Reliability and validity of a novel custom-built isokinetic dynamometer

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ABSTRACT

Purpose: The purpose of this study was to validate and assess the reliability of a custom-built isokinetic dynamometer. **Methods:** Twelve healthy, male participants (27 ± 4.5yr, 80.6 ± 4.2 kg, 179.8 ± 2.2 cm) performed concentric knee extensions on **1)** a dynamometer constructed using a leg extension machine with a computer controlled cable resistance machine (Quantum) and **2)** a commercially available dynamometer (Cybex, Humac Norm) to determine reproducibility of the Quantum. Validity and reliability was assessed by comparing 15 maximal effort consecutive knee contractions through 90° flexion on each leg using the Quantum at a linear velocity of 0.5 m·s^{-1} and on the Cybex at an angular velocity of 180°·s^{-1}, performed twice on the Quantum and once on the Cybex. Peak power (W), mean power (W), and fatigue rate (%) ((avg first 5 contractions – avg last 5 contractions)/ avg first 5 contractions)) x 100) were quantified. Student's paired *t*-tests, coefficient of variation (CV) and intra-class correlation coefficient (ICC) were used to examine reproducibility within and between devices. **Results:** Significant, yet consistent, differences were demonstrated for peak power between dynamometers (*Quantum:* 706 ± 176 W, *Cybex:* 439 ± 101W, p<0.0001); however, the ICC (0.72) indicated a reasonably strong association. Repeated tests on the Quantum revealed very high reliability (ICC=0.93), with no observed difference in peak power between tests (p<0.85). The CVs for mean power were 9.4% and 13.4% for the Quantum and Cybex, respectively. Fatigue rates were similar between repeated trials on the Quantum (*test1*: 14.5 ± 4.5%, *test2*: 13.8 ± 4.3%, p<0.53) but differed between devices (*Quantum:* 14.1 ± 4.3%, *Cybex:* 5.2 ± 5.9%, p<0.003). **Conclusion:** Although, absolute power outputs differed between devices, the off-set was consistent within subjects across devices and likely related to movement pattern and lever arm differences. As such, the Quantum independently represents a valuable and reliable tool for executing and reporting maximal knee contraction power.

INTRODUCTION

Demonstration and assessment of muscle function and strength is important for establishing specific interventions for either physical therapy, athletic performance, or research (1-5). Isokinetic dynamometry is used to quantify the force of a muscle contraction at a constant velocity, with accommodating resistance (1-4). It is important to obtain accurate measures of standardized values for interpreting results to verify a meaningful change has been invoked (6-8). Various dynamometers exist, however, the 1080 Quantum offers testing and training versatility while functioning similarly to current dynamometers that are at the higher end of the price spectrum.

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METHODS

- Twelve male participants
- *Randomized, crossover*
  - *2 visits on the 1080 Quantum (reliability)*
  - *1 visit on the Cybex (validity)*
- **1080 Quantum**
  - 15 maximal concentric knee contractions per leg at 0.5 m·s^{-1}
  - 2-s return
  - 10-minute rest between legs
  - 2-7 days rest between visits
- **Humac Norm**
  - 15 maximal concentric knee contractions per leg at 180°·s^{-1}
  - 45°·s^{-1} return
  - 10 minute rest between legs

RESULTS & DISCUSSION

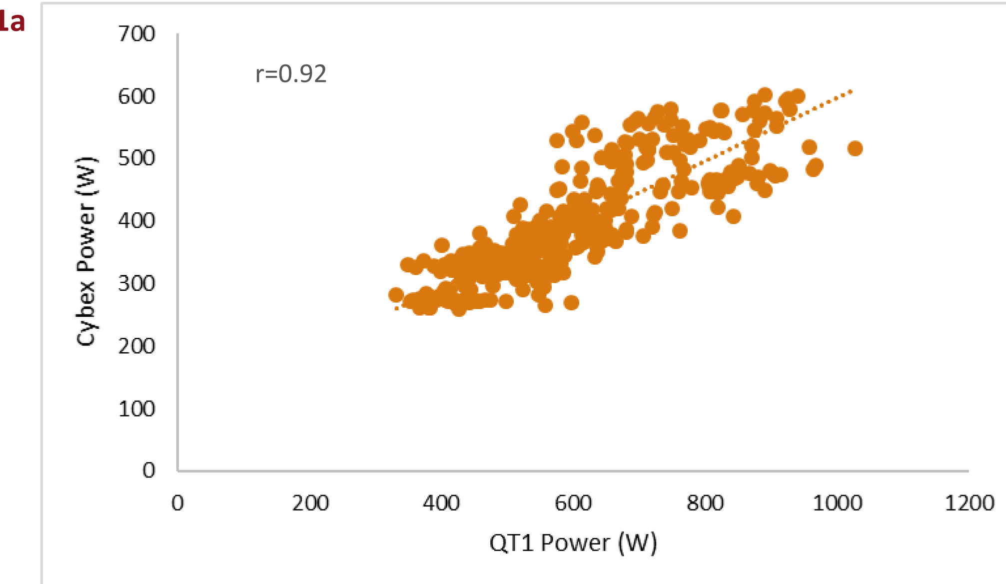
Table 1 Mean and SD, *p*, ICC, CV and SEM values for QT1 vs. QT2 and QT1 vs. Cybex for peak power, mean power and muscle fatigue rate

	QT1 (mean and SD)	***QT2*** (mean and SD)	***p***	***ICC***	***CV*** (%)	***SEM*** (W)
peak power (W)	706.1 ± 176.6	710.0 ± 172.9	0.845	0.93	6.6	47.91
mean power (W)	601.1 ± 143.3	600.4 ± 132.7	0.95	0.982	4.5	27.02
muscle fatigue rate (%)	14.5 ± 4.5	14.3 ± 4.6	0.857	0.818	19.9	2
	QT1 (mean and SD)	***Cybex*** (mean and SD)	***p***	***ICC***	***CV*** (%)	***SEM*** (W)
peak power (W)	706.1 ± 176.6	439.5 ± 100.8	0.0001	0.724	13.9	75.33
mean power (W)	601.1 ± 143.3	396.1 ± 89.7	0.0001	0.893	10.7	75.09
muscle fatigue rate (%)	14.5 ± 4.5	5.2 ± 6.0	0.003	NS	47.6	5.82

***QT1 –** Quantum Test 1; **QT2 –** Quantum Test **2; ICC –** Intra-class Correlation (p<0.05) Coefficient; **CV –** Coefficient of Variation; **SEM –** Standard Error of Measurement*

- 1080 Quantum Test 1 (QT1) vs Test 2 (QT2) for peak power (*p*=0.845), mean power (*p*=0.950) and muscle fatigue (*p*=0.857) rate were similar between tests
- For all comparisons, QT1 vs. Cybex were statistically different (peak power *p* <0.0001, mean power *p* <0.0001, muscle fatigue rate *p* = 0.003)
- Intraclass correlation coefficient (ICC) between QT1 vs. QT2 were very highly correlated for peak and mean power, with a low coefficient of variation (CV)
- ICC of QT1 vs. Cybex revealed a moderate to high correlation with a moderate CV (<15%) for peak and mean power

1a



1b

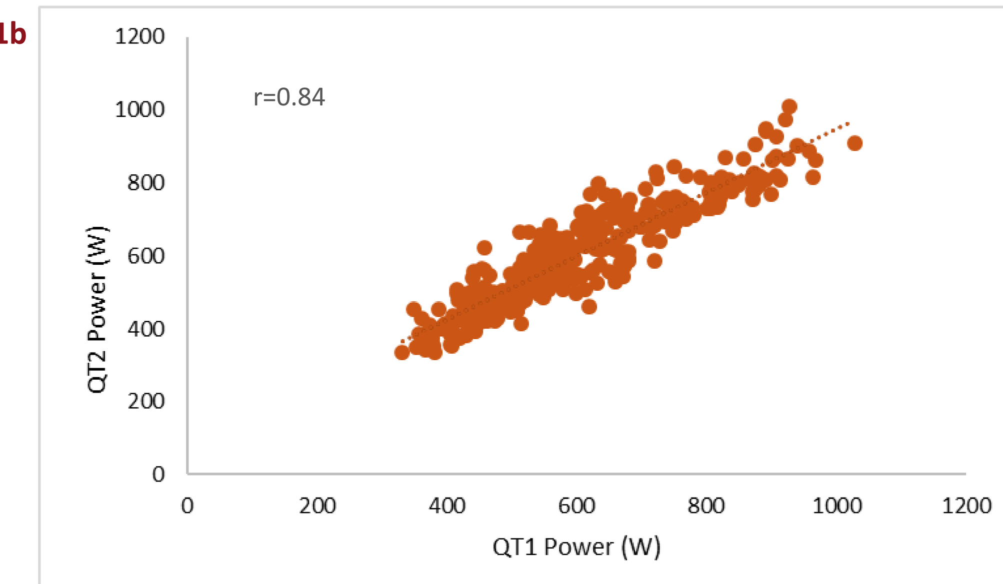
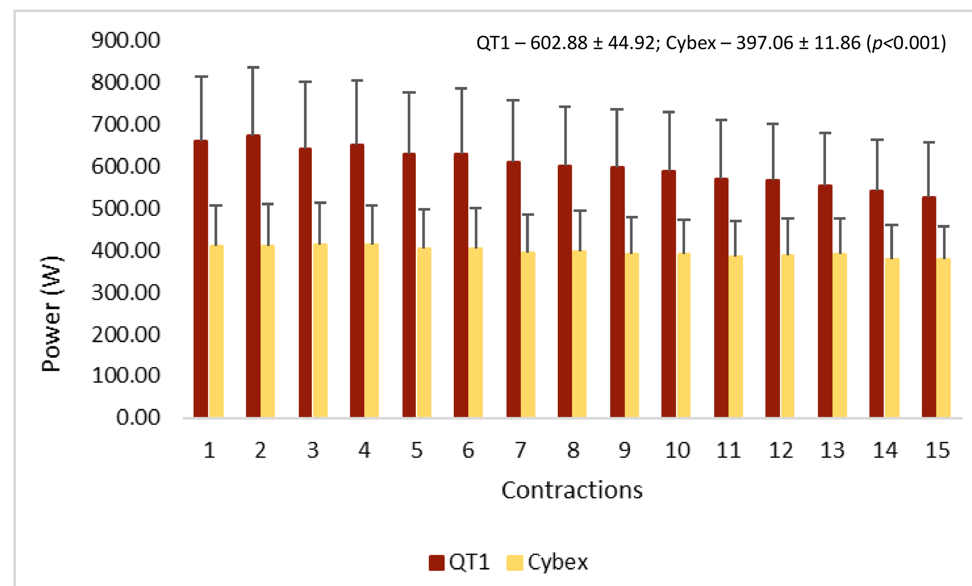


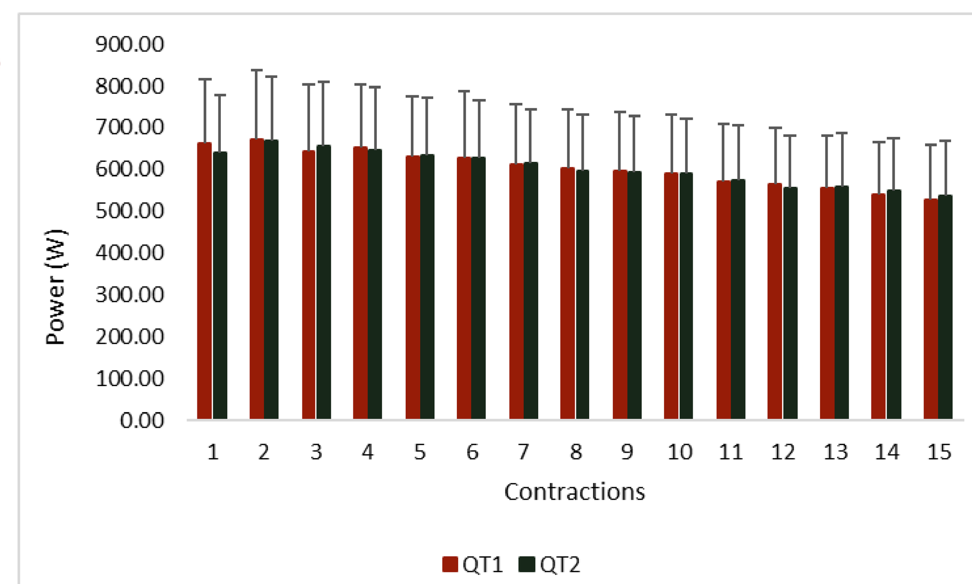
Figure 1 (above) – Power outputs for individual contractions for **a)** QT1 vs. Cybex and **b)** QT1 vs. QT2

Figure 2 (below) -- Combined data of both legs for peak power from the first (1) to last (15) contraction between **a)** 1080 Quantum Test 1 (QT1) vs. Cybex and **b)** QT1 vs. 1080 Quantum Test 2 (QT2)

2a



2b



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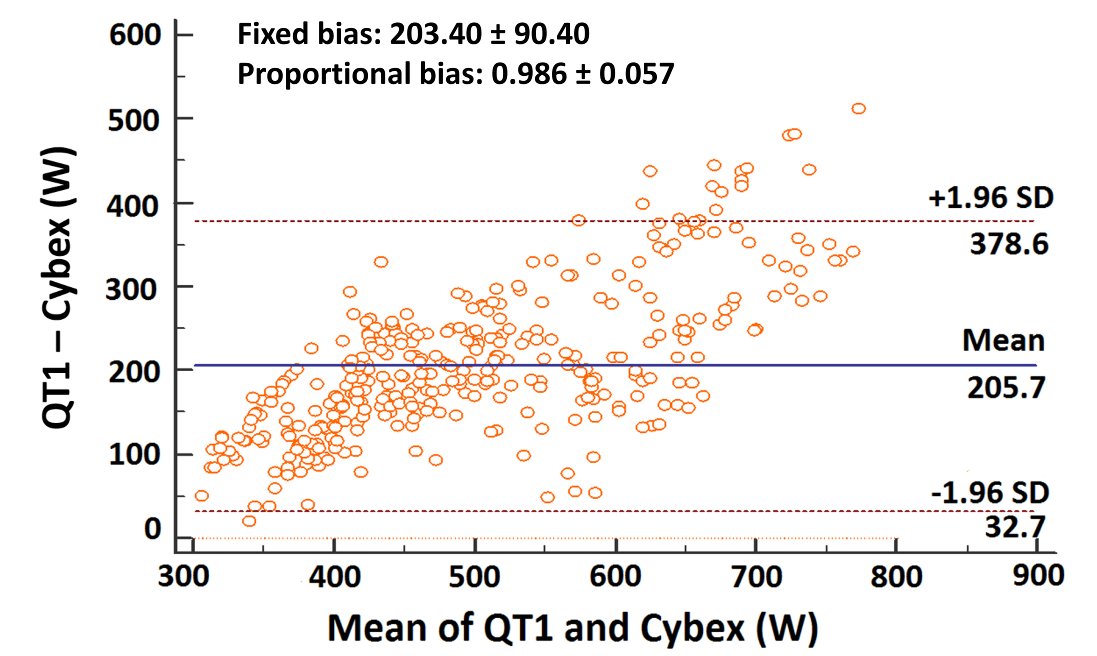

Figure 3. Bland-Altman Plot – This figure demonstrates agreement with the difference of values between the two machines (1080 Quantum vs. Cybex) on the y-axis and the mean of the two machines on the x-axis.

CONCLUSIONS

Potential Mechanisms and Future Directions

Our novel combination of a 1080 Quantum dynamometer with a selectorized leg extension machine was intended to match the kicking motion and measurement achieved through traditional use of an expensive human dynamometer, such as the Cybex or the Biodex. However, the axes of rotation and associated lever arms/cams combined with these two devices introduce notable variability in the properties of the mechanical load experienced by the participant which explains some degree of consistent variation between devices, and potentially muscle loading and fatigue.

Future planned investigation includes the same protocol with a leg extension machine attached to the 1080 Quantum that possess a "snail" shaped cam, instead of the "egg-shaped" one that was presently used.

We demonstrated that there are imperfectly matched values between the Quantum and Cybex dynamometers; however, this was expected considering these two machines are constructed differently. Despite differences in the absolute power outputs, suggesting the machines should not be used interchangeably, the measures are highly repeatable with a good degree of accuracy, and findings indicate that the 1080 Quantum is sufficiently reliable on a test re-test basis. We conclude that the novel 1080 Quantum dynamometer has the potential to be utilized in future studies employing measures of human performance with a pre/post design.

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