Performed vs. predicted static endurance of the back extensors: Correlation or conflict

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Abstract. *Background and objective:* Identifying methods of accurately predicting endurance capacity of the back extensor muscles is of immense value to both patients and clinicians. This study aimed to develop a multiple regression equation using demographic and anthropometric measurements to predict back endurance and to investigate the association between performed back endurance results and back endurance predictions.
Materials and methods: 376 healthy women and men aged 21–62 y were recruited consecutively. All participants underwent the Biering-Sørenson test of Static Muscular Endurance. Height and weight were measured using standard procedures. Percentage body fat was estimated using bioelectrical impedance analysis. Body mass index, lean body mass and body fat mass were calculated. Based on these a regression model was used to generate predictive equation for endurance time.
Results: The final regression model which included demographic and anthropometric variables could account for 43% of the variability in back muscle endurance. Pearson's product correlation coefficient for the association between performed static endurance and the predicted endurance were ($r = -0.129$; $p = 0.074$) and ($r = 0.671$; $p = 0.000$) for male and female participants respectively. Paired t-test showed significant difference ($p = 0.000$) between the performed static endurance and predicted endurance among the male participants but not among the female counterparts ($p = 0.959$). Endurance time of males (119 ± 49.8 secs.) was significantly greater ($p = 0.014$) than that of the females (106 ± 47.6 secs.).
Conclusion: Regression equation seems to be moderately valid in predicting endurance time of the back extensors among females only. We conclude that simple anthropometric measures cannot accurately predict back endurance without significant errors. The larger error of prediction obtained for the male participants could be indicative of an increasing influence of motivational/psychosocial factors that are known to be independent of motor ability in physical performance testing.

Keywords: Static endurance, back extensor muscles, Sørenson test, endurance time, predictive equation

1. Introduction

Different back function tests of force, strength, endurance, mobility and fatigue have been studied for their efficiency in detecting associations of back function and low-back pain (LBP) [10,19], for monitoring the effects of intervention or rehabilitation [18], pre-employment [7] return to work [15], work capacity, back disorders, preventive medicine and maintenance or enhancement of back muscle function [26]. Back strength and endurance testing are the most commonly employed methods for testing back function in health and disease in clinical and epidemiological research [4, 12,25].

Back extensor muscles' endurance has been reported to be related to low back health [2,4,5,11,14,20]. Two broad methods of testing spinal muscle endurance have been reported. These include EMG studies during specific postures or movements and mechanical assessment using the period of time a person can maintain specific postures or perform specific movements with or without external load [22]. The mechanical endurance tests include: static or isometric endurance testing; dynamic or isotonic endurance testing; and isokinetic testing [22,24]. Of the assessment strategies available,

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static endurance testing seems to be cost-effective and requires little equipment for testing [24].

The Biering-Sørensen test of Static Muscular Endurance (BSME) as a clinical tool for diagnosis of low back muscular endurance has been widely used to assess the endurance capability of the back extensor muscles in health and disease [1,4,24]. The BSME has been reported to be valid, reliable, safe, practical, responsive, easily administered, inexpensive; it is also distinguished by a substantial quantity of compiled data [1,6,24]. Biering-Sørensen [4] investigated whether indicators of prognostic value for LBP are identifiable by means of various anthropometric and physical performance measurements. Previous investigations have used the BSME as a predictor of low-back health, based on endurance time [4,5]. Furthermore, several anthropometric measures such as BMI, body weight, height, and body fat have been reported to predictive of low back muscle performance [3,8,9,17,26]. The assessment of back muscles endurance is believed to be problematic among patients with LBP. Therefore, identifying methods of accurately predicting endurance capacity of the back extensor muscles is of immense value to both patients and clinicians. This study aimed to develop a multiple regression equation using demographic and anthropometric measurements to predict back endurance and to investigate the association between performed back endurance results and back endurance predictions.

2. Method

2.1. Subjects

A sample of 376 consecutive subjects, 183 women and 193 men, aged 21–62 y were recruited for this study. Eligible participants were not engaged in any systematic exercise program of the lumbar or hip extensor muscles at the time of the study. Participants were excluded if they had a history of symptomatic LBP within one year to the time of the study, if they had any obvious spinal deformity or neurological disease, if they were involved in competitive sport or athletics, if they reported a history of cardiovascular diseases contraindications to exercise, if they were pregnant, and if they had any disability limiting the ability to exercise. They were screened via interview to ensure compliance with the selection criteria. The participants were volunteers who included staff, students and patients' relatives recruited via research advert and invitations from University of Ibadan, University College Hospital, Ibadan and the surrounding metropolis, Ibadan, Nigeria. The ethical approval for this study was obtained from the University of Ibadan/University College Hospital, Institutional Review Committee. The participants were fully informed about the purpose of the study and their consents were obtained before measurements were taken.

2.2. Anthropometric measurements

Anthropometric measurements included height, weight, Body Mass Index (BMI), Lean Body Mass (LBM) and Body Fat Mass (BFM). A height meter (Seca Mod. 220 C€, Germany) calibrated from 0–200 cm was used to measure the height of each participant to the nearest 0.1cm. The participants' heels, the back and the occiput were touching the stadiometer scale with the participants looking straight ahead during measurement. Body weight in light clothes was measured to the nearest 0.1 kg using a weighing scale (Seca Mod. 762 1019009 C€, Vogel and Halke, Germany) calibrated from 0–120 kg with the participant in standing and shoes off. A Bioelectric Impedance Analysis (BIA) device (Omron BF306; Mod. HBF-306-E. C€, Japan) was used to measure the percentage body fat (PBF) of all participants. BMI, LBM and BFM were calculated.

BMI was calculated by dividing weight in kilograms by height in metres squared (Wkg/Hm^2). Body Fat Mass (BFM) was calculated from the BIA estimate of the Percentage Body Fat (PBF) using the formula: BFM = (PBF X total body weight)/100. Lean body mass (kg) was calculated from the PBF estimate of the BIA. LBM (kg) was calculated by subtracting BFM (kg) from total body weight (kg).

2.3. Procedures

The BSME otherwise known as the Sørensen test was used in the assessment of back extensor muscles endurance. It measures how long (to a maximum of 240 seconds) a subject can keep the unsupported trunk (from the anterior iliac crests level up) horizontal while lying prone on an examination table [4,24]. The test procedure was explained and demonstrated to the participants at inclusion. Prior the test, the participants warmed up using a Sportop bicycle ergometer (B600 model, UK) unloaded for 2 min at self determined speed, 5 min before the test as recommended by Alaranta [1]. During the test, the participant lay on a standard treatment table in the prone position with the upper

Fig. 1. The Biering-Sørenson test of Static Muscular Endurance.

edge of the iliac crests aligned with the edge of the table such that the upper body was suspended horizontally (Fig. 1). The lower body was fixed to the table by two non-elastic straps, located around the pelvis and ankles respectively with a pillow used to relieve stress on the ankle joint. With the arms held along the sides [2] the participant was asked to isometrically maintain the upper body in a horizontal position. Horizontality was ensured by asking the participant to maintain contact between his/her back and a weighted ball hanging from a Guthrie Smith frame (Fig. 1). Once a loss of contact with the weighted ball for more than 10 seconds was noticed the participant was encouraged once to immediately maintain contact again. If the position was not immediately corrected, or if the participant claimed he could no longer hold the position due to fatigue, discomfort or pain the test was ended. The total time from the onset of the test to trunk flexion and loss of the static neutral position was recorded as the endurance time or the isometric holding time (in seconds) with the stop watch (Quartz USA). The test was conducted only once and thereafter the participants were discharged [1].

2.4. Data processing

Descriptive statistics of means and standard deviation were used to summarize the data. Independent t-test was used to compare the physical characteristics and the endurance time among both genders. Pearson's correlation was used to analyze the relationship between endurance time and age, weight, body mass index (BMI), percent body fat (PBF), lean body mass (LBM) and body fat mass (BFM) among the male and female participants respectively. Regression analysis was also used to generate equation for predicting static endurance of the back extensors from demographic and anthropometric variables. Paired sample correlation analysis was used to determine the degree to which the performed static endurance was associated with the predicted endurance. Paired t-test was used to compare the difference between performed static endurance and predicted endurance. The α level was set at 0.05. Data analysis was carried out using SPSS 13.0 version software (SPSS Inc., Chicago, Illinois, USA).

3. Results

The participants mean (SD) age was 38.9 $\pm$ 13.5y. The male (38.9 $\pm$ 13.9 y) and female (38.9 $\pm$ 10.6 y) mean age was similar. The physical characteristics, measures of adiposity and the mean endurance time for both males and females are presented in Table 1. The males were significantly taller and heavier than their female counterparts. However, the females had a significant higher BMI than the males. The males demon-

Table 1
Independent t-test Comparison of the physical characteristics and the mean endurance time among both male and female participants

Variables	Male ($N = 193$) Mean ± S.D	Female ($N = 183$) Mean ± S.D	t-value	p-value
Age	38.9 ± 13.9	38.9 ± 3.16	−0.490	0.961
Height	1.68 ± 1.07	1.62 ± 1.07	7.981	0.000*
Weight	63.8 ± 11.1	63.8 ± 13.0	−0.020	0.984
BMI	22.6 ± 3.78	24.5 ± 4.69	−4.390	0.000*
PBF	20.5 ± 7.00	32.8 ± 7.37	−16.50	0.000*
LBM	50.2 ± 6.79	42.1 ± 6.00	12.2	0.000*
BFM	13.6 ± 6.75	21.6 ± 8.80	−9.93	0.000*
ET	119 ± 49.8	106 ± 47.6	2.48	0.014*

*Indicates significance.
Key: BMI = Body Mass Index; PBF = Percentage Body Fat; LBM = Lean Body Mass; BFM = Body Fat Mass (Fat weight); ET = (Endurance Time); S.D = Standard Deviation.

strated a higher endurance time than the female counterparts. Pearson's product moment correlation analysis revealed an inverse but significant correlation between endurance time and age, weight, BMI, PBF and BFM among the male and female participants respectively as presented in Table 2.

Regression analysis showed a significant linear relationship between endurance time and the dependent variables (the demographic and the anthropometric variables). A regression equation was generated for predicting endurance time from age and anthropometric variables such as Height, Weight, BMI, PBF, LBM and BFM. The final regression model accounted for 43% of the variance in back endurance. The regression equation for predicting endurance time (Y) from age, Height, BMI, PBF, LBM and BFM for males is:

Y = 257.985 − 1.673 (Age) − 76.70 (Height) − 3.873 (BMI) + 0.710 (PBF) + 0.534 (LBM) − 1.133 (BFM)

The regression equation for females is respectively:

Y = 420.960 − 1.535 (Age) − 108.286 (Height) − 0.906 (Weight) − 0.900 (BMI) − 0.889 (PBF) + 0.492 (LBM) + 0.386 (BFM)

The Pearson's product moment correlation between performed static endurance (endurance time in sec.) and the equation-based endurance time were $r = -0.129$; $p = 0.074$ and $r = 0.671$; $p = 0.000$, for male and female participants respectively. However, a moderate correlation was obtained between performed static endurance and the equation predicted endurance among the female participants. Performed static endurance (119 ± 49.8 s) versus equation predicted endurance (27.0 ± 16.2 s) showed a significant difference ($t = 23.46$; $p = 0.000$) among the male participants. However, the performed static endurance (106 ± 47.6s) and the equation predicted endurance (106 ± 31.7 s) was not significantly different ($t = -0.052$; $p = 0.959$) among the female participants.

4. Discussion

This study investigated the degree to which performed static endurance was associated with equation-based predicted endurance. The result revealed a moderate correlation between the performed and predicted back endurance among women only. This study also found no significant difference in the endurance time from physical performance testing compared with endurance time from the prediction equation among the female participants. The final regression model which included demographic and anthropometric variables could account for approximately 43% of the variability in back muscle endurance. Based on the outcome of this study, regression equation seems to be moderately valid in predicting endurance time of the back extensors among females only.

In the regression equation, total body weight was not a variable for predicting endurance among males, however, height, weight, BMI and PBF reflected better among females. Previous reports on the influence of anthropometric measures on physical performance testing results have been inconsistent and controversial. Some reports implicate anthropometric factors such as BMI, body weight, height, and body fat to influence back function testing results [3,8,9,17,26] while a study reported no significant influence at all [23]. However, we opine that the significant anthropometric difference between the male and female participants could contribute to the endurance differences.

The males in this study had significantly greater performed static endurance when compared with their female counterparts. Numerous reports suggest that females have a greater muscular endurance capacity when compared to males [4,11,16,21] but denied in other studies reporting the opposite [13,20]. The present study involved homogenously local Africans; however, it is not known whether ethnic and racial differences have an influence on the pattern of low back endurance.

Finally endurance time was found to be inversely correlated with age and the anthropometric variables respectively among both genders. This finding is consistent with previous investigations which con-

Table 2
Pearson's product moment correlation analysis between endurance time and the dependent variables of all the male and female participants

Dependent variables	Male participants ($N = 193$)	Female participants ($N = 183$)
	Pearson Product Moment Correlation coefficient (r) (p-value)	(p-value)
Age	-0.572^{**} (0.000)	-0.559^{**} (0.000)
Height	0.140 (0.053)	-0.234^{**} (0.001)
Weight	-0.326^{**} (0.000)	-0.461^{**} (0.000)
BMI	-0.432^{**} (0.000)	-0.407^{**} (0.000)
PBF	-0.546^{**} (0.000)	-0.535^{**} (0.000)
LBM	-0.017 (0.814)	-0.240^{**} (0.001)
BFM	-0.521^{**} (0.000)	-0.525^{**} (0.000)

$^{*}p < 0.05$, $^{**}p < 0.01$.
Key: BMI = Body Mass Index; PBF = Percentage Body Fat; LBM = Lean Body Mass; BFM = Body Fat Mass (Fat weight); ET = (Endurance Time).

firmed the presence of age influence on isometric endurance time [3,4,25]. Our finding is also consistent with studies that reported correlation among anthropometric measures and endurance time among healthy subjects of both genders [3,8,9,17].

A potential limitation of this study was the sample bias, as the participants were volunteers who were recruited consecutively, therefore future studies should address the problem of external validity. We tried to minimize the effect of motivation on performance of the test by giving the participants full information about the nature of the test and they were all given uniform and standardized encouragement during testing. However, studies are warranted that will address how different variables may influence back muscle endurance.

In conclusion, regression equation seems to be moderately valid in predicting endurance time of the back extensors among females only. The prediction of back endurance would be useful in endurance exercise prescription or to determine the pre-injury back endurance and it may be of immense value to both patients and clinicians. It is important to note that simple anthropometric measures cannot accurately predict back endurance without significant errors. The increase of in the prediction error for the male participants could be indicative of a possible higher influence of motivational/psychosocial factors that are known to be independent of motor ability in physical performance testing. Healthy Nigerian male adults had significantly greater timed back extensor muscles' endurance compared with their female counterparts. Age and the different measures of adiposity were inversely related with endurance capacity of the back extensor muscles with no gender bias.

References

[1] H. Alaranta, Strength and Endurance testing, in: *The Clinical Application of Outcomes Assessment*, Appleton and Lange, 2000, pp. 158–162.

[2] H. Alaranta, H. Hurri, M. Heliovaara, A. Soukka and R. Harju, Non-dynamometric trunk performance tests: Reliability and normative data, *Scandinavian Journal of Rehabilitative Medicine* **26** (1994), 211–215.

[3] M.C. Battié, S.J. Bigos, L.D. Fisher, T.H. Hansson, M.E. Jones and M.D. Wortley, Isometric lifting as a strength predictor of industrial back pain, *Spine* **14**(8) (1989), 851–856, Ex.26–72.

[4] F. Biering-Sørensen, Physical measurements as risk indicators for low-back trouble over a one-year period, *Spine* **9** (1984), 106–119.

[5] F. Biering-Sørensen, A one-year prospective study of low back trouble in a general population. The prognostic value of low back history and physical measurements, *Dannish Medical Bulletin* **31** (1984), 362–375.

[6] C. Demoulin, M. Vanderthommen, C. Duysens and J. Crielaard, Spinal muscle evaluation using the Sorensen test: a critical appraisal of the literature, *Joint Bone Spine* **B73** (2006), 43–50.

[7] I. Ebrahimi, G.R. Hosseini, S.M. Salavati, H. Farahini and A.M. Arab, Clinical trunk muscle endurance tests in subjects with and without low back pain, *Medical Journal of the Islamic Republic of Iran* **19**(2) (2005), 95–101.

[8] L.E. Gibbons, T. Videman and M.C. Battié, Determinants of isokinetic and psychophysical lifting strength and static back muscle endurance: A study of male monozygotic twins, *Spine* **22** (1997), 2983–2990.

[9] M.T. Gross, E.S. Dailey, M.D. Dalton, A.K. Lee, T.L. McKiernan, W.L. Vernon and A.C. Walden, Relationship between lifting capacity and anthropometric measures, *Journal of Orthopaedic and Sport Physical Therapy* **30** (2000), 237–247.

[10] D.P. Gross, M.C. Battié and J.D. Cassidy, The prognostic value of functional capacity evaluation in patients with chronic low back pain: part 1 timely return to work, *Spine* **29** (2004), 914–919.

[11] K. Jörgensen and T. Nicolaisen, Trunk extensor endurance: determination and relation to low-back trouble, *Ergonomics* **30** (1987), 259–267.

[12] A. Keller, J.G. Johansen, J. Hellesnes, J.I. Brox and W.S. Marras, Predictors of isokinetic back muscle strength in patients with low back pain, *Spine* **24** (1999), 275–280.

[13] P.G. Kroll, L. Machado, C. Happy, S. Leong and B. Chen, The relationship between five measures of trunk strength, *Journal of Back and Musculoskeletal Rehabilitation* **14**(3) (2000), 89–97.

[14] J. Latimer, C.G. Maher, K. Refshauge, I. Colaco and G.L. Smidt, The reliability and validity of the Biering-Sorensen test in asymptomatic subjects and subjects reporting current or previous nonspecific low back pain, *Spine* **24** (1999), 2085–2089.

[15] M. Lemstra, W.P. Olszynski and W. Enright, The sensitivity and specificity of functional capacity evaluations in determining maximal effort. A randomized trial, *Spine* **29** (2004), 953–959.

[16] A.F. Mannion and P. Dolan, Electromyographic Median Frequency Changes During Isometric Contraction of the Back Extensors to Fatigue, *Spine* **19** (11) (1994), 1223–1229.

[17] A.F. Mannion, M. Müntener, S. Taimela and J. Dvorak, A randomized clinical trial of three active therapies for chronic low back pain, *Spine* **24** (1999), 2435–2448.

[18] A.F. Mannion, S. Taimela, M. Müntener and J. Dvorak, Active therapy for chronic low back pain, Part 1. Effects on back muscle activation, fatigability, and strength, *Spine* **26** (2001), 897–908.

[19] W.S. Marras, K.G. Davis, S.A. Ferguson, B.R. Lucas and P. Gupta, Spine loading characteristics of patients with low back pain compared with asymptomatic individuals, *Spine* **26** (2001), 2566–2574.

[20] T. Mayer, R. Gatchel, J. Betancur and E. Bovasso, Trunk muscle endurance measurement: isometric contrasted to isotonic testing in normal subjects, *Spine* **20** (1995), 920–926.

[21] S.M. McGill, A. Childs and C. Liebenson, Endurance times for back stabilization exercises: Clinical targets for testing and training from a normal database, *Arch Phys Med Rehabil* **80** (1999), 941–944.

[22] M.T. Moffroid, Endurance of trunk muscles in persons with chronic low back pain. Assessment, performance, training, *Journal of Rehabilitation Research and Development* **34**(4) (1997), 440–447.

[23] M.T. Moffroid, S. Reid, S.M. Henry, L.D. Haugh and A. Ricamato, Some endurance measures in persons with chronic low back pain, *Journal Orthopaedic Sports Physical Therapy* **20** (1994), 81–87.

[24] C.E. Moreau, B.N. Green, C.D. Johnson and S.R. Moreau, Isometric back endurance tests: a review of the literature, *Journal of Manipulative and Physiological Therapeutics* **24**(2) (2001), 110–120.

[25] A. Ropponen, The role of heredity, other constitutional structural and behavioral factors in back function tests, Studies in Sport, *Physical Education and Health* (2006), 78, University of Jyväskylä, Jyväskylä.

[26] A. Ropponen, E. Levälahti, T. Videman, J. Kaprio and M.C. Battie, The role of genetics and environment in lifting force and isometric trunk extensor endurance, *Physical Therapy* **84** (2004), 608–621.