Isometric endurance of the back extensors in school-aged adolescents with and without low back pain

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Abstract. *Background and objective*: Studies on back extensor endurance in adolescents are scarce. This study sought to establish reference data and pattern of back extensor endurance in school-aged adolescents with and without low-back pain (LBP) from Nigeria.
Subjects and methods: This study recruited 625 adolescents aged 11 to 19 years from eight randomly selected secondary schools. The modified Biering-Sørensen test of Static Muscular Endurance (BSME) was used to assess isometric endurance of the back extensors. Demographic and anthropometric data were collected. A modified LBP questionnaire was used to assess the presence of LBP. Descriptive and inferential analyses were used to analyze data. Significance was set at 0.05 α-level.
Results: The mean isometric holding time (IHT) of all the participants was 132.9 $\pm$ 65.6. Males had significantly higher significant ($p = 0.026$) IHT than females. Adolescents without LBP had a higher significant IHT ($p = 0.042$) than those with reported history of previous LBP and those with present LBP ($p = 0.000$) respectively. Using percentile values, poor endurance was defined as IHT that is $<$ 90.0 s and $<$ 67 s for males and females respectively; medium endurance was defined as IHT that ranged between 90 and 193 s and 67 and 170 s for males and females respectively while good endurance was defined as IHT that is $>$ 193 s and $>$ 170 s for males and females respectively. IHT was significantly related to each of body mass index, hip circumference and waist-to-hip ratio ($p < 0.05$).
Conclusion: Isometric back extensors endurance in Nigerian adolescents was comparable to the original Biering-Sørensen mean value. Majority of the participants had medium endurance performance with the back endurance pattern in the ratio 1:2:1. Male had higher isometric back extensors endurance than females. Decreased isometric back extensors endurance was associated with the presence of LBP in adolescents.

Keywords: Back muscles' endurance, Sørensen test, back extensor muscles, isometric-holding time, adolescents, Nigerians

1. Introduction

Muscular endurance of the back extensors has been reported to be assessed less frequently than muscular strength, although the endurance capabilities of these muscles may be as important as or even more important than strength in the prevention and treatment of low back pain (LBP) [37]. Assessment of endurance of the back extensor muscles is important in the clinical evaluations of disability or rehabilitation outcome [29]. Low levels of static endurance in the back extensor muscles are associated with higher rates of LBP [43], decreased proprioceptive awareness [12], poor balance [20], and decreased productivity in the workplace [32], increased muscular fatiguability [2,39] and overloads soft tissue and passive structures of the lumbar spine [49].

The back extensor muscles' endurance can be assessed by both simple isometric and more sophisticated isokinetic dynamometers. However, the Biering-

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Sørensen test of Static Muscular Endurance (BSME) as a simple clinical tool for the assessment of low back muscular endurance has been reported to be valid, reliable, safe, practical, responsive, easily administered and inexpensive [2,47]. The BSME either in its original version or as variants is believed to provide a global measure of back extension endurance capacity [34]. The BSME has been used to evaluate back extensor endurance holding times in overseas populations in both patients and healthy subjects with substantial compiled mean values [2,21,30]. The BSME has become the tool of reference for evaluating muscle performance in patients with LBP, most notably before and after rehabilitation programs [7]. However, studies on back extensor endurance in adolescents are scarce, despite the reported relationship between LBP and isometric back endurance and growing epidemics of LBP during the adolescent years which may be a precursor for chronic LBP in adulthood [15]. This study sought to establish reference data and pattern of back extensor endurance in school-aged Nigerian adolescents.

2. Materials and methods

The World Health Organization [50] definition of adolescents as people ranging from 10 to 19 years of age was adopted. The participants were fully informed about the purpose of the study and their assents were obtained before measurements were taken. A total of 625 school-aged adolescents whose ages ranged between 11 and 19 years were consecutively recruited into the study. Participants were excluded if they had any obvious spinal deformity or neurological disorder such as post-polio syndrome, if they were involved in competitive sport/athletics or in any systematic exercise program of the lumbar or hip extensor muscles, and if they reported a history of cardiovascular diseases contraindications to exercise. The participants were students from eight randomly selected secondary schools from Ile-Ife, Osun state, Nigeria.

2.1. Procedures

Demographic data of all the participants were collected. The height of each participant was measured to the nearest 0.1 m with a height meter (Seca Mode. 220 CЄ, Germany) calibrated from 0–200 cm. The participant's heels, the back, and the occiput were touching the scale with the participants looking straight ahead during the measurement. Weight was measured to the nearest 1.0 kg with a weighing scale (Hanson bathroom scale) calibrated from 0–120 kg with the participant in light apparel and standing with shoes off. Waist Circumference (WC) was measured to the nearest 0.1 cm with reference taken midway between the lowest rib and the iliac crest to the nearest millimetre using a flexible tape in the horizontal plane with the participant breathing normally [45]. Hip Circumference (HC) was measured to the nearest 0.1 cm with reference at the level of the greater trochanters to the nearest millimetre using a flexible tape [45] and was used in the calculation of Waist-to-Hip Ratio (WHR). Body mass index (BMI) was calculated by dividing weight in kilograms by height in meters squared (Wkg/Hm^2). Waist-to-hip ratios (WHR) were obtained by dividing waist circumference by hip circumference while Waist-to-height ratios (WHtR) were obtained by dividing waist circumference by height. A modified four section questionnaire which sought information on demographic characteristics, activities in school, daily activity and lifestyle, and the history of LBP by Sanya and Ogunmike [41] was used to assess participants' demographic profile and presence of LBP.

The BSME was used in the assessment of back extensor muscles endurance [3]. It measures how long (to a maximum of 240 seconds) the participant can keep the unsupported trunk (from the anterior iliac crests level up) horizontal while lying prone on a plinth with their hands held by their sides. The test procedure was explained and demonstrated to the participants at inclusion. The participant lies on the examination table in the prone position with the upper edge of the iliac crests aligned with the edge of the table. The lower body was fixed to the table by two non-elastic straps, located around the pelvis and ankles respectively with a towel used to relieve stress on the ankle joint. With the arms held along the sides touching the body, 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. Once a loss of contact with the suspended 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 (Fig. 1). 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)

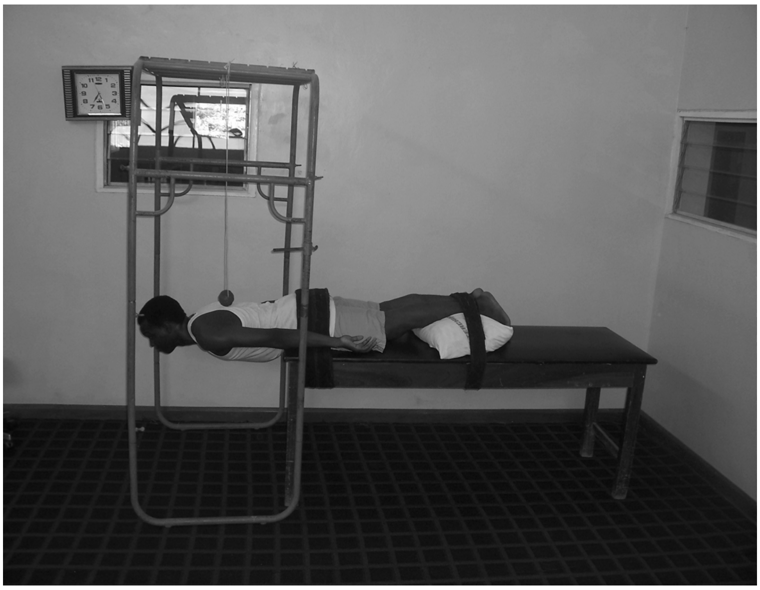

Fig. 1. The Biering-Sørenson test of Static Muscular Endurance (Courtesy of Mbada et al., 2009).

with the stop watch (Quartz USA). The test was conducted only once and thereafter the participants were discharged [2].

2.2. *Data analyses*

Data were summarized using the descriptive statistics of mean, standard deviation and percentile. Inferential statistics involving Independent t-test, Pearson's moment correlation and Analysis of Variance (ANOVA) were also used. Percentile values were used as cut-off points to determine the pattern of static back endurance, less than 25th percentile i.e. isometric holding time < 90.0 s and < 67 s were regarded as poor endurance for male and female participants respectively, between 25th and 75th percentile i.e. isometric holding time 90–193 s and 67–170 s were regarded as medium endurance for males and females respectively. While greater than 75th percentile i.e. isometric holding time > 193 s and > 170 s were regarded as good endurance for males and females respectively. The α-level was set at 0.05. The data analysis was carried out using SPSS 13.0 version software (SPSS Inc., Chicago, Illinois, USA).

3. Results

Six hundred and twenty five participants, (290) (46.4%) male and 335 (53.6%) female adolescents were involved in this study. The participants' ages ranged between 11 and 19 years with the mean age of 13.5 ± 1.55 y. The general characteristics of the participants are presented in Table 1. The mean isometric holding time (IHT) of all the participants was 132.9 ± 65.6 s. Independent t-test comparison (Table 2) showed that the IHT of male participants was significantly higher ($p = 0.026$) than that of the female participants. Weight and the different measures of adiposity (BMI, WC, HC and WHtR) were significantly higher among the female participants.

Three hundred and nine participants (49.4%) had previous episode of LBP within the last one year while 70 participants (11.2%) had present episodes of LBP. The independent t-test comparison showed that participants without LBP (138.2 ± 65.6 s) had a significantly higher IHT ($t = -2.036$; $p = 0.042$) than those with reported history of previous LBP (127.6 ± 65.2 s). Similarly, participants without LBP (138.2 ± 65.6 s) had higher significant IHT ($t = 3.649$; $p = 0.000$) than those with present LBP (106.3 ± 57.2 s).

The pattern of the endurance performance of all the participants is presented in Table 3. 316 (50.6%) of the participants were within the medium endurance performance category. The pattern of performance of isometric back endurance as good, medium or poor respectively, was observed in this study to be ratio 1:2:1. The frequency of participants in the poor endurance category was more among those with LBP. Pearson's product moment correlation analysis showed a significant

Table 1
Physical characteristics and isometric holding time of all participants ($N = 625$)

	Mean ± S.D	Min	(Q1) 25th percentile	median	(Q3) 75th percentile	Max
Age	13.5 ± 1.55	11.0	12.0	13.0	15.0	19.0
Height	1.55 ± 0.10	1.29	1.48	1.55	1.60	1.85
Weight	46.0 ± 10.0	24.0	39.0	45.0	53.0	98.0
BMI	19.1 ± 3.03	10.8	17.1	18.7	20.6	41.9
WC	67.9 ± 6.35	54.5	63.8	67.5	71.0	95.0
HC	81.9 ± 8.72	61.3	75.0	81.3	87.5	126.3
WHR	0.83 ± 0.05	0.70	0.80	0.83	0.87	1.30
WHtR	0.44 ± 0.03	0.40	0.41	0.43	0.46	0.60
IHT	132.9 ± 65.6	14.0	80.0	126.0	182.0	240.0

Key: BMI – Body Mass Index; WC – Waist Circumference; HC – Hip Circumference; WHR – Waist-to-Hip Ratio; WHtR – Waist-to-Height Ratio; IHT – Isometric Holding Time. Q1 – Ist Quartile; Q3 – 3rd Quartile.

Table 2
Independent t-test comparison of physical characteristics and endurance time of male and female participants

Variables	Male	Female	t- cal	p-value
Age (years)	13.7 ± 1.69	13.4 ± 1.38	3.057	0.002
Height (m)	1.55 ± 0.11	1.54 ± 0.79	0.902	0.000
Weight (Kg)	44.6 ± 9.76	47.1 ± 10.1	3.211	0.730
BMI (Kg/m^2)	18.4 ± 2.30	19.7 ± 3.43	5.590	0.000
WC (cm)	67.1 ± 5.62	68.7 ± 6.84	-3.165	0.002
HC (cm)	79.8 ± 7.49	83.6 ± 9.32	-5.571	0.000
WHR	0.84 ± 0.05	0.82 ± 0.06	4.191	0.000
WHtR	0.43 ± 0.32	0.45 ± 0.41	-3.954	0.000
IHT	144.3 ± 64.3	123.1 ± 65.1	4.090	0.026

p is significant at 0.05.
Values of the different variables are expressed as mean and standard deviation (± S.D).
Key: BMI = Body Mass Index; WC = Waist circumference; HC = Hip circumference; WHR = Waist to hip ratio; S.D = Standard Deviation; IHT = Isometric Holding Time.

Table 3
Pattern of isometric back endurance specified in participants with and without LBP

Description	LBP frequency	No LBP frequency	Total frequency
Good	71 (23.0%)	83 (26.3%)	154 (24.6%)
Medium	151 (48.9%)	165 (52.2%)	316 (50.6%)
Poor	87 (28.2%)	68 (21.5%)	155 (24.8%)

Key: Males (Good endurance is > 193 s; Medium endurance is between 90 and 193 s; Poor endurance is < 90 s); Females (Good endurance is > 170 s; Medium endurance is between 67 and 170 s; Poor endurance is < 67 s).

Table 4
Pearson's product correlation between IHT and the physical characteristics of the participants ($N = 625$)

Dependent variables	Pearson's r	p value
Age	−0.048	0.233
Weight	−0.076	0.057
Height	−0.008	0.848
BMI	−0.104	0.010*
HC	−1.250	0.002*
WC	−0.760	0.056
WHR	0.093	0.020*

*p < 0.05; **p < 0.01.
Key: BMI = Body Mass Index; HC = Hip Circumference; WC = Waist Circumference; WHR = Waist-to-Hip Ratio; WHtR = Waist-to-Height Ratio.

inverse correlation between IHT and each of age, BMI, HC, and WHR among the participants (Table 4).

4. Discussion

Muscular endurance is defined as the ability of a muscle to contract repeatedly or generate tension, sustain that tension, and resist fatigue over a prolong period of time [6]. Very few studies have assessed the endurance of the back extensor muscles [8,36,40,42]. This study was motivated by dearth of normative databases or reference values on endurance time of the back extensors in health and disease especially among adolescents. The mean endurance time for all the participants in this study was 132.9 ± 65.6 s. The mean endurance value in this study was comparable with the original Biering-Sørensen holding times (138 s) among adults [3]. Endurance time among healthy participants (138.2 ± 65.6 s) in this study was higher than that reported by Doymaz et al. [8] (97.84 ± 38.94 s) among healthy Turkish adolescents and also higher than the mean endurance values of 113 s reported by Mbada and Ayanniyi [29] in a study among healthy Nigerian adults. However, Moreau et al. [34] in a review of literature submitted that the mean extensor endurance time for mixed-sex groups ranges from 77.76 to 129 s and 39.55 to 54.5 s for healthy subjects and those with LBP respectively. Also, the mean extensor endurance time in mixed-sex groups ranged from 80 to 194 s and 146 to 227 s for men and women respectively. The differences in back extensor muscles' endurance resulting in a wide range of mean endurance times from previous studies may be as a result of numerous methodological variations and sample or population differences. We also suggest that ethnic and racial differences may have strong influence on low back endurance performance results. However, further researches are warranted to confirm these speculations.

This present study found greater back extensor muscles endurance among adolescent males than their female counterparts. This result is at variance with many previous studies among adults that found significantly longer position-holding times in healthy female subjects [3,17–19,22,24,48] and in female patients with LBP [3,35]. However, the result of this study agrees with some few other reports that found higher back muscle endurance in adult men than in women [1,13, 27,33]. Several hypotheses have put forward to explain the gender-related difference in muscular endurance of the back extensor muscles. Gatzke [10] noted that the substantial anatomical, physiological and morphological differences that exist between men and women may affect their exercise capacity and influence the magnitude of response to exercise. Marras et al. [25] reported that the geometry of the trunk of females and males differs. Specifically, due to the gender dependent differences in body segment proportions (females generally have shorter legs and longer torsos than men); hence the forces differ between males and females [46]. Such factors can significantly impact variables such as spine loading [25], mechanical efficiency, and predisposition to injury [5,46].

Similar to studies among adult patients with prior LBP [16,19] or current chronic LBP [16,21,22,41] and to subjects with no history of LBP [16,19,24,26], adolescents with history of previous or present LBP exhibited decreased endurance of the back extensors compared to their healthy counterparts. However, this finding is at variance with some other studies though among adults that reported no significant difference in the endurance time among patients with LBP and that of the healthy subjects [9,44].

The pattern of isometric back extensor muscles endurance described as good, medium or poor performance respectively observed in this study was in ratio 1:2:1. The pattern of endurance performance reported by Luoto et al. [22] in a study among 126 adults without LBP was in ratio 3:3:3. Luoto et al. [22] found good performance in 43 subjects using 104–240 s and 110–240 s as cut-point for men and women respectively; medium performance in 40 subjects using 58–104 s and 58–110 s as cut-point for men and women respectively and poor performance in 43 subjects using < 58 s as cut point for men and women respectively. Nonetheless, the cut-off point used to describe pattern of isometric back endurance by Luoto et al. [22] may not be applicable in this study. Firstly, because the participants in this study were adolescents while those by Luoto et al. [22] were adults. Secondly, higher endurance cut-off values were given to the female subjects compared to their male counterparts. However, this present study found higher back extensor muscle endurance in male subjects than their female counterparts. Similar to a previous study by Mbada et al. [29], this study used percentile values as cut-off points to define pattern of static back endurance as good, medium and poor respectively. It therefore showed that majority of the participants in this study had medium back extensor muscles' endurance.

From this study, age was not significantly related to endurance time in adolescents. This result agrees with findings that reported that age had either little or no influence at all on isometric endurance of back extensor muscles [11] but at variance with other studies that confirmed the presence of age influence in isometric endurance time [4,18]. The relationship between muscular endurance performance and body fat using BMI as a surrogate of adiposity has been much studied. However, very few studies have investigated the influence of measures of central adiposity such as WC, WHR, body fat mass and percentage body fat on muscular endurance of the back extensors [8,28]. This present study investigated the relation between each of BMI, HC, WC, WHR and WHtR on IHT during the BSME. The result revealed that only BMI, HC and WHR showed a significant inverse relationship with muscular endurance of the back extensors among the adolescents. Our finding is consistent with studies that reported significant negative correlation between muscle endurance and fat distribution [8,11,14]. We therefore agree with the submission of Ropponen et al. [34] that anthropometric factors are important in low back muscle performance. Therefore, as the measures of adiposity increase, endurance time of the back extensor muscles decreases.

Identifying high or low muscular endurance has been reported to alert the patient and clinician to a need for possible modifications to the usual treatment regime [31]. McIntosh et al. [31] reported that when evaluating muscle performance in the extremities, an examiner can compare the normal and abnormal sides to quantify diminished function. They concluded that this type of intrinsic control is not available for evaluation of the trunk. Therefore, comparing back endurance test results of patients with LBP to reference data of healthy subjects may help identify the presence of impairment and in turn inform the plan for appropriate intervention based on the assessment of the extent of the muscular dysfunction.

This present study is limited in its external validity, though the schools were randomly selected but the participants were recruited consecutively in those schools. Also, the classification of the participants in this study was based on self report, as no further examination was carried out after they have met the set inclusion criteria. Further research on normative values for isometric back endurance in adolescents is warranted.

5. Conclusion

This study established reference values of isometric back extensor muscles endurance in adolescents with and without LBP. Isometric back extensors endurance in Nigerian adolescents was comparable to the normal Biering-Sørensen mean value. Nigerian male adolescents had significantly higher back extensor muscles endurance than their female counterparts. Adolescents with reported previous or present LBP had decreased back extensors endurance than their unimpaired counterparts. Also, some measures of adiposity (BMI, HC, and WHR) were significantly related to back extensors endurance in adolescents.

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