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REVIEW OF THE LITERATURE

Isometric Back Extension Endurance Tests: A Review of the Literature

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ABSTRACT

Objective: To review the literature that describes and evaluates the use of isometric back extension endurance tests.

Data Collection: Relevant articles in English were retrieved through a search of MEDLINE and the *Index to Chiropractic Literature*. Key search terms were *back muscle endurance, isometric back endurance, trunk extensors, back muscle performance, and Sorensen test.*

Data Synthesis: The principal criterion for inclusion was as follows: any study that discussed or tested an isometric type of back endurance extension test. Studies that were excluded did not use an isometric testing protocol. Thirty-seven of the initial studies are included in this review.

Results: Six different types of isometric back extension endurance testing methods were found. Three of these procedures require special testing devices. Much of the research on this topic has centered on a procedure known as the *Sorensen test*. Normative databases have been established for the Sorensen test and 2 other test types. Validity and reliability have been assessed for some of the procedures.

Conclusions: The influence of motivation and effort exerted by the subject are limiting factors in all of the tests reviewed. These psychologic factors warrant further research. On the basis of the literature reviewed, we determined that the Sorensen is probably the most clinically useful of these tests; it is easy to perform, requires no special equipment, and enjoys the most support from the literature. (J Manipulative Physiol Ther 2001;24:110-22)

Key Indexing Terms: Low Back Pain; Muscle; Physical Endurance; Isometric Back Endurance; Diagnosis; Sorensen Test; Back Extension

INTRODUCTION

During the past 4 decades, many methods of back muscle testing have been studied in an attempt to predict, prevent, and rehabilitate low back pain (LBP).[1] Methods have included spinal muscle strength assessment, flexibility, coordination, correlation of demographic factors with LBP, range of motion, and spinal muscle endurance. A recent focus has been placed on back muscle endurance and its relationship to LBP. Knowledge of the relationship between LBP and isometric back endurance is sparse and somewhat conflicting.[2,3]

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Several types of methods of testing spinal muscle endurance have been studied. Most commonly, these are (1) measures of isometric, or static, endurance, (2) active measures of endurance within a nonfixed range of motion (isotonic), and (3) isokinetic testing that places subjects in a fixed range of motion as well as a fixed rate of joint motion acceleration.

Of the assessment strategies available, isometric endurance testing seems to be cost-effective and requires little equipment for testing. Because of these features, we chose to focus on isometric endurance assessment; we felt that if there was evidence to support it as a clinically useful and valid procedure, it would be the type of testing that clinicians would choose to use to measure spinal muscle endurance. We also explored the literature for evidence regarding the endurance of the lumbar spine extensors specifically, because many methods are purported to test the lumbar spine extensors.[4-7]

The purpose of this study was to review the literature that investigates the use of isometric back extension endurance testing. Different testing methods and evidence regarding their utilization are presented in this review.

DISCUSSION

Articles were retrieved through a search of MEDLINE (January 1966 through February 1999) and the *Index to Chiropractic Literature* (ICL; 1985-1997). Key search terms used were as follows: *back muscle endurance, isometric back endurance, trunk extensors, back muscle performance*, and *Sorensen test*. References in retrieved articles were searched for additional sources. The criteria for inclusion were as follows: any study that discussed or tested an isometric back endurance extension test was included; studies that did not use isometric testing protocols were excluded; all articles eligible for inclusion had been published in English. Thirty-seven studies met the criteria for inclusion,[1-33,35-38] and their testing protocols were sorted so that similar procedures were reviewed together. This resulted in 6 distinct categories of isometric back extension endurance tests.

After data regarding isometric endurance tests were synthesized, we conducted a literature search of the PsycINFO database (1887 through October 1999) to find research relating to psychologic factors associated with endurance that might significantly impact test results. Relevant papers were reviewed and included in the Discussion section of the present review.

In the sections that follow, data from the literature reviewed are presented for 6 types of isometric low back extension endurance procedures. For each type of test, the following 5 areas are focused on:

- Summary description (background, testing method, average performance measures)
- Evidence regarding the validity of the test (does it do what it is purported to do?)
- Evidence regarding the reliability of the test
- Evidence regarding correlation of the test with other tests
- Evidence regarding the clinical utility of the test.

I. Sorensen Test (represented in 29 studies)

Summary. The Sorensen test is the method most frequently investigated and reported in the literature. Among other back functional measures, Biering-Sorensen[4] describes this method of testing isometric back endurance; it measures how long (to a maximum of 240 seconds) the subject can keep the unsupported trunk (from the upper border of the iliac crest) horizontal while prone on an examination table. During the test, the buttocks and legs are fixed to the table by 3 wide canvas straps and the arms are folded across the chest (Fig 1). The subject is asked to maintain the horizontal position until he or she can no longer control the posture or has no more tolerance for the procedure or until symptoms of fatigue are reached. Several authors report using Biering-Sorensen's exact method for clinical studies.[3,4,6,8-15] A number of other studies involve minor variations of the Sorensen test. Some of these variations include placing the hands on the head, using fewer than 3 straps to support the subject, and using devices such as an inclinometer on the subject's back to determine when the horizontal position has been breached. These variations have been referred to collectively as *modified Sorensen tests.*[1,2,16-26,28-33,37,38]

According to the literature, the mean extensor endurance time for mixed-sex groups ranges from 77.76 to 129 seconds in healthy subjects.[23,24,28,29] On average, women have longer extension endurance times than men (Table 1).[20,24,25]

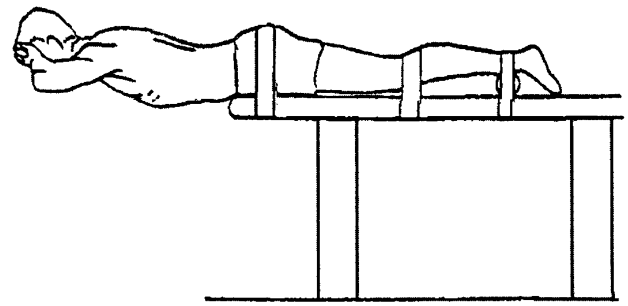

Fig 1. *Testing position for Sorensen test. Subject holds horizontal position either to fatigue or to a set stopping time. This figure illustrates modified Sorensen position, because hands are at side of head rather than crossed in front of chest.*

For men, the mean endurance time is 84 to 195 seconds; for women, it is 142 to 220.4 seconds. For subjects with LBP, the mean endurance time range is 39.55 to 54.5 seconds in mixed-sex groups,[26,29] 80 to 194 seconds for men, and 146 to 227 seconds for women (Table 2).

Evidence of validity. Alaranta et al[16] provide a data chart for the Sorensen test that combines the results of testing pain-free subjects and the results of testing LBP subjects; this might represent some measure of social validity for the test (Table 3).

According to the literature, the Sorensen procedure appears to provide a global measure of back extension endurance capacity. During the Sorensen test, the multifidus demonstrates more electromyographic activity[32] and faster fatigue rates than the iliocostalis lumborum.[32,33] This observation is attributed to the higher level of activity of the multifidus during trunk extension as well as to the fact that the multifidus is responsible for counteracting forces in the sagittal plane, whereas force contributions from the iliocostalis lumborum are more likely in the frontal plane.[32] In addition, when electromyography (EMG) and acoustic myography are used in healthy subjects, the paraspinal muscles demonstrate symmetric activity at the L4 level.[31]

However, controversy exists as to the amount of endurance that is provided by the lumbar extensors in contrast with the hip extensor muscles. Most authors state that the hip extensors contribute to the performance of the test; according to published EMG recordings, the contributions to endurance time range from not significant[30] to strong.[20] Moffroid et al[26,27] find a significant positive correlation between EMG median frequency slopes of the biceps femoris and Sorensen test results. They conclude that the Sorensen test fatigues the biceps femoris more than the erector spinae and that it indicates more about the endurance of the hip extensors than about that of the trunk extensors.

Probably the most controversial aspect of the Sorensen test is the claim of its ability to identify people who will have LBP in the future.[4] Three studies investigate this issue directly.[4,23,17] In the original study of 928 subjects (449 men and 479 women), Biering-Sorensen[4] investigates whether indicators of prognostic value for LBP are identifiable by

Table 1. *Mean endurance times for Sorensen test in normal subjects*

	Time (s)							
	Male subjects				Female subjects			
Reference	n	X	SD	Range*	n	X	SD	Range*
Jorgensen and Nicolaisen[9]	53	180	45-240	NA	23	207	75-240	NA
Sparto et al[30]	10	109	27	60-145	—	—	—	—
Jorgensen and Nicolaisen[6]	53	180	NA	45-240	—	—	—	—
Holmstrom et al[18]	40	171.5	34.2	119-266	—	—	—	—
Gibbons et al[17]	30	84	45	NA	—	—	—	—
Latikka et al[22]	100	92	46.0	10-240	—	—	—	—
Biering-Sorensen[4]	144	195	NA	NA	152	199	NA	NA
Kankaanpaa et al[21]	100	153.6	47.9	NA	133	182.6	47.3	NA
Mannion and Dolan[24]	21	116	40	NA	208	142	55	NA
Nicolaisen and Jorgensen[3]	24	184	59	NA	8	219	33.0	NA
Hultman et al[19]	36	150	49	NA	—	—	—	—
Mannion et al[25]	—	—	—	—	17	220.4	88.5	NA
Nordin et al[12]	—	—	—	—	101	190	80	32-300
Moffroid et al[11]	—	—	—	—	14	200.1	66.8	84-318

X, Mean; *NA,* not available.
*Recorded as reported in study reviewed.

Table 2. *Mean endurance times for Sorensen test in subjects with low back pain*

	Time (s)							
	Male subjects				Female subjects			
Reference	n	X	SD	Range	n	X	SD	Range
Jorgensen and Nicolaisen[6]	11	148	NA	45-240	—	—	—	—
Holmstrom et al[18]*	71	166.7	55.6	28-291	—	—	—	—
Holmstrom et al[18]†	57	137.5	57.1	21-253	—	—	—	—
Gibbons et al[17]	13	80	46	NA	—	—	—	—
Biering-Sorensen[4]‡	21	164	NA	NA	34	151	NA	NA
Nicolaisen and Jorgensen[3]§	11	148	61.2	NA	6	146	61.6	NA
Nicolaisen and Jorgensen[3]‖	16	194	59.9	NA	10	227	37.1	NA
Hultman et al[19]¶	86	134	47	NA	—	—	—	—
Hultman et al[19]**	18	85	41	NA	—	—	—	—

X, Mean.
*Subjects had once had LBP but exhibited no certain clinical signs on examination.
†Subjects had LBP at time of evaluation and exhibited clinical signs.
‡Subjects had had LBP within previous week.
§Subjects had once had LBP, leading them to miss work.
‖Subjects had once had LBP but could still work.
¶Subjects had had LBP at least once, but last time was more than 2 months before study.
**Subjects had LBP for 3 years and had taken more than 3 months of sick leave within previous year.

means of various anthropometric and physical performance measurements; she reports that isometric back endurance time is of significance for predicting the first-time occurrence of LBP during a 1-year follow-up period in men but not in women. The Sorensen test discriminates between men who have never had LBP and those with a first-time occurrence in the follow-up. However, it has a negative association for women that is not statistically significant.[4]

Two reports confirm Biering-Sorensen's original study and one report does not. Hultman et al[19] note that the risk of belonging to a population of patients who have recurrent or chronic LBP increases significantly when isometric extensor endurance is decreased in comparison with that in healthy subjects.[19] Another study shows that the isometric endurance test is the only physical capacity measurement that shows a significant correlation with new LBP for both sexes. These authors report that the adjusted relative risk (odds ratio) of new LBP is more than 3 times greater among poor performers than among medium and good performers. This provides confirmation of Biering-Sorensen's study by showing that the relationship to incurrence of new LBP is not linear; instead, it is concentrated in the poorest performers.[23] In a final study, no factor (cross-sectional area of the paraspinal muscles as measured by magnetic resonance imaging [MRI], proton density, isokinetic lifting, psychophysical lifting, or static back muscle endurance) is a significant predictor of LBP in a 12-month follow-up period.[17]

Evidence of reliability. For healthy subjects, the test-retest reliability of the Sorensen test and modified Sorensen tests ranges from 0.54 to 0.99 for those studies reporting intraclass correlation coefficients (ICCs) and from 0.20 to 0.91 for those reporting Pearson correlation coefficients (*r* values; Table 4). For physically active LBP subjects, ICCs range from 0.82 to 0.96[26,29]; inactive LBP subjects demon-

Table 3. *Normative data for static back endurance test*

	Time (s)											
	Male subjects (n = 242)						Female subjects (n = 233)					
	Blue collar		White collar		All		Blue collar		White collar		All	
Age (y)	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
35-39	87	38	113	47	97	43	91	61	95	48	93	55
40-44	83	51	129	57	101	57	89	57	67	51	80	55
45-49	81	45	131	64	99	58	90	55	122	73	102	64
50-54	73	47	121	56	89	55	62	55	99	78	69	60
35-54	82	45	123	55	97	53	82	58	94	62	87	59

Reprinted with permission from: Alaranta H, Hurri H, Heliovaara M, Soukka A, Harju R. Non-dynamometric trunk performance tests: reliability and normative data. Scand J Rehabil Med 1994;26:211-5.
X, Mean.

Table 4. *Test-retest reliability values for Sorensen test in normal subjects*

			Time (s)		
Reference	n	Reliability value	X	SD	Range
Mannion and Dolan[24]	5	ICC = 0.99	201	65	NA
			205	63	NA
Mannion et al[25]	10	ICC = 0.98	NA	NA	NA
Simmonds et al[29]	48	ICC = 0.73	74.1	27.6	NA
Van Dieen and Heijblom[35]	10	ICC = 0.54	NA	NA	NA
Alaranta et al[16]	93	$r = 0.63$	96	51	NA
			99	58	NA
Moffroid et al[11]	14	$r = 0.87$	200.1	66.8	84-318
			177	56.2	60-270
Hyytiainen et al[8*]	29	$r = 0.74$	134.31	51.12	32-240
			135.24	51.27	26-240
Mayer et al[2]	12	$r = 0.20$	NA	NA	NA
Holmstrom et al[18]	15	$r_s = 0.91$	NA	NA	NA
Jorgensen and Nicolaisen[9]	10	$r = 0.89$	267	51.7	210-388
			287	66.9	227-423

When 2 data sets were reported, both are presented.
X, Mean; *ICC*, intraclass correlation coefficient; *r*, Pearson product-moment coefficient of correlation; r_s, Spearman rank-order correlation coefficient; *NA*, not available.
*Although this study did not include data from performances restricted by pain, there was no categorization of no-pain group vs pain group.

strate an ICC of 0.39.[26] Jorgensen and Nicolaisen[9] report a test-retest reliability value of 0.89 but do not specify what statistical function they used to calculate the value other than "the reliability coefficient."

Less research has been performed to assess the interrater reliability of the Sorensen test in healthy subjects. Two studies report ICC values of 0.99[29] and 0.59[28]; 2 other studies report *r* values of 0.66[16] and 0.80.[8] Only one study reports interrater reliability data on subjects with LBP, yet it presents an ICC of 0.99 (n = 44).[29] A study of 30 adolescents results in an *r* value of 0.88.[14] It has been suggested that Sorensen test error is probably due to interactions among subjects, inconsistent performance by subjects and/or raters, or random error.[28]

Correlation with other findings. Age, activity level, and expressions of weight and body mass provide most of the evidence in the research for correlation with the Sorensen test. Age has a significant negative correlation with Sorensen test times in 3 reports, a decline in endurance with age being demonstrated.[1,4,22] Younger men have faster paraspinal fatigue rates than older men in one study, but age does not have a significant effect on the endurance times of women.[21] A final study reports no correlation between endurance and age.[18]

Inactive subjects demonstrate statistically significant lower Sorensen times than active subjects (exercising 30 min/wk),[26] and more frequent and intense exercise in the past year has significant associations with longer endurance times.[1] Strangely, number of years of work time with physical loading demonstrates a significant positive relationship, whereas leisure time activity produces conflicting results.[1,18]

Percent body fat and weight have significantly negative associations with the Sorensen test in 3 studies,[1,21,22] and there is no statistically significant difference in Sorensen test times between obese and nonobese subjects.[26]

Some factors that have statistically significant correlations with extensor endurance time but are reported in 2 or fewer of the studies that we reviewed are height,[22] abdominal muscle endurance,[19] better health than others of the same age,[1] total work from isokinetic lift,[22] percentage of maximal voluntary contraction (MVC) of the extensor muscles (a negative correlation),[18] maximum force from isokinetic lift,[1,22] strength of trunk flexion, and extension.[4]

No significant correlation with Sorensen endurance times was observed with any of the following: maximum isometric strength,[18] a psychophysical lift test,[22] perception of strain

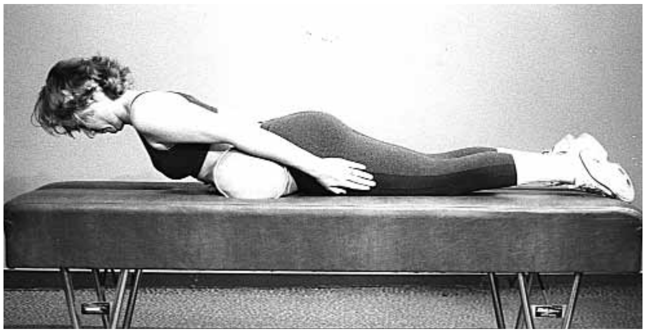

Fig 2. *Posture that is assumed for prone isometric chest raise as described by Ito et al.*[5]

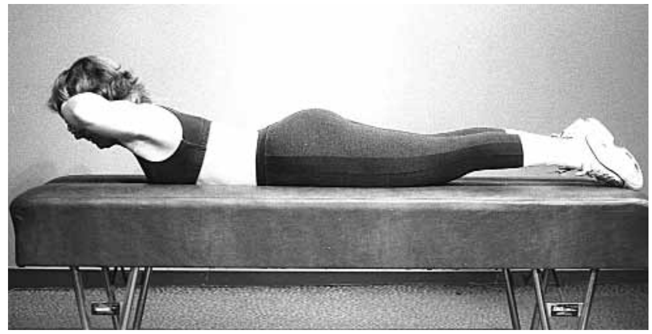

Fig 3. *Isometric chest raise procedure as described by McIntosh et al.*[7]

during the test,[22] extensor muscle torque,[19] measurements of lower limb length or inequality,[4] smoking,[18,26] prior physical training, cross-sectional area of back extensor muscles, cross-sectional area of the psoas muscle, or trunk flexion endurance.[13]

Evidence of clinical utility. Because the Sorensen test requires the subject to sustain the position to fatigue,[33] there may be health risks if it is applied to some patients with back pain. However, authors seem to accept that the Sorensen test is a relatively safe procedure for testing subjects with or without LBP.[4,11-14,16,23,26,27] The test generally requires the subject to exert muscle contractions well below the MVC.[2,11] Subjects with no LBP sustain contraction for endurance at the following levels: slim, strong subjects, 20% to 25% of MVC[9]; subjects with no LBP or LBP that does not prevent work, 60%[19]; untrained and overweight subjects, 70% to 75%[9]; subjects with chronic LBP, 85%.[19]

Regardless of how much contraction takes place, some subjects have difficulty during the test—an issue to consider in clinical use of the procedure. In Biering-Sorensen's[4] study, 24% of the sample cannot complete the test, primarily because of back pain followed by pain in the legs or abdomen.[4] Latikka et al[22] report a 50% failure rate because of back pain or fatigue. Cramps of the calves, neck pain, discomfort in the head, abdominal pain, and breathlessness[22,28] are also complaints in a minority of subjects.

With respect to theory, one author takes issue with the Sorensen test, claiming that lumbar lordosis probably increases during the procedure because of extended hip and knee joints.[33] Some authors suggest avoiding hyperextension of the lumbar spine during trunk muscle exercise.[5,39,40]

2. Prone Isometric Chest Raise (represented in 2 studies)

Summary. A study from Japan by Ito et al[5] measures extensor endurance with the subject in a prone position while holding the sternum off the floor (Fig 2). A small pillow is placed under the lower abdomen to decrease the lumbar lordosis. The subject is asked to maintain maximal flexion of the cervical spine, pelvic stability being maintained through gluteal muscle contraction. Subjects are asked to maintain this position for as long as possible, to a maximum of 300 seconds.[5] Ito et al[5] report a mean performance time of 208.2 seconds in healthy male subjects (n = 37) and 85.1 seconds in male subjects with chronic LBP (n = 40). For healthy female subjects (n = 53), the mean time is 128.4 seconds; for female subjects with chronic LBP (n = 60), it is 70.1 seconds.

McIntosh and members of the Canadian Back Institute[7] report a similar procedure that they call the *isometric chest raise*. The subject is placed prone with the legs extended and the hands positioned at the temples perpendicular to the body. The subject is then instructed to raise the head, arms, and chest from the floor and to hold the position as long as possible while breathing normally (Fig 3). Endurance time (in seconds) is recorded by an examiner.[7] A significant difference between age groups for this isometric chest raise procedure has been determined.[7]

Evidence of validity. On the basis of the 548 healthy subjects in their study, McIntosh et al[7] provide a normative data chart illustrating percentiles for the performance for men and women of various ages (Table 5). This may represent some degree of social validity. Ito et al[5] do not report any information pertaining to validity; McIntosh et al[7] state that their test assesses the endurance of the upper back extensor muscles, but no data are available to confirm this claim.

Evidence of reliability. Ito et al[5] report test-retest r values of 0.97 and 0.94 for healthy men and women, respectively, and an ICC of 0.97 for both sexes.[5] Chronic LBP produces test-retest r values of 0.93 and 0.95 for men and women, respectively, and an ICC of 0.93 for both sexes.[5] McIntosh et al[7] report test-retest reliability as $r = 0.633$ for the isometric chest raise.

Correlation with other findings. No information regarding correlation with other findings is reported.

Evidence of clinical utility. In the test by Ito et al,[5] an abdominal pillow is used in an effort to decrease the lumbar lordosis and avoid overloading the lumbar spine in a hyperextended position. One hundred ninety subjects (both control subjects and subjects with LBP) report that they did not experience difficulty in performing the test. Ito et al[5] state that their procedure should be safe to perform; McIntosh et al[7] do not report any safety concerns.

3. Prone Double Straight-leg Raise (represented in 1 study)

Summary. For the prone double straight-leg raise, the subject begins in the prone-lying position, hips extended, with the hands underneath the forehead and the arms perpendicu-

Table 5. *Normative percentile data for static chest raise*

Table available in print only

Table 6. *Normative percentile data for prone double straight-leg raise*

Table available in print only

lar to the body. The subject is then instructed to raise both legs until knee clearance is achieved (Fig 4). The examiner monitors knee clearance by sliding one hand under the thighs. The time is recorded in seconds, and the test is terminated when the subject is no longer able to maintain knee clearance. McIntosh et al[7] notice a significant difference in performance of the procedure among subjects of different ages.

Evidence of validity. McIntosh et al[7] state that the test assesses the lower back extensor muscles, but there are no supporting data. Normative percentile data for different age groups of men and women are provided (Table 6).

Evidence of reliability. Test-retest reliability for the prone double straight-leg raise is reported as $r = 0.81$.[7]

Correlation with other findings. No information regarding correlation with other findings is reported.

Evidence of clinical utility. No information regarding clinical utility is reported, other than that no special equipment is needed.

4. Pulling Test (represented in 3 studies)

Summary. In the pulling test, the subject stands facing an apparatus called a *strain-gauge dynamometer*. From this fixed dynamometer, a wire is connected to a strap around the shoulders of the subject (Fig 5). In this position, the subject attempts maximal backward extension with the pelvis supported. The subject performs a steady pull for 3-5 seconds, and the MVC is calculated as the maximal value in 3-5 attempts. For the extensor endurance test, the subject then pulls at 60% of MVC under the control of a supervisor until no longer able to maintain the 60% value. Pulling time is registered in seconds.[9]

Mean pulling times reported for healthy men are 54 seconds (n = 24),[3] 54 seconds (n = 24),[6] and 52 seconds (n = 53).[9] Times for healthy women are 80 seconds (n = 8)[3] and 73 seconds (n = 23).[9] No difference is observed in endurance times for subjects who are more heavily weighted in the head, arms, and trunk than for lighter subjects.[9] Women have longer endurance times.[3]

Significant differences exist in pulling test times between healthy subjects and subjects with LBP. In the first study reporting this data, male subjects who have once in their lives had LBP that made it impossible for them to work have statistically significant lower endurance times than healthy male subjects and male subjects who have once had LBP but continue to work. A similar trend is observed for women but is not statistically significant.[3] A later study confirms these findings.[6]

Evidence of validity. Jorgensen[34] reports that the muscles being tested by the pulling test are the lumbar paravertebral muscles. In the studies that we examined from Jorgensen and Nicolaisen,[3,6,9] no EMG data were found specifically pertaining to the pulling test, but Jorgensen[34] refers to work published by Vink et al[41] that analyzes the multifidus, lumbar longissimus, and lumbar iliocostalis muscles during isometric trunk extensions. Jorgensen[34] also points out that the paravertebral muscles act together with the hamstrings and calf muscles as important postural muscles.

Evidence of reliability. Jorgensen and Nicolaisen[9] demonstrate a test-retest reliability of 0.82 using a nonspecified "reliability coefficient" for the pulling test (n = 10).

Correlation with other findings. Although subjects with LBP have lower endurance times than healthy subjects, there is no significant difference between these groups with respect to trunk extensor strength.[3,6] No correlation is found

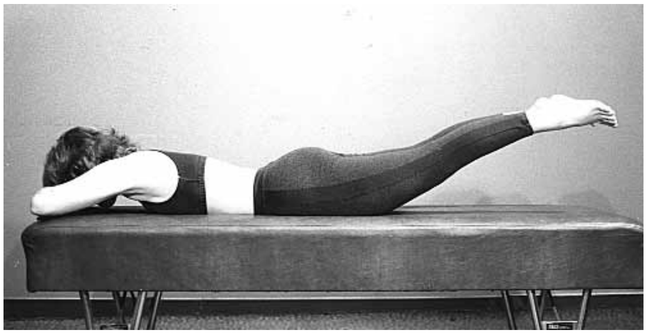

Fig 4. *Prone double straight-leg raise is isometric extension endurance test described by McIntosh et al.[7]*

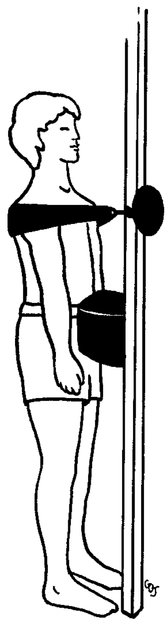

Fig 5. *Drawing shows pulling test described by Jorgensen and Nicolaisen.[9] Subject stands facing strain-gauge dynamometer, is then strapped to dynamometer, and attempts maximal backward extension while pelvis is supported. Subject pulls at 60% of MVC under control of supervisor until no longer able to maintain 60% value.*

between extensor endurance time and fat-free weight or sitting height.[9]

Evidence of clinical utility. This test requires the use of a strain gauge apparatus. Jorgensen and Nicolaisen[6,9] state that the machine is not too costly and is therefore reasonable to consider for clinical practice. Jorgensen and Nicolaisen[6,9] also report that the pulling test demonstrates less variation in measurement than the Sorensen test and recommends that the pulling test rather than the Sorensen test should be considered for clinical use.[6,9] The MVC needs to be established for the subject before the endurance test.[21] One author states that establishing an MVC in subjects with back pain might compromise the safety of the procedure.[11]

5. DBC110 Test (represented in 1 study)

Summary. A specially designed measurement and training unit, the DBC110 (DBC International Ltd, Vantaa, Finland)

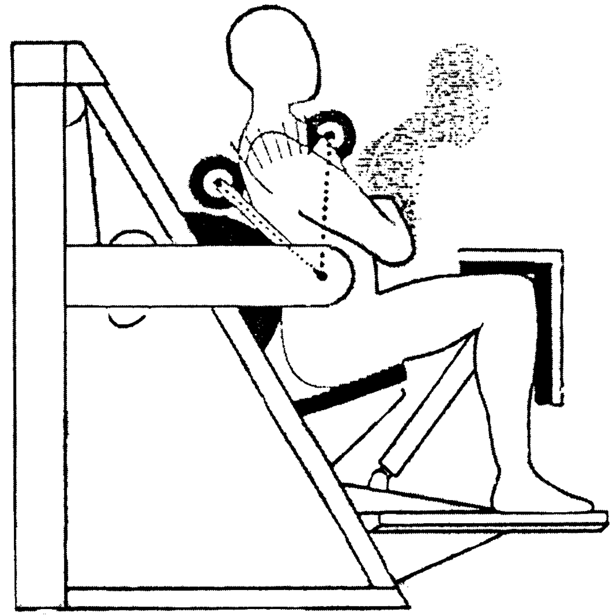

Fig 6. *Drawing shows DBC110 testing and training device. Reprinted with permission from: Taimela S, Kankaanpaa M, Airaksinen O. A submaximal back extension endurance test utilising subjective perception of low back fatigue. Scand J Rehabil Med 1998;30:107-12.*

is used for this test (Fig 6). The subject sits with the knees and feet fixed, and the pivot point of the movement axis is set at the L3 spinal level. After a warm-up, 4 MVC isometric extensions are measured at 1-minute intervals; the best of the 4 measurements is selected as the true MVC. A 50%-of-MVC target load level is then set, and the subject performs isometric back extension until he or she either can no longer hold the target level (± 5%) or experiences maximal fatigue.[20] Twenty subjects with chronic LBP and 15 pain-free control subjects are evaluated on the DBC110; the results are 1.7 minutes for the chronic LBP group and 2.0 minutes for the pain-free group, leading to a significant difference in mean endurance time between the two groups.[20]

Evidence of validity. The gluteus maximus muscle is usually active simultaneously with the erector spinae muscles during back extension. EMG readings demonstrate that the gluteus maximus muscle fatigues faster in a group of women with chronic LBP than in a group of control subjects in the same back endurance task using the DBC110.[20]

Evidence of reliability. Reliability data for the DBC110 testing device are not available.

Correlation with other findings. A higher Oswestry score, a higher visual analog scale pain score, and a lower MVC all correlate with lower endurance time for this testing procedure. EMG readings of the paraspinal and gluteus maximus muscles and reports of exhaustion by subjects also correlate directly with endurance time.[20]

Evidence of clinical utility. MVC needs to be established for the subject before the endurance test,[20] which might compromise the safety of the back structures.[11]

6. Sitting Dynamometer Tests (represented in 2 studies)

Summary. Sitting dynamometer tests require special equipment. One of the 2 machines that can be used is the Biodex Medical dynamometer (Biodex Medical Systems, Inc, Shirley, New York)[35]; the other is the Darcus strain-gauge dynamometer.[36] For the Biodex device, the subject is seated on the dynamometer and the MVC torque is assessed. After 5 minutes of rest, the subject performs a sustained contraction at 50% of the maximum. When the torque can no longer be maintained above a 90% target level, the test is stopped and the endurance time recorded. The test is repeated after 30 minutes of rest, during which time the subject is not allowed to step from the dynamometer (this is to exclude variation due to repositioning).

For the Darcus strain-gauge dynamometer, the subject sits on a stool facing the testing apparatus. A vertical bar 0.25 m long is fixed to the axis of the dynamometer, and the subject is attached to this bar with a strap around the shoulders. A strap around the hips prevents forward movement of the pelvis (Fig 7). During the test, the applied force is randomly varied between 5% and 60% of the previously established maximal isometric strength. Only 3 subjects are assessed, their mean endurance time being 115.33 seconds and the minimum endurance time being 89.67 seconds.[36]

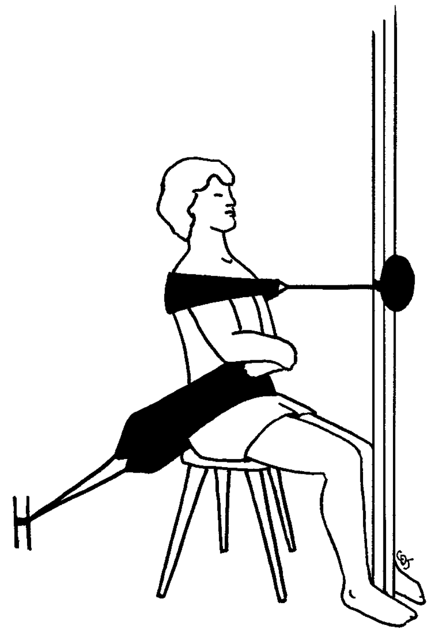

Fig 7. *Drawing shows Darcus strain-gauge dynamometer. Subject sits on stool facing testing apparatus, vertical bar is fixed to axis of dynamometer, and subject is attached to bar with strap around shoulders. Strap around hips prevents forward movement of pelvis.*

Evidence of validity. For the Biodex dynamometer, EMG analysis demonstrates that the multifidi, iliocostalis lumborum, and iliocostalis thoracis muscles are active during the test.[35] On the Darcus machine, investigators measure local muscle blood flow during sustained contractions of the back and arm muscles. They do not specify which back muscles in addition to the erector spinae muscles are studied.[36]

Evidence of reliability. Van Dieen[35] determines the test-retest reliability of the Biodex system to be 0.54 (ICC) between days and 0.94 when the subject is given a retest within 5 minutes of the first test.[35] No reliability data are found for the Darcus machine.

Correlation with other findings. Assessment of 3 subjects on the Darcus machine demonstrates a high correlation between endurance time and relative force exerted.[36]

Evidence of clinical utility. The clinical utility of these devices is questionable, a fact noted even by one of the authors of one of the studies.[35] Biodex testing lacks reliability for this performance measure and has not been studied with a large enough sample size.[35]

Comments Regarding the Sorensen Literature

Wide variation was observed among studies in how the Sorensen test was conducted. Dissimilarities in endpoints and subject positioning could have contributed substantially to the wide range of results observed in endurance times, particularly in healthy subjects. Three different endpoints for the test were reported: visual determination of the subject's failing to maintain the starting horizontal position because of fatigue[1-4,8-14,16-19,21-31]; a set time cut-off of 240 seconds*; and a set time cut-off of 300 seconds.[12] In addition, 13 variations of the testing position were reported, some similar and some not so similar to Sorensen's original procedure.

Sampling strategies also may explain some of the variation observed. Hyytiainen et al,[8] for example, reported data for subjects whom, because of a lack of reporting regarding the pain status of the sample, we had to assume were healthy. Although they did not include data from performances restricted by pain, Hyytiainen et al[8] did not separate subjects who might have had LBP at the time of the study from those who did not. This could certainly have lowered the mean endurance times, as demonstrated by looking at the data reported by other authors on subjects with LBP.

The normative data chart presented by Alaranta et al[16] also deserves some scrutiny. Although they described the data as normative and rationalized their decision to include both subjects with and subjects without LBP, theirs is not a true normative data chart, because all of the subjects were not normal. Nevertheless, the chart can provide a general reference for clinicians in practice and is quite useful.[16]

There is controversy regarding whether the literature is strong with respect to a correlation between having a low Sorensen test time and having LBP in the future. Two of 3 studies possessing this type of design demonstrated such a relationship. Combining this knowledge with a review of studies correlating retrospective patient data and Sorensen test times might help to provide a better answer to this question. Nicolaisen and Jorgensen[3] studied 77 Danish postal workers (24 women, 53 men) and divided the subjects into 3 groups on the basis of LBP history. They found that women

*References 3, 4, 6, 8, 10, 13, 14, 16, 21, 22, and 23.

who had once had LBP severe enough to prevent them from working had significantly shorter extensor endurance times than women who either had no history of LBP or had had LBP that did not preclude work. The Sorensen time was lower in men with LBP that precluded work than in the other men, but there was not a statistically significant difference.[3] These findings were confirmed by all but one[17] of several studies over the next decade: summarily, subjects with previous serious LBP had significantly lower endurance capacity than normal subjects.[6,14,18,19,29] Accordingly, we feel that the combined literature supports the idea that the Sorensen test can detect low isometric extension endurance and might be useful for identifying subjects who are at risk for developing LBP in the future.

One interpretation of the reliability measures performed through use of ICCs suggests that a value greater than 0.75 represents good reliability whereas a value less than 0.75 represents moderate to poor reliability. It has been suggested that the ICC should be greater than 0.90 to ensure reasonable validity.[42] According to these general guidelines, the literature lends some support to the Sorensen test, including variations of it, as a stable testing procedure. With respect to test-retest reliability, the Sorensen procedure demonstrated ICCs of 0.54 to 0.99 in healthy subjects and 0.82 to 0.96 in subjects with active LBP; clinicians could therefore depend on the test to produce reasonably reliable results from day to day. The only comment we make regarding the reliability data reported as Pearson coefficients of correlation (*r*) is that this is not a recommended statistical method for testing reliability[42] because the value of *r* can exaggerate the impression of reliability.[43] Therefore, we feel that it would be inappropriate to make a clinical recommendation from this information.

On the basis of the studies reporting interrater reliability results, we determined that the Sorensen test demonstrated moderate (ICC = 0.59) to good (ICC = 0.99) interrater reliability for healthy subjects and can be expected to provide similar results when used by other clinicians in similar testing environments.

Additional problems exist with regard to sample sizes. Some of the best reliability results were obtained on sample sizes of 10 or fewer subjects, which some would argue is an insufficient number from which to draw conclusions. When we included only those studies with 10 subjects or more, we found that test-retest ICCs for normal subjects range from 0.73 to 0.98, demonstrating good to excellent reliability. Looking at studies involving 10 or more subjects, we found the test-retest ICCs for subjects with LBP to be 0.39, 0.82, and 0.91; the test therefore seemed to demonstrate greater variability during its use with subjects with LBP.

Variations in testing positions reported in the literature might also explain some of the variance observed in the reliability data. For example, the study demonstrating the worst test-retest reliability was the only one that used a Roman Chair device for performing the test. Although the study team called this procedure a Sorensen test, it least resembled both Sorensen's original procedure and any of the other reported variations of the Sorensen test.[2]

In general, we feel that the literature provides reasonable support for recommending the Sorensen test for assessing isometric low back extension endurance. The test appears cost-effective, it is easy to perform and can be done in little time, and no special equipment is needed. The test demonstrates good reliability from day to day and between examiners. Different measures of validity have also demonstrated that the test produces results relating to assessing isometric back extension endurance, and the test has been declared safe for patients.

Interpretations of the Prone Chest Raise and Prone Double Straight-Leg Raise Literature

The prone chest raise and the prone double straight-leg raise are similar in that no special equipment is required, but they have not been subjected to many research efforts. Both test types have been performed on large numbers of subjects and are associated with normative data charts that can easily be referred to when patients are being assessed in the office. Because no validity tests have been performed on either of these two methods, it is not possible to conclude that they actually assess the endurance of the extensor muscles, though they seem to provide a global measure of extension endurance. Reliability measures of these procedures are sparse, yet Ito et al[5] demonstrated good reliability with their version of this procedure. Nevertheless, both testing procedures are cost-effective and safe to use on patients.

Comment Regarding the Pulling Test Literature

The pulling test is an easy procedure to perform, once the initial capital outlay has been made for the purchase of a standing strain-gauge dynamometer. In this procedure, the subject exerts endurance at a set target force rather than exerting force of an amount unknown to the subject, such as in the Sorensen procedure, prone chest raise, and prone double straight-leg raise tests. This target may be of value in controlling the fatigue perception of the subject, because the subject knows what the target actually is and can focus on that until fatigue.

Jorgensen and Nicolaisen[9] compared their unspecified reliability value of 0.82 with a reliability value from the Sorensen test (0.89) and stated that the pulling test has less variation between measurements, according to an analysis of the range of values obtained during testing. They therefore recommended the pulling test over the Sorensen test for clinical use.[6,9] This seems to be a premature recommendation based on a single study with 10 subjects; in contrast, the Sorensen test is associated with numerous studies with larger sample sizes and ICCs suggesting good reliability.

As seen in the Sorensen test data, subjects with previous serious LBP had less endurance capacity than normal subjects—a fact worth considering in clinical practice. Furthermore, the dynamometer does allow the user to record the actual force exerted by the subject, which is not done in any of the tests previously discussed. The procedure appears to be safe, but it might be limited with respect to clinical utility because of its lack of cost-effectiveness.

Comment Regarding the DBC110 and Sitting Dynamometer Literature

The two testing types that are the most costly and the least studied are those involving the use of the DBC110 and the sitting dynamometer, the more promising of these devices being the former. Both are high-tech testing devices that have been little studied for validity or reliability in testing endurance of low back extension. We do not feel that a reasonable recommendation for clinical use for isometric back extension endurance testing can be made at this time, judging from the evidence reviewed.

Comment Regarding Subject Motivation and Psychologic Factors

To what degree isometric extension endurance tests actually measure physiologic performance remains to be determined. A more objective assessment of fatigue might be obtained by measuring the rate of fatigue-induced changes that occur in the muscle through use of EMG.[24,35] For the clinician, two major disadvantages of using EMG frequency analysis are cost and time.[5] EMG power spectral analysis provides the opportunity to compare the subject's perceived level of fatigue with the actual fatigue rate of individual muscles.[33] In one study, subjects with chronic LBP and control subjects had increased EMG readings when performing the Sorensen test, but the readings for the subjects with LBP were significantly higher; the authors proposed that this was caused by a decrease in the contractile apparatus or by impaired motor unit recruitment due to poor motivation or pain.[37]

Psychologic issues of motivation and fatigue must be better studied in relation to isometric extension endurance testing before a statement can be made regarding anatomical and physiologic contributions to this diagnostic test. Some authors have proposed that a disadvantage of endurance testing is its dependence on subject motivation, inasmuch as subjects maintain a given submaximal target force to their own perceived limit of fatigue.[4,24,33,35] Many factors influence a person's perception of exertion. In our brief review of the PsycINFO database, we found 3 major psychologic issues that influence endurance performance: personality types, cultural context, and task feedback.

Subjects who possess personalities motivated by achievement and competition tend to be better at endurance tasks. Traits of these individuals include competitiveness,[44] self-motivation,[45] leadership qualities,[46] ambition, organization, deference, dominance, endurance, self-control, tough-mindedness,[47] lower rates of perceived exertion,[48] less negative feelings during endurance tasks,[48] the ability to activate emotion appropriate for the task,[49] and control of fatigue and pain.[49] These traits might be critical in differentiating poor endurance performers from good performers, even when physiologic parameters are similar. For example, 11 runners were tested through use of a 30-minute endurance run at 90% of the maximum volume of oxygen intake; the results demonstrated that those who could not complete the run had significantly higher rates of perceived exertion and significantly more negative feelings than did the finishers. All cardiovascular measurements except heart rate were not significantly different between those who could complete the run and those who could not.[48]

The effect of personality traits on endurance may extend beyond athletes to nonathletes, inasmuch as certain personality types are susceptible to working beyond their endurance and recuperative capacities. These people include business executives, doctors, lawyers, accountants, clergymen, and housewives.[50] It is possible that personality traits influenced the extension endurance data reported by Alaranta et al.[16] Because blue-collar workers are constantly exercising their backs during work and because number of years of work time with physical loading has a significant positive correlation with longer endurance times[1,18] one might think that blue-collar workers would have more physical capacity for endurance than white-collar workers. However, this was not the case in the study by Alaranta et al.[16] In their study of 475 workers who performed a modified Sorensen test in which the ankles were fixed and the arms were held along the sides, white-collar workers outperformed blue-collar workers in every age group except one (Table 3). In interpreting this observation, Alaranta et al[16] suggested that physical incapacity among blue-collar workers should be more vigorously addressed.

Personality characteristics common in those who perform well on endurance tasks may suggest that the white-collar workers performed better because they were more psychologically suited to the tasks and responded accordingly. It is possible that subjects perform better on these tests because of motivational factors alone. If this is true, the validity of the test in the context of physical performance alone must be questioned.

It is certain that cultural behaviors can affect endurance capacity. Performing to fatigue might be more acceptable or be encouraged more in certain cultures than in others; this could limit the results of studies reviewed to certain geographic locations. For example, a study examining the Chinese cultural model of motivation for learning upholds that every child is expected to strive with an enduring desire to learn. This includes strong cultural values for self-determination, diligence, endurance of hardship, and concentration.[51] In this light, Ito et al[5] reported endurance times in a sample of Japanese (professional) subjects that were substantially higher than the endurance times reported in North America by other authors. Although differences in methods certainly might have contributed to the difference, it is possible that cultural context is at least partially responsible for the higher values. The impact of cultural context on measurements of isometric extension endurance needs to be assessed in order for published research to be more externally valid.

The term *task-centered feedback* refers to how a participant in an endurance task monitors progress; this is a motivational factor underlying behavior during endurance activities. Sustained physical and sensory involvement generates clear, concrete, and inherently reinforcing feedback to the participant; this contrasts with the type of feedback that is obtained in settings in which feedback is not novel or not clear.[49,52] Subjects performing isometric endurance tests receive little to no feedback from the environment; subjects perform to fatigue, yet there is no inherent reward, inasmuch as they do not move anything or go anywhere. Furthermore, the endpoint (fatigue) is a negative one and there are no intermediate or short-term goals for the subject to work toward. Future research should consider how to overcome the issue of this unclear feedback system. One way to approach it might be to provide standardized verbal coaching to the subject during the test as a form of short-term feedback until he or she reaches exhaustion.

Limitations of This Study

Only 2 databases were used to search for isometric back extension endurance information, and it is possible that other relevant information might have been found in other databases. We chose to search MEDLINE because of the breadth and quality of journals indexed therein, and we chose to search the ICL to find out whether there was any work done in this area reported in chiropractic periodicals not recognized by *Index Medicus*. We did not look at any ICL entries dated 1998 or 1999 because we did not have access to a computerized version of the database at the time of the literature search phase of this review, and the 1985-1997 ICL search yielded no results for inclusion in the study. It is possible that the ICL indexes one or more articles germane to isometric endurance testing that were published in 1998 or 1999. However, the *Journal of Manipulative and Physiological Therapeutics* is indexed in MEDLINE as well, so we would not have missed any publications from this periodical; articles in other journals might have been missed in the years we did not search.

Perhaps a search in the *Cumulative Index to Nursing and Allied Health Literature* would have provided a few more studies from the physical therapy field for analysis. Several studies on isometric endurance testing came from Scandinavian researchers. We are unaware of any predominately Scandinavian databases to search through, but it is conceivable that such a database would reveal more studies.

Our search of PsycINFO was not exhaustive. We conducted the PsycINFO search simply to survey the psychologic research available on the topics of endurance, motivation, and fatigue, because this factor did not receive much attention in the 37 studies analyzed in our review. A vast amount of literature is available on these topics; the breadth and depth of psychologic research available prohibited us from discussing all of it in the present article. To attempt to append a thorough assessment of that literature here would be sophomoric and would add far too many pages to this already lengthy review. We hope that this paper will stimulate someone to investigate the relationship between psychologic factors and back endurance testing.

Although it was not part of the design of this review to rate the quality of research presented in the studies, variation in research quality was observed. This factor could account for variation in study results, and we did not attempt to provide for this possibility by rating the studies. Perhaps a more thorough assessment of the literature—one that would include more databases and rank reviews of the included research—could provide a more definitive statement of the clinical utility of this group of diagnostic tests.

One problem in synthesizing the data reported in the literature is that various authors used different criteria for determining which subjects were healthy and which subjects were normal. We attempted to provide for this with appropriate annotations in the data tables and in the text. In addition, the variability in how authors reported their data, particularly reliability data, posed a significant challenge to assimilating this information in our review. When data were not available, we recorded this fact rather than try to judge whether it was necessary to report it.

CONCLUSION

Six different types of back extension endurance tests were found in the literature. A major finding of this review is that when the Sorensen test, the pulling test, or the prone isometric chest raise was used to test isometric extension endurance of the low back, subjects with LBP demonstrated lower endurance times. Some data support the assertion that this might provide a mechanism for identifying subjects who are at risk of having LBP in the future. On the basis of the literature reviewed, we feel that the Sorensen test might be of value when used as a screening tool for preventive measures if it is used in subjects with a history of severe LBP.

Regardless of the procedure used, a disadvantage of back muscle endurance testing is that it depends on the motivation of the subject to complete the test to his or her own perceived limit of fatigue. No cost-effective clinical means of addressing this issue has been identified, and little research incorporating psychologic outcome measures for motivation and perceived effort during isometric low back endurance testing has been identified.

Summarily, the pulling test requires the use of a strain-gauge dynamometer and garners some support from 3 studies. The prone static chest raise and the prone double straight-leg raise are easy to use in the clinic, but neither has a very substantial research base to support it at this time. The Sorensen method enjoys abundant positive support in the literature; this test seems to be a valid, reliable, and useful outcome measure for tracking changes in isometric extension endurance capacity in the clinical setting.

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