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Peak Torque Comparison between iSAM 9000 and Biodex Isokinetic Devices

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Abstract

Isokinetic dynamometers (new and updated) need to clearly establish validity and reliability. The iSAM 9000 (iSAM), a newer isokinetic device, generates a strength index score to qualify job candidates to reduce injury incidence. Further data is needed to better inform the use of isokinetic dynamometry for this purpose, across different isokinetic devices. This study compared peak torque values between isokinetic devices (iSAM and Biodex) for concentric shoulder and knee flexion and extension, and also assessed reliability and coefficients of variation (CV) in strength scores. Test-retest reliability was measured by thirty-six healthy participants completing two different sessions (5 repetitions each joint) on each device for both shoulder and knee movements. Using the average of the three best readings, results showed the iSAM produced less peak torque for the majority of knee movements, and more peak torque for shoulder flexion compared to the Biodex. There was a larger CV for right knee flexion, left and right shoulder extension produced by the iSAM compared to the Biodex. Test-retest reliability was high ($r \geq 0.75$), as indicated by correlation coefficients. Despite both devices having good reliability, there were significant differences in peak torques produced. Caution is warranted when comparing results obtained across isokinetic devices.

Keywords: Muscle Strength Dynamometer, Rehabilitation, Return to Work

1. Introduction

Isokinetic assessment of muscle performance is widely accepted for use in clinical, rehabilitation, and research environments. Isokinetic is generally accepted as a diagnostic tool for muscle performance and patient/subject health and is used to better inform decisions such as patient readiness, progress, and return-to-work (Caruso, Brown, & Tufano, 2012).

In the isokinetic market, dynamometers are constantly upgraded, and newer models are introduced. Given their intended role in rehabilitation and the changes in the isokinetic industry, it is important that validity and reliability (mechanical and human) of isokinetic dynamometry be clearly established. In a recent literature review, Caruso, et al. (2012) reported that while most studies show data reproducibility results (test-retest reliability) that are acceptable or better, there are numerous factors that elevate variability, such as dynamometer dynamics and software, anatomical postures during testing, performance variable examined, angular velocity at which repetitions are performed, and the specific joint measured. For example, in comparisons of knee and shoulder joints, the knee showed excellent levels of reliability under test-retest conditions across a variety of studies while the shoulder joint showed greater variability in test-retest data across fewer studies(Caruso et al., 2012). Also, the authors found that variability in test re-test data increases in tests using higher angular velocities.

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Similar results have been reported when comparing performance data across two isokinetic devices. Though there is general agreement of outcomes across devices, factors such as joint type, angular velocities, testing and stabilization protocols, and the measured performance variable may impact assessment results (Cotte & Ferret, 2003).

One lesser known isokinetic dynamometer on the market is the iSAM 9000 (iSAM). Injury Reduction Technology (INRTEK), introduced the device to measure muscle function (flexion and extension) of the shoulder, knee, and trunk in one self-contained unit. INRTEK uses an algorithm to determine a strength index for the major muscle groups involved in the performance of manual labor. From the isokinetic strength rating algorithm, the company recommends a maximum work level for each individual pre-screened. The qualification of job candidates through their testing protocols have yielded significant reductions in injury incidence and severity (Perrin, 2006). This translates to significant cost savings for the company and employee. Previous research on the validity and reliability of the first-generation iSAM showed the device to be mechanically valid and reliable when compared to the Cybex 6000 at the angular velocity of $60°\cdot s^{-1}$ (Orri & Darden, 2008). However, in directly comparing the two devices, their results showed significantly higher peak torque values for the iSAM on almost all measures. Also, lower correlations were reported between the machines during the shoulder flexion and extension exercises. The researchers attributed the peak torque discrepancies to differences in stabilization protocols (e.g. shoulder strapping), the lack of gravity correction procedures, and device dynamics(Orri & Darden, 2008).

The second-generation iSAM, with updates in the dynamometer, subject stabilization, and software is in need of reliability and validity data. In addition, research that further delineates variables related to the agreement between and within isokinetic devices is needed to better inform the use of dynamometry. The current study compares the second-generation iSAM with the Biodex dynamometer, a more prevalent device used in many rehabilitation clinics and research laboratories with a long-term goal of determining the applicability of INRTEK's strength rating algorithm to other isokinetic devices more accessible to clinicians. Specifically, the present study sought to compare peak torque values between different isokinetic devices (iSAM and Biodex) for concentric knee and shoulder flexion and extension, and establish test-retest reliability for both devices and joints.

2. Material and methods

2.1 *Research Design*

A repeated-measures design was used to (1) compare peak torque values and the variation in scores between the iSAM and the Biodex System 3 isokinetic dynamometers, and (2) establish the test-retest reliability for both devices. The study's procedures, informed consent, and health history questionnaire were approved by the university's Institutional Review Board.

2.2 *Participants*

Thirty-six undergraduate students (16 females and 20 males; age: 23.5 $\pm$ 5.99 years, height: 1.73 $\pm$ 0.10 m, weight: 76.82 $\pm$ 14.46 kg) from the university's Exercise Science and Physical Education programs were recruited for this study. The inclusion criterion was being free from any condition that would prevent maximal effort from being exerted throughout the range of motion tested. All participants completed two sessions on each isokinetic device. A Latin square was used to assign the order in which sessions were completed. Participants were instructed to refrain from exhaustive exercise (aerobic and resistance) for 24 hours prior to each session.

2.3 *Procedures*

Upon arrival to the laboratory, each participant was secured to the isokinetic device using the appropriate chest, waist, and thigh straps according to the manufacturers' specifications. The center of the joint axis was aligned with the center of the isokinetic input arm axis for each device. For knee joint testing, the position of the distal aspect of the pad on the input arm was aligned with the lateral malleolus. The length of the shoulder isokinetic input arm was set to minimize elbow flexion. All settings for the seat and isokinetic input arms were recorded and duplicated for the subsequent session.

To standardize the body position of each participant during testing on both devices, each participant held onto the chest straps with both hands when performing knee testing and held onto the chest straps with the contra lateral hand for shoulder testing.

INRTEK's testing protocol was used for both devices since it is used to determine the strength index from their strength algorithm. The order in which the shoulder and knee joints were tested started with either the left shoulder or right knee with the joint being tested bilaterally prior to moving to the next joint. After each participant was secured to the iSAM or Biodex for a particular joint and side of the body, a warm-up set consisting of 3-5 repetitions with progressively increasing intensity was completed. Isokinetic speed was set to $60°\cdot s^{-1}$. After completing the warm-up and a 30 second rest period, participants completed two sets of five repetitions of concentric flexion and extension with 15 seconds of rest between sets. Isokinetic flexion and extension torque and angle data for the knees and shoulders from the iSAM and Biodex were exported to Excel to perform gravity correction procedures (see below) and identify the best three peak torque values out of the ten repetitions, which were averaged and used for statistical analysis.

2.4 *Data Analysis*

The gravitational moment due to each isokinetic input arm (Mi) was determined by dropping the input arm through each participant's range of motion. The moment produced when the input arm was in the horizontal plane was recorded. The gravitational moment (Mg) due to the weight of each participant's tested limbs was calculated by estimating the weight of the limb, location of center of mass (Dempster, 1955), and estimating limb length (Drillis & Contini, 1966).The sum of Mi and the corresponding Mg was used to correct for the effect of gravity.

Separate 2-way (session x device) repeated measures analysis of variance (RMANOVAs) were used to assess statistical differences in peak torque and coefficient of variation (CV) for all joints tested. Since the best three scores for each session were averaged to determine peak torque, the CV was calculated using these three scores. Test-retest reliability across both sessions for each device was assessed after conducting a Shapiro-Wilks test to evaluate normality. All statistical tests were performed using SPSS (version 22, IBM Corporation, Armonk, NY).The alpha level was set to 0.05. Results were reported as means $\pm$ SD.

3. Results

All sessions were completed within three weeks with an average of 5 days of rest between successive sessions (varied from 2 to 14 days). Table 1 shows the peak torques and CVs for flexion and extension at both knee joints. Results of the RMANOVA for the left knee reveal a significant main effect for device ($F(1, 35)=24.975$, $p<0.001$) during knee flexion with the iSAM having larger scores. The main effect for session during left knee flexion was close to being significant ($F(1, 35)=3.941$, $p=0.055$) with peak torque values for session 1 having the tendency to be larger. RMANOVAs for the right knee showed a significant main effect for device for peak torque extension ($F(1,35)=8.204$, $p=0.007$) and peak torque flexion ($F(1,35)=61.106$, $p<0.001$) with peak torque scores being larger on the Biodex. There was also a significant main effect for session during knee extension ($F(1,35)=5.331$, $p=0.027$) with session 1 producing larger peak torque scores, and a significant main effect for device for CV during knee flexion ($F(1,35)=7.169$, $p=0.011$) with greater CV being reported for iSAM.

Table 1: Peak torque values and CV for iSAM and Biodex isokinetic devices for the knee

	Left Knee				Right Knee			
	iSAM		Biodex		iSAM		Biodex	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
Extension (Nm)	156.4 (42.3)	151.2 (33.9)	159.5 (55.6)	157.1 (54.7)	146.0 (43.9)	140.1 (38.6)	159.6 (58.7)	152.3 (53.7)
CV (%)	2.74 (2.50)	3.10 (2.57)	2.91 (1.85)	3.28 (2.21)	3.07 (2.01)	3.63 (2.43)	3.09 (2.54)	3.23 (2.25)
Flexion (Nm)	74.9 (29.5)	68.6 (25.6)	84.0 (33.0)	82.8 (28.9)	75.1 (30.0)	74.3 (27.0)	92.3 (33.7)	88.4 (29.5)
CV (%)	4.58 (2.88)	4.53 (2.72)	3.97 (2.48)	4.63 (3.37)	6.56 (4.62)	5.24 (4.90)	3.65 (2.38)	4.23 (3.03)

Mean (SD)

Table 2 shows the peak torque values and CVs for flexion and extension at the left and right shoulder joints. RMANOVA results for the left shoulder reveal a significant main effect for session ($F(1,35)=6.059$, $p=0.019$) during peak torque extension with session 1 producing larger values. There was also a significant main effect for device for CV during extension ($F(1,35)=7.191$, $p=0.011$) with Biodex scores showing a greater CV. In addition, there was a significant main effect for device for peak shoulder flexion torque ($F(1,35)=86.590$, $p<0.001$) with larger peak torque values being measured on the iSAM. RMANOVA for the right shoulder revealed a tendency for a significant main effect for session for peak extension torque ($F(1,35)=3.525$, $p=0.069$) with session 1. Also, there was a tendency for a significant main effect for session for extension CV ($F(1,35)=3.727$, $p=0.062$) with greater CV in session 1. In addition, there was a significant main effect for device for peak flexion torque ($F(1,35)=32.129$, $p<0.001$)with significantly greater peak torque scores on the iSAM. The results of the Shapiro-Wilks test showed that the assumption of normality being violated for most of the test measures ($p< 0.05$). Despite repeated attempts to transform the data, we were unable to avoid this violation of normality. Therefore, spearman rank correlation was used to assess test-retest reliability instead of intraclass correlation. All nonparametric spearman correlation coefficients statistically significant ($p<0.001$) and are listed in Table 3. They show a high degree of test-retest reliability between sessions for each device.

Table 2: Peak torque values in Nm and CV for iSAM and Biodex isokinetic devices for the shoulder.

	Left Shoulder				Right Shoulder			
	iSAM		Biodex		iSAM		Biodex	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
Extension (Nm)	55.8 (30.9)	54.3 (29.8)	55.7 (30.3)	52.3 (29.7)	57.7 (29.5)	56.0 (29.4)	58.1 (30.4)	56.1 (30.0)
CV (%)	4.13 (2.83)	4.34 (3.00)	5.81 (3.86)	5.74 (5.32)	3.92 (3.05)	4.18 (2.59)	5.56 (4.23)	5.29 (3.77)
Flexion (Nm)	67.7 (21.4)	67.1 (22.3)	61.5 (22.1)	59.5 (23.4)	64.6 (22.2)	65.1 (23.1)	60.5 (22.9)	58.8 (22.6)
CV (%)	2.67 (1.66)	3.37 (2.20)	2.96 (2.38)	3.21 (2.38)	3.14 (2.37)	3.13 (2.23)	3.18 (1.90)	4.12 (4.38)

Mean (SD)

Table 3: Spearman rank order correlation coefficients for iSAM and Biodex peak torque scores.

Test	iSAM (r)	Biodex (r)
Left Knee Extension	0.745	0.904
Left Knee Flexion	0.856	0.891
Right Knee Extension	0.896	0.880
Right Knee Flexion	0.915	0.937
Left Shoulder Extension	0.977	0.975
Left Shoulder Flexion	0.972	0.963
Right Shoulder Extension	0.960	0.952
Right Shoulder Flexion	0.966	0.954

Discussion

This investigation sought to compare peak torque values between two isokinetic devices and report their test-retest reliability to determine if INRTEK's algorithm might be applicable to isokinetic devices more commonly found in rehabilitation clinics.We found differences in peak torque values and CV between the two devices. Also, each device had good reliability despite statistically significant differences between sessions. While several studies have reported the test-retest reliability of the knee joint on various isokinetic devices (see(Caruso et al., 2012; Feiring, Ellenbercker, & Derscheid, 1990)), only a small number of studies have evaluated the test-retest reliability of shoulder flexion and extension. The current investigation adds to this body of literature.

Orri & Darden(2008)demonstrated consistently larger peak torque scores for iSAM compared to the Cybex for knee and shoulder movements. While the current study shows statistically significant differences between the iSAM and Biodex, our results did not show one device consistently having larger scores over the other. While the previous study compared the iSAM to a different isokinetic device, the Cybex 6000, it also did not use a gravity correction. Nelson & Duncan (Nelson & Duncan, 1983) reported 4% and 15% error in peak torque for knee extension and flexion, respectively. For the practitioner, this percent error increases dramatically when evaluating the flexion-extension ratios(Winter, Wells, & Orr, 1981).Furthermore, the second generation iSAM device was updated to improve subject stabilization so that the strapping procedure was similar to the Biodex strapping method. Differences between the current study and Orri& Darden (Orri & Darden, 2008) were likely due to a combination of these rationales.

A possible explanation for the differences between devices for peak torque values in the current study may be due to differences in the range of motion permitted by each device. The thickness of the seat cushion for the iSAM limits the amount of knee flexion that is performed by the subject. For the shoulder, the iSAM range of motion tested was 0° to 150° of shoulder flexion whereas the Biodex allowed for 180° of shoulder flexion movement. While we recorded the peak torque values for both devices that occurred within the limited range of motion for the iSAM, we did not eliminate peak torques that occurred during the acceleration phase of the movement. The iSAM algorithm utilizes the peak torque that has occurred across the entire range of motion recorded even if it occurs during this acceleration phase. Therefore, the acceleration phase could have been included within the iSAM data but may not have been included in the Biodex data for all the participants. Due to the assignment of testing order, we could not set the Biodex range of motion to match that of the iSAM for each session. In addition; the isokinetic input arms for the iSAM could not be moved in the medial-lateral direction. For participants with more narrow shoulder dimensions, this could alter the torque-producing capabilities in the flexion and extension movements.

Differences in peak torque values across the two sessions were observed in the present study. However, there was no consistent pattern in these differences across all joints tested. This suggests that the observed differences may not be due to a learning effect. Rather, the varying time period between subsequent sessions may be a contributing factor. Previous studies have used a smaller window of time (e.g. 7 days or less) (Ly & Handelsman, 2002; Pentland, Lo, & Strauss, 1993)between sessions compared to the current study (2-14 days).

This variability in testing was due to the investigators attempting to complete data collection around a University holiday. While we did not document physical activity status of our participants, the majority were physically active. It is possible that the 48 hours of rest prior to testing was not a sufficient rest period to prevent their previous training session from adversely impacting the results of this study. Nevertheless, this variable window of time for the rest period is a limitation to our study.

The CV was slightly higher (~2-7%) for both devices and all joints tested in the present study when compared to previous studies using similar velocities (Caruso et al., 2012; Wyse, Mercer, & Gleeson, 1994). Parcell et al. (2002) demonstrated no significant difference in peak torque at $60°·s^{-1}$ when across a variety of rest intervals ranging from 15 to 300 s. However, the authors did conduct a more thorough warm-up (i.e., 5 min ride on cycle ergometer at 100 W intensity followed by 3-4 sub maximal isokinetic knee extension repetitions) compared to the present study. Therefore, the elevated CV reported in the current investigation may be attributed to the use of the specific iSAM testing protocol, including its warm-up procedure.

Given the velocity used in the present study($60°·s^{-1}$), this high degree of test-retest reliability (r = 0.75-0.98) was somewhat consistent with previous isokinetic studies evaluating the knee joint(Caruso et al., 2012; Orri & Darden, 2008). The nonparametric spearman correlation coefficient for left knee extension on the iSAM was lower than all the other coefficients. According to the guide recommended by Hinkle, Wiersma, and Jurs(2003), these correlation coefficients are categorized as showing high-to-very high positive relationships between the peak torque values produced across both sessions. In a recent literature review, Caruso, Brown, & Tufano(Caruso et al., 2012) reported less reliability for the shoulder, particularly at higher velocities. Due to the limitation of the iSAM device, we were only able to test at $60°·s^{-1}$. Using this slower velocity enabled us to report greater reliability in addition to using the average of the three largest peak torque scores for each session. This method was chosen a priori since it mimics the protocol used by INRTEK to assess job applicants and return-to-work screenings.

While both devices demonstrated good reliability as evidenced by the nonparametric spearman correlation and CV, there were differences in the peak torques scores between the two devices. While the test-retest reliability of concentric knee flexion and extension has been established in the literature, information about the reliability of the shoulder joint, particularly at slower velocities, is limited. The current study was able to demonstrate high reliability for concentric shoulder flexion and extension at $60°·s^{-1}$for both isokinetic devices. It does not appear that INRTEK's proprietary algorithm can be applied directly to other isokinetic testing devices (the Biodex device, in this study). Changes to their testing protocol and isokinetic device may enhance this possibility in the future. From a larger perspective, clinicians should avoid applying the results of one isokinetic device to the other, which is consistent with previous research (Francis & Hoobler, 1987; Gross, Huffman, Phillips, & Wray, 1991).Differences in peak torque scores of the present study would also warrant the use of normative data specific to each isokinetic device.

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