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Comparison of maximal voluntary isometric contraction and hand-held dynamometry in measuring muscle strength of patients with progressive lower motor neuron syndrome

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Abstract

Context. Maximal voluntary isometric contraction, a method quantitatively assessing muscle strength, has proven to be reliable, accurate and sensitive in amyotrophic lateral sclerosis. Hand-held dynamometry is less expensive and more quickly applicable than maximal voluntary isometric contraction. **Objective.** To investigate if hand-held dynamometry is as reliable and valid as maximal voluntary isometric contraction in measuring muscle strength in patients with an adult-onset, non-hereditary progressive lower motor neuron syndrome. **Design.** Two testers performed maximal voluntary isometric contraction and hand-held dynamometry measurements in six muscle groups bilaterally in patients with progressive lower motor neuron syndrome to assess reliability and validity of both the methods. **Setting.** Outpatient units of an academic medical center. **Patients.** A consecutive sample of 19 patients with non-hereditary progressive lower motor neuron syndrome (median disease duration 32.5 months, range 10–84) was tested. **Outcome measures.** Comparison between maximal voluntary strength contractions as measured by hand-held dynamometry and maximal voluntary isometric contraction. **Results.** Low intra- and interrater variation in all muscle groups were found, intraclass correlation coefficients vary between 0.86 and 0.99 for both methods. Both methods correlated well in all muscle groups with Pearson's correlation coefficients ranged between 0.78 and 0.98. Scatter plots indicated a trend to under-estimate muscle strength above 250 N by hand-held dynamometry as compared with maximal voluntary isometric contraction. **Conclusions.** For longitudinal evaluation of muscle strength in patients with progressive lower motor neuron syndrome (i.e. between 0 and 250 N), muscle strength can be accurately quantified with both hand-held dynamometry and maximal voluntary isometric contraction. Hand-held dynamometry has the advantage of being cheap and quickly applicable. However, our results indicate that hand-held dynamometry is less sensitive than maximal voluntary isometric contraction in detecting subnormal muscle strength in strong muscle groups (i.e. > 250 N), due to limited strength of the tester.

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Keywords: Progressive lower motor neuron syndrome; Dynamometry; Maximal voluntary isometric contraction; Muscle strength

1. Introduction

Quantitative muscle strength testing is used as a measure for monitoring disease progression or response to therapeutic interventions in various neuromuscular disorders as facioscapulohumeral dystrophy, peripheral

neuropathies, postpolio syndrome and amyotrophic lateral sclerosis (ALS) [1–9]. The usefulness of maximal voluntary isometric contraction (MVIC), a method quantitatively assessing muscle strength, was investigated in ALS. This technique has proven to be reliable, accurate and sensitive [3,7,9,10].

Therefore, the Research Group on Neuromuscular disease (NMD) of the World Federation of Neurology (WFN) selected MVIC as the 'gold standard' for assessment

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of muscle strength in treatment trials for MND (motor neuron disease) [11]. However, this instrument is expensive, not transportable and making measurements with it is time consuming. Therefore, this technique is less suitable for application in severely disabled patients. Hand-held dynamometry (HH-Dyn) overcomes a number of these difficulties by being cheap, portable and thus quickly applicable [12]. Many studies have shown that quantifying muscle strength with a hand-held dynamometer can be done reliably [4,12–16]. This raises the question whether HH-Dyn is as reliable and valid as MVIC in measuring muscle strength. Recently, a comparative study to MVIC and HH-Dyn in ALS patients was published, which showed that HH-Dyn provides a strength estimate with a precision close to MVIC in weak muscle groups [17]. The present study was undertaken to confirm the results of this study by comparing MVIC and HH-Dyn, but with a different type of hand-held dynamometer and in a different patient population, namely patients with a progressive disease restricted to the lower motor neuron (LMN), i.e. adult-onset, non-hereditary progressive spinal muscular atrophy (PSMA). As the nomenclature of this entity is still a matter of some debate, we will use the term ‘progressive LMN syndrome’ from now on.

2. Patients and methods

2.1. Patients

Nineteen patients (11 men, 8 women), varying in age from 37 to 71 years (median 57 yrs), were included in this study. They were all diagnosed with progressive LMN syndrome. Patients had a median disease duration of 32.5 months (range 10–84 months) from the time of onset of weakness.

Inclusion criteria were: (1) evidence of progressive LMN involvement on neurological examination (weakness, atrophy and fasciculations) in one or more regions (brainstem, cervical, thoracic and lumbosacral) according to the [1994] El Escorial criteria, and (2) electrophysiological evidence of LMN involvement in clinically affected or non-affected regions without evidence of conduction block, as previously described [18]. *Exclusion criteria* were: (3) sensory signs on neurological examination, (4) history of diseases that may mimic motor neuron disease (i.e. radiculopathy, acute poliomyelitis, diabetic amyotrophy), (5) family history of inherited adult spinal muscular atrophy or Kennedy’s disease, (6) definite signs of central motor neuron involvement (Babinski signs, pseudobulbar signs, and (sub)clonic reflexes) and (7) structural lesions (tumors, intervertebral disk herniation, vascular lesions, syringomyelia) on either myelography with CT tomography or magnetic resonance imaging (MRI) of the spinal cord/cranio-cervical junction.

2.2. Clinical evaluators

Two testers (JV—resident Neurology and EM—technician Clinical Neurophysiology) independently performed MVIC and HH-Dyn measurements in this study. Prior to the onset of the study the first tester (JV) was trained by a neurologist specialized in HH-Dyn and had 1 year experience with the dynamometer. She, in turn, trained the other tester, and both practiced on patients and healthy individuals before the study started. Both testers trained for 6 months with MVIC, prior to the start of the study. Instructions for MVIC were given by an experienced researcher.

2.3. Instruments and measurement techniques

2.3.1. Maximal voluntary isometric contraction

For MVIC the quantitative muscle assessment (QMA) system (version 1.32) was used. This system consists of an adjustable strap, attaching the limb to a force transducer (interface SM250 force transducer). Patients were tested on an adjustable examining table (Neurological Plinth Model 40), enclosed in a stable aluminum frame, which anchors the transducer. The generated force is transmitted to a strain gauge system, and is then recorded and amplified by the computer-assisted analog/digital data collection system (S/N A98C36). The measured force is expressed as the amount of kilograms (kg) that the patient exerts against the strain gauge.

Measurements were performed in a standardized manner in accordance with the testing protocol of Andres et al. [7]. The following muscle groups were tested in a fixed order: right shoulder abductors, right elbow flexors, right elbow extensors, left shoulder abductors, left elbow flexors, left elbow extensors, right ankle dorsiflexors, left ankle dorsiflexors, right knee flexors, left knee flexors, left knee extensors, right knee extensors. The elbow flexors and elbow extensors were tested in both neutral and supinated position.

All muscle groups were tested twice within 10–15 s. The patients were informed about the test purpose and procedure before the start of the study and verbal encouragement was given during the tests.

2.3.2. Hand-held dynamometry

HH-Dyn was performed by using a CITEC hand-held dynamometer, C.I.T. Technics BV, Groningen, The Netherlands. This is an electronic dynamometer equipped with a resetting button and a curved applicator. The weight is approximately 250 g. Force is measured in Newtons (N) and the measuring range is 0–500 N. Tests were carried out with the ‘break’ technique, in which the tester slowly overcomes the strength of the patient and stops at the moment the patient gives way. Positions of patient and instrument were standardized as described by van der Ploeg et al. [12]. Testing positions for some muscle groups (shoulder

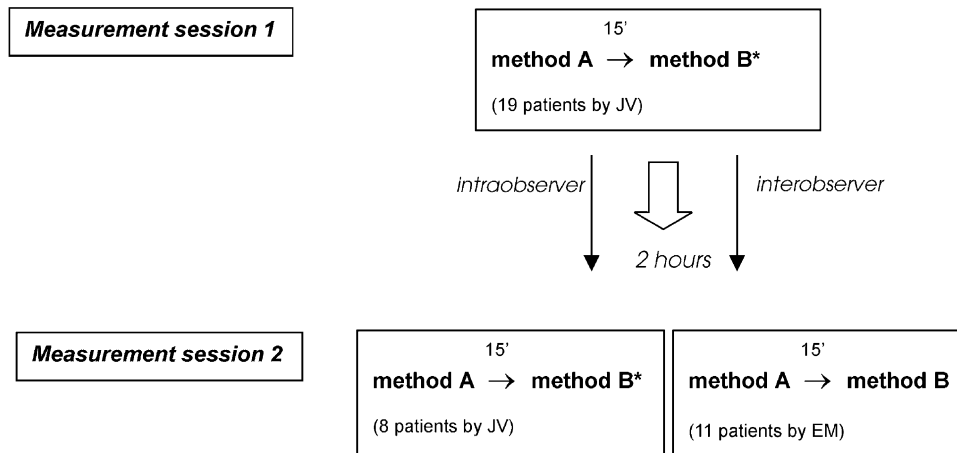


Fig. 1. Study design. Measurement session 1: method A/B: either MVIC or HH-Dyn. Measurement session 2: *Denotes randomization of the sequence of the method was randomized before start of the study.

abductors, knee flexors/extensors) were adjusted to the testing positions for MVIC in order to optimize comparison between both methods. The sequence of testing and number of repetitions is the same as described under MVIC.

Both devices were calibrated at the start and once every 2 weeks during the study.

2.4. Study design

In the first measurement session all muscle groups in 19 patients were tested by JV with both methods as described above, with a 15 min break in between. The sequence of the method (either first MVIC or HH-Dyn) was randomized before the start of the study (Fig. 1).

A second measurement session was planned for all patients after a 2 h break. Eight out of 19 patients were tested by the same tester as in the first measurement session (JV) in order to assess intrarater variation of both methods. Again, after randomization of the method. The other 11 patients were tested by the second tester (EM), in order to assess interrater variation. In the latter situation randomization of the sequence of the methods was omitted, because there is no recollection effect.

We choose for an approximate 2 h interval between both sessions to seek for a balance between a short interval which is necessary to minimize biological variation, and a long interval which is needed to minimize recollection. This last phenomenon was also minimized by randomizing the sequence of testing and the large number of muscle groups that was investigated.

2.5. Statistical analysis

2.5.1. Reliability of MVIC and HH-Dyn

To assess the reliability of the MVIC and HH-Dyn measurements, we used the intraclass correlation coefficient

(ICC) and its 95% confidence interval (CI). The ICCs were calculated by comparing the highest measurements of corresponding muscle groups between the first and second measurement session (a) carried out by the same evaluator (JV; intrarater variation) and (b) carried out by both evaluators (JV and EM; interrater variation).

2.5.2. Validity: comparison between MVIC and HH-Dyn

To compare the measurements of both methods, Pearson's product moment correlation coefficient (PMCC) was used. PMCCs were calculated by comparing the highest measurements results for each muscle group between both methods as assessed in the first measurement session.

Additionally, we constructed Bland–Altman plots of MVIC measurements against the difference scores between the two measurement methods (MVIC and HH-Dyn), to check for a systematic error between both methods [19]. For calculation of the difference scores we multiplied MVIC values given in kilograms (kg) with a factor 9.81 to convert them to Newtons (N). For each method we used the highest measurement results for each muscle group as assessed in the first measurement session. Separate scatter plots were performed for different strength ranges: for all MVIC values (Group A), for MVIC measurements ≤ 250 N (Group B) and for MVIC measurements > 250 N (Group C). We were interested in strength ranges below and beyond 250 N because for the average examiner, HH-Dyn measurements above 250 N are too high to be performed carefully [20]. Perfect correspondence between both methods would be represented by a horizontal line through an ordinate of zero. The difference scores as a function of MVIC value were also expressed in standardized regression coefficients and linear regression lines. All analyses were done with SPSS/PC + Statistics 10.0.7 (SPSS Inc, Illinois, USA).

Table 1

Intraclass correlation coefficients (95% CI) for intra- and interrater reliability of MVIC and HH-Dyn measured in a group of 19 patients with progressive LMN syndrome

Muscle group	Intrarater ICCs (n = 8)		Interrater ICCs (n = 11)	
	Right	Left	Right	Left
<i>Shoulder abduction</i>				
MVIC	0.99 (0.98–0.99)	0.99 (0.95–0.99)	0.91 (0.63–0.98)	0.86 (0.36–0.96)
Dynamometry	0.98 (0.93–0.99)	0.97 (0.85–0.99)	0.91 (0.61–0.97)	0.86 (0.43–0.96)
<i>Elbow flexion</i>				
MVIC	0.99 (0.96–0.99)	0.99 (0.96–0.99)	0.95 (0.81–0.98)	0.98 (0.95–0.99)
Dynamometry	0.98 (0.92–0.99)	0.99 (0.96–0.99)	0.99 (0.96–0.99)	0.97 (0.92–0.99)
<i>Elbow flexion (supination)</i>				
MVIC	0.99 (0.42–0.99)	0.99 (0.91–0.99)	0.98 (0.93–0.99)	0.92 (0.68–0.98)
Dynamometry	0.98 (0.91–0.99)	0.98 (0.92–0.99)	0.94 (0.74–0.98)	0.90 (0.61–0.97)
<i>Elbow extension</i>				
MVIC	0.98 (0.84–0.99)	0.99 (0.98–0.99)	0.99 (0.91–0.99)	0.99 (0.97–0.99)
Dynamometry	0.98 (0.92–0.99)	0.99 (0.97–0.99)	0.97 (0.78–0.99)	0.97 (0.70–0.99)
<i>Elbow extension (supination)</i>				
MVIC	0.98 (0.93–0.99)	0.99 (0.96–0.99)	0.96 (0.84–0.99)	0.98 (0.82–0.99)
Dynamometry	0.92 (0.43–0.98)	0.99 (0.95–0.99)	0.96 (0.80–0.99)	0.97 (0.26–0.99)
<i>Ankle dorsiflexion</i>				
MVIC	0.96 (0.79–0.99)	0.86 (0.05–0.98)	0.96 (0.73–0.99)	0.89 (0.45–0.98)
Dynamometry	0.96 (0.67–0.99)	0.97 (0.83–0.99)	0.90 (0.35–0.98)	0.88 (0.12–0.98)
<i>Knee flexion</i>				
MVIC	0.97 (0.84–0.99)	0.91 (0.53–0.98)	0.95 (0.83–0.98)	0.97 (0.91–0.99)
Dynamometry	0.98 (0.95–0.99)	0.99 (0.95–0.99)	0.97 (0.91–0.99)	0.94 (0.66–0.98)
<i>Knee extension</i>				
MVIC	0.99 (0.96–0.99)	0.99 (0.97–0.99)	0.97 (0.90–0.99)	0.99 (0.99–0.99)
Dynamometry	0.97 (0.86–0.99)	0.99 (0.95–0.99)	0.94 (0.64–0.98)	0.98 (0.83–0.99)

Correlation coefficients were calculated by comparing the highest measurements of corresponding muscle groups between the first and second measurement session carried out by the same assessor (intrarater variation) or by both assessors (interrater variation).

3. Results

3.1. Reliability of MVIC and HH-Dyn

Intra- and interrater variability for both methods are presented in Table 1. The table shows high ICCs for intrarater variability, ranging from 0.86 to 0.99 for MVIC

and from 0.92 to 0.99 for HH-Dyn. The ICCs for interrater variability were also high, ranging from 0.86 to 0.99 for both MVIC and HH-Dyn.

3.2. Validity: comparison between MVIC and HH-Dyn

PMCCs between both methods were high for all tested muscle groups, and ranged between 0.78 and 0.98 (Table 2).

Table 2

Strength range and PMCC of MVIC versus HH-Dyn in 19 patients with progressive lower motor neuron syndrome

Muscle group	Strength range ^a				PMCC	
	MVIC		Dynamometry		Right	Left
	Right	Left	Right	Left		
Shoulder abduction	27–217 (2.8–22.1)	3–187 (2.6–19.1)	31–240 (3.2–22.5)	53–207 (5.4–21.1)	0.92	0.82
Elbow flexion	11–319 (1.1–32.5)	13–312 (1.3–31.8)	27–303 (2.8–30.9)	15–310 (1.5–31.6)	0.96	0.94
Elbow flexion (supinated)	52–294 (5.3–30.0)	43–290 (4.4–29.6)	78–278 (7.9–28.3)	45–288 (4.6–29.4)	0.90	0.96
Elbow extension	18–182 (1.8–18.5)	16–193 (1.6–19.7)	26–205 (2.7–20.9)	20–225 (2.0–22.9)	0.96	0.98
Elbow extension (supinated)	36–163 (3.7–16.6)	30–181 (3.1–18.4)	44–191 (4.5–19.5)	30–212 (3.1–21.6)	0.92	0.97
Ankle dorsiflexion	29–283 (3.0–28.8)	22–266 (2.2–27.1)	67–307 (6.8–31.3)	64–260 (6.5–26.5)	0.88	0.78
Knee flexion	23–262 (2.3–26.7)	14–251 (1.4–25.6)	34–295 (3.5–30.1)	16–271 (1.6–27.6)	0.83	0.83
Knee extension	25–503 (2.5–51.3)	26–530 (2.6–54)	50–348 (5.1–35.5)	25–364 (2.5–37.1)	0.91	0.91

Correlation coefficients were calculated by comparing the highest measurements for each muscle group between both methods as assessed in the first measurement session.

^a Strength range results are expressed in Newtons and kilograms as well in brackets.

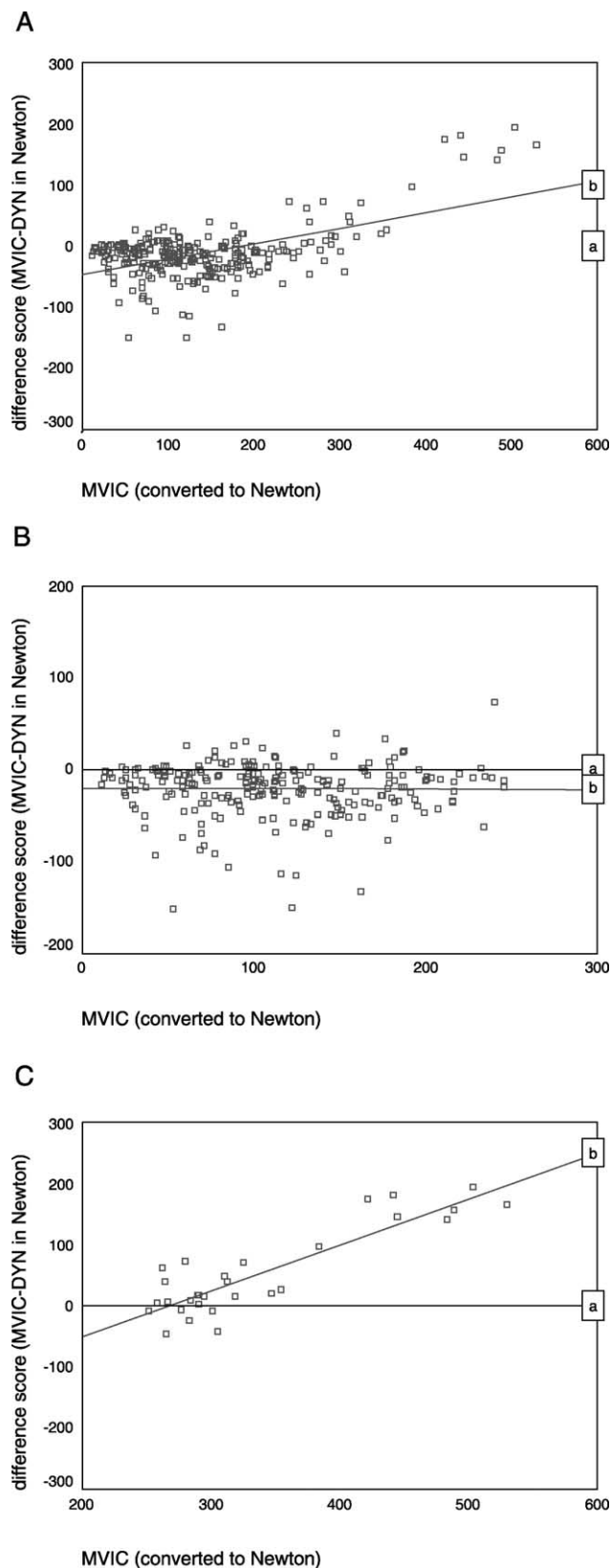


Fig. 2. Bland–Altman plots: difference scores between MVIC and HH-Dyn in relation to MVIC values. 1: A = full range of MVIC measurement; B = MVIC measurements ≤ 250 N; C = MVIC measurements > 250 N. 2: (a) zero line and (b) the fitted regression line.

In order to compare our work to other work published with hand-held dynamometry we express the strength results in both Newton and kilograms (Table 2).

Standardized regression coefficients (β) for group A ($n = 265$ paired measurements), group B ($n = 235$ paired measurements) and group C ($n = 30$ paired measurements) were $\beta = 0.55$ ($p < 0.001$), $\beta = -0.007$ ($p = 0.92$) and $\beta = 0.88$ ($p < 0.001$), respectively (Fig. 2).

4. Discussion

We evaluated two methods for quantitative strength measurement, MVIC and HH-Dyn, under strictly standardized test procedures, in 19 patients with progressive LMN syndrome. Although several authors have reported on testing reliability and accuracy of both methods [4,12–15,21,22], comparison is cumbersome because previous studies vary as regards to test populations, type of device, measurement technique ('break' or 'make') and statistical approach. Moreover, only few studies dealt with a direct comparison of these techniques [17,23].

To our knowledge, we are the first to compare directly HH-Dyn to MVIC in patients with progressive LMN syndrome. This disease is characterized by degeneration of purely LMNs and with different subgroups regarding distribution of weakness and progression rate [24]. As in ALS, patients with progressive LMN syndrome may suffer from rapidly progressive muscle weakness. Much effort is put in designing and conducting trials in ALS with various compounds that may have a beneficial effect on the relentlessly progressive course [25–28]. So far, PSMA has been excluded from these trials, but there is no compelling reason to do so, since involvement of the LMN mainly determines the outcome of ALS. Therefore, we decided to confine ourselves to this disease entity.

Intra- and interrater variability for HH-Dyn as well as for MVIC were excellent in our patient group. There have been several intra- and interobserver studies performed for HH-Dyn [4–6,12–15,21,29]. Most of these support the conclusion that consistent ratings can be obtained. For MVIC, the intra- and interobserver variability were comparable to the established reliability in previous studies [3,7,10].

The data obtained by MVIC and HH-Dyn correlate very well for all tested muscle groups. In another study, comparing HH-Dyn and MVIC for muscle strength assessment in 21 patients with various neuromuscular diseases (e.g. ALS, myositis, FSHD, spinal muscular atrophy) comparable PMCCs (between 0.76 and 0.90) were found [23]. Except for knee extension, they tested the same muscles, but eliminated muscle groups producing forces higher than 147 N. Moreover, a different kind of hand-held dynamometer (Microfet) was used and HH-Dyn

tests were carried out by the ‘make technique’ instead of the ‘break technique’.

The Bland–Altman plot for force values in all strength ranges (Fig. 2A) showed that there is a positive relationship between a higher MVIC and the difference scores between MVIC and HH-Dyn. The results of our study indicate this is due to force measurements above 250 N. In other words, up to 250 N we could not demonstrate a clear systematic difference between both measurement methods, but beyond 250 N under-estimation of muscle strength as measured by HH-Dyn is found compared to MVIC, probably due to limited strength of the tester. Similarly, in ALS patients, a trend to under-estimate muscle strength by HH-Dyn forces above values of 196 N has been observed [17].

We experienced that for a reliable and valid measurement with both methods thorough training and considerable pre-measurement practice were needed in order to assure strict standardization of the measurement technique and equal skills of the testers. This applied not only to the MVIC technique but also to HH-Dyn despite its advantage of being more quickly applicable than MVIC.

In conclusion, HH-Dyn may replace MVIC in monitoring muscle strength within certain conditions. For reliable measurements familiarity with the measurement technique and strict standardization of the testing procedure are prerequisites. Further, for longitudinal evaluation of muscle strength in patients with progressive LMN syndrome, in mildly to moderate weak muscle groups (i.e. as high as 250 N) muscle strength can be accurately quantified with both HH-Dyn and MVIC. The former has the advantage of being cheap and quickly applicable. However, there are strong indications that HH-Dyn is less sensitive than MVIC in detecting subnormal muscle strength in strong muscle groups (exceeding the strength of the tester).

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