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Original research

Hand-held dynamometry strength measures for internal and external rotation demonstrate superior reliability, lower minimal detectable change and higher correlation to isokinetic dynamometry than externally-fixed dynamometry of the shoulder

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ABSTRACT

Objectives: To investigate inter and intra-rater reliability of hand held (HHD) and externally fixed (EFD) dynamometry for shoulder internal (IR) and external rotation (ER) strength and their correlation to isokinetic testing.
Design: Within participant, inter and intra-rater reliability study.
Participants: Twenty active, healthy male and female participants underwent testing by two examiners.
Outcome measures: Intra-class coefficients (ICC), percentage standard error of measurement (%SEM), and percentage minimal detectable change (%MDC) were calculated for inter-rater, intra-day and intra-rater, inter-week reliability. Maximum and average of three repetitions were compared to the isokinetic results at three speeds (60°/sec, 180°/sec, 240°/sec) for both concentric and eccentric contractions.
Results: Inter and intra-tester values demonstrated good to high agreement (HHD, ICC range = 0.89−0.97, %SEM = 4.80−8.60%, %MDC = 13.29−23.70%; EFD, ICC = 0.88−0.96, %SEM = 6.60−11.00%, %MDC = 18.40−30.04%). HHD and EFD showed moderate to very strong correlations to the isokinetic testing (HHD, r = 0.45−0.86; EFD, r = 0.49−0.83).
Conclusions: The results of this study indicate that both EFD and HHD are suitable for clinical practice and research. Hand-held dynamometry is preferred due to its higher intra- and inter-rater reliability and smaller MDC and lower SEM.

1. Introduction

The rate of shoulder injury is high in sports that require repetitive overhead movements such as swimming, volleyball, tennis and baseball (Agel, Palmieri-Smith, Dick, Wojtys, & Marshall, 2007; McFarland & Wasik, 1998; Sell, Hainline, Yorio, & Kovacs, 2014; Walker, Gabbe, Wajswelner, Blanch, & Bennell, 2012). Shoulder rotation strength imbalances have been reported as a risk factor for the development of shoulder pain or injury in these sports (Bak, 2010; Gandhi, ElAttrache, Kaufman, & Hurd, 2012; Rupp, Berninger, & Hopf, 1995). Strength has most commonly been reported as the absolute strength of internal or external rotation and also as the ratio between these two variables (Ellenbecker & Roetert, 2003; Wilk, Andrews, Arrigo, Keirns, & Erber, 1993). Preseason, a decrease in external rotation (ER) strength is associated with in-season injury in baseball pitchers (Byram et al., 2010) and a subsequent decrease in pitch velocity (Gandhi et al., 2012; Mullaney, McHugh, Donofrio, & Nicholas, 2005). Similarly, in swimming, weakness in either ER (Beach, Whitney, & Dickoff-Hoffmanor, 1992; McMaster, Long & Caiozzo, 1992; Rupp, Berninger, & Hopf, 1995) or internal rotation (IR) strength (Bak, 2010; Tate et al., 2012) have been reported in symptomatic shoulders. The measurement and monitoring of shoulder rotation strength or

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ratios in these overhead sports could therefore be useful in injury prevention. It is hypothesised that these measures can be used to quantify any strength deficits and assist in return to sport decisions following injury or surgery to the shoulder.

In the literature there are a number of methods for measuring shoulder strength including hand-held (HHD) (Bohannon, 1986; Dollings, Sandford, O'Conaire, & Lewis, 2012; Hayes, Walton, Szomor, & Murrell, 2002), externally-fixed (EFD) (Beshay, Lam, & Murrell, 2011; Kolber, Beekhuizen, Cheng, & Fiebert, 2007) and isokinetic dynamometry (Ellenbecker & Roetert, 2003; Leggin, Neuman, Iannotti, Williams, & Thompson, 1996; Noffal, 2003). Isokinetic testing is considered a reliable and valid mode of shoulder strength testing (Leggin et al., 1996; Plotnikoff & MacIntyre, 2002), however is not without limitations. These include significant financial, time and portability restraints. Hand-held and externally-fixed dynamometry has been investigated as an option to overcome the constraints of isokinetic testing in both clinical and research settings (Beshay et al., 2011; Dollings et al., 2012; Kolber et al., 2007). For these to be clinically useful they need to be inexpensive, portable, time efficient and demonstrate acceptable absolute and relative reliability (Stark, Walker, Phillips, Fejer, & Beck, 2011; Wollin, Purdam, & Drew, 2016).

Hand-held dynamometry of the hip has been shown to be affected by examiner gender and upper body strength (Thorborg, Bandholm, Schick, Jensen, & Hölmich, 2013a), with increased reliability in experienced clinicians with greater than ten years of experience (Kemp, Schache, Makdissi, Sims, & Crossley, 2013). In the shoulder, some studies suggest that a similar strength bias exists (Schrama, Stenneberg, Lucas, & van Trijffel, 2014; Wadsworth, Nielsen, Corcoran, Phillips, & Sannes, 1992; Wikholm & Bohannon, 1991). Recent studies have demonstrated HHD reliability in symptomatic (Hayes et al., 2002) and non-symptomatic shoulders (Beshay et al., 2011; Dollings et al., 2012). In these studies it should be noted that a range of protocols have been undertaken. One study (ICC > 0.90) used examiners (no reference to gender) with over 10 year's experience (Dollings et al., 2012). While another study (ICC > 0.80) in comparison, utilised both male and female examiners, however, they still had >10 years of experience (Beshay et al., 2011). Nevertheless, shoulder HHD is demonstrated to be reliable despite gender differences.

Two forms of HHD exist, being the 'make test', whereby the examiner holds the dynamometer still while the participant exerts a maximal isometric force against the dynamometer and the 'break test', where examiner matches the maximal isometric force then continues to exert force until the maximal effort is overcome and the joint gives way (Bohannon, 1988; Stratford & Balsor, 1994). The majority of studies have utilised the 'make test' (Beshay et al., 2011; Dollings et al., 2012) and while both methods have been proven to be reliable (Bohannon, 1988), a 'break test' yields a higher force result (Bohannon, 1988; Stratford & Balsor, 1994) so could be argued to be a more relevant measure to represent an athletes true strength.

Externally-fixed dynamometry has shown promise in overcoming some of the limitations of HDD. In addition to not requiring a skilled examiner to perform the test at the hip, EFD has been shown to be reliable in students with 1 h of training (Thorborg, Bandholm & Hölmich, 2013b), and at the shoulder, both intra and inter-related reliability have been demonstrated with ICCs > 0.8 (Beshay, Lam & Murrell, 2011) and ICC > 0.9 respectively (Kolber et al., 2007).

It is important to note that there is little published on the minimal detectable change (MDC) and standard error of measurement (SEM) for shoulder rotation strength measures. To date, no previous study has compared intra- and inter-rater absolute and relative reliability of HHD and EFD against isokinetic measurement within the one study. Prior to implementing dynamometry when monitoring therapy programs, the intra- and inter-rater reliability as well as the SEM and MDC need to be established to allow clinicians to make an informed decision on the best method for use in the clinic, injury prevention programs and in research (Hopkins, 2000). The aims of this study were to: (i) determine and compare inter and intra-rater reliability of HHD and EFD; (ii) compare HHD and EFD to an isokinetic shoulder strength measurement test.

2. Methods

A convenience sample of twenty healthy, active individuals employed at a sports institute gave written informed consent to participate in the study. Participants' comprised of ten male (mean ± 1 standard deviation (SD), age = 31.2 ± 9.0, height = 176 ± 6.1 cm, weight = 78.4 ± 9.7 kg, BMI = 25.2 ± 2.0) and 10 female (age = 30.1 ± 8.0, height = 167 ± 6.5 cm, weight = 64.2 ± 9.6 kg, BMI = 23.0 ± 3.2). Participants were injury free at the time of testing and participated in regular physical activity totalling at least 2.5 h a week. All participants had no previous experience of dynamometry or isokinetic testing. To ensure heterogeneity two sports physiotherapists conducted the strength testing; with the male examiner (weight = 85 kg, height = 185 cm) having 5 years' experience and the female examiner (weight = 68 kg, height = 170 cm) 15 years' experience. This study was approved by the Australian Institute of Sport Ethics Committee (Approval No. 20130414).

Inter-examiner data was collected over two days during week one of testing. Intra-examiner, inter-week (female examiner only) data were collected on the same day and time one week apart. The participants were instructed to maintain their normal activity with the avoidance of upper body resistance training the day of, the week between, and prior to testing for both sessions. Isokinetic testing was undertaken following the dynamometry protocol on the same day and time of week two. To reduce this effect on the EFD and HHD all isokinetic tests were completed following the HHD and the EFD dynamometry. The participant test order was computer randomised for tester order, dynamometry method, test side (left or right) and rotation direction (internal or external). Both examiner and participants were blinded to the results. All participants had 10 min rest between each of the 3 methods of testing for both examiners.

Participants position for all strength tests was standardised (Fig. 1) to standing with feet shoulder width apart and slightly flexed knees and hips, elbow by the side but not touching the body and in 90°of flexion, wrist in anatomical neutral (palm facing midline). This position was demonstrated to the participants to ensure they did not use either excessive abduction or adduction and leverage over the trunk, to ensure isolated rotation. Participants were asked to brace themselves to avoid losing balance during testing. The dynamometer was placed such that the transducer head was aligned just proximal to the ulnar styloid process for both the EFD and HHD. Participants performed a sub-maximal practice test followed by 3 test efforts. HHD was conducted using a Chatillion (K DFX 200, Ametek Inc., USA) and a Power Track II Commander (PowerTrack ™ II Commander, JTECH Medical, USA) connected to a seatbelt and a glass suction handle (Model S338, CR Laurance of Australia Pty Ltd, Australia) was used for all EFD measures (Fig. 1). The isokinetic strength was measured on a Humac Norm (CMSI Humac/Norm testing and rehabilitation system Model 770, USA) which had been recently serviced and upgraded to the most recent software (HUMAC 2009v10.000.0039NORM). All dynamometry values were recorded in peak Newtons and converted to torque by multiplying the force by the lever length (m) as measured as the distance from the medial joint line of the elbow to