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The Reliability of the Seated Medicine Ball Throw as Assessed with Accelerometer Instrumentation

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Abstract The Seated Medicine Ball Throw (SMBT) is low-risk, easy to perform, requires minimal equipment, and is a valid measure of upper body explosiveness. The Ballistic Ball™ (BB) medicine ball contains inertial sensors which estimate peak velocity, and transmits these values to an iPad™ app via Bluetooth™. This method of gathering data may be superior to using horizontal distance as there is less chance of confounding factors and it is easier to administer. The objective of this study was to evaluate the reliability of the BB peak velocity measurement in the SMBT. Twenty healthy, rested, recreationally-active, undergraduate students volunteered to participate in this study. After a standard dynamic warm-up, subjects were taught proper throwing technique. For familiarization, subjects performed repeated SMBTs with a 10 lb BB until horizontal distance thrown for 3 consecutive trials was within 0.25m. After 20 minutes of rest, subjects repeated the warm-up protocol, then performed 6 trials with the same 10 lb BB for which peak velocity was recorded. The test-retest reliability of these 6 trials was analyzed using intraclass correlations (ICC). The ICCs between consecutive trials ranged from 0.94 to 0.98. Peak velocity for trials 1-6 were: 3.85±1.14 m/s, 3.86±1.06 m/s, 3.94±1.22 m/s, 3.85±1.13 m/s, 3.95±1.21 m/s, 3.92±1.20 m/s, respectively. The high ICC values suggest excellent reliability of the peak velocity measurement from the BB device. The BB peak velocity as assessed during a SMBT is a reliable method for assessment of upper body explosiveness.

Keywords: *ballistic ball, peak velocity, medicine ball, upper-body explosiveness*

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1. Introduction

In populations ranging from athletes to older adults, upper body power is needed to fulfill functional tasks; reduced upper body power is associated with increased risk of all-cause mortality [1,2,3]. Upper body power testing is helpful in quantifying changes in upper body power in variety of scenarios, such as baseline testing of ability in healthy, aging, and injured populations [2], and assessment of training program effectiveness [5].

Effective measurement of upper body power requires reliable and valid testing methods. Upper body power tests used in the literature are often expensive, require extensive technical expertise, and may involve significant amounts of time for analysis [4]. Medicine ball (MB) throws are a potentially more accessible method to clinicians and practitioners for testing of upper body power across a variety of populations. MB throws have a distinct advantage over other power tests as they involve a dynamic effort, multiple planes of motion, and require effective stabilization of the upper and lower body during the effort, potentially increasing the specificity of these tests to other functional and sport tasks [5].

The seated medicine ball throw (SMBT) test is generally low-risk, easy to perform, and requires minimal equipment [2]. Horizontal distance thrown in the SMBT has been validated as a measure of upper body explosiveness in older adults [2], children [6], college students [7], and amateur rugby sevens players [8]. Horizontal distance thrown is determined by three factors: velocity during take-off, height at release, and the angle of the release [9]. Peak velocity is perhaps the most useful measure to select of the three determinants of distance thrown because it occurs as a direct result of the impulsive ability of the thrower [9]. Release height and angle of release have a variable influence on horizontal distance thrown [10], yet both are unrelated to upper body power output. Therefore, a more direct and isolated method of power measurement (i.e. peak velocity of the MB during a throw) may provide more valid and reliable assessment of upper body explosive ability.

The Ballistic Ball (BB; Assess2Perform, Montrose, Colorado, USA) is a MB with an embedded accelerometer. The accelerometer estimates peak velocity using a proprietary algorithm. The BB has been validated during against motion capture in professional rugby union players using the supine chest throw [4] and resistance-trained males and females using the standing chest throw [9].

While the accuracy of the device has been validated in these two populations, the BB has not been assessed in a more general, active population or in the SMBT. Therefore, the purpose of this study is to assess the reliability of the BB peak velocity measurement in active, recreationally trained adults performing a SMBT.

2. Methods

2.1. Participants

Twenty healthy (no reported injuries within the last 6 weeks), recreationally-active (i.e. participating regularly in exercise activities), and rested (no reported training of upper extremities in the preceding 48 hours) undergraduate students (8 females, 12 males, height: 170.2 ± 10.5 cm, mass: 73.2 ± 16.0 kg, age: 23.8 ± 3.3 y) volunteered as subjects for this study. Before the start of testing, subjects received a verbal briefing of study procedures, then gave written informed consent. This study was approved by the University Committee for the Protection of Human Subjects.

2.2. Procedures

No single study has provided a comprehensive protocol for the SMBT, thus the following was developed to evaluate the reliability of the BB based on prior studies and our pilot testing: Prior to testing, subjects completed a short dynamic warm up protocol which included 30 jumping jacks, 6 walking lunges (per side), 6 side lunges (per side), 10 m side shuffle, 10 m high skips, 5 explosive push-ups, 5 ballistic squats, and 5 SMBT practice throws with a 6 lb (2.72 kg) MB. After resting for 2 minutes, subjects became familiarized with the SMBT using a 10 lb (4.55 kg) BB. Subjects performed repeated trials, with 1 minute rest periods, until they achieved three consecutive throws within 0.25 m of each other. Previous research with the backwards overhead MB throw used a similar protocol to achieve familiarization with three trials within 0.5m as the criteria [5]; this was halved for the present study due to the shorter distance of the SMBT. Horizontal distance and velocity of each throw was measured and recorded from the BB. After familiarization, subjects rested for 20 minutes, then repeated the warm up protocol. Using the same 10 lb BB, subjects then completed 6 throws with the same technique as familiarization throws; invalid trials were repeated so that a total of 6 valid trials were collected. While we felt 6 trials was probably greater than might be used in a practical setting, the high number of trials ensured we would detect the presence of a learning effect should one exist after the familiarization period.

Subjects were instructed to hold the BB in a static position on their chest until prompted to throw by the sound of a bell from the BB app. During the throw, subjects were instructed to keep their upper back in contact with the bench at all times, and to throw with maximal effort (see Figure 1). Subjects were encouraged to throw at a 40-45 degree angle to maximize distance, but this was not measured nor restricted. Gillespie and Keenum [10] found that horizontal distance was greater when angle of release was not controlled while performing the two-hand seated shot put throw (identical to a SMBT). Horizontal distance was measured from the base of the bench to the rearmost point of contact with the ground on landing using a tape measure.

Any trials in which the subject's upper back broke contact with the bench were recorded and noted as invalid trials. In addition, excessive spin and implausible velocity values were recorded as invalid trials; pilot testing indicated that when the subject's throw technique resulted in substantial spin of the BB, very large, implausible peak velocity values were reported by the BB app. Finally, a trial in which it was clear that a subject did not give a maximum effort was declared invalid.

The BB estimates kinematic and kinetic variables using data from the embedded accelerometer and gyroscope. The BB connects via Bluetooth to an iPad app from the BB manufacturer. Due to issues with drift common to inertial sensors, each BB throw repetition must start in a standard, static position to calibrate an accurate reference frame. Only peak velocity was used in this study because measures of mechanical power output would be based on velocity estimations by the device, hence accuracy of power measurements would be dependent upon accuracy of velocity measurements. The BB's measurement of peak velocity has been examined previously in other populations and modifications of the SMBT; Roe et al. [4] assessed BB peak velocity during a supine throw against 3D motion analysis in professional male rugby players. Similarly, Sato et al. [9] examined BB peak velocity during two variations of the standing MB chest throw against 3D motion analysis in resistance-trained adults.

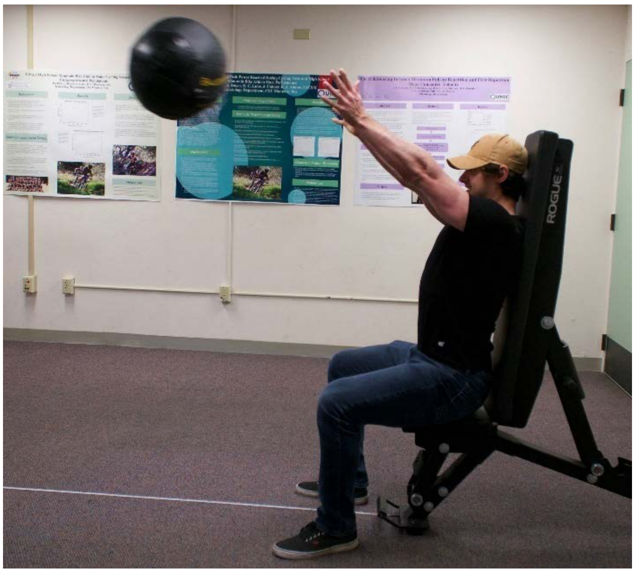

Figure 1. Seated Medicine Ball Throw (SMBT) test

2.3. Statistical Analysis

The current study examined the test-retest reliability of the BB peak velocity (m/s) as assessed during a maximal SMBT attempt. Six trials of the SMBT were conducted. There is ongoing debate regarding the appropriate statistical analysis to establish the reliability of a test [11-17]. With that said, a number of statistical approaches were combined to examine reliability of the trial data. The trial to subsequent trial analysis included: interclass (Pearson's r) and intraclass reliability coefficients (ICC), the mean difference between trials, and the standard error of measurement (SE_m). The 90% upper and lower limits (UL, LL) were also calculated for the aforementioned statistics. A Bland-Altman plot was also constructed in order to examine error uniformity [12]. The coefficient of variation percent (CV%, UL, LL) was also expressed to examine the typical error from the log-transformed trial data. The statistical analysis was carried out with a Microsoft Excel 2013 as well as a spreadsheet provided by Hopkins [14]. The spread sheet of velocity data was peer reviewed for accuracy prior to analysis as suggested by AlTarawneh and Thorne [18]. Thegs statistical analysis employed is consistent with a host of previous reliability investigations [19-22]. Finally, the smallest detectable difference (SDD), which is the magnitude a change in performance must exceed to be sure that a "true" change actually occurred, was calculated using the SE_m across all trials and equation 1 [11,16].

$$SDD = 1.95 \times \sqrt{2} \times SEM \quad (1)$$

3. Results

The participants (n=20) completed 6 trials of successful SMBT with the BB and their demographics are provided in Table 1. Table 2 provides the BB peak velocity achieved resulting from the SMBT (meters/second).

The trial data was log-transformed as recommended by Hopkins [14] for the purpose of quantifying typical error, noting that the trial data did not appear to suggest non-uniform error. The typical error expressed as a coefficient of variation ranged from CV%=4.2-6.8 percent.

Table 1. Demographics (mean±sd)

N	Age (years)	Height (cm)	Mass (kg)
Combined n=20	23.8±3.3	170.2±10.5	73.2±16.0
Female n=8	22.5±2.9	160.8±7.1	63.6±8.9
Male n=12	24.7±3.4	176.5±7.2	79.7±16.7

Table 2. Seated Medicine Ball Throw Velocity Trial Scores

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
3.85±1.14	3.86 ±1.06	3.94±1.22	3.85±1.13	3.95±1.21	3.92±1.20

Data represented as mean±sd, velocity: meters/second.

Figure 2 is a scatter plot comparing trial 1 and 2 scores and appears to exhibit a strong linear relationship. Figure 3 is a Bland-Altman plot of trial 1 and 2 scores and appeared void on non-uniform error. It should also be noted that only one trial pair exceeded the limits of agreement suggesting adequate repeatability [12]. Similar plots for the additional sequential trial pairs were very similar to Figure 2 and Figure 3 and for brevity are not provided in the manuscript.

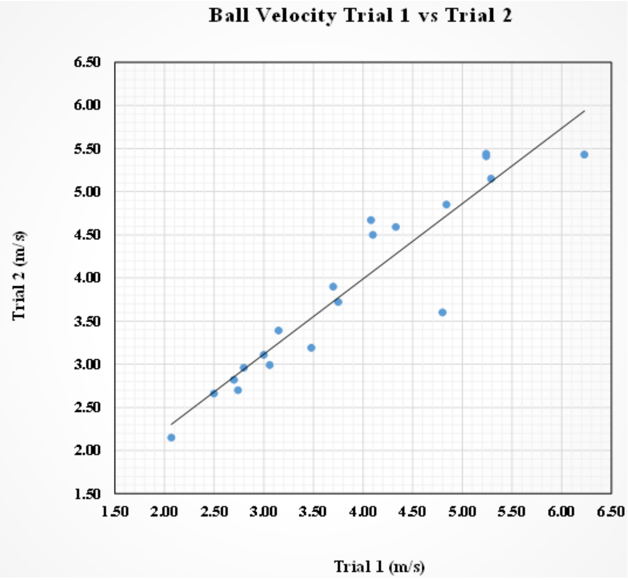

Figure 2. Scatter Plot Velocity Trial 1 and 2 Scores

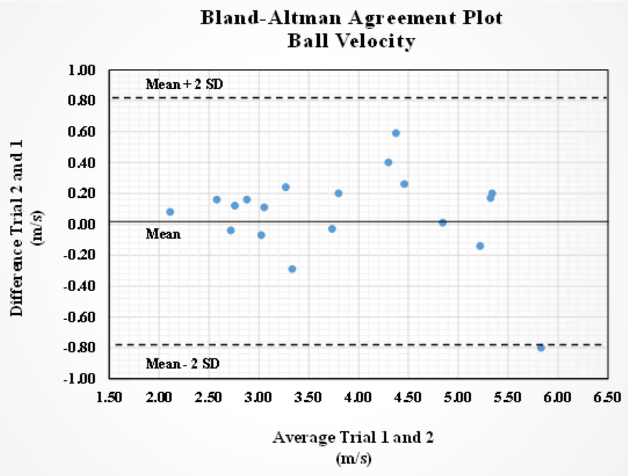

Figure 3. Bland-Altman plot comparing the trial average scores versus the difference scores (Trial 1 and 2)

Table 3 – Table 7 provide the reliability statistics for the sequential trial scores. The mean difference between trial scores ranged from 0.11 to -0.09 m/s. The interclass reliability coefficients ranged from r=0.98 to 0.94. The intraclass reliability coefficients ranged from ICC=0.98 to 0.94. The ICC across all 6 trials was ICC=0.96. The standard error of measure for the sequential trials ranged from SE_m=0.28 to 0.17 (m/s). The SE_m across all 6 trials was SE_m=0.23 (m/s). The SDD was 0.64 m/s.

Table 3. Seated Medicine Ball Throw Velocity Trial 1 and 2 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m/s)	0.01±0.40	0.16	-0.15
r	0.94	0.97	0.87
ICC	0.94	0.97	0.88
Typical Error (CV%)*	6.8	9.4	5.3
SE_m	0.28	0.39	0.22

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SE_m- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m/s- meters/second

Table 4. Seated Medicine Ball Throw Velocity Trial 2 and 3 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m/s)	0.08±0.36	0.22	-0.06
r	0.96	0.98	0.92
ICC	0.96	0.98	0.91
Typical Error (CV%)*	6.8	9.4	5.4
SE_m	0.26	0.35	0.20

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SE_m- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m/s- meters/second.

Table 5. Seated Medicine Ball Throw Velocity Trial 3 and 4 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m/s)	-0.09±0.32	0.03	-0.22
r	0.97	0.99	0.93
ICC	0.97	0.98	0.93
Typical Error (CV%)*	6.2	7.6	4.3
SE_m	0.23	0.31	0.18

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SE_m- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m/s -meters/second.

Table 6. Seated Medicine Ball Throw Velocity Trial 4 and 5 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m/s)	0.11±0.30	0.22	-0.01
r	0.97	0.99	0.94
ICC	0.97	0.99	0.94
Typical Error (CV%)*	5.2	7.2	4.1
SE_m	0.21	0.29	0.17

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SE_m- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m/s- meters/second.

Table 7. Seated Medicine Ball Throw Velocity Trial 5 and 6 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m/s)	-0.04±0.24	0.05	-0.13
r	0.98	0.99	0.96
ICC	0.98	0.99	0.96
Typical Error (CV%)*	4.2	5.8	3.3
SE_m	0.17	0.23	0.13

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SE_m- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m/s- meters/second

4. Discussion

The purpose of this study was to assess the reliability of the BB peak velocity measurement in active, recreationally trained, adult college students while performing a SMBT. It was hypothesized that the BB peak velocity would prove to be reliable once participants were given a sufficient familiarization period of throws. The data collected in this study to assess BB peak velocity reliability included 6 trials of the SMBT. While the reliability of the SMBT has not been broadly reported in the existing literature, the BB peak velocity trial scores of the present study suggest that the peak value measurement obtained during the SMBT is a reliable measure.

The interclass reliability coefficient (i.e. Pearson) ranged from r=0.94-98 when comparing the sequential trial pair scores. The interclass reliability coefficient is higher than test-retest reliability coefficients previously reported for other commonly used physical performance tests [17]. The lower limit of the 90% confidence intervals for the interclass reliability coefficient ranged from L_L=0.87-0.96, which is considered as high [17] to very high [23]. This level of test-retest reliability is similar to that reported by Harris et al. [2] who reported the test-retest reliability of a seated MB throw test (ball mass 3.0 kg) for distance of r=0.96 in a sample of older adults.

The intraclass reliability coefficient (ICC) across all 6 trials was ICC=0.96. The ICC ranged from ICC=0.94-0.98 which is greater than the ICC's reported for many commonly employed physical performance tests [24]. Further, the lower limit of the 90% confidence interval for the intraclass reliability coefficient ranged from ICC L_L=0.88-0.96, considered as "average acceptable" to "above average acceptable" by some [24] or "good" to "excellent" by others [15]. The ICC's assessed during the current study are similar to those reported by Harris et al. [2] who reported an ICC= 0.989 for a seated medicine ball throw test (MB mass: 3.0 kg) for distance in a sample of older adults. Sato et al. [9] reported similar ICCs for the BB velocity scores during standing chest throws (ICC=0.79-0.89, 8 lb (3.64 kg) ball; ICC=0.89-0.97, 12 lb (5.45 kg) ball).

The SE_m is considered a metric of absolute reliability [13]. The SE_m across all 6 trials was SE_m=0.23 (m/s). Because of measurement error within a given test, in order to be certain that a change has occurred, a "true" change would need to be greater than the measurement error of the test [11,16]. The SDD is a measure of this magnitude, suggesting that one can be confident that a change of greater than 0.64 m/s can be confidently considered "real" in a healthy adult population using the SMBT. For example, if a 25 year old female were to improve the peak velocity of her SMBT from 2.5 m/s to 3.3 m/s in response to a training program, we can be very certain that a change of this magnitude was an example of a real change, whereas a change from 2.5 m/s to 2.9 m/s is much less clear.

When non-uniform error is reflected in the scores (not visually apparent in the current study), the SE_m is biased, overestimating error in the lower scores and underestimating the error in the higher scores. In such cases Hopkins [14] suggests log-transforming the scores and then expressing the error as 'typical error' or CV% in order to correct for non-uniformity of error. The typical error expressed as a CV across all 6 trials in the current study was CV%=5.9 percent. The CV% of 5.9% equates to 0.23 m/s which is identical to the SE_m (SE_m=0.23 m/s). That the CV% was equal to the SE_m is confirmation that the trial scores were void of non-uniformity of error (i.e. trial scores were homoscedastic).

We also examined the BB peak velocity scores on an individual basis to determine how many outlier scores occurred across the six trials. An individual's trial score that exceed the individual's 6 trial mean score plus 2 standard deviations was considered as an outlier. Based on the aforementioned criteria no outliers were identified. We viewed this information to indicate that the familiarization preparation was adequate and that there was sufficient recovery time between the SMBT trials.

Visual inspection of the BB peak velocity trial means in Table 2 does not suggest a systematic change across the 6 trials. Further, the BB trial data indicated that 10 of the 20 participants scored their highest peak velocity in the first three trials, 8 scored highest during trials 4-6, and 2 had identical maximum scores during trials 1-3 as well as trials 4-6. The lack of a systematic change in BB peak velocity scores across trials again suggests that there was ample recovery time between trials as well as an appropriate familiarization sequence.

The current study is one of only two that we are aware of that has reported the BB peak velocity data. The BB (10 lb MB; 4.55 kg) peak velocity scores collected in the current study averaged 3.90±1.16 m/s across all 6 trials. For comparison, Sato et al. [9] reported BB velocity scores of 3.94±0.51 and 3.92±0.64 m/s for 8 and 12 lb (3.64 and 5.45 kg) MB standing chest throws among active adults engaged in resistance training. Roe et al. [4] assessed the validity of the BB (8 lb (3.64 kg) ball) peak velocity during a supine throw in professional male rugby players. However, Roe and colleagues [4] did not report any velocity scores (only validity/reliability statistics). Given the paucity of research with the BB, one might consider the BB peak velocity scores collected in the current study as a preliminary reference range to gage other recreationally-active undergraduate students against when executing the SMBT.

Many studies involving the SMBT or seated shotput (performed similarly to the SMBT, but with a shot) have attempted to reduce performance variability by controlling the angle of release during the throw with physical barriers and/or targets [7,25,26] while others have not [6,8-10]. Generally, studies that did not strictly control the angle of release did advise participants to throw at approximately a 45-degree angle to optimize performance [10,27-29]. Interestingly, Gillespie and Keenum [10] found that individuals performing a seated shot put threw farther when the release angle was uncontrolled and found that the controlled-angle and uncontrolled-angle conditions were similarly reliable. During the familiarization procedures of our study, we did not control the angle of release, but we coached participants to throw at approximately a 45-degree angle to optimize throw distance, similar to past studies [10,27,28,29]. The high reliability of the peak velocity measurement in the present study supports the adequacy of coaching, but not restricting, the angle of release.

In order to a trial to be considered valid, the upper back of participants had to stay in contact with the bench throughout the throw. This was the only error that occurred in the final 6 trials of the present study, occurring 16 times total for the entire sample, for an average of 0.83 errors per participant. Other studies have placed a strap anchored to the bench across subjects' chests to prevent this movement off of the bench [8,10,25,26]. While the strap presumably prevents this error from occurring, the present study is the only one known to the authors to report error rate, thus the efficacy of the strap to prevent these errors is unknown. Additionally, the effect of the chest strap on throw performance and reliability is also unknown. The probability of this error occurring was 21% (16 errors across 76 trials). Extrapolating to the practical setting, 1 invalid trial in 5 is not terribly cumbersome, and is probably less cumbersome than the effort to strap a subject to whatever their back rests against during the test. This is particularly true when using a chair to perform the test [e.g. [2]], which is likely less heavy and stable than a steel-framed weight bench, which is likely unavailable in many of the settings in which the SMBT is useful.

Both male and female participants were included in this study. However, given differences in the magnitude and different movement strategies employed in explosive performance between males and females [30,31], it may be warranted to evaluate males and females separately in future studies.

While previous studies using the SMBT have reported their methods, there is little consistency in reported methods between studies. From the findings of the present study and those of previous studies, we suggest the following protocol for the SMBT:

1) To warm up prior to the SMBT, a combination of lower and upper body callisthenic and dynamic mobility exercises, and SMBT trials with a lighter weight should be used for warm up and coaching of throw technique.
2) Subjects should sit on a bench or chair, with the back of the chair against the wall. The subject should hold the MB against their chest, then push the MB off their chest explosively. If the distance the MB is thrown is the measurement of interest, then the angle of release should be approximately 40-45 degrees; subjects should be coached to this angle, not restricted by equipment. The upper back should stay in contact with the chair or bench throughout the throw; loss of contact results in an invalid trial.
3) For familiarization, subjects should repeat trials until the peak velocity of three consecutive trials are within 0.23 m/s of one another for the BB, and within 0.25 m when using distance. This familiarization can be as close as 20 minutes to testing. It is during this time that the test administrator should provide feedback on technique and angle of release to maximize distance (the latter only necessary if distance thrown is the outcome of interest).
4) After familiarization, a minimum of three trials should be performed in the final testing. These three trials should be within 0.23 m/s (when using the BB) or 0.25 m (when measuring distance thrown). Additional trials may be performed to meet that criteria, until three valid trials are obtained.
5) The average of the best two of the three valid trials should be used.

5. Conclusion

Because upper body muscular power output is considered a key component of health-related physical fitness in all populations, establishing accurate and reliable familiarization protocol and discovering reliable ways to measure it is essential. The results from our investigation suggest that the Ballistic Ball's peak velocity measurement as assessed in a SMBT is a reliable method for assessment of upper body explosiveness in the college-aged recreationally active population.

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References

[1] Foldvari, M., Clark, M., Laviolette, L.C., Bernstein, M.A., Kaliton, D., Castaneda, C., Pu, C.T., Hausdorff, J.M., Fielding, R.A., and Singh, M.A., "Association of muscle power with functional status in community-dwelling elderly women," The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 55 (4). M192–M199. April 2000.

[2] Harris, C., Wattles, A.P., DeBeliso, M., Sevene-Adams, P.G., Berning, J.M., and Adams, K.J., "The seated medicine ball throw as a test of upper body power in older adults," Journal of Strength and Conditioning Research, 25 (8). 2344-2348. 2011.

[3] Metter, E.J., Talbot, L.A., Shrager, M., and Conwit, R.A., "Arm-cranking muscle power and arm isometric muscle strength are independent predictors of all-cause mortality in men," Journal of Applied Physiology, 96 (2). 814-821. 2344-2348. February 2004.

[4] Roe, G., Shaw, W., Darrall-Jones, J., Phibbs, PJ., Read, D., Weakley, JJ., Till, K., and Jones, B., "Reliability and validity of a medicine ball-contained accelerometer for measuring upper-body neuromuscular performance," Journal of Strength and Conditioning, 32 (7). 1915-1918, July 2018.

[5] Stockbrugger, BA. and Haennel, RG., "Contributing factors to performance of a medicine ball explosive power test: a comparison between jump and nonjump athletes," Journal of Strength Conditioning Research, 17 (4). 768-774. 2003.

[6] Davis, KL., Kang, M., Boswell, BB., DuBose, KD., Altman, SR., and Binkley, HM., "Validity and reliability of the medicine ball throw for kindergarten children," Journal of Strength Conditioning Research, 22 (6). 1958-1963. 2008.

[7] Nash, A., "Seated medicine ball toss as a predictor of upper-body strength in untrained women," Kentucky Newsletter for Health, Physical Education, Recreation and Dance, 44 (2). 27-30. 2008.

[8] Ferreira de Jesus Leite, M.A., Sasaki, J.E., Monteiro Lourenco, C.L., Ribeiro Zanetti, H., Gonsalves Cruz, L., Ribeiro da Mota, G., and Lacerda Mendes, E., "Medicine ball throw test predicts arm power in rugby sevens players," Brazilian Journal of Kineanthropometry and Human Performance, 18 (2). 166-176. 2016.

[9] Sato, K., Carroll K.M., Wagle, J.P., Lang, H.M., Smith, A.P., Abbott, J.C., Hierholzer, K.M., and Stone, M.H., "Validation of inertial sensor to measure velocity of medicine balls," Journal of Trainology, 7 (1). 16-20. 2018.

[10] Gillespie, J. and Keenum, S., "A validity and reliability-analysis of the seated shot put as a test of power," Journal of human movement studies, 13 (2). 97-105. 1987.

[11] Beckerman, H., Roebroeck, M.E., Lankhorst, G.J., Becher, J.G., Bezemer, P.D., and Verbeek, A.L., "Smallest real difference, a link between reproducibility and responsiveness," Quality of Life Research, 10 (7). 571-578. August 2001.

[12] Bland, JM. and Altman, DG., "Statistical methods for assessing agreement between two methods of clinical measurement," The Lancet, 327 (8476). 307-310. February 1986.

[13] Bruton, A., Conway, J., and Stephen, H., "Reliability: what is it, and how is it measured?" Physiotherapy, 86 (2). 94-99. 2000.

[14] Hopkins, W.G., 2013, A new view of statistics. Internet Society for Sport Science, http://www.sportsci.org/resource/stats/.

[15] Koo, T. and Li, M., "A guideline of selecting and reporting intraclass correlation coefficients for reliability research," Journal of Chiropractic Medicine,15 (2). 155-163. 2016.

[16] Kropmans, T.J.B., Dijkstra, P.U., Stegenga, B., Stewart, R., de Bont, L.G.M., "Smallest detectable difference in outcome variables related to painful restriction of the temporomandibular joint," Journal of Dental Research, 78(3). 784-789. Mar.1999.

[17] Safrit, MJ., Wood, TM., I*ntroduction to measurement in physical education and exercise science*," CV Mosby Co. Third edition 1995.

[18] AlTarawneh, G., and Thorne, S. "A pilot study exploring spreadsheet risk in scientific research". arXiv [cs.CY]. Retrieved from http://arxiv.org/abs/1703.09785. March 2017.

[19] Ah Sue, R., Harris, C., Berning, J., Sevene, T., Adams, K.J., and DeBeliso, M., "Determination of trials needed for measurement consistency of standing long jump in female collegiate volleyball athletes: a brief report," International Journal of Sports Science, 7 (1). 1-5. 2017.

[20] Crandall, J., Phillips, D., and DeBeliso, M., "The reliability of reactive agility testing in 5th grade females," Journal of Athletic Enhancement, 6 (3). June 2017.

[21] Tano, G., Bishop, A., Climstein, M., DeBeliso, M., "The reliability of the prowler in high school male football players," Journal of Sports Sciences, 4 (4). August 2018.

[22] White, K., DeBeliso, M., Sevene, T., and Adams, K., "The reliability of the 300-yard shuttle run in high school girls basketball players," Journal of Sports Sciences, 3 (5). 214-218. 2015.

[23] Miller, D.K. *Measurement by the physical educator: why and how*, McGraw-Hill, 2014.

[24] Baumgartner, T.A., Jackson, A.S., Mahar, M.T., and Rowe, D.A., *Measurements for evaluation in physical education and exercise science*, McGraw Hill, New York, 8th Ed. 2007.

[25] Lyttle, A.D., Wilson, G.J., and Ostrowski, K.J., "Enhancing performance: maximal power versus combined weights and plyometrics training," Journal of Strength and Conditioning Research, 10 (3). 173-179. 1996.

[26] Murphy, A.J. and Wilson, G.J., "Poor correlations between isometric tests and dynamic performance: relationship to muscle activation," European Journal of Applied Physiology, 73. 353-357. 1996.

[27] Mayhew, J.L., Bemben, M.G. and Rohrs, D.M., "Seated shot put as a measure of upper body power in adolescent wrestlers," Pedatric Exercise Science, 4. 78-84. 1992.

[28] Mayhew, J.L., Bemben, M.G., Rohrs, D.M., Piper, F.C., and Willman, M.K., "Comparison of upper body power in adolescent wrestlers and basketball players," Pedatric Exercise Science, 7. 422-431. 1995.

[29] Mayhew, J.L., Bemben, M.G., Rohrs, D.M., Ware, J., and Bemben, D.A., "Seated shot put as a measure of upper-body power in college males," Journal of Human Movement Studies, 21. 137-148. 1991.

[30] Beckham, G.K., Suchomel, T.J., Bailey, C.J., Grazer, J.L., Kim, S.B., Talbot, K.B., Stone, M.H. "Influence Sex and Maximum Strength on Reactive Strength Index-Modified," Journal of Sport Science and Medicine, 18 (1). 65-72. March 2019.

[31] Ikeda, Y., Kijima, K., Kawabata, K., Fuchimoto, T., Ito, A. "Relationship between side medicine-ball throw performance and physical ability for male and female athletes," European Journal of Applied Physiology, 99. 47-55. 2007.

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