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Trunk static and dynamic sagittal endurance in healthy young Nigerian adults

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Abstract.
BACKGROUND: Flexion/extension trunk muscle endurance imbalance is more clinically significant than isolated trunk endurance
deficits.
OBJECTIVE: This study provides reference values and correlates of trunk flexion/extension endurance ratio among healthy
young Nigerian adults.
METHODS: A total of 208 volunteers participated in this study. Static Back Extensors Endurance (SBEE), Dynamic Back
Extensors Endurance (DBEE), Static Abdominal Muscles' Endurance (SAME) and Dynamic Abdominal Muscles' Endurance
(DAME) were assessed following standard protocols. Data was analyzed using descriptive and inferential statistics.
RESULTS: The mean age, SBEE, DBEE, SAME and DAME were 22.2 ± 1.76 years, 78.3 ± 41.5 secs, 21.1 ± 9.69 reps, 39.1 ± 24.5 secs and 16.5 ± 15.8 reps respectively. Static and dynamic trunk flexion/extension endurance ratio was 0.63 ± 0.50 and
0.86 ± 0.74 respectively. There were significant differences in trunk static (0.81 ± 0.57 secs vs. 0.53 ± 0.42 secs; p = 0.001)
and dynamic (1.04 ± 0.48 reps vs. 0.74 ± 0.83 reps reps; p = 0.001) flexion/extension endurance ratio in men and women,
respectively.
CONCLUSION: This study established a set of reference values for static and dynamic trunk flexion/extension endurance ratios
among healthy young Nigerians. Men had significant higher trunk flexion/extension endurance than women.
Keywords: Static endurance, dynamic endurance, flexion/extension endurance ratio, Nigerians

1. Introduction

Numerous studies have linked vertebral column stabilization incapacity and poor trunk performance to excessive fatigability of trunk extensors [1,2] and flexors [3,4]. Decreased muscular endurance and strength [5] precipitates trunk muscle imbalance between the extensors and flexors which leads to undue loading on the spine [6] and development of Low-Back Pain (LBP) [3,7]. Despite the foregoing, it is believed that muscular endurance among patients with LBP is assessed less frequently than muscular strength [8].

Decreased endurance of the trunk muscles induces increased muscular fatigability [1–4] which may precipitate or perpetuate LBP due to the increased stress on passive structures [9]. Consequently, some studies have suggested that muscle endurance, rather than muscle strength is a more important factor in maintaining spinal health and core stability [10] and in prevention of LBP [11]. Nonetheless, the predictive value and the training effect of trunk muscle endurance and risk of LBP is still inconclusive [12,13]. Specifically, Hamberg-van Reenen et al. [12] in a systematic review found strong evidence that there is no relationship between trunk muscle endurance and the risk of LBP. However, inconsistent findings in previous studies are implicated on factors not limited to quality of reporting and methodological variations in sample size, statistical applications, assessment methods and sample heterogeneity, and definition of endurance as a construct [14,15].

Measuring performance of trunk flexor and extensor muscles is useful in identifying risk factors, prognostic indicators, and assessing progress of patients after a rehabilitation program [7]. McIntosh et al. [16] posit that identifying high or low muscular endurance can alert the patient and clinician to a need for possible modifications to the usual treatment regime. Drawing from the foregoing, Mbada et al. [14] advocated that clinicians who treat LBP can use normative data on low back endurance as a means to diagnose decreased back muscle endurance or as an outcome tool to evaluate residual disability. Previous investigators have reported that back extensor endurance capacity was diminished in patients with LBP compared with healthy individuals [6,7,11,15]. Furthermore, a decrease in both abdominal and lumbar muscle endurance in these patients predispose to muscular imbalance of the trunk which consequently leads to a lumbar syndrome [17,18].

Relative ratios rather than the use of absolute values of abdominal and lumbar muscle endurance is believed to be of superior value in identifying endurance deficits, and guide clinical decision making for progression of exercise and functional training [4]. A reduced ratio of trunk extensors to flexors strength/endurance discriminates between patients with LBP and healthy controls [4,19,20]. This is because absolute endurance is probably secondary to the relationship between muscle groups as it is thought that muscle imbalances are a primary cause of back problems [21]. Unfortunately, most available data on trunk extensors to flexors ratio are on muscle strength [22–25] compared with endurance [4,21]. The available data reveals that the most commonly cited trunk extensors to flexors ratio is 1.3:1 for healthy individuals [26] with the extensors being stronger [27]. McGill [21] reported trunk flexion/extension endurance ratios to be 0.75 for healthy and >1 for patients with LBP. Nonetheless, flexor/extensor ratios vary across studies and populations [4,21,22,27,28]. In addition, trunk endurance capacity assessments have been reported to have gender-related difference [7,15,29]. There seems to be no available large scale data on endurance of the trunk extensors/flexors ratio in apparently healthy people.

Hence, the objective of this study was to establish trunk flexion/extension endurance ratio. Also, the study investigated the influence of demographic and anthropometric parameters on tests results.

2. Methods

A total of 208 consecutive apparently healthy individuals, 76 men and 132 women, aged 20–25, volunteered for this study. The volunteers comprised of students and staff of Obafemi Awolowo University (OAU), Ile-Ife, Nigeria. Exclusion criteria were a positive history of LBP or abdominal muscle pain for a minimum of one year prior to the study; being pregnant; participation in high-intensity regular exercise or elite sports; a history of cardiovascular diseases or any obvious neurological condition (e.g. stroke, postpolio syndrome) and participation in a previous test of trunk extensors/flexors strength or endurance. Familiarity with physical performance test procedures has been reported to influence tests results and outcomes [30]. Healthy self-description was the methods for identifying healthy volunteers in this study. A healthy volunteer in this study was a person who reportedly met the eligibility criteria of being free from the stated diseases, medical conditions or other activities that might impact the tests results.

Ethical approval for this study was obtained from the Ethical Review Committee of the OAU Teaching Hospitals Complex, Ile-Ife, Nigeria. The participants were fully informed about the purpose of the study and individual consent was obtained. This study was carried out at the gymnasium of the Department of Medical Rehabilitation, OAU.

Anthropometric and body composition parameters assessed in the study included height, weight, trunk length, sitting weight, Body Mass Index (BMI), Percent Body Fat (PBF), Lean Body Mass (LBM), Body Fat Mass (BFM). A height-meter (Seca Alpha Brand) calibrated from 0 to 200 cm was used to assess height of each participant to the nearest 0.1 cm following standard procedures. Body weight in light clothes was measured to the nearest 0.1 kg using a weighing scale (Inter Ikea systems B.V. 1999) calibrated from 0 to 120 kgf with the participant in standing position with shoes off.

BMI was calculated as the ratio of weight in kilograms to height squared i.e. BMI = *Weight over Height^2*.
Trunk length was measured using a tape measure (cm) as the distance from the anterior superior iliac spine to the acromion process with the participant in an erect position.
Sitting weight was measured with the participant in sitting on bathroom weighting scale in the sacroischial support sitting posture (the sacrum, ischial tuberosities and their supporting soft tissue with supported on the backrest of a chair). The average of

the two readings on the weighting scale was recorded as the sitting weight [31]. Bioelectric Impedance Analysis (BIA) machine (Omron BF306) was used to estimate PBF following the manufacturer's guideline.
Lean Body Mass (kgf) was calculated from the percentage body fat estimate of the BIA. Lean body mass = total body weight – fat weight, while BFM was estimated using the formula – BFM

$$= \frac{\textit{percentage body fat} \times \textit{total body weight}}{100}.$$

2.1. Assessment procedures

The Biering-Sorensen test of Static Muscular Endurance (BSME), Repetitive Arch-Up Test (RAUT) and the Partial curl-up test of the Canadian Standardized Test of Fitness were used to assess Static Back Extensors Endurance (SBEE), Dynamic Back Extensors Endurance (DBEE), Static Abdominal Muscles' Endurance (SAME) and Dynamic Abdominal Muscles' Endurance (DAME) respectively. The assessment procedure comprised three phases including warm up (a low-intensity aerobic warm-up procedure of 5-min timed walking at a self-determined pace and gentle active stretching), the endurance tests and a cool down phase comprising the same low intensity exercise as the warm-up for about five minutes.

2.1.1. Assessment of static back endurance

The Biering-Sorensen test of Static Muscular Endurance (BSME) was used to assess the static trunk extensors' endurance. During the BSME the participant laid on a plinth in the prone position with the upper edge of the iliac crests aligned with the edge of the plinth with the hands held by the sides. The lower body was fixed to the plinth by two non-elastic straps located around the pelvis and ankles. Horizontality in the test position was ensured by asking the participants to maintain contact between his/her back and a hanging weighted ball. Once a loss of contact for more than 10-s was noticed, the participant was encouraged to immediately maintain contact again (Fig. 1). The test was terminated once the participant claimed to be fatigued and could not immediately correct or hold the position. The total time of holding the static neutral position was recorded as the endurance time or the isometric holding time (in seconds) using the stop watch (Quartz USA) as previously described earlier studies [7,15,29].

2.1.2. Assessment of dynamic back endurance

Repetitive Arch-Up Test (RAUT) was used to assess the dynamic trunk extensors endurance (Figs 2, 3). Although, repetitive back arching is believed to generate shear compression forces on the extended spine with each repetition due to muscular co contraction [32], RAUT in various forms has been employed in many quantitative functional capacity evaluation in health and disease [33,34]. During the RAUT the participant was placed in a prone position with the arms positioned along the sides on a folding plinth. The iliac crest was positioned at the edge of the fold of the plinth. The lower body was fixed to the non-folding part of the plinth by two non-elastic straps located around the pelvis and ankles. With the arms held along the sides touching the body, the participant was asked to flex the upper trunk downward to 45 ◦ degrees as indicated by the planting inclined angle of the plinth. The subject then raised the trunk upwards from the inclined angle to horizontal position followed by downward return to 45 ◦ to complete a cycle. The movement was repeated as many times as possible at a constant pace, synchronous with a metronome count. The repetition rate was one repetition per 2 to 3-s. The test was terminated on reported fatigue – exhaustion or once the movement could not reach the horizontal level or became jerky or non-synchronous despite verbal encouragement [29,35,36]. A metronome (Willner, Germany) was used to set a uniform tempo or pace or speed for the RAUT (Figs 2 and 3).

2.1.3. Assessment of static flexor endurance

Static Abdominal Muscular Endurance test (SAME) was used to assess static flexor endurance. Two strips of tape were placed parallel to each other and 8.9 cm apart. With the chin tucked in, the participant was in a crook lying position on the mat with knees bent to 90 ◦, the participant extended the arms so that the fingertips of both hands touched a strip of tape perpendicular to the body on both side. At the onset of the test the participant was asked to slide the fingertips along the mat until they reached the second set of tape strips, and then hold for as long they could without moving their fingertips away from the second tape strip. Once a loss of ability to hold the static curl-up position was noticed the test was terminated (Figs 4–5). The total time from the onset of the test and termination was noted and recorded with a stopwatch (in seconds) as the SAME or endurance time [37,38].

2.1.4. Assessment of dynamic flexor endurance

Dynamic Abdominal Muscular Endurance (DAME) using the partial curl-up test of the Canadian standardized tests of fitness was employed in this study. Two strips of tape were placed parallel to each other and 8.9 cm apart. With the chin tucked in, the participant was in a crook lying position on the mat with knees bent to 90 ◦, the participants extended their arm so that the fingertips of both hands touched a strip of tape perpendicular to the body on both side. The participant was asked to slide the fingertips along the mat until they reach the second tape strip, and then return to the starting position. When the researcher signalled to start the test, the participants slowly curled the upper spine until the fingertips touched the second strip of tape. The participant returned to the original position with the shoulders touching the mat. The researcher's hand was placed on the mat below the point where the back of the participant's head touched the researcher's hand. The curl-up must be slow, controlled, and continuous, with a cadence of 20 curl-ups per minute (3-s/curl-up). The number of curl-ups performed by the participant synchronous to the metronome tempo was counted and recorded as DAME (Figs 4, 5). A metronome (Willner, Germany) was used to set a uniform tempo or pace or speed for the dynamic flexor endurance test [37,38].

A standard plinth with adjustable movable part to 30 ◦ 45 ◦ and 60 ◦ was used for conduct of the BSME and RAUT tests. The endurance tests were assessed in random order but each test was conducted only once while a fifteen minute interval was allowed between each test in accordance with a previous study to allow for adequate rest and recovery from potential fatigue [39]. Data of participants who terminated the endurance tests due to pain or loss of concentration other than volitional fatigue were excluded.

2.2. Data analysis

The data were summarized using descriptive statistics of mean, standard deviation and percentiles. Independent t-test was used to compare the endurance tests results between men and women participants. Chi square test was used to determine the association between pattern of trunk flexion/extension ratio and the demographic variables. Pearson product moment correlation analysis was used to test the relationships among different endurance constructs and each of the demographic and anthropometric variables. The Statistical Package for Social Sciences (SPSS) software version 16 was used to analyze data. Alpha level was set at $\alpha = 0.05$.

3. Results

The general characteristics of all participants by gender is presented in Table 1. There were significant gender differences in anthropometric characteristics ($p < 0.05$) except for BMI ($p = 0.337$). The dynamic and static trunk flexion/extension endurance scores by gender are presented in Table 2. The SBEE, DBEE, and SAME scores were significantly higher in men ($p < 0.05$).

Table 3 outlines the mean and percentile data for static and dynamic trunk flexion/extension endurance ratios. The mean static trunk flexion/ extension endurance ratios (men vs. women) were 0.81± 0.57-s vs. 0.53 ± 0.42-s, respectively while the mean dynamic trunk flexion/ extension endurance ratios were 1.04 ± 0.48 reps vs. 0.74 ± 0.83 reps, respectively. Table 4 shows the static and dynamic trunk flexion/extension ratio of all participants, by gender. There was a significant difference in the trunk static (t = 3.962; p = 0.001) and dynamic (t = 2.742; p = 0.001) flexion/ extension ratio between men and women.

Table 5 shows the result of the Chi square test of association between pattern of static and dynamic trunk flexion/extension ratio and sex. There were significant associations between static and dynamic trunk flexion/ extension ratio and gender ($p < 0.05$). Pearson's r correlations between static and dynamic trunk flexion/extension endurance ratios and the general anthropometric characteristics were all unremarkable.

4. Discussion

This study provides reference values and correlates of static and dynamic trunk flexor/extensor muscles endurance ratio in apparently healthy Nigerian adults. McGill [21] reported flexion/extension endurance ratios to be 0.75 for healthy and > 1 for lower back pain subjects. Also, Reiman et al. [40] and Chan [41] found static flexion/extension endurance ratios of 1.63 and 1.54 among high school basketball players and male intercollegiate rowers respectively. In the present study the static and dynamic trunk flexion/extension endurance ratio stood at 0.61 and 0.83 respectively. Furthermore, some other studies investigated dynamic endurance using different types of equipment-based approach involving dynamometers and Iso-station devices [15,29]. The literature reports only few studies using such device as the tests require high loads and seem to be less reproducible and well tolerated compared with static endurance tests. However, other studies have used less technological approaches [7, 15,29,37]. To our knowledge, this is the first study to present dynamic flexion/extension endurance ratios. There seems to be a dearth of studies presenting dynamic flexion/extension endurance ratio. However, dynamic endurance may be needed more than static endurance as most of the daily tasks involve dynamic movement [42,43].

Given the growing support for quantification of endurance, ratios rather than absolute values for trunk extensors and flexors in healthy subjects are useful for patient evaluation and for providing clinical training targets [4]. An altered ratio of trunk flexor to extensor endurance is associated with a positive history of LBP [44]. McNeill et al. [11] submitted that use of ratios tends to avoid interpretational problems created by the general weakness of the patients and any lack of motivation of either patients or healthy subjects. McGill [21] explained that if a ratio gives a result less than or equal to 1.0 it is acceptable while a ratio greater than 1.0 is unacceptable. This is because an alteration the expected trunk flexion/extension endurance ratio is implicated with a past history of disabling LBP, with the extensors having less endurance capacity than the endurance imbalance is considered to be more important than isolated trunk endurance deficits [45].

Significant gender differences were found in the static and dynamic trunk flexion/extension endurance ratios in this study. The ratio for static endurance was 0.83-s and 0.50-s for men and women, respectively, while the mean ratio for dynamic endurance was 1.03 repetitions and 0.72 repetitions men and women, respectively. A similar pattern of higher flexion/ extension endurance ratio was observed in the McGill et al. study with the mean ratio of 0.84-s 0.72- s, for men and women, respectively [21]. It is adduced that the differences in the flexion/extension endurance ratio by gender is a result of the significant differences in their anthropometric descriptors. It has been reported that anthropometric and morphologic differences that exist between male and female can significantly impact variables such as spine loading [46], mechanical efficiency, predisposition to injury [47] and the magnitude of response to performance test [48].

The static and dynamic trunk flexion/extension endurance ratio values provided in this study can be used to compare a patient's endurance ratio score at intake or as an outcome measure in clinical practice. With the use of reference endurance ratio values, clinicians who treat LBP can determine departure from the norm for trunk flexion/extension endurance ratio by age and sex. Nonetheless, the data in this study are from young healthy and rather fit individuals, and as such may have limited generalizability to the general Nigerian population. In addition, the comparability of this study with other studies may be limited because of the variability in methodology especially with respect to the choice of sit-up versus curl-up tests. However, assessment of abdominal muscles endurance with the curl-up tests have been reported to have acceptable applicability and psychometric properties among healthy and patient populations compared with the traditional bent-knee sit-up tests [49,50]. Specifically, the partial curl-up test of the Canadian standardized tests of fitness are reported to evoke moderate levels of activity in the rectus abdominis muscles while protecting the resultant spine load and has been adapted into several low back fitness programs [37,38,49].

5. Conclusion

This study establishes a set of reference values for static and dynamic trunk flexion/extension endurance ratios among healthy young Nigerians. These values can be used to diagnose patients' endurance ratios at baseline and also as an outcome measure in back muscles' endurance rehabilitation. Men had significant higher trunk flexion/extension endurance than women. Leanness and overweight/obesity had significant influence on static and dynamic flexion/extension endurance ratios.

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Conflict of interest

The authors declare no conflict of interest.

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