Title: Reliability and Validity of a Medicine Ball-Contained Accelerometer for Measuring Upper-Body Neuromuscular Performance.

Running head: Reliability and Validity of a Medicine Ball Throw.

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Abstract

The aim of the study was to assess the between-day reliability and validity of a medicine ball contained-accelerometer (MBA) for assessing upper-body neuromuscular performance during a throwing task. Ten professional rugby union players partook in the study. Between-day reliability was assessed from the best score attained during 2 sets of 3 throws, on 2 testing occasions separated by 7 days. Validity was assessed against a criterion measure (Optioelectronic system) during 75 throws from a sub group of three participants. The MBA exhibited a *small* between-day error of 2.2 % (90% CI's; 2.0 to 4.6 %) and an *almost perfect* relationship with a criterion measure $r = 0.91$ (90% CI's; 0.87 to 0.94)). However, the mean bias and standard error were *moderate* (7.9% (90% CI's; 6.6 to 9.2%) and 4.9% (90% CI's; 4.2 to 5.7%) respectively). Practitioners using an MBA to assess neuromuscular performance of the upper-body must take into account the overestimation and error associated with such assessment with respect to a criterion measure. However, as the error associated with between-day testing was *small*, and testing is easy to implement in applied practice, an MBA may provide a useful tool for monitoring upper-body neuromuscular performance over time.

Key words: testing, monitoring, fatigue

Introduction

Professional sport relies on many different technologies to quantify and monitor training outputs, and provide feedback to coaches and athletes (6). Examples include the use of global positioning systems (GPS) for monitoring distances, velocities and accelerations (2), timing gates to monitor linear speed (7) and linear position transducers to provide force, velocity and power of barbell lifts (9). However, practitioners regularly use new technology without understanding the validity and reliability of the devices in use (6). Recently a new technology allowing measurement of velocity from medicine ball throws has been made available to practitioners. This may offer a diagnostic tool for the assessment of upper-body neuromuscular performance, which is important for monitoring fatigue (8), measuring and tracking performance (10) and use in upper-limb rehabilitation programmes (1). However, this technology is yet to be validated, or assessed for reliability. Therefore, the aim of the present study was to examine the between-day reliability and validity of a medicine ball-contained accelerometer (MBA) for assessing throwing velocity during an upper-body power exercise.

Methods

Subjects

Ten male professional rugby union players (age 19.7±1.1 years, body mass 98.3±13.2kg, height 186.2±7.6cm) were recruited from a professional rugby union club. All players were in their second year of their professional contracts. Testing was undertaken during the preseason period, throughout which subjects typically engaged in 8 individual training sessions across 5 days per week including 2 upper-body and 2 lower-body resistance training sessions, along with rugby skills training and conditioning. Subjects were excluded if they had a current upper-limb injury, or history of upper-limb injury that prevented them from performing the testing procedure. Ethics approval was granted by University ethics board and informed consent was acquired from all participants.

Design

Reliability data of the 8 kg medicine ball-contained accelerometer (MBA; Ballistic Ball, Assess2Perform, USA) was collected on two separate days (7 days apart) during a week at the end of the playing season. Testing was undertaken at the same time of day to ensure diurnal variation did not affect performance. All participants were provided with regular dietary advice from the club's nutritionist, but dietary intake was not controlled for in the present study. Subjects had approximately 48 hours rest prior to each testing session. Subjects were in a supine position on the floor, on their back with hips and knees bent to approximately 45 degrees and feet flat on the floor. The MBA was held with elbows extended and hands supporting the medicine ball from underneath. Elbow width was at the discretion of the participant. Subjects were instructed to throw the MBA into the air as hard as possible without their feet, buttocks, back or shoulders leaving the floor. Subjects performed two sets of three throws. Intra-set rest was approximately 20 seconds while inter-set rest was 2 minutes. The highest score achieved was used in the final analysis.

The validity of the MBA was assessed against a criterion measure (Optioelectronic system; Qualisys – Qqus system, software version 2.14) in a University biomechanics laboratory, where three subjects performed 25 throws each. Five (18mm) reflective markers were attached to the MBA (superior, inferior poles, and a 3-marker cluster on the anterior face) and were

tracked during each throw using 8 Qualisys cameras sampling at 200Hz. The kinematic data were processed and filtered in Qualisys, before data was transferred to Visual 3D (version 6). In Visual 3D, the 5 tracking markers were used to create three virtual markers within the MBA centre (offset 50% between superior and inferior markers). Anterior split (offset 50% between two cluster tracking markers, on a plane with the med ball centre) and anterior y (offset 50% between the top cluster marker and the anterior split marker). A virtual segment was then created for the MBA using these virtual markers. The advantage of creating virtual markers to track the objects kinematics is to minimise any error that may come from one marker moving or shifting on the surface of the MBA. A pipeline (segment velocity) was used to extract the velocity signal for segment 'med ball' against the 'laboratory' as a reference. The peak velocity achieved during the upward phase of the throw was used for analysis against the MBA's output.

Statistical Analysis

The between-day reliability statistic of typical error (TE) was calculated as; $S_{diff} / \sqrt{2}$ where S_{diff} is the standard deviation of the difference score and converted to a coefficient of variation (CV; TE expressed as a percentage) for all tests using a Microsoft Excel spreadsheet (4). The standardised typical error was rated as trivial (<0.19), small (0.2-0.59), medium (0.6-1.19) or large (1.2-1.99) (4). The smallest worthwhile change was calculated as 0.2 multiplied by the between-subject standard deviation and calculated as a percentage of the mean (5). The agreement between the criterion measure (Qualisys) and the practical measure (MBA) was assessed using an excel spreadsheet (4) designed to calculate the mean bias ([x□ / x□] x 100), standard error of the estimate (STEXY function) and Pearson correlation coefficient, all with 90% confidence limits (4). The mean bias and standard error were standardised using the SD of the criterion to allow for qualitative rating. The standardised mean bias was rated as *trivial* (<0.19), *small* (0.2-0.59), *medium* (0.6-1.19) or *large* (1.2-1.99) (4). The standardised standard error was rated as *trivial* (<0.1), *small* (0.1-0.29), *moderate* (0.3-0.59) or *large* (>0.59).(4) The magnitude of correlation was rated as *trivial* (<0.1), *small* (0.1-0.29), *moderate* (0.3-0.49), *large* (0.5-0.69), *very large* (0.7-0.89) or *nearly perfect* (0.9-0.99) (4).

Results

The between-day CV of the test was 2.2 % (2.0 to 4.6 %) (raw; 0.11 m/s (0.10 to 0.23 m/s)) and was rated as *small*. The smallest worthwhile change was 1.5% (raw; 0.07 m/s). When the medicine ball was compared to the criterion measure, mean bias was *moderate* (7.9% (6.6 to 9.2%), raw; 0.39 m/s (0.33 to 0.45 m/s)), typical error of the estimate was *moderate* (4.9% (4.2 to 5.7%), raw; 0.24 m/s (0.21 to 0.28 m/s)), while the correlation was *almost perfect* (r = 0.91 (0.87 to 0.94)). The regression plot is presented in Figure 1.

The regression equation to estimate the criterion measure (Y) from the practical measure (X) is:
Y = intercept + (slope x X)
Y = 0.948 + (0.648 x X)

INSERT FIGURE 1 HERE

Discussion

This study examined the reliability and validity of a MBA for assessing throwing velocity during an upper-body power exercise. Between-day reliability analysis revealed a *small* typical

error of 2.8 % (2.0 to 4.6). Practitioners wishing to track upper-body neuromuscular performance over time using an MBA can use this statistic to assess if a meaningful change has occurred. Hopkins (3) proposed a method whereby the change score of an individual (± error bars representing the CV) is graphed with an important threshold (e.g. the smallest worthwhile change). A change is 'clear' when the error bars lie outside of the important threshold and 'unclear' when the error bars cross the important threshold (3). It must be pointed out that the subjects in this study were trained athletes, and as such, the between-day error may be different for other populations of different training backgrounds and athletic abilities.

INSERT FIGURE 2 HERE

In addition, correlation analysis demonstrated an *almost perfect* relationship between the MBA and criterion measure, indicating excellent validity. However, the findings show that the MBA overestimated throwing velocity by 7.9%, and demonstrated a *moderate* standard error (4.9%) when compared to the criterion measure. Therefore, practitioners using an MBA to measure upper-body neuromuscular performance must take into account the error and bias when making inferences about such performance. Practitioners wishing to estimate the criterion from the MBA may do so using the equation provided, while appreciating the associated error with this.

Practical applica tions

Practitioners using an MBA to assess neuromuscular performance of the upper-body must take into account the overestimation and error associated with such assessment with respect to a criterion measure. However, as the error associated with between-day testing was *small*, and testing is easy to implement in applied practice, an MBA may provide a useful tool for monitoring upper-body neuromuscular performance over time in trained athletes.

Conclusion

This study investigated the reliability and validity of a medicine ball-contained accelerometer for measuring throwing velocity during a throwing task. Although it exhibited an *almost perfect* relationship with a criterion measure, it *moderately* overestimated throwing velocity and had a *moderate* standard error. Despite this, the between-day assessment error was only *small,* making it a potentially useful test to monitor changes in upper-body neuromuscular performance over time in trained athletes.

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Figure 1. Regression plot for agreement between the criterion measure (Qualisys) and the practical measure (medicine ball).

Figure 2: An example of change in the performance of 2 athletes. Data are percentage change in an individual's performance (± CV error bars) with grey area representing the smallest worthwhile change. Adapted from Hopkins (3).