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Can a 15 m-overground wheelchair sprint be used to assess wheelchair-specific anaerobic work capacity?

Jan W. van der Scheer [a,*], Sonja de Groot [a,b], Riemer J.K. Vegter [a], DirkJan (H.E.J.) Veeger [c,d], Lucas H.V. van der Woude [a,e]

[a] University of Groningen, University Medical Center Groningen, Center for Human Movement Sciences, The Netherlands
[b] Amsterdam Rehabilitation Research Center, Reade, Amsterdam, The Netherlands
[c] Research Institute MOVE, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands
[d] Department of Mechanical, Maritime and Materials Engineering, Delft University of Technology, Delft, The Netherlands
[e] University of Groningen, University Medical Center Groningen, Center for Rehabilitation, The Netherlands

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ABSTRACT

Objective: To evaluate whether outcomes based on stopwatch time and power output (PO) over a 15 m-overground wheelchair sprint test can be used to assess wheelchair-specific anaerobic work capacity, by studying their relationship with outcomes on a Wingate-based 30 s-wheelchair ergometer sprint (WAnT).
Methods: Able-bodied persons ($N = 19$, 10 men, aged 18–26 y) performed a 15 m overground sprint test in an instrumented wheelchair and a WAnT. 15 m-outcomes were based on stopwatch time (time and mean velocity over 15 m) and on PO (primary outcome: highest mean unilateral PO over successive 5 s-intervals (P5-15m)). WAnT-outcomes were mean unilateral PO over 30 s and the highest mean unilateral PO over successive 5 s-intervals. Correlation coefficients (Pearson's r) and coefficients of determination (R^2) were calculated between 15 m-sprint outcomes and WAnT-outcomes.
Results: Time over 15 m (7.2 s (±1.0)) was weakly related to WAnT-outcomes ($r = -0.61$ and -0.60, $R^2 = 0.38$ and 0.36, $p < 0.01$), similar to mean velocity over 15 m (2.1 m·s^{-1} (±0.3), $R^2 = 0.43$ and 0.39, $p < 0.01$). P5-15m (38.1 W (±14.0)) showed a moderate relationship to WAnT-outcomes ($r = 0.77$ and 0.75, $R^2 = 0.59$ and 0.56, $p < 0.001$).
Conclusions: It seems that outcomes based on stopwatch time over a 15 m-overground sprint cannot be used to assess wheelchair-specific anaerobic work capacity, in contrast to an outcome based on PO (P5-15m). The 15 m-sprint with an instrumented wheel can be implemented in rehabilitation practice and research settings when WAnT equipment is not available, although care is needed when interpreting P5-15m as an outcome of anaerobic work capacity given that it seems more skill-dependent than the WAnT.

1. Introduction

Manual wheelchair propulsion is important in daily-life mobility and participation of the majority of persons with spinal cord injury (SCI) [1,2]. Essential wheelchair propulsion-activities in daily life (ADL) of persons with SCI are often short (<1 min) but intensive [3,4], e.g. sprinting a short distance, ascending a ramp, and propulsion over uneven surfaces [1,5]. The duration and intensity of these ADL indicate a predominant use of anaerobic metabolism for delivering energy [6–8]. Anaerobic metabolism therefore seems important for mobility of manual wheelchair-dependent persons with SCI; especially in those with low fitness levels whose wheelchair-ADL can evoke high intensities [3]. The capacity of anaerobic energy systems specific for wheelchair propulsion-ADL can be estimated by assessing wheelchair-specific anaerobic work capacity [9], using power output outcomes over a Wingate-like sprint test in a wheelchair ergometer or roller (WAnT; all-out 30 s-wheelchair sprint with heavy resistance) [8,10,11]. However, such ergometers or rollers are often not available in rehabilitation centers. This hampers assessment of anaerobic work capacity necessary for fitness monitoring during and after SCI rehabilitation [12,13], and during multicenter intervention studies [14]. Alternative tests for anaerobic work capacity are therefore needed, especially simpler and more feasible alternatives.

Using a stopwatch to record performance time, a short overground wheelchair sprint test in a standardized setting can be such an alternative when assuming that, similar to the WAnT, it

* Corresponding author at: University Medical Center Groningen, Center for Human Movement Sciences, Sector F, Postbus 196, 9700 AD Groningen, The Netherlands. Tel.: +31 50 363 8846.
E-mail addresses: j.w.van.der.scheer@umcg.nl, jvdscheer@gmail.com (J.W. van der Scheer).

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requires a high-intensity short-duration muscular effort. A 15 m-overground sprint test has been used in cohort studies as part of a wheelchair skills test to monitor wheelchair skill performance over time in persons with spinal cord injury during and after rehabilitation [15–17], and as such has been implemented in rehabilitation practice [18]. Stopwatch time over this 15 m-sprint test has shown excellent test-retest reliability, discriminative ability between persons with high- and low-level spinal cord lesions [15], and sensitivity to changes in performance during inpatient rehabilitation of persons with spinal cord injury [17]. The relationship between overground wheelchair sprint performance and WAnT-outcomes has already been shown in wheelchair athletes: distance on a 30 s-overground wheelchair sprint test was related to WAnT-outcomes ($r = 0.9$) and was also related to 20 m-overground sprint time ($r = -0.9$) [19], while others found 100 m sprint times correlated to WAnT-outcomes ($r = -0.7$ to -0.9) [8]. However, it is still unknown whether stopwatch time over the 15 m-sprint relates to WAnT-outcomes in non-athletes, i.e. persons who are generally not highly skilled or trained for overground sprinting, and whether this relationship is influenced by differences in load between the tests. In the WAnT, load is relatively high (comparable to overground propulsion on a 6 degree slope) and adjusted for each participant to optimize PO [20]. In the 15 m-sprint test, load will generally be lower and can be dependent on body mass and factors such as surface type and tire pressure [21,22].

It is not yet known how PO is expressed in a 15 m-overground sprint and whether it can be used to derive an alternative for WAnT-outcomes. Determination of PO during overground propulsion is now possible and feasible in rehabilitation practice due to the recent development of commercially available force and torque-instrumented wheels, which simply replace regular wheelchair wheels [23,24]. These wheels allow determination of PO outcomes over an overground sprint, for example the highest mean PO over successive 5 s-intervals as used in the WAnT [8,10,11]. In the WAnT, the highest PO usually occurs during the first 5–10 s [7], which resembles time needed to complete a 15 m-overground sprint [16,19]. The relationship between PO outcomes of the 15 m-sprint and WAnT needs further study, especially given the generally lower load in the 15 m-sprint that, in contrast to the WAnT, may result in handrim velocities >2–3 $m \cdot s^{-1}$. These high velocities may lead to upper-body coordination problems and ineffective power transfer to the handrim [20].

Able-bodied persons participated in this initial study on 15 m-sprint outcomes as alternatives to WAnT-outcomes, since they are usually equally (in)experienced and form a somewhat more homogeneous and well-accessible group compared to non-athletic wheelchair users [25]. The aim of this study was to evaluate whether outcomes based on stopwatch time and PO over a 15 m-overground wheelchair sprint test can be used to assess wheelchair-specific anaerobic work capacity, by studying the relationship between 15 m-sprint and WAnT-outcomes in a group of able-bodied persons.

2. Methods

2.1. Participants

A convenience sample of able-bodied persons ($N = 19$, 10 men; college students; see Table 1 for characteristics) voluntarily participated after being informed about the study protocol and signing a written informed consent. The study was approved by the local ethical board of the Faculty of Human Movement Sciences (VU University Amsterdam, the Netherlands).

2.2. Equipment

A common daily wheelchair was used for the 15 m-overground sprint (Sopur Starlight 622; Sunrise Medical GmbH, D-69254 Malsch/Heidelberg, Germany; weight: 11.4 kg, wheel camber: 0°, seat width: 0.46 m, angle seat-backrest: 90°). The regular rear wheels of the wheelchair were replaced on the left side by a force and torque-instrumented wheel (OptiPush, MAX Mobility, Antioch, USA) and on the right side by an inertia-compensated dummy wheel (each wheel: 5.7 kg, wheel size: 0.61 m (24 inch), handrim diameter: 0.52 m, tire pressure: $8 \cdot 10^5$ Pa). The instrumented wheel allows measurement of propulsive torque around the wheel axle and the angle over which the wheel is rotated. Data collection was manually started and stopped 5 s before and after the start of the 15 m-sprint, and data were wirelessly transferred to a laptop at 200 Hz.

We used a custom-built stationary ergometer [26] for the WAnT that allows measurement of propulsion torque and (resultant) velocity of both wheels, as well as individualization of load based on previously described protocols (e.g. [25]). The ergometer dimensions were adjusted so that it matched as closely as possible the wheelchair used in the overground sprint (ergometer camber +1°; seat width +2 cm). Ergometer data were sampled at 100 Hz. Real-time wheelchair velocities of both wheels (indicated by dimensionless bars) were presented on a computer screen.

2.3. Protocol

One 15 m-sprint and one WAnT were performed on two separate days. To minimize confounding anthropometric changes, learning effects or insufficient recovery, these test days were performed in a counter-balanced order and were separated by 2–7 days of rest. Participants were asked to refrain from heavy exercise at least 48 h before a test day, and to refrain from alcohol, smoking or heavy meals in the 2 h before the experiment. On both days, participants were familiarized with the equipment, which took 5–10 min and also served as a warming-up. For the 15 m-overground sprint, this included acquaintance with overground propulsion, in addition to experiencing how to safely perform an overground sprint start. For the WAnT, this included familiarization with ergometer propulsion and learning to maintain the same relative velocity between both wheels using the computer screen.

The protocol of the 15 m-sprint test was similar as the protocol implemented in rehabilitation centers and as used in previous cohort studies on spinal cord injury [15–18], including the use of a stopwatch to record time which has shown excellent test–retest reliability [15]. The sprint was performed on a linoleum floor with the instrumented and dummy wheel in place. Two markers were placed on the floor, 15 m apart. The participant sat in the wheelchair, with the front casters turned backward and behind the first marker. At the starting signal (5 s after starting data collection of the instrumented wheel), the participant propelled the wheelchair toward the second marker as fast as possible while

Table 1
Participant characteristics ($N = 19$, 10 men).

Characteristic	Mean ± SD (range)
Age (y)	23 ± 2 (18–26)
Height (m)	176 ± 10 (163–195)
Body mass (kg)	69 ± 12 (50–94)
Elbow angle[a] (°)	106 ± 6 (95–118)
Fiso[a] (N)	297 ± 92 (142–446)
Wheelchair experience (h)	1 ± 2 (0–9)

Fiso = wheelchair-specific isometric force.
[a] Measured when hands were on top of the handrim.