Validity of Instrumented Medicine Ball Measurements

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Introduction.
Medicine balls are a popular training tool for athletes. While previous research has demonstrated the importance of medicine ball throwing for sports performance and rehabilitation [1-6], its simplicity and training environment make it challenging to quantify metrics for these applications. Therefore, the ability to measure movement-specific outcomes using a medicine ball (e.g. power, velocity) would provide coaches and clinicians a better understanding of the physical capabilities of an athlete/patient and allow them to quantitatively track performance throughout a training or rehabilitation program. The Ballistic Ball, a proprietary instrumented medicine ball (FIT7502 LLC, Colorado, USA), contains an inertial measurement unit (IMU) in the center of the ball. The ball works by transmitting data from the IMU to a software application, where the data is used to quantify various metrics from each throw, such as power, speed, force, launch angle, and distance thrown. The purpose of this study was to assess the validity of different Ballistic Ball throw metrics performed across a range of exercises and conditions.

Methods.
This study was determined to be non-human subjects research by the Sanford IRB. Data was collected from a single individual (M|26yrs|79.4kg|1.77m). Three throw types (vertical, rotational, and chest pass) with two balls (4.54 kg (10lbs), 100.33cm circumference and 3 kg, 72.39cm circumference) were collected. Concentric-only (static) and eccentric-concentric (dynamic) conditions were recorded for each throw type. The subject performed two sets of six repetitions for each throw type and condition at maximal and submaximal intensities. A total of 156 throws were conducted. Optical motion capture was used to collect 3D positional data of the medicine ball with eight motion capture cameras (Oqus 7+, Qualisys AB, Sweden) operating at 300 Hz. A set of 13 retroreflective markers were placed on each medicine ball, including a cluster of four tracking markers, two clusters of three tracking markers, and three markers along the radius of the ball to define the spherical shape. Peak speed, POP-100™ (a proprietary variable of FIT7502), and launch angle were calculated and compared with the variables reported in the software application. Analysis of variance (ANOVA) tests were used to determine differences between devices and the effect of the device, exercise performed, condition of the exercise (static or dynamic), intensity, ball size, and potential interaction effects. A combination of Pearson's correlation, linear regression, and Bland-Altman analyses were used to assess the between device agreement.

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Results.

Across all trials, a near-perfect agreement between the IMU and gold-standard motion capture system was observed for peak speed and launch angle, with a significant but relatively small bias. ANOVA tests revealed no significant differences between motion capture and the Ballistic Ball for peak speed with no significant interaction of devices for exercises, conditions, intensities, and ball sizes. Launch angle was significantly affected by the interaction of the device, movement, and condition ($F=8.61$, $p<0.01$); Bonferroni *post hoc* analysis revealed significant differences between motion capture and the Ballistic Ball ($p=0.049$). Simple main effects revealed a significant difference for launch angle between motion capture and the Ballistic Ball for the chest pass exercise in the dynamic condition at submaximal effort with the larger ball size ($p<0.05$). POP-100™ was significantly affected by the interaction of the device ($F=47.57$, $p<0.01$), condition, and ball size, as well as by the interaction of the device, movement, and ball size ($F=10.81$, $p<0.01$); *post hoc* analysis revealed significant differences between motion capture and the Ballistic Ball ($p<0.01$). Simple main effects showed a significant difference for POP-100™ between motion capture and the Ballistic Ball for the chest pass exercise in the static condition at maximal intensity with the smaller ball ($p<0.05$).

Discussion.

The purpose of this study was to assess the validity of the metrics output by the Ballistic Ball. While no agreement was observed between motion capture and the Ballistic Ball for POP-100™ for static throws, POP-100™ was found to be a valid measurement for throws containing a countermovement as part of the throw condition. Additionally, the Ballistic Ball provides valid measurements of launch angle for vertical throw exercises at various conditions and effort levels. Peak speed was shown to be valid across a range of exercises, conditions, and effort levels with negligible bias. The overall validity of the Ballistic Ball offers clinicians and coaches a tool that they can confidently use to quantify medicine ball performance metrics for athletic development and rehabilitation.

References.

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