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Original Research

Establishing the reliability of a novel battery of range of motion tests to enable evidence-based classification in Para Swimming

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ABSTRACT

Objectives: To evaluate the reliability of swimming-specific range of movement tests developed in order to permit evidenced-based classification in the sport of para swimming.
Design: Test-retest intra- and inter-examiner reliability.
Setting: International Swimming training camps and university exercise science departments.
Participants: 42 non-disabled participants (mean age 23.2 years) and 24 Para swimmers (mean age 28.5 years).
Main outcome measures: Intra- and inter-examiner reliability of a battery of novel active range of motion tests.
Results: Good to excellent intra-examiner reliability was found for the majority (32/34) of tests in non-disabled participants (ICC = 0.85–0.98). SEM values ranged from 1.18° to 6.11°. Similarly, good to excellent inter-examiner reliability was found for the majority (35/42) of tests in non-disabled participants (ICC = 0.85–0.98). SEM values range from 0.73° to 6.52°. Para swimmers exhibited significantly reduced range of motion compared to non-disabled participants.
Conclusions: The large majority of ROM tests included in this novel battery were reliable both within and between examiners in non-disabled participants. The tests were found to differentiate between non-disabled participants and Para swimmers with hypertonia or impaired muscle power.

1. Introduction

Paralympic classification systems aim to promote participation in sport by people with disabilities by minimizing the impact impairment has on the outcome of competition (Tweedy & Vanlandewijck, 2011). Classification systems which achieve this aim will ensure that successful athletes are not simply those with the least impairment, but will be those that have the most advantageous combination of physiological and/or psychological attributes and who have trained them to best effect (Tweedy & Vanlandewijck, 2011). In 2007, the IPC Classification Code mandated the development of evidence-based systems of classification in Paralympic sport which are informed by scientific research (IPC, 2007).

The Paralympic games are the largest organized sporting event for athletes with disabilities with 164 participating countries and more than 1.8 million tickets sold at the 2016 Rio Paralympic Games (IPC, 2016). In Para Swimming, there are eight physical impairments comprising; impaired muscle strength, impaired passive range of movement (ROM), limb deficiency, leg length difference, short stature, hypertonia, ataxia, and athetosis (IPC, 2007). Eligible swimmers compete across ten classes in freestyle, backstroke and butterfly events (S1-S10) and nine classes in breaststroke events (SB1-SB9). The current classification process involves two-steps: 1) evaluation of impairment via a bench test (Dummer, 1999) and 2) a technical assessment known as a water test. The bench test involves evaluation of joint range of motion, which may be critical to

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determining an athlete's class in Para swimming. Impaired ROM is defined as a reduction in one or more joints which is reduced permanently (IPC, 2007). Impaired ROM from health conditions such as cerebral palsy, resulting in spasticity or contracture, for example are currently evaluated using a passive joint-by-joint assessment conducted by a trained classifier using a goniometer which is then scored against a passive functional ROM on a zero to five scale (IPC, 2017). The water test involves allocation of points based on an athlete's ability to perform key water skills specific to swimming such as a dive start and push-off when turning. The classifier then totals the points obtained from the bench test and the water test using established criteria and expert opinion to determine a class (IPC, 2017).

For classification, these measures of impaired ROM in the bench test have advantages in that they use widely utilized methods known to clinicians and the equipment is inexpensive and available world-wide. However, there are several limitations of these measures, which make them unsuitable methods of ROM assessment for classification. Firstly, the current system utilizes a ratio scaled measure with a goniometer (Tweedy & Vanlandewijck, 2011) but then converts the outcome to a point scale (zero to five) based on relative range of motion rather than allocating absolute values. As such, an athlete that scores four points on a ROM measure does not necessarily have twice the ROM as someone that scores two points. Weak relationships have been found between non-ratio scale measures currently used in classification and sports performance (Beckman, Connick, & Tweedy, 2016). Secondly, ROM is currently assessed using passive ROM techniques, where the classifier moves the athlete's joints through a range applying external forces to the body, which has questionable repeatability compared to active ROM techniques (Boon & Smith, 2000; Cools et al., 2014; De Winter et al., 2004; Muir, Corea, & Beaupre, 2010). Thirdly, the reliability of the majority of ROM tests currently included in the classification system are not known or their reliability is difficult to determine due to significant variability in the positioning of the participant and the equipment selected (i.e. inclinometer, goniometer, visual assessment or a combination) (van de Pol, van Trijffel, & Lucas, 2010). Fourthly, ROM is assessed using a joint-by-joint method which is not parsimonious, is time intensive and little evidence exists to show the impact of individual joint ROM on swimming performance. For example, only weak correlations exist between current ROM classification measures and swimming propulsion and joint kinematics (Evershed, Frazer, Mellifont, & Burkett, 2012). Additionally, measures of impairment should only assess body structures that will impact on performance in body positions relevant to sports performance (Tweedy & Vanlandewijck, 2011) and that can be achieved by all eligible athletes regardless of impairment type or severity. The current ROM tests do not necessarily assess ROM in positions relevant to swimming, and neglect certain swimming specific positions such as streamline and prone shoulder flexion. These limitations threaten the validity of the classification system and can result in failure to delineate performance between some classes and disadvantaging athletes with certain types of physical impairment within classes (Evershed et al., 2012; Howe & Jones, 2006; Oh, Burkett, Osborough, Formosa, & Payton, 2013).

Given the limitations of current passive ROM tests and in order to permit evidence-based methods of classification, the development of a battery of novel ROM measures for swimming is required (Tweedy, Beckman, & Connick, 2014). The characteristics of the battery are required to comply with the IPC Position Stand on Classification which states that tests of impairment be objective, reliable, precise, ratio-scaled and valid (Tweedy & Vanlandewijck, 2011; Tweedy et al., 2014). Additionally, the tests of impairment should be impairment specific, as resistant to training as possible, comprehensive by addressing movement relevant to the sport, and parsimonious.

The aim of the study was to enable evidence-based classification in Para swimming by establishing the reliability and preliminary normative values for a battery of swimming-specific range of motion tests by: 1) evaluating the intra-examiner and inter-examiner reliability of each novel ROM measure in non-disabled participants; 2) providing preliminary normative values for a novel ROM assessment battery in non-disabled participants and a group of trained Para swimmers; and 3) determining if differences exist for the novel ROM battery outcomes between non-disabled participants and Para swimmers.

2. Methods

2.1. Participants

Two groups of participants were tested: Group 1 comprised 42 (20 males, 22 females) non-disabled physically active, injury free individuals engaging in at least 90 min of moderate physical activity per week. These participants were recruited from two Australian Universities. Group 2 comprised 24 (17 males, 7 females) elite Para swimmers who were nationally or internationally classified (classes S1-S8) and were undertaking planned training regimes and competing at national or international level. Group 2 included athletes with spinal cord injury (SCI), polio, cerebral palsy (CP) or acquired brain injury (ABI) - conditions that can result in one of, or a combination of impaired ROM, impaired strength or impaired coordination. These Para swimmers were categorized into two subgroups: those with hypertonia associated with CP and ABI ($n = 11$, 9 males, 2 females); and those with impaired muscle power resulting from SCI or polio ($n = 13$, 8 males, 5 females). While both subgroups may demonstrate some impairment in ROM, each subgroup has different ROM patterns due to the nature of their health condition. Athletes were from England, Spain, Italy and Czech Republic.

2.2. Study design and procedures

Data collection was conducted by three PhD trained staff with professional qualifications in the movement sciences with experience working with elite athletes with disabilities. All reliability testing was undertaken within University Exercise Science facilities. Assessment of Para swimmers was undertaken at various training facilities within Europe. All participants provided written informed consent and the study was approved by the Human Research Ethics Committees of the lead author's institution.

Non-disabled participants and Para swimmers completed a baseline questionnaire regarding demographics, training (number and types of sessions per week) and injury history. Anthropometric measures (standing height (m), body mass (kg), body mass index (BMI)) were also assessed prior to ROM assessment. Range of motion (ROM) testing was conducted with an Acumar Digital Inclinometer (Lafayette Instrument Co. Lafayette, IN), which was zeroed and aligned with the appropriate reference point (horizontal or vertical) before each test. A universal goniometer (Baseline Evaluation Instruments, White Plains, NY) was also used to compare reliability and ease of administration for elbow flexion and extension (inter-examiner study). Trunk functional reach measures were obtained with a supported fixed tape measure.

Measures from the 42 non-disabled participants were used to establish preliminary normative values. Fifteen of these non-disabled participants also took part in intra-examiner reliability testing while a further 16 took part in inter-examiner testing. Para swimmers completed the ROM test battery on one occasion to