Comparative Analysis of Low-Cost Alternatives for the Assessment of Muscle Strength

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BACKGROUND

Dynamometers are tools that can be used to measure the force properties of a muscle. The most frequently cited muscle properties measured include peak force and rate of force development. These tools are widely used by researchers in the medical and sports sciences (Weir 2009). Electromechanical Dynamometers (ED) are often considered the gold standard due to their ability to detect clinically relevant changes at a high sampling frequency and modifiability to test most muscles (Meyer et al., 2020) The utility of measuring the performance properties of muscles in clinical and sports settings cannot be understated. However, EDs generally have low portability, require large physical space, and are cost-prohibitive (~$50,000). These limitations of EDs have spurred the development of many novel hand-held (HHD) and tension dynamometers with small profiles and lower costs. The Dynamo from VALD ($1,000) and Progressor 150 from Tindeq ($150) are two recently released devices. These devices are available to clinicians and sports scientists but have not yet been tested in independent research settings for their psychometric properties (Merry et al., 2019).

Thus, our primary aim of this study was to investigate the validity of VALD and Tindeq's devices compared to an ED. The secondary aim was to explore the validity of various methods of extracting peak forces and rate of force development.

RESULTS

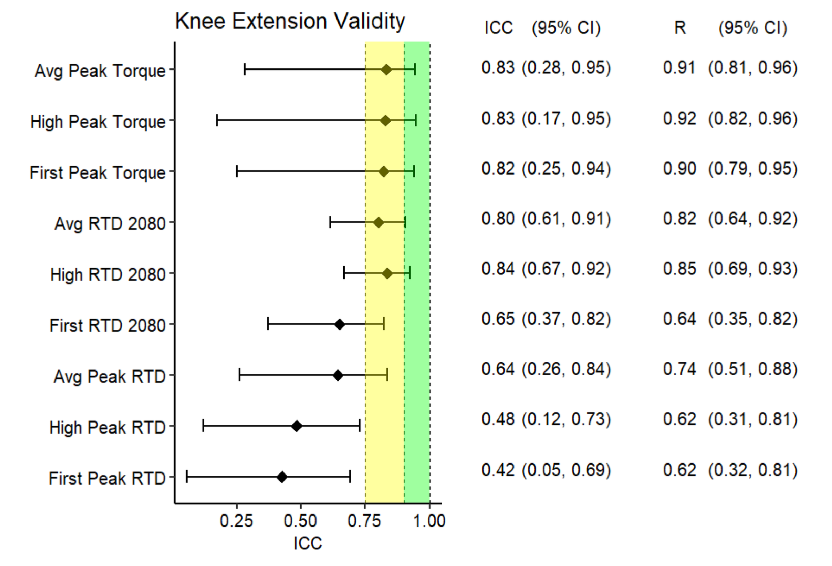


Fig 2. Tindeq Validity for Knee Extension. Comparisons of ICC (2,1) and correlations across method and muscle property. Similar peak torque correlations were found across method (ICC = .82-.83). Agreement among average and high RTD 20-80% had similar correlations (ICC=.80-.84).

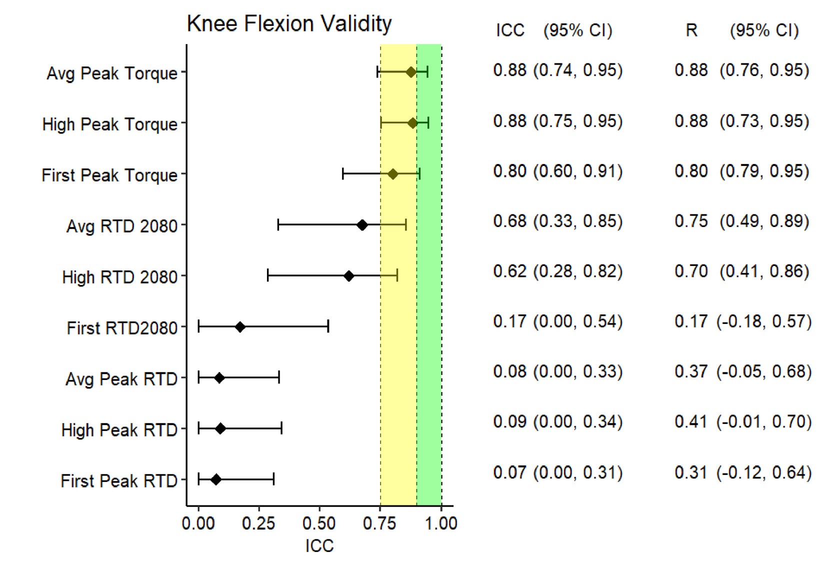


Fig 3. Tindeq Validity for Knee Flexion. Comparisons of ICC (2,1) and correlations across method and muscle property. Similar peak torque correlations were found across method (ICC = .80-.88). Agreement among RTD measures was consistently low (ICC=.07-.68).

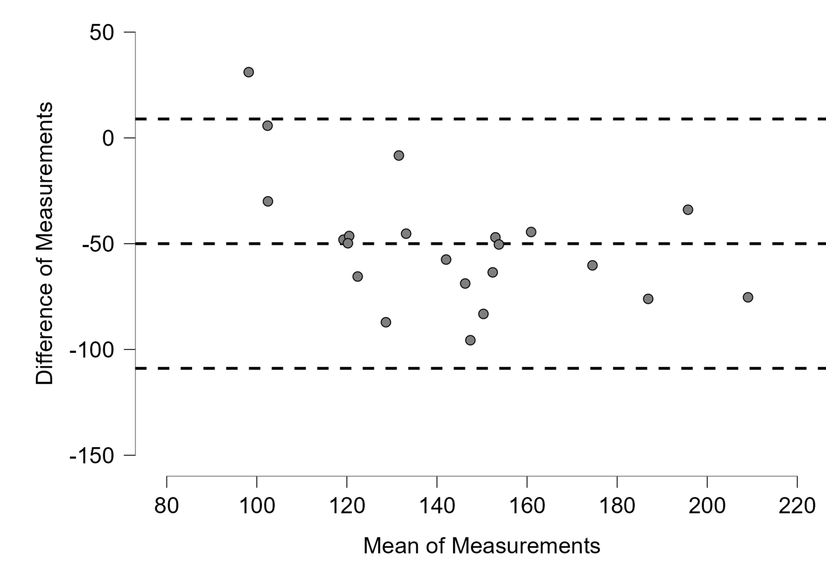


Fig 4. VALD Bland Altman Plot for Knee Extension Peak Torque. The average of differences (middle line) was -50 Nm indicating systematic bias, where VALD consistently underestimates HUMAC. The limits of agreement (top and bottom lines) were -110 Nm to 10 Nm. VALD's knee flexion ICC = 0.281.

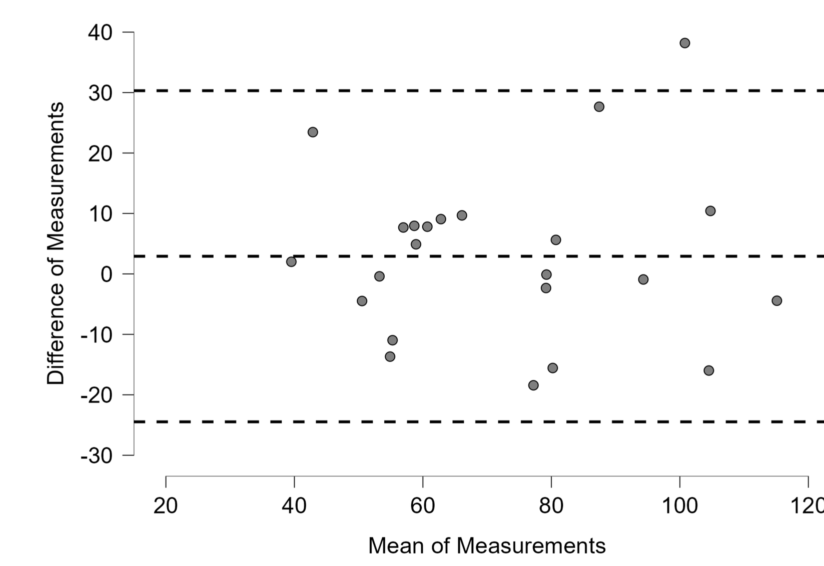


Fig 5. VALD Bland Altman Plot for Knee Flexion Peak Torque. The average of differences (middle line) was near zero indicating minimal bias. The limits of agreement (top and bottom lines) were -25 Nm to 30 Nm. VALD's knee flexion ICC = 0.81.

METHODS

Demographics

Individuals (N=30) between the ages of 19 and 36 who did not have a lower limb injury within the last six months from the date of testing, did not present with pain, and could perform the movements without discomfort.

- Participants: Male n=12 / Female n=18
- Mass: 76.81±18.73 kg
- Height: 171.66±7.91 cm
- Age: 23.10±3.97 years

Assessment of Knee Extensors and Flexors

Participants were seated in the HUMAC dynamometer at 90˚ of knee flexior with a torso, waist, and thigh strap used for stabilization

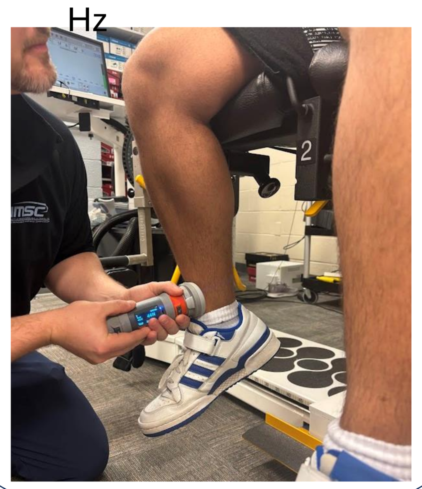
- 1-3 familiarization trials, 3 maximal effort trials
- Positioning and movements were standardized across devices

HUMAC NORM

CSMi
Sampling Rate: 2500 Hz

VALD

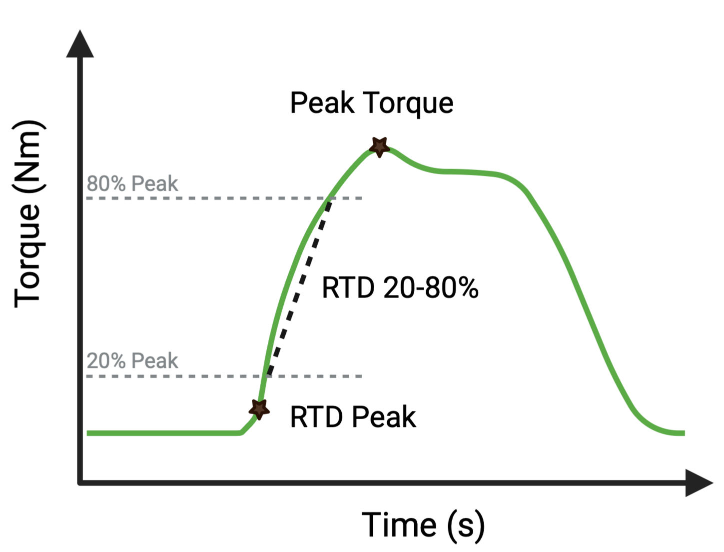
Dynamo
Sampling Rate: 225 Hz



TINDEQ

Progressor 150
Sampling Rate: 80 Hz

Fig 1. Extracted force properties of muscle. Torque (Nm) = Force x Lever Arm. RTD (Nm/s) = Force x Lever Arm per second.



Statistical Analysis

Validating Novel Devices against HUMAC Norm

- Intraclass Correlation Coefficients (ICC)
- Bland Altman Plots and limits of agreement

Interpretation of ICC described by Koo and Li (2015).

- Poor (ICC = 0.0 - 0.5)
- Moderate (ICC = 0.5 - 0.75)
- Good (ICC = 0.75 - 0.9)
- Excellent (ICC = 0.9 - 1.0)

Table 1. Descriptive Statistics for Knee Extension of the Dominant side

	Tindeq[a]		VALD[b]		Humac	
	Mean	SD	Mean	SD	Mean	SD
Average Peak Torque (Nm)	159.83	± 58.10	118.24	± 25.78	182.57	± 61.76
High Peak Torque (Nm)	165.92	± 58.96	-	-	190.61	± 62.16
First Peak Torque (Nm)	158.82	± 60.09	-	-	183.82	± 61.32
Average RFD 2080 (Nm/s)	566.80	± 280.85	-	-	626.17	± 325.23
High RTD 2080 (Nm/s)	698.62	± 379.23	-	-	744.43	± 352.05
First RTD 2080 (Nm/s)	574.72	± 319.35	-	-	608.11	± 332.45
Average Peak RTD (Nm/s)	1220.71	± 615.71	-	-	1548.96	± 832.91
High Peak RTD (Nm/s)	1449.54	± 724.93	-	-	1933.37	± 1193.37
First Peak RTD (Nm/s)	1207.71	± 620.93	-	-	1791.59	± 1247.76

Notes: Mean ± standard deviations among performance variables measured on Progressor 150 (Tindeq, Sweden) on two lab visits and on the HUMAC Norm (USA). Kilogram, kg; Newton-meter, Nm; Newton-meter per second, Nm/s; rate of torque development, RTD; Standard deviation, SD. [a] indicates sample size of 29 subjects. [b] indicates sample size of 22 subjects.

Table 2. Descriptive Statistics for Knee Flexion of the Dominant side

	Tindeq[a]		VALD[b]		Humac	
	Mean	SD	Mean	SD	Mean	SD
Average Peak Torque (Nm)	71.29	± 21.57	73.81	± 22.55	68.84	± 21.28
High Peak Torque (Nm)	75.32	± 22.75	-	-	72.83	± 22.62
First Peak Torque (Nm)	69.72	± 20.92	-	-	67.27	± 19.99
Average RFD 2080 (Nm/s)	368.67	± 220.74	-	-	451.16	± 276.92
High RTD 2080 (Nm/s)	509.29	± 353.77	-	-	632.89	± 478.45
First RTD 2080 (Nm/s)	355.49	± 264.66	-	-	365.90	± 217.09
Average Peak RTD (Nm/s)	694.37	± 373.11	-	-	2039.22	± 872.88
High Peak RTD (Nm/s)	826.93	± 443.11	-	-	2408.13	± 963.65
First Peak RTD (Nm/s)	71.29	± 21.57	-	-	68.84	± 21.28

Notes: Mean ± standard deviations among performance variables measured on Progressor 150 (Tindeq, Sweden) on two lab visits and on the HUMAC Norm (USA). Kilogram, kg; Newton-meter, Nm; Newton-meter per second, Nm/s; rate of torque development, RTD; Standard deviation, SD. [a] indicates sample size of 29 subjects. [b] indicates sample size of 22 subjects.

DISCUSSION

This study is the first to examine the psychometric properties of the Tindeq and VALD dynamometer. The Tindeq device demonstrated good validity in both knee extension and flexion in comparison with the HUMAC. Previous studies have concluded similar findings with knee extension (ICC=0.97, Norris et al., 2023). Additionally, we found that RTD computed from the 20-80% interval yielded consistently higher (ICC=.62-.84) validity than the instantaneous peak RTD method (ICC=.07-.64).

The VALD device showed good validity for knee flexion, however, knee extension demonstrated poor validity. Similarly, studies using HHDs have found lower validity in knee extension, this has been attributed to the difficulty with stabilizing the device against a high and rapid force output (Mentiplay et al., 2016). Furthermore, it is speculated that psychological bias could have affected knee extension results as participants may have limited their effort to prevent contact with the rater during trials.

There was no stabilization mechanism used in the HHD trials other than rater strength which may have influenced results if the rater could not provide a sufficient counterforce. In contrast, the Tindeq relied solely on the integrity of the chains affixed to the participant, minimizing external influences.

CONCLUSIONS

- The Tindeq device showed good agreement with the gold standard in both movements, while VALD only exhibited agreement with knee flexion.
- The average of three trials consistently outperformed the other methods for measuring muscle force properties.
- The results suggest that clinicians seeking the highest validity should take the average of three trials, otherwise first trial results may provide sufficient agreement.