Isometric Back extensor tests: A review of the literature

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Purpose

The purpose of this paper was to review the literature that investigates the back extensor musculature during different isometric back tests and to summarize the findings and discuss the clinical usefulness of these tests. A review of the testing methods and the various authors conclusions are presented in this review.

Introduction

Isometric muscle testing can help to predict and determine low back pain across the population. Practitioners not only require reliable and relevant tests, they also require tests that are easy to perform, require little or no specialized equipment, thus making them of more use in a clinical setting. Tests that limit motion of the spine, specifically isometric tests, can minimize aggravating a patient's condition and as a result a patient is more inclined to participate and put forth a substantial effort. This makes isometrics tests a superior choice.

Endurance and strength in addition to proprioception of the low back are parameters that appear to be testable and predictable in patients with lower back complaints. Tests that are of a predictive nature for injury are useless once the injured patient is sitting in the practitioner's office. Instead, tests that predict the outcome of a patient's treatment or the extent of their injury are more clinically useful. The literature is vast and consequently involves vast amount of tests, comparisons and procedures.

The most recent review of isometric tests, was published in February 2001 by Chad Morea et al. Their findings suggested that the influence of motivation and effort were factors affecting the outcome of the examined tests and they concluded that the Sorensen test was the most clinically useful of the isometric tests. Over the past decade since their publication, more research has been published on isometric muscle testing and therefore a more recent summary and review of the literature is needed. A review of the literature and how isometric tests may relate in a clinical setting is summarized in this review.

Methods

A search of PubMed and the Index to Chiropractic Literature was done. The following MeSH terms were used in various combinations: Back/physiology, Back/physiopathology, Biomechanics, Electromyography, Exercise, Exercise Test, Exercise Tolerance, Isometric Contraction(s), Lumbosacral Region, Muscle Fatigue, Muscle Skeletal, Physical Endurance. The following text words were used, within the abstracts or titles of papers: back extension, back extension exercise, electromyography, isometric back extension, static extension. . Abstracts of each study were read first to determine if the study fit the inclusion criteria, if the acceptance or rejection of the study could not be determined by the abstract alone the methods section of the study was read to clarify its inclusion or exclusion. Studies that were not excluded were divided into three different categories. The first being isometric back tests that were performed to failure, or fatigue by the study participants during the test or exercise. Isometric back tests were defined by the reviewers as any test involving the static activation of back extension musculature that did not result in movement of the upper torso relative to the lower torso or extremities. The terms fatigue and failure were often used interchangeably in the literature and were defined by the authors of this review as the point at which a test subject could no longer perform the test required within the appropriate parameters and the term failure will be used to denote fatigue and failure. The second category examined isometric back tests that were not performed to failure and the third category reviewed studies that examined both isometric back tests that were performed to failure as well as those that were not performed to failure. Once the studies had been categorized they were read and each paper was then discussed as to their methods, results and clinical usefulness. This review did not rank or rate the quality of the studies reviewed as this was not the purpose of the review, but was to summarize the studies and comment on their usefulness in a clinical setting.

Table # 1 – Inclusion and Exclusion Criteria

Inclusion Criteria:	
	Studies published from 2001 to present
	Studies looking at back extensor musculature during isometric back tests or exercises.
	Studies published in the English language
Exclusion Criteria:	
	Studies published before 2001
	Studies only involving isometric flexion exercises
	Studies involving only dynamic exercises, with no isometric component.
	Studies using isometric extension exercises as an outcome measure for other tests/exercises
	Studies not primarily interested in the low back.
	Literature reviews

Discussion

The collected papers were then divided between the reviewers. Each reviewer used the inclusion and exclusion criteria listed above in Table 1 to narrow the number of studies from 43 to 23.

Isometric tests performed to failure

Essendrop et al. 2002, also looked at the upright position test, specifically intra-abdominal pressure compared to sustained forward flexion at 45 degrees to fatigue. In their study, they also used a perceived exertion scale, or Borg scale, and suggested that intra-abdominal pressure can cause an extension torque to relieve load on structures of the lower back. Dupeyron et al. 2009, examined five tests including forward flexion at 45 degrees with weight (20 kg), forward flexion at 45 degrees without weight, standing extension, standing upright while holding 20 kg and the Sorensen test. Using standing upright without any weight as a control, they examined intra muscular pressure and O_2 saturation of the extensor musculature and found that O_2 saturation decreased in the Sorensen test and forward flexion at 45 degrees without weight but had no change in standing extension. Intra muscular pressure increased in the Sorensen test, forward flexion with weight (20 kg) and standing extension. They also found that muscular blood volume decreased in the Sorensen test in the last 25% of the time that the test was held. Of note, Dupeyron et al. 2009, only used right hand dominant young male subjects and used the consistent load of 20 kg for all subjects regardless of body mass, instead of a percentage of body mass.

Coorevitis et al. 2005, looked at a modification to the Sorensen test, in which subjects placed their hands at the side of their face as opposed to Sorensen's original description of the test, where the subject's hands were crossed in front of their chest. They looked at the statistical modeling of fatigue during their modified Sorensen test and compared the traditional linear regression model to logarithmic quadratic or exponential modeling. They determined that traditional linear regression is an acceptable technique to determine fatigue in the Sorensen's test. Of interest was the utilization of predetermined 3D lumbar lordosis modeling to determine the end point of the testing. Coorevitis et al. 2008, used this modeling again when they compared 3D data from the lumbar position to tactile feedback as a determination of fatigue during their modified Sorensen's test, concluding that this modification of the Sorensen's test is valid to measure back muscle fatigue.

Arab et al. 2007, compared 5 tests, the Sorensen test, the prone isometric chest raise test (the Ito test), prone double straight leg raise, supine isometric chest raise test and the supine double straight leg raise test and concluded that the prone double straight leg raise test had more sensitivity, specificity and predictive value in low back pain then the other listed tests.

Champagne et al. 2008 compared the Sorensen test and another modified Sorensen (that employed 45 degrees of hip flexion). They observed simultaneous hip extensor muscle fatigue with paraspinal muscle fatigue. They did notice at the L5 level a difference in fatigue between the tests. To these authors this indicated a task variability in fatigue which was supported by the findings of Elfving et al. 2006, who also suggested that different tasks would cause fatigue differently after comparing a modified Sorenson (at 40 degrees of flexion) to a seated upright extension. However, they utilized verbal encouragement during the modified Sorensen test and not during the seated upright extension test which may have caused a bias. They also suggested that different positions taken by the spine will change the lever arm of the back extensor muscles, thus giving a mechanical advantage in some positions but not in others.

Champagne et al. 2009, later utilized the modified Sorensen test, as described in their 2008 paper, comparing fatigue and perceived exertion in young and elderly males. They concluded that there was no difference in perceived exertion during extensor endurance in young and elderly subjects. Although elderly showed a trend in decreased endurance time, it was not statistically significant. This could be explained by adaptations, such as decreased muscle mass and increased type I muscle fiber proportion as a result of the natural aging process.

Gruther et al. 2009, looked at training effect and perceived fear with regards to the Sorensen test versus static and dynamic truck extension and flexion. They concluded that the Sorensen test was a good and reliable test, as no training or emotional effect on the subjects was found. Keller et al. 2001, had also determined that no training effect occurred for the Sorensen test, however, indicated that it was not as clinically useful since the critical difference, defined as the difference between two measures to make them statistically different, was too high. They also examined the Astrand Bicycle test and an upright position test. They indicated that the Astrand bicycle test had a lower critical difference as well as no training effect and that the upright position test could not determine a difference between healthy and unhealthy subjects. Leitner et al. 2008, found that chronic low back pain subjects performed significantly poorer on the Sorensen test when compared to a healthy population. Keller et al. 2001, had also concluded that the Sorensen test was able to detect differences between a healthy and unhealthy population.

The Ito test, also known as the prone extension test (PET), was examined by Muller et al. 2010, to determine it's validity and reliability in comparison to the Sorensen test. They attempted to standardize the Ito test in order to remove any variability in test set up for future studies utilizing this test. They found an increased activation of the bicep femoris and semitendinosis in the Sorensen test when compared to the Ito test. However, the Ito test had higher illiocostalis muscular activity. They therefore concluded that the Ito test might assess back muscle endurance more specifically then the Sorensen test, thus indicating that the Ito test may be a superior test for assessing low back pain patients.

Table # 2 - ***12 studies met the inclusion criteria of examining or utilizing isometric tests that were performed to failure (as referenced above)***

#	Authors	Year	Title
1	Arab, A., et al	2007	*Sensitivity, specificity and predictive value of the clinical trunk muscle endurance tests in low back pain.*
2	Champagne, A. et al	2008	*Back and hip extensor muscles fatigue in healthy subjects: task-dependency effect of two variants of the Sorensen test.*
3	Champagne, A. et al	2009	*Comparison between elderly and young males' lumbopelvic extensor muscle endurance assessed during a*

			clinical isometric back extension test. Journal of Manipulative and Physiological Therapeutics
4	Coorevits, P., et al	2005	*Statistical modelling of fatigue-related electromyographic median frequency characteristics of back and hip muscles during a standardized isometric back extension test.*
5	Coorevits, P., et al	2008	*Assessment of the validity of the Biering-Sorensen test for measuring back muscle fatigue based on EMG median frequency characteristics of back and hip muscles.*
6	Dupeyron, A., et al	2009	*Muscle oxygenation and intramuscular pressure related to posture and load in back muscles.*
7	Essendrop, M., et al	2002	*Intra-abdominal pressure increases during exhausting back extension in humans.*
8	Elfving, B., et al	2006	*Task dependency in back muscle fatigue – Correlations between two test methods.*
9	Gruther, W., Wick, et al	2009	*Diagnostic accuracy and reliability of muscle strength and endurance measurements in patients with chronic low back pain.*
10	Keller, A., et al	2001	*Reliability of Isokinetic trunk extensor test, Biering-Sorensen Test, an Astrand Bicycle Test.*
11	Muller, R., et al	2010	*Isometric back muscle endurance: An EMG study on the criterion validity of the Ito test.*
12	Paul, B., et al	2008	*Low back pain assessment based on the brief ICF core sets diagnostic relevance of motor performance and psychological tests.*

Table # 2.1 - ***Tests Examined in the failure category (referenced from above)***

Tests Examined	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Sorenson Test	x	x	x			x			x	x	x	X
Modified Sorensen Test.		x	x	x	x			x				
Prone double straight leg raise.	x											
Supine isometric chest raise.	x											
Supine double straight leg raise.	x											
Seated upright.								x				
Prone isometric chest raise.	x										x	
Upright Position Test.							x			x		
Bending forward @ 45 degrees.						x						
Bending forward @ 45 degree angle holding 20 kg.						x						
Bending forward @ 45 degree angle holding 15 % of body mass.							x					
Standing prolonged bending backwards.						x						
Upright prolonged standing holding 20 kg.						x						

Isometric tests that were not performed to failure

Ng et al. 2002, examined low back range of motion testing in 3 cardinal planes, including flexion, extension, lateral flexion bilaterally and rotation bilaterally in a standing isometric B200 Isostation apparatus. They examined EMG muscle activation during maximal contractions in subjects with and without back pain. They concluded that certain muscles, namely latissimus dorsi and illiocostalis lumborum, demonstrate difference in activity in different planes of motion and therefore may require testing in more then one range of motion.

Plamondon et al. 2002, examined the prone back extension (PBE) in 20 male subjects with no history of LBP. Six variations of the Sorensen test were held for six seconds in order to identify specific positions that offer the most resistance to the back extensor musculature. They found that the differences between PBE exercises were small with regards to muscle activation and level of resistance unless the arms were extended. was No advantage with stabilizing the legs in the activity of the erector spinae muscles was found during the exercise. The also determined that PBE exercises offers a resistance level for endurance development, since they are generally low resistance exercises.

da Silva et al. 2005, measuring the strength and fatigue between a healthy and unhealthy subjects, where unhealthy subjects were defined as those with chronic low back pain (CLBP). They compared three tests; Sorensen test, standing lift test and the upright position test and concluded that no one test was more sensitive in determining low back status between the two subject groups. They did find that Sorensen test and the upright position test produced more fatigue in the back muscles then did the lift test.

Stevens et al. 2006 looked at the muscle activity of three exercises commonly performed on all fours. Subjects were instructed to perform single leg extension, single leg extension with contra lateral side arm extension and single leg extension with contralateral arm extension while maintaining 30 degrees of increased flexion of the hip. The static component of these exercises was that the subjects were asked to maintain the position for five seconds. The researchers looked at the activity of the internal oblique, external oblique, rectus abdominus, lumbar multifidus, gluteus maximus, latissimus dorsi and the lumbar and thoracic portions of the iliocostalis. Their findings concluded that a contribution from all musculature both global and local contribute to trunk stability.

Ekstrom et al. 2008, examined various exercises, including but not limited to, resisted prone trunk extension in both end range and neutral, seated trunk extensions, bridging in spinal neutral. The authors found that the activity of the longissimus throacis and the multifidus was most active during lumbar extension to end range with an applied resistance. Prone lumbar extension to neutral and resisted lumbar extension while seated also produced high amplitudes of EMG of the back extensors. Bridging exercises produced smaller amounts of EMG activity.

da Silva et al. 2009, assessed the effect of pelvic stabilization and hip position in trunk extensor activity using repetitive flexion extension cycles in the prone position and an isometric back extension (in the Sorensen position). The found that pelvic stabilization did not affect back muscle activity. Of note, back muscle activity was the same for males and females. In addition, flexion of the hip decreased the activity of the bicep femoris muscle. The authors did mention that their study may have been limited by the stability of the pelvis and they did not take in to account anthropometry of their subjects.

Lariviere et al. 2009, utilized a functional endurance test (FET) with repeated cyclic intermittent back extensions held for 8 seconds per cycle. Their results supported the validity of the FET and demonstrated that it has the potential to better assess the strength-endurance capacity of CLBP relative to conditions more specific to common occupational tasks.

Table # 3 - ***7 studies which met the inclusion criteria of examining or utilizing isometric tests that were not performed to failure (as referenced above)***

#	Authors	Year	Title
1	da Silva, R., et al	2005	*Back muscle strength and fatigue in healthy and chronic low back pain subjects: A comparative study of 3 assessment protocols.*
2	da Silva, R.,et al	2009	*Effect of pelvic stabilization and hip position on trunk extensor activity during back extension exercises on a roman chair.*
3	Ekstrom, R.,et al	2008	*Surface electromyographic analysis of the low back muscles during rehabilitation exercises.*
4	Lariviere, C.,et al	2009	*A submaximal test to assess back muscle capacity: Evaluation of construct validity.*
5	Ng, J., et al	2002	*EMG activity normalization for trunk muscles in subjects with and without back pain.*
6	Plamondon, A., et al	2002	*Estimated moments at L5/S1 level and muscular activation of back extensors for six prone back extension exercises in healthy individuals.*
7	Stevens, V., et al	2007	*Electromyographic activity of trunk and hip muscles during stabilization exercises in four-point kneeling in healthy volunteers.*

Table # 3.1 ***- Tests examined that were not performed to failure (referenced from above)***

Test Examined	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Sorensen Test	x	x					
Standing Lift Test	x						
Upright position test	x						
4 point stance				x			
Functional Endurance Test (FET)				x			

Standing Isometric (measuring apparatus – B200 Isostation)					x		
Prone Back Extension (PBE) Exercises		x	x			x	
Prone trunk extension to End range against resistance			x				
Seated extension			x				
Bridging exercises (variety of positions)			x				

Isometric tests that were both performed to failure and tests that were not performed to failure

Lariviere et al. 2006, examined gender differences in the fatigability of muscles during intermittent isometric contractions. The fatigue test to exhaustion was performed utilizing a standing static dynamometer measuring L5/S1 extension moment. Fatigue criterion equalled time to exhaustion. They determined that males were stronger than females, however showed significantly shorter time to exhaustion values, which were corroborated by electromyographic indices of fatigue. The gender effect on time to exhaustion disappeared when accounting for strength. Females were more fatigue resistant than males as assessed with both mechanical and EMG criteria. They used different neuromuscular activation patterns, alternating activity between synergist muscles, a strategy that had previously been hypothesized to delay muscle fatigue.

In 3 separate studies a functional endurance test (FET) utilizing a standing triaxial dynamometer, with the pelvis stabilized to isolate the back extensor musculature was used by Lariviere et al. 2008, in both part I and II of the studies. It was determined that EMG indices of muscle fatigue is a practical way of assessing the absolute endurance as well as the strength capacity of chronic low back pain subjects when they perform an intermittent and time limited absolute endurance test.

Lariviere et al. 2009, looked at the ability to predict back muscle absolute endurance and strength with the use of EMG signals collected during a FET. They determined that it appears to be possible to predict the capacity of back muscles using an intermittent and time-limited (sub-maximal) fatigue task. Therefore, this FET may have the potential to better infer back muscle capacity for realistic occupational tasks, as more specific muscle fatigue mechanisms are involved.

Table # 4 - ***4 studies that met the inclusion criteria of examining isometric tests that were both performed to failure and tests that were not performed to failure (as referenced above)***

#	Authors	Year	Title
1	Lariviere, C., et al	2006	*Gender influence on fatigability of back muscles during intermittent isometric contractions: A study of neuromuscular activation patterns.*
2	Lariviere, C.,et al	2008	*The assessment of back muscle capacity using intermittent static contractions. Part I – Validity and reliability of*

			electromyographic indices of fatigue.
3	Lariviere, C.,et al	2008	*The assessment of back muscle capacity using intermittent static contractions. Part II – Validity and reliability of biomechanical correlates of muscle fatigue.*
4	Lariviere, C.,et al	2009	*Toward the development of predictive equations of back muscle capacity based on frequency – and temporal – domain electromyographic indices computed from intermittent static contractions.*

Table # 4.1 ***- Tests examining both isometric tests that were both performed to failure and tests that were not performed to failure (as referenced above)***

Tests Examined	**1**	**2**	**3**	**4**
Functional endurance test (FET) utilizing a standing triaxial dynamometer, with the pelvis stabilized to isolate the back extensor musculature.		x	x	x
Trunk dynamometer that consists of a triaxial force platform mounted on a steel frame that allows stabilization of the feet, knees and pelvis.	x			

Research papers that were excluded as they did not meet the inclusion criteria or met the exclusion criteria

Following our search of the literature, a total 20 papers were excluded as they either did not meet the inclusion criteria and/or met the exclusion criteria.

Table # 5 - ***Papers that were excluded***

#	**Authors**	**Year**	**Title**
1	Clark, B., et al	2001	Electromyographic activity of the lumbar and hip extensors during dynamic truck extension exercises.
2	Daggfeldt, K., & Thorstensson, A.	2003	The mechanics of back-extensor torque production about the lumbar spine.
3	Escamilla, R., et al	2010	Core muscle activation during swiss ball and traditional abdominal exercises.
4	Essendrop, M., et al	2002	Measures of low back function: A review of reproducibility studies.
5	Fenwick, C., et al	2009	Comparison of different rowing exercises: Trunk muscle activation and lumbar spine motion, load and stiffness.
6	Hubley-Kozey, C., et al	2010	Temporal coactivation of abdominal muscles during dynamic stability exercises.
7	Kaser, L., et al	2001	Active therapy for chronic low back pain – part 2. Effects on paraspinal muscle cross-sectional area, fiber type size, distribution.

8	Lariviere., C., et al	2002	Electromyographic assessment of back muscle weakness and muscle composition: Reliability and validity issues.
9	Mannion, A., et al	2001	Active therapy for chronic low back pain. Part 1. Effects on back muscle activation, fatigability, and strength.
10	Mayer, J., et al	2002	Electromyographic activity of the truck extensor muscles: Effect of varying hip position and lumbar posture during roman chair exercise.
11	Murphy, D., et al	2006	Inter-examiner reliability of the hip extension test for suspected impaired motor control of the lumbar spine.
12	Plamondon, A., et al	2004	Back muscle fatigue during intermittent prone back extension exercise.
13	Roussel, N., et al	2008	Reliability of the assessment of lumbar range of motion and maximal isometric strength in patients with chronic low back pain.
14	Shin, G., et al	2009	Creep and fatigue development in the low back in static flexion.
15	Shin, G., et al	2010	EMG activity of low back extensor muscles during cyclic flexion/extension. Journal of Electromyography and Kinesiology.
16	Stevens, V., et al	2008	The effect of increasing resistance on trunk muscle activation during extension and flexion exercises on training devices.
17	Tarnanen, S., et al	2008	Effect of isometric upper-extremity exercises on the activation of core stabilizing muscles.
18	Tidstrand, J., & Horneij, E.	2008	Inter-rater reliability of three standardized functional tests in patients with low back pain.
19	Tsao, H., et al	2010	Motor training of the lumbar paraspinal muscles induces immediate changes in motor coordination in patients with recurrent low back pain.
20	Verna, J., et al	2002	Back extension endurance and strength.

Table # 5.1** - ***Research papers that were excluded as they did not meet the inclusion criteria or met the exclusion criteria (referenced from above)

Reason for Exclusion	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Not examining an isometric test or exercise	x		x		x	x	x			x	x									
Used a static extension exercise to examine torques and intra abdominal pressure. Therefore did not directly examine a isometric test or exercise.		x																		
Literature review looking at out-of date research				x																
Extension exercise used maximal voluntary contraction (MVC) in order to determine the reliability of EMG parameters. Therefore did not directly examine isometric test or exercise.								x												
Looked at the Sorensen test as an outcome measure.									x											
Looked at activation patterns of musculature.											x									
Used isometric exercises to evaluate kinetic exercise. Therefore, not directly examining an isometric test or exercise.												x								
Looked at static isometric to determine the inter observer reliability of equipment in different ROM in patients with CLBP. Therefore, did not directly examine an isometric test or exercise.													x							
Didn't look at back extensor musculature														x						

during isometric back tests or exercises. Looked at creep and fatigue development in L\S with static flexion																				
Didn’t look at back extensor musculature during isometric back tests or exercises. Looked at EMG during cyclic flexion/extension.															x					
Did not look at isometric tests. Used them to determine the validity of different training devices.																x				
Didn’t look at back extensor musculature during isometric back tests or exercises. Looked at isometric upper extremity exercises.																	x			
Didn’t look at back extensor musculature during isometric back tests or exercises.																		x		
Looked at back muscle activity during rapid arm movement and not back muscle activity during isometric back contractions.																			x	
Looked at a modified Sorensen test as an outcome measure to determine the effect of dynamic progressive resistance exercise training program on a variable angle roman chair.																				x

*Refer to Table # 1 regarding inclusion and exclusion criteria

Conclusion

Multiple studies using different people in various countries results in a variety of definitions, particularly in health related fields. An important question when using an experimental group in a research setting is what criteria are used to determine healthy subjects. Body mass index and matching subjects would appear to be a common method standardizing subjects, with respect to height and weight in order to reduce bias. However, the authors of this paper have seen the term healthy simply defined as the absence of CLBP and free of disease. Perhaps when considering a population on a whole this would be sufficient, however the inclusion of unhealthy individuals as defined by those who have CLBP is too broad a definition. An important area that needs to be addressed is a universal definition of CLBP and its associated causes. In recent years, studies that have categorized patients based on the cause of their back pain have found that patients responded better to treatment interventions when the appropriate treatment is applied, based on the cause of their complaint. Categorizing the type or cause of CLBP should also be considered when designing studies involving unhealthy populations, particularly those with CLBP, since the nature or cause of an individual's CLBP may be different within the unhealthy population, within the same study.

Clinically, the Ito test appears to be a more versatile method of testing individuals for muscular endurance in comparison to the Sorensen test, as it does not require additional equipment. It has been suggested that the prone double leg lift/raise is a superior test to both the Ito and Sorensen tests,[1] however more studies need to be performed comparing these tests. It would also be of benefit to study the effect of different angles of hip flexion, since some authors mentioned in this review have found different activity levels depending on body position and angle. More direct comparisons between isometric tests and how predictable failure of repetitive exercises should also be considered.

Extrapolating from the work of Ekstrom et al. 2008, and Stevens et al. 2006, future examination of the fatigue of global stabilizers and how their lever arms have an effect on fatigue would be of practical benefit, since individuals are often in a variety of positions throughout the day performing a variety of tasks actively engaging their global stabilizers.

It is well recognized within the literature that females are more resistant to fatigue then males in relative endurance tasks, where the same proportion of maximal strength should be exerted. Some papers have contradicted such a claim and find no differences between males and females. A question that should be addressed is the morphology of the individuals, not simply explaining if they are obese or 'athletic type' builds. A difference may be found in the upper body mass of men and particularly women not only comparatively within gender but also between them, despite the best efforts of researcher to match individuals to body mass and height. Thus morphology of subjects would be better matched both within and between populations.

Consistency in the accepted definitions of fatigue and failure should be clearly stated within studies. Having a variety of definitions in not clinically useful since fatigue and failure within a clinical setting differs from a research setting. The authors of this review considered failure and fatigue to be interchangeable terms and have defined them as the point in which a subject of an experiment could no longer perform the task of isometric extension. Contrastingly, the studies reviewed here often defined fatigue or failure to be a percentage of maximal voluntary contraction (MVC). Studies comparing MVC and percentage of MVC as it relates to failure, most likely has a high degree of validity and reliability since many papers use a percentage of MVC to determine fatigue. Although the authors of this paper have not searched the literature or studied the data to reject or accept a percentage of MVC as failure, in clinical practice without the option of sophisticated equipment, failure as defined by the inability of the individual to perform the task is the only feasible option.

In summary clinicians need tests that will allow them to evaluate a patient's ability to perform low force repetitive type tasks that are more indicative of real world occupational duties. It is not relevant to have tests that predict people who are already symptomatic, as they present to your office when their symptoms are already present. More useful tests would be those that predict or evaluate a recovered patient's ability to return to repetitive real world tasks. Tests that are isometric and endurance in nature are the easiest tests to evaluate patients, as they do not require any equipment nor extended periods of time to perform and would appear to be more clinically useful.

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