG SPEED RANGES (UK ATHLETES)

- Wheelchair racers (mixed) – 2.7 to 7.5 m.s\(^{-1}\) (0.9 m.s\(^{-1}\) increments);\(^1\)
- Male wheelchair basketball – 1.5 to 3.8 m.s\(^{-2}\) (0.2–0.4 m.s\(^{-1}\) increments);\(^2\)
- Female wheelchair tennis – 0.9 to 1.8 m.s\(^{-1}\) (0.2 m.s\(^{-1}\) increments);\(^2\)
- Male wheelchair tennis (open class) – 1.2 to 3.0 m.s\(^{-1}\) (0.2 m.s\(^{-1}\) increments);\(^2\)
- Male wheelchair tennis (quadriplegic class) – 1.0 to 2.4 m.s\(^{-1}\) (0.2 m.s\(^{-1}\) increments).\(^2\)

DETERMINATION OF PEAK OXYGEN UPTAKE

- Following the sub-maximal incremental test each athlete has a 5-min recovery period or rests until their heart rate is less than 100 b.min\(^{-1}\);
- The initial treadmill/WERG speed is based on the sub-maximal incremental test;
TABLE 1.1  Speed and gradient during the sub-maximal incremental test performed on a treadmill adapted for wheelchair athletes

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (m.s$^{-1}$)</td>
<td>Based on previous visit</td>
<td>No change</td>
<td>+ 0.5</td>
<td>+ 0.5</td>
<td>+ 0.5</td>
</tr>
<tr>
<td>Gradient (%)</td>
<td>0</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Note
Sometimes a gradient of 1% is preferable for more able but lighter athletes, with a gradient of 0.5% used for quadriplegics.

- Treadmill: during this test the speed of the treadmill remains constant and the treadmill gradient is increased by 0.7% at 3-min intervals;
- WERG: during this test the speed is increased by 0.2 to 0.5 m.s$^{-1}$ at 1-to 2-min intervals.

DATA TO BE COLLECTED

- Heart rate is monitored continuously. Peak HR is defined as the highest value recorded during this test;
- Expired air samples are collected over the last two consecutive stages of the test;
- The criteria for a valid VO$_2$ peak are at least two of the following conditions: (1) a plateau in VO$_2$ (≤ 2 ml·kg$^{-1}$.min$^{-1}$) over the last two incremental stages of the test, (2) a peak RER value ≥ 1.10, and (3) a peak HR ≥ 95% of age-predicted maximum (200 b.min$^{-1}$ minus chronological age);
- The VO$_2$ peak of wheelchair athletes should be reported in absolute units (L.min$^{-1}$). However, to compare the body size-independent VO$_2$ peak values of male wheelchair athletes the mass exponent of 0.82 may be adopted (i.e., ml·kg$^{-0.82}$.min$^{-1}$) (Goosey-Tolfrey et al., 2003).

ASSESSMENTS OF MAXIMAL INTENSITY EXERCISE

A typical 30 s Wingate test (WAnT), or multiple-sprint test can be performed using either an arm crank ergometer or wheelchair on a WERG. The indices of WAnT include peak power (PPO), mean power and fatigue index. If performed in a wheelchair, these measures can be related to top speed.

Arm-cranking

A resistance in ratio with body weight of 0.06:1 is recommended for SCI athletes with good trunk stability. The resistance should be less than that used for able-bodied because of the reduced muscle mass resulting from paralysis.
WERG

To satisfy the muscle force-velocity relationships an optimal braking load is required. However, no optima have been agreed. Protocols with limited resistance create a ceiling for achievable PPO rather than muscular function. Hence, some researchers have kept wheeling speed to 3 m.s$^{-1}$, to avoid difficulties in propulsion technique.

Normative Data

The PPO is reported to be inversely related to the level of lesion; that is, the lower the injury level the greater the peak power output. For more information please refer to Hutlzer (1998).

FIELD-BASED TESTING

Since laboratory tests require the use of specialised and expensive equipment that is not accessible to every one, efforts have been made to develop appropriate field tests.

ACCELERATION AND SPEED TEST

Rationale

In wheelchair racing the ability to sprint is required both for long-distance races e.g. change in pace, sprint start/finish as well as the speed required completing shorter distances as fast as possible. For multiple-sprint based wheelchair sports (basketball, rugby and tennis) the player’s ability to accelerate from a standstill is considered more important than sprinting per se. For these athletes testing speed over distances such as 20 m is often irrelevant.

TEST PROCEDURE

1. Set timing gates at the desired intervals (0, 10, 20, 30 & 60 m intervals depending upon test and split times needed). Ensure that there is enough space for athletes to slow down safely at the end of each sprint;
2. Mark a starting line and finishing line with cones visible to the wheelchair athlete;
3. The starting position is with the front wheel (racing chair) or front castors placed up to the starting line;
4. To eliminate reaction time the participant starts when he or she is ready;
5. The participant sprints as fast as possible through to the finish line, making sure not to slow down;
6. The required split times (e.g., 10 m) and the final sprint time are recorded to the nearest 0.01 s. The best times are recorded as the final result, even if they come from different trials;

7. Maximum speed: The object is to cover 20 m as fast as possible from a flying start, could be obtained from a 30 m set-up that involves timing gates positioned at 0, 10 and 30 m;

8. Acceleration: The object is to cover the distance as fast as possible from a stationary start; distances of 20 m and 60 m test are commonly reported in the wheelchair literature.

AEROBIC CAPACITY – MULTISTAGE FITNESS TEST (MSFT) OR THE 12-MINUTE COOPER PUSH

Rationale

In wheelchair sports endurance is also required, especially for those athletes who can sustain a high intensity of exercise e.g. marathons. Sport scientists working with multiple sprints based wheelchair sports have recognised the importance for aerobic fitness as a base. The existence of such a base will help sustain high peak fitness throughout the year and/or across a major tournament.

1. MSFT: A shuttle test on a 400m athletics track can be used to measure an athlete’s endurance fitness. Cones are positioned 20m around the track. The athlete has to keep to a set pace determined by an audio cassette. Each time the cassette buzzes, the athlete has to be at the set cone. After each minute, the time delay between the buzzes decreases, so the pushing speed has to increase for the athlete to maintain pace. The athletes have to push for as long as possible, until they can not keep up with the speed of the tape. The point in the test at which each athlete drops out is recorded. In addition to an athletics track this test can be conducted indoors on a basketball court and ice rink (sledge hockey). It is important to note that if a turn is required during the administration of the test, then wheelchair configuration and participants’ chair skills can influence the outcome.

2. 12-minute push: The objective of this test is going as far as possible in 12 min. This test can be done either on a track or WERG. The distance covered in the 12 min is recorded.

MONITORING TRAINING INTENSITY

During the last decade, HR monitors have become a widely used training aid for a variety of paralympic sports and HR data based on blood lactate concentrations have become available for the disabled. However, although training principles may be similar across many wheelchair sports, those employed
by the able-bodied athlete are not directly transferable to the wheelchair athlete (Tolfrey et al., 2001). Wheelchair athletes have unique physiological responses during upper-limb exercise because of vascular insufficiency of the lower extremities and adrenergic dysfunction (Jacobs et al., 2002). Consequently, for those unaware of the specific details of these physiological limitations, prescribed training programmes based on HR data might not be appropriate for some paralympic athletes. For exercise prescription the physiologist must be aware of the following:

- Heart rate is affected in those individuals with a lesion above the sixth thoracic vertebra (T6). Heart rate will remain low during exercise. Therefore the age-predicted maximal heart rate seen in many physiology text books (220-chronological age), needs to be adjusted to 200-age;
- At moderate HR exercise intensities (85% or lower) the relative exercise intensity (peak $\dot{V}O_2$) for male élite level wheelchair racers may be slightly underestimated if able-bodied ACSM guidelines are used (Tolfrey et al., 2001). However, at the upper end of the exercise intensity continuum (i.e. ≥ 85% peak $\dot{V}O_2$), the continued use of % peak HR as a proxy measure for % peak $\dot{V}O_2$, based upon the able-bodied guidelines is recommended;
- The use of HR monitors for quadriplegics is not recommended. Rather, use ratings of perceived exertion (RPE) for the workout.

NOTES

1 Roller = length 0.78 m; circumference 0.53 m & mass 39.5 kg.
2 Roller = length 1.14 m; circumference 0.48 m & mass 38.5 kg.

REFERENCES

RECOMMENDED READING


