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Are luggage scales a viable alternative to hand-held dynamometers for the measurement of shoulder scaption strength?

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Background: The accurate and reliable measurement of muscle strength is a valuable tool in most medical practices. The use of dynamometers allows for objective muscle strength assessment. Even so, dynamometry has its limitations due to increased cost and inconvenience in the clinic. Isokinetic dynamometers, the gold standard, are typically very large and expensive. However, smaller hand-held dynamometers are a cheaper and more efficient alternative. Hand-held dynamometers have been shown to demonstrate comparable reliability to the more expensive isokinetic dynamometers, despite their reduced cost and ease of use. Even though hand-held dynamometers are cheaper and more convenient to use in the clinical setting, their price tag is still burdensome for most medical practices, commonly costing $1000 or more. The aim of this study is to assess the reliability of luggage scales vs. dynamometers for measuring shoulder scaption strength.
Methods: One hand-held dynamometer was compared to two luggage scales using a set-up intended to mimic clinical testing. The set-up consisted of each device being tethered to the floor with the opposite end tied to a length of paracord that had been placed through a shoulder-height pulley and fastened to a flat plate used to hold the weight. In total, ten trials were completed, where a 2.3 kg (5 lb), 4.5 kg (10 lb), and 11.3 kg (25 lb). weight was measured by each device. Analysis of variance was used to compare the numerical data for the three groups.
Results: Our results indicate that there were no significant differences in the force measurements between each device ($P = .99$). The average force measurements between the three dynamometers were: 2.3 kg trial: 2.3 kg, 2.4 kg, and 2.2 kg; 4.5 kg trial: 4.5 kg, 4.6 kg, and 4.5 kg ; and 11.3 kg trial: 11.4 kg, 11.3 kg, and 11.4 kg. for the digital dynamometer, digital luggage scale, and the analog luggage scale, respectively. Subgroup analysis showed there was also no difference in force measurements between the 3 devices for the 2.3 kg, 4.5 kg, and 11.3 kg. trials ($P = .14$, $P = .49$, and $P = .40$, respectively).
Conclusion: Our data demonstrates that two inexpensive luggage scales showed no statistically significant differences in measurements compared to an expensive hand-held dynamometer. Utilization of luggage scales to measure shoulder scaption strength should yield similar results to handheld dynamometers. This may be an alternative, objective measure of manual muscle strength that is both efficient and economical.

The accurate and reliable measurement of muscle strength is an important tool in most medical practices. Typically, manual muscle testing (MMT) is the preferred method of muscle strength assessment in the clinical setting due to its simplicity; however, this form of strength assessment is highly variable due to its subjective nature.[4,8]

The use of measurement devices such as dynamometers provides a way of performing muscle strength assessment that is more objective than traditional methods.[4,8,13,20] Even so, dynamometry has its limitations due to increased cost and inconvenience in the clinic.

Traditionally, the gold standard measurement of muscle strength involved large machines, such as isokinetic dynamometers, which are expensive and immobile, making them unrealistic

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for use in the common clinical setting. Although these machines are largely impractical, they are considered the gold standard for muscle strength assessment, consistently providing accurate and reliable results.[13,20]

Alternatively, smaller hand-held dynamometers are usually cheaper and more efficient for clinicians.[1,3] Hand-held dynamometers have demonstrated comparable reliability to isokinetic dynamometers despite their reduced cost and ease of use.[3,20,18]

Even though hand-held dynamometers are cheaper and more convenient to use in a clinical setting, the devices can still be very costly to most medical practices, commonly costing $1000 or more.

The aim of this study is to assess the accuracy and reliability of luggage scales as an alternative to handheld dynamometers. These devices are readily available and less expensive than handheld dynamometers.

Methods

One handheld digital dynamometer was compared to a digital luggage scale (Digital LS) and an analog luggage scale (Analog LS). The digital dynamometer used was the dynamometer HFG-45 Hand-Held Force Gauge by Transducer Techniques, the Digital LS was the Horizon Digital Travel Luggage Hanging Scale with Strap, and the Analog LS was the the Samsonite Manual Luggage Scale (Samsonite, Luxembourg City, Luxembourg) (see Fig. 1 A-C). Both the dynamometer and Digital LS have a grayscale liquid crystal display screen, while the Analog LS has a dial that displays the measurements.

During measurements, a stabilization device (Fig. 2) was anchored to the floor by a 11.3 kg weight to provide a source of resistance when taking measurements with each dynamometer. The device was constructed of a BlueHawk (BlueHawk, Gilbert, AZ, USA) utility hanger securely attached to a 6 × 51 mm interlocking spring snap (carabiner) by a length of heavy-duty cord rope. The device was 101.6 cm (40 in) in length from the floor to the tip of the carabiner, and this length was consistent throughout the experiment. Each device was clipped to a carabiner tied to a separate length of paracord rope that had been placed on a pulley connected to an intravenous stand (Fig. 3). A flat plate was tethered to the end of this piece of paracord so that variable weight could easily be taken on and off between each use. This set-up is intended to mimic the use of these devices for measuring the strength of shoulder scaption.

In total, ten trials were completed, where a 2.3 kg (5 lb), 4.5 kg (10 lb), and 11.3 kg (25 lb). weight was measured by each device. The 11.3 kg (25 lb). weight was chosen as this is the weight used for the constant shoulder score.[25] The smaller weights were chosen to test accuracy at lower forces, which may be the case after shoulder injury. A random order sequence was generated by a random number generator and assigned to each trial for testing each device numbered 1 through 3 (eg, 5 lb. Trial 1: 1, 3, 2; Trial 2: 3, 1, 2; etc.)

Data from all measurements were collected into Microsoft Excel. Analysis of variance was used to compare the numerical data for the three groups.

Results

Our results indicate that there were no statistically significant differences in the force measurements between each device ($P = .990$). The average force measurements (Table I) between the three devices were: 2.3 kg (5 lb trial) : 2.3 kg, 2.4 kg, and 2.2 kg; 4.5 kg (10 lb trial) : 4.5 kg, 4.6 kg, and 4.5 kg ; and 11.3 kg (25 lb trial) : 11.4 kg, 11.3 kg, and 11.4 kg. for the dynamometer, digital LS, and analog LS groups, respectively. Subgroup analysis showed there was also no difference in force measurements between the 3 devices for the 2.3 kg, 4.5 kg, and 11.3 kg. trials ($P = .14$, $P = .49$, and $P = .40$, respectively, see Fig. 4).

Discussion

Over 40 million people in the US alone are plagued by musculoskeletal problems, which account for 10%-15% of all primary care clinic visits.[10,11] Each one of these visits consists of some form of muscle strength assessment. There are many ways in which a

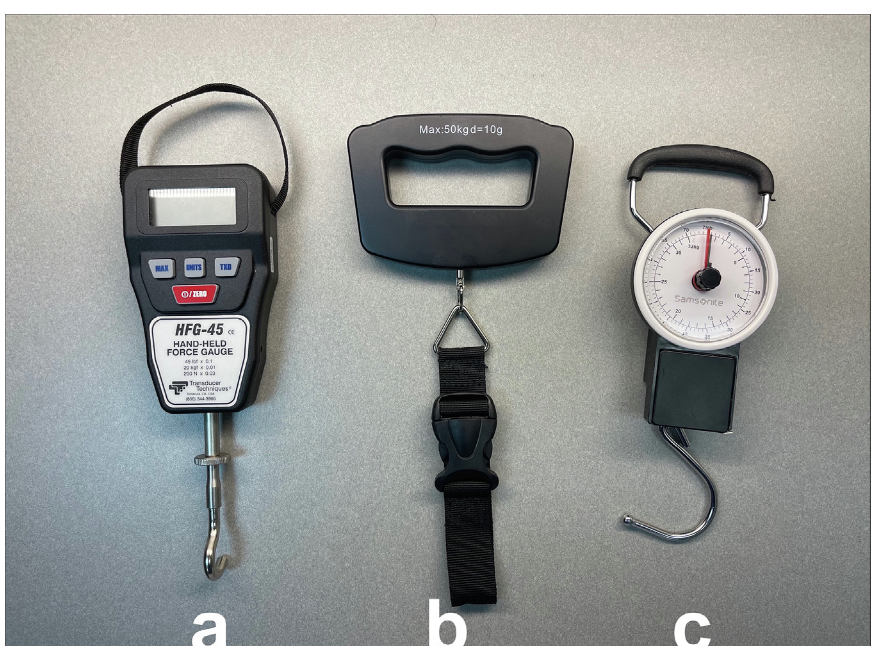

Figure 1 (A) Digital dynamometer HFG-45 Hand-Held Force Gauge by Transducer Techniques. (B) Horizon Digital Travel Luggage Hanging Scale with Strap. (C) Samsonite Manual Luggage Scale.

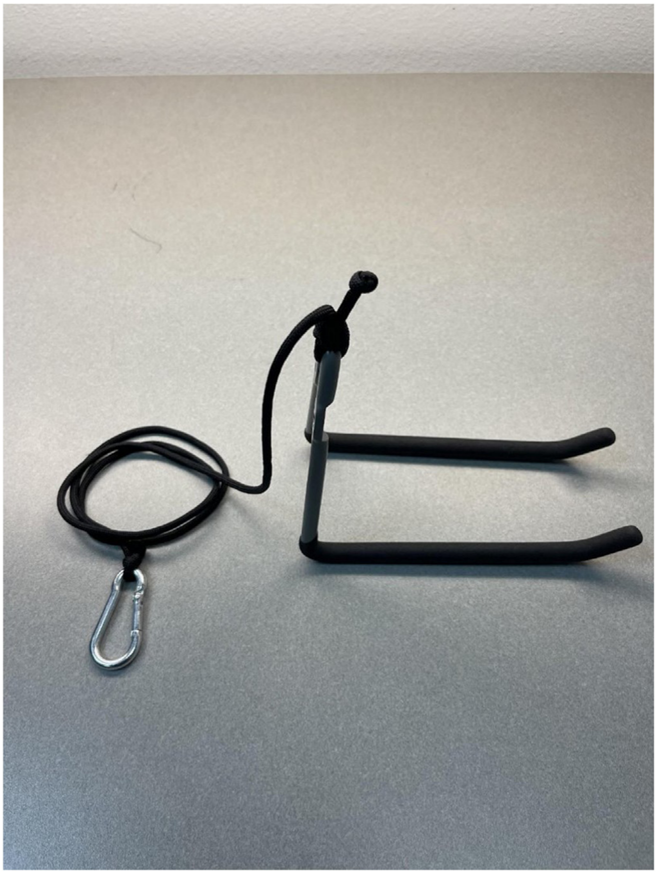

Figure 2 Portable stabilization device constructed with BlueHawk utility hanger, paracord rope, and a 6 × 51 mm carabiner.

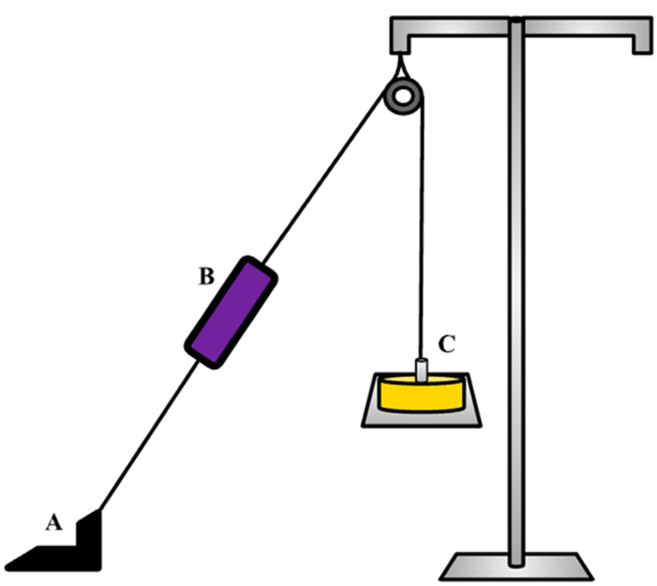

Figure 3 Trial set-up with labels for essential equipment. *(A)* Floor anchor; *(B)* Force measurement device; *(C)* Weight.

physician can carry out said assessment, and this study demonstrates that one way to obtain an objective measure of strength is via inexpensive improvisatory dynamometers consisting of an anchor, paracord, and a luggage scale, all for under $50. Both devices

Table I
Average and standard deviations calculated using data gathered during ten trials of testing each force measurement device using 2.3 kg, 4.5 kg, and 11.3 kg weights.

	Dynamometer	Digital LS	Analog LS
2.3 kg trial	2.3 ± 0.1	2.4 ± 0.2	2.2 ± 0.1
4.5 kg trial	4.5 ± 0.1	4.6 ± 0.2	4.5 ± 0.1
11.3 kg trial	11.4 ± 0.2	11.3 ± 0.3	11.4 ± 0.2

LS, luggage scale.
Dynamometer = Dynamometer HFG, 45 Hand-Held Force Gauge by Transducer Techniques, Digital LS, Horizon Digital Travel Luggage Hanging Scale with Strap, Analog LS, Samsonite Manual Luggage Scale.

tested were able to consistently measure the force applied within 0.3 kg of the actual weight with a standard deviation of less than 0.3 kg over the ten trials. This level of precision is more than adequate for the objective assessment and tracking of muscle strength. Luggage scales may be a viable alternative to hand-held dynamometers on the market for objective muscle strength assessment.

MMT was first described by Dr. Robert Lovett in 1912 while studying infantile paralysis.[15,22] It was then adapted to the commonly used 0-5 scale in 1943 by the Medical Research Council, where 0 indicates no muscle contraction, 1 indicates a flicker or trace contraction, 2 indicates active movement with gravity eliminated, 3 indicates active movement against gravity, 4 indicates active movement against gravity with manual resistance, and 5 indicates normal strength.[7] This ordinal grading scale for MMT is widely used in the clinical setting because of its ease and efficiency. It requires no equipment and demonstrates high intraobserver reliability.[2,22]

Although swift and straightforward, MMT suffers from many well-described shortcomings. While the low end of the scale, 0 through 3, is much more specific because the ordinances are less subjective and have a built-in control, gravity, it begins to lack utility at the higher levels. This dissolution of value is due to the fact that at the upper levels of the scale, there is a large variation in strength among the human population. Studies have shown that trained examiners are unable to identify up to a 50% loss in strength when compared to age-matched norms and are unable to distinguish a difference in muscle strength of up to 25% between a single patient's strong and weak sides.[11] Moreover, when using the medical research council scale, the examiners are using their own acumen to discern normative values and make subjective assessments on the strengths of individuals based on their age, sex, and body habitus. This is a dynamic process that requires skill and repetition, and even when done with the utmost care still results in crude measurements that make it difficult to track subtle changes in strength between clinic visits.[1]

The gold standard for strength assessment instrument testing is an isokinetic dynamometer. The first one, Cybex I (Humac Norm, Stoughton, MA, USA) was developed in the 1960s and was unique because it was the first commercially available machine that could measure the forces produced by muscles during dynamic movement.[17] Cybex, as well as many other brands including Biodex (IPRS Mediquipe Limited, Little Blakenham, England) are still innovating and producing units today that generate torque curves for a variety of movements, giving very specific and reliable data on muscle strength; however, these machines have their own limitations. Additionally, they are cumbersome stationary units that often take up an entire room and require training to use properly. For these reasons, the isokinetic dynamometer is infrequently used at the community level and is often only accessible at the most well-funded medical, training, and rehabilitation centers.[17]

Far more common than isokinetic dynamometers are smaller and less expensive hand-held dynamometers. First used at the tail

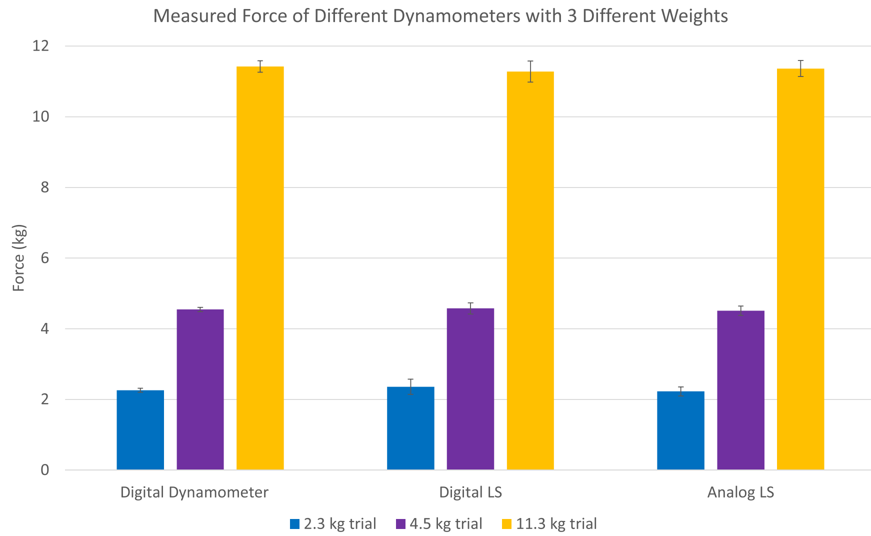

Figure 4 Average and standard deviations (error bars) calculated using data gathered during ten trials of testing each force measurement device using 2.3 kg (5 lb), 4.5 kg (10 lb), and 11.3 kg (25 lb) weights. Digital Dynamometer = HFG-45 Hand-Held Force Gauge by Transducer Techniques, Digital LS = Horizon Digital Travel Luggage Hanging Scale with Strap, Analog LS = Samsonite Manual Luggage Scale. *LS*, luggage scale.

end of the 19th century, these devices have been redesigned countless times to get to the current iterations.[14] Throughout the 1990s, they were extensively studied to determine their intra- and inter-rater reliability and precision compared to both the isokinetic dynamometers as well as traditional MMT. Hand-held dynamometers have some inherent weaknesses, two of which include the fact that the upper end of the measurements obtained are limited by the strength of the examiner and the challenging nature of ensuring proper stabilization and positioning of the patient during the muscle tests to ensure the force sensor is perpendicular to the plane of the force being exerted.[3,12,19,24] Despite these weaknesses, the majority of studies indicate that hand-held dynamometers have high rates of reliability. A study by Leggin et al published in 1996 compared the use of two hand-held dynamometers with the isokinetic dynamometer. They found that both the Nicholas MMT (Fabrication Enterprises Inc., Elmsford, NY, USA) (~$1000) and Isobex 2.0 (Cursor, Bern, Switzerland) (~$2000) had high reliability comparable to the Biodex isokinetic dynamometer (~$50,000). A study by Hayes et al in 2002 demonstrated that interrater reliability was excellent among 4 raters using a PowerTrack MMT (JTech Commander, Norfolk, VA, USA) hand-held dynamometer (~$1000) when measuring shoulder elevation, external and internal rotation, and liftoff (intraclass correlation coefficient [ICC] 0.79-0.92) and found that MMT was much less reliable for the same movements (ICC 0.38-0.72).[8] Beshay et al had similar results in 2011 while using an HFG-110 hand-held dynamometer (~$750) to measure intrarater and interrater reliability with shoulder internal and external rotation, abduction, liftoff, and adduction in both symptomatic and asymptomatic patients (intrarater ICC 0.94-0.95; interrater ICC 0.89-0.93).[3] Other similar studies found hand-held dynamometers had good to high reliability in measuring strength in these same muscle groups as well as when used to assess strength associated with wrist extension, hip flexion, elbow extension and flexion, knee extension and flexion, and ankle dorsiflexion.[3-5,8,9,16,20-23] Based on these study results, hand dynamometers may be a reliable and more practical means to obtain an objective strength assessment at a routine clinic visit over the more cumbersome and costly isokinetic dynamometers. Unfortunately, even though these smaller devices can be used with minimal training and are highly portable, they are not economical. These devices often cost over $1000, which is far too extortionate for many clinics, especially those in underserved areas that do not have the funding for a beneficial but costly nonessential piece of equipment.

This issue is not a novel one, as physicians and researchers continue to look for more cost-effective options to improve health care. As recently as 2018, Dr. Philippe Collin published a pilot study using a floor weight scale as an inexpensive alternative to objectively measure shoulder scaption strength.[6] Our study demonstrates that affordable luggage scales have similar accuracy, precision, and reliability when compared to hand-held dynamometers at a fraction of the cost.

Conclusion

Our data demonstrates that two inexpensive luggage scales showed no statistically significant differences in measurements compared to an expensive hand-held dynamometer. Utilization of luggage scales to measure shoulder scaption strength should yield similar results to handheld dynamometers. This may be an alternative, objective measure of manual muscle strength that is both efficient and economical.

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