Comparative assessment of abdominal muscles endurance between nulliparous and parous women

Badanie porównawcze wytrzymałości mięśni brzucha u kobiet nierodzących i kobiet po porodzie

Chidozie E. Mbada PhD PT [1(A-F)], **Omotola G. Siku-Sotade** BMR PT [1(A,B,D-F)], **Adebanjo B. Adeyemi** FWACS [2(A,D-F)], **Olubusola E. Johnson** PhD PT [1(A,D-F)], **Adekemi E. Olowookere** MSc Nurs. RN, RM [3(A,D-F)], **Adenike F. Faremi** MSc Nurs. RN [3(A,D-F)], **Joel O. Faronbi** MSc Nurs. RN [3(A,D-F)]

[1] Department of Medical Rehabilitation, College of Health Sciences, Obafemi Awolowo University, Ile – Ife, Nigeria
[2] Departments of Obstetrics, Gynaecology & Perinatology, College of Health Sciences, Obafemi Awolowo University, Ile-Ife, Nigeria
[3] Department of Nursing Sciences, College of Health Sciences, Obafemi Awolowo University, Ile-Ife, Nigeria

Key words
abdominal muscles' endurance, nulliparous, parous, women

Abstract
Background: Normative databases on abdominal muscles performance in women are essential in the diagnosis of musculoskeletal impairment and as reference values for post-partum rehabilitation targets. This study quantified and investigated the predictors of the static and dynamic abdominal muscles endurance of nulliparous and parous women.
Methods: Two hundred and fifty five consenting volunteers (131 nulliparous and 124 parous women) participated in this study. Partial curl-up test of the Canadian Standardized Test of Fitness was used to assess Static Abdominal Muscles Endurance (SAME) and Dynamic Abdominal Muscles Endurance (DAME) respectively. Demographic and anthropometric data were also obtained. Data were analyzed using descriptive and inferential statistics. The Alpha level was set at 0.05.
Results: The mean SAME and DAME of all the participants were 33.90 ±20.78 seconds and 16.26 ±8.76 repetitions respectively. Nulliparous women exhibited significantly higher mean SAME (42.71 ±22.59 vs. 24.59 ±13.50 seconds) and DAME (19.45 ±8.96 vs. 12.88 ±1.17) (p=0.001) values respectively. Both SAME and DAME values differed significantly (p<0.05) across the parous group. The primiparae had higher SAME and DAME values than their multiparae counterparts (p<0.05). A significant correlation existed between SAME and DAME (p=0.001). Age, number of births and anthropometric parameters were significant predictors of SAME and DAME (p<0.05).
Conclusion: This study established a set of reference mean values for static and dynamic abdominal muscles endurance in nulliparous and parous women. Parity was associated with a significant decrease in the static and dynamic abdominal muscles endurance capacity. Age, high level of adiposity and the number of births were significant predictors of decreased abdominal muscles endurance. It is adduced that decreased abdominal muscles endurance in women may be precipitated and perpetuated by parity.

Słowa kluczowe
wytrzymałość mięśni brzucha, kobiety nierodzące, kobiety rodzące

Streszczenie
Wprowadzenie: Wartości normatywne siły mięśni brzucha u kobiet są istotne zarówno w diagnostyce zaburzeń mięśniowo-szkieletowych, jak i stanowią punkt odniesienia w ustalaniu celów rehabilitacji po porodzie. Niniejsze badanie określa wielkość oraz analizuje predyktory statycznej i dynamicznej wytrzymałości mięśni brzucha u kobiet nierodzących i rodzących.
Metody: W badaniu wzięło udział dwieście pięćdziesiąt pięć kobiet (131 nierodzących i 124 rodzących). W celu oceny statycznej i dynamicznej wytrzymałości mięśni brzucha (ang. *Static Abdominal Muscles Endurance*, SAME; *Dynamic Abdominal Muscles Endurance*,

The individual division on this paper was as follows: A – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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DAME) wykorzystano test Partial Curl-Up Test (test częściowego unoszenia tułowia wykonywany w pozycji leżenia tyłem o nogach ugiętych) będący składową testu sprawności Canadian Standardized Test of Fitness. Od badanych uzyskano także dane demograficzne i antropometryczne. Do analizy danych wykorzystano statystyki opisowe oraz dedukcyjne. Wartość alfa ustalono na poziomie 0,05.
Wyniki: Średnie wyniki SAME i DAME wszystkich uczestniczek wynosiły odpowiednio 33,90 ±20,78 sekund i 16,26 ±8,76 powtórzeń. Kobiety nierodzące odznaczały się znamiennie wyższą średnią wartością pomiarów SAME (42,71 ±22,59 vs. 24,59 ±13,50 sekund) oraz DAME (19,45 ±8,96 vs. 12,88 ±1,17) (p=0,001). Wartości pomiarów SAME i DAME także różniły się znamiennie (p<0,05) w obrębie samej grupy kobiet rodzących. Kobiety, które urodziły 1 dziecko odznaczały się wyższymi wartościami pomiarów SAME i DAME niż te, które rodziły więcej razy (p<0,05). Stwierdzono znamienną korelację pomiędzy wartościami pomiarów SAME i DAME (p=0.001). Wiek, ilość porodów oraz zmienne antropometryczne okazały się być znamiennymi predyktorami wartości SAME i DAME (p<0,05).
Podsumowanie: Wyniki niniejszego badania pozwalają na stworzenie zestawienia referencyjnych wartości średnich wytrzymałości statycznej i dynamicznej mięśni brzucha u kobiet rodzących i nierodzących. Ciąża wpływa znamiennie zarówno na spadek wytrzymałości statycznej, jak i dynamicznej mięśni brzucha. Wiek, otyłość i liczba porodów są ważnymi predyktorami spadku wytrzymałości mięśni brzucha. Wskazuje się, że zmniejszenie wytrzymałości mięśni brzucha może być wywoływane i utrwalane przez macierzyństwo.

BACKGROUND

Pregnancy and child bearing are natural physiologic events which causes the body to undergo significant physiological, psychosocial and physical changes[1-3]. Musculoskeletal changes in pregnancy including joint laxity, reduced trunk muscles strength and endurance and consequent postural alterations are largely physiologic[3-5] but are the precursors of back and pelvic pain and spinal instability in these women[6,7]. Heckman and Sassard[8] corroborated that the normal physiological changes of pregnancy may induce mechanical and structural changes in the spine contributing to possibly postpartum back pain.

The strain and stress on the abdominal muscles by the developing foetus, thereby causing it to stretch to the point of its limit by the end of pregnancy[9,10] coupled with the hormonal influence on the muscles[11,12] constitute one of the most significant mechanical and structural changes in pregnancy. These physiological changes in the anterior and lateral abdominal dimensions affect the body image and posture of women and also compromise the normal body mechanics and the kinesiology of the abdominal corset[10,13,14]. The resultant abdominal muscles weakness imposes additional stress on lower back muscles with consequent hyperextension of the lower spine, reduced spinal stability and increased risk of low-back pain and spinal injury[6,7,15].

Strong abdominal muscles are important for women of childbearing age to support and cradle the developing child, protecting the new mother's organs and back from the increasing weight she carries[16]. The recovery of abdominal muscles function in most postpartum women is associated with a conscious involvement in rehabilitation programmes involving physical activity and exercises[17-20]. As a result, normative databases on abdominal muscles performance in women are essential in the diagnosis of musculoskeletal impairment and as reference values for post-partum rehabilitation targets. However, there is a dearth of studies on the assessment and determinants of abdominal muscles endurance in women. Therefore, this study quantified and investigated the predictors of static and dynamic abdominal muscles endurance of nulliparous and parous women using the Partial Curl-Up Test of the Canadian Standardized Tests of Fitness.

METHODS

Participants

The participants for this study were apparently healthy women recruited from the Obafemi Awolowo University (OAU), Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC), Ile-Ife, Osun State, Nigeria. Inclusion criteria for participation in the study involved being female of sixteen years and older with or without histories of childbirth. Eligible participants who reported a positive history of low-back pain within one year prior to the study, those who reported any abdominal muscle or visceral pain or with any obvious spinal deformity or neurological conditions and those with a positive history of cardiovascular diseases were excluded from the study.

Procedures

Ethical approval for the study was obtained from the Ethical Review Committee of the OAUTHC. The participants were fully informed about the purpose of the study and their consents were obtained before measurements were taken. Demographic data of the participants were obtained using a structured proforma.

Measurement

A height meter calibrated from 0-200 cm was used to measure the height of each participant to the nearest 0.1cm. A weighing scale calibrated from 0–120kg was used to measure the body weight of participants in kilograms to the nearest 0.1Kg. Body Mass Index (BMI) was calculated as the ratio of weight in kilograms to height in meter squared. Bioelectric Impedance Analysis (BIA) machine (Omron BF 306 (HBF-306-E), Kyoto, Japan) was used to measure Percentage Body Fat (PBF) following the manufacturer's instructions. The participants were instructed to stand erect with the two feet together while holding the BIA machine in both hands with the arms straight at 90^0 of shoulder flexion so that the palmar surface of the hands covered the metal sensor of the BIA. During the assessment, the participants were instructed to remove all metal objects (such as earrings, chains, wrist watches etc.). Dryness of the palms was ensured by using a dry towel for cleaning if the palms were wet (participants with symptoms of hyperhidrosis were not recruited).

Lean body mass (kg) was calculated from the PBF by subtracting fat weight (kg) from total body weight (kg). *Lean Body mass = Total body weight – Fat weight*.

Fat weight was calculated from PBF using the following formula: *Percentage body fat = (fat weight/total body weight) X 100. Therefore, Fat weight = (percentage body fat X total body weight)/100.*

Assessment

Assessment of the participants' abdominal muscles endurance comprised three phases including warm up (a low-intensity aerobic warm-up procedure of five minutes timed-walking at a self-determined pace and gentle active stretching), static and dynamic abdominal muscles endurance tests and a cool down phase comprising the same low intensity exercise as the warm-up for about five minutes. The Partial Curl-Up Test of the Canadian Standardized Tests of Fitness was used to quantify both static and dynamic abdominal muscles endurance. Prior to the tests, the procedures were explained and demonstrated to the participants. Static Abdominal Muscles Endurance (SAME) and Dynamic Abdominal Muscles Endurance (DAME) were assessed in random order but each test was carried out only once. A fifteen minute interval was allowed between each assessment in accordance with a previous study to allow for adequate rest and recovery from potential fatigue[21]. Data of participants who terminated the tests due to pain in the abdominal muscles or loss of concentration other than volitional fatigue were excluded.

Assessment of static abdominal muscles endurance (SAME): - Two strips of tape were placed parallel to each other at 3.5 inches apart. The participant lay supine on the mat with knees at right angles, the participant extended their arm so that the fingertips of both hands touched a strip of tape perpendicular to the body on both sides (Plate 1). 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, and the period of static hold was timed with a stopwatch (Quartz Stopwatch: SW1027). The test was terminated once the participant could no longer hold the test position[22]. The total time from the onset of the test and loss of ability to hold the static curl-up position was recorded as SAME or endurance time (in seconds) with the stopwatch (Plate 2).

Assessment of dynamic abdominal muscles endurance (DAME): Two strips of tape were placed parallel to each other at 3.5 inches apart. The participants lay supine on a mat with knees bent at right angle, the participant extended their arm so that the fingertips of both hands touched a strip of tape perpendicular to the body on both sides. Two additional strips of tape were located parallel to the first two strips 8cm apart. The participant was asked to slide the fingertips along the mat until it reached the second set of tape strips, and then returned to the starting position. When the researcher signalled to start the test, the participant slowly curled the upper trunk 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 hands were placed on the mat below the point where the back of the participant's head touched the researcher's hand. The curl-up was slow, controlled and continuous with a rhythmic cadence of 20 curl-ups per minute using a Metronome (Metronom System Maelzel, Wittner, Germany). The metronome was used to maintain the speed of movement. The number of curl-ups performed by the participant synchronous to the metronome tempo was counted and recorded as DAME[22] (Plate 3). All assessments and measurements were carried out at the gymnasia of the Departments of Medical Rehabilitation, OAU and Physiotherapy, OAUTHC, Ile-Ife, Nigeria respectively.

Rather than the traditional sit-up tests, the present study employed the Partial Curl-Up Test of the Canadian Standardized Tests of Fitness for assessment of static and abdominal muscles endurance. Trunk-curl tests are preferred over the sit-up

Plate 1
Starting point for Static Abdominal Muscles Endurance Assessment

tests even though both have similar activity levels and patterns. Trunk-curl tests are reported to be safer, easier and more suitable tests of abdominal endurance compared with the traditional bent-knee sit-up tests[23-25]. In addition, the Partial Curl-Up Test of the Canadian Standardized Tests of Fitness are reported to produce reasonable levels of activity in the rectus abdominis muscles while immunizing the resultant spine load and has been adapted into several low back fitness programs[26-28]. However, Partial curl-up tests had had poor to average reliability and validity[29].

Data Analysis

The variables in this study have normal distribution; hence data obtained were summarized using descriptive statistics of mean and standard deviation. An independent t-test was used to compare the abdominal muscles endurance level of nulliparous and parous women. Bivariate analysis of multiple regression was used to determine the predictors of SAME and DAME respectively. A scatter plot was used to represent the relationship between SAME and DAME. An Analysis of Variance (ANOVA) was used to compare the SAME and DAME of the parous group who were classified into four groups based on the number of parity. The Alpha level was set at 0.05. The data analysis was carried out using SPSS 13.0 version software (SPSS Inc., Chicago, Ill., USA).

RESULTS

A total of 255 women [131 (51.4%) nulliparous and 124 (48.6%) parous] whose ages ranged between 16 and 60 years with the mean of 27.78 ±9.57 years participated in this study (Table 1). The primiparae constituted a total of 41 (16.1%) of the parous population. The women were classified based on the number of births as presented in Table 1. The mean SAME and DAME of all the participants in this study was 33.90 ±20.78 seconds and 16.26 ±8.76 repetitions respectively. Comparison of the general characteristics and abdominal muscles endurance of the nulliparous and parous participants using the independent t-test is presented in Table 2. The result shows that the parous participants were significantly older and heavier (p=0.001) than the nulliparae. The measures of adiposity (BMI, PBF and BFM) were significantly higher among the parous participants (p=0.001). The results also indicated that the nulliparae had a significantly higher mean SAME (42.71 ±22.59 vs. 24.59 ±13.50 seconds; p=0.001) and DAME (19.45 ±8.96 vs.12.88 ±1.17 repetitions; p=0.001) respectively.

Table 3 shows the result of the comparison of the general characteristics and abdominal muscles endurance (SAME and DAME) of the

Plate 2
Midway into full Static Abdominal Muscles Endurance Assessment

Plate 3
Midway into full Dynamic Abdominal Muscles Endurance Assessment

primiparae and multiparae participants. The multiparae were significantly older (p=0.001) but were not significantly taller or heavier (p>0.05) than their primiparae counterparts. However, BMI and PBF were significantly higher (p<0.05) among the multiparae participants. The primiparae had significantly higher SAME (of 30.10 ±13.10 sec vs. 21.87 ±12.46 sec; p=0.001) and DAME (16.05 ±7.98 vs. 11.31 ±6.20 repetitions; p=0.001) respectively when compared with the multiparae.

Table 4 shows the One-way ANOVA and LSD post-hoc multiple comparisons of the general characteristics and the abdominal muscles endurance of the parous participants grouped on the number of births. The result indicated that participants with one birth had the highest mean SAME and DAME of 30.01 ±13.10 seconds and 16.05 ±7.98 repetitions respectively; while participants with ≥ 4 births had the least mean SAME and DAME of 18.59 ±16.58 seconds and 9.06 ±5.36 repetitions respectively. Furthermore, the result showed that SAME and DAME decreased with a higher number of births (p<0.05). Also, anthropometric variables were significantly higher among parous participants with a higher number of births (p<0.05).

Figures 1 and 2 show the scatter plot of the relationship between SAME and DAME among the nulliparous and parous group respectively. From the result, significant direct correlation was found between SAME and DAME for nulliparous and parous participants respectively (p<0.05). Multiple regression analysis revealed that factors such as age, weight, height, BMI, PBF, LBM, BFM, and the number of births are significant predictors of SAME and DAME among nulliparous and parous participants.

The regression equation for predicting SAME from age, height, weight, BMI, PBF, LBM, BFM, number of births is: Y= 99.285 – 0.188 (Age) – 11.736 (Height) – 0.287 (Weight) + 0.611 (BMI) - 0.672 (PBF) - 0.619 (LBM) + 0.691 (BFM) – 4.329 (no. of births), where Y is the SAME; BO is a constant. The variability for

Table 1

Distribution of participants based on parity

Variables	Categories	Number	%
Parity	Nulliparous	131	51.4
	Parous	124	48.6
Parous	Primiparae	41	38.1
	Multiparae	83	66.9
Multiparae	2 births	36	43.3
	3 births	30	36.2
	≥ 4 births	17	20.5

Table 2

Independent t–test comparison of the general characteristics. anthropometric parameters and static and dynamic abdominal muscles endurance between nulliparous and parous women

Variables	Nulliparous Mean±S.D (N = 131)	Parous Mean±S.D (N = 124)	t-cal	p-value
Age	22.10 ±3.30	33.79 ±10.34	-12.301	0.001
Height	1.63 ±0.07	1.63 ±0.06	-0.209	0.835
Weight	58.21 ±9.04	68.08 ±12.58	-7.222	0.001
BMI	21.83 ±2.90	25.50 ±4.51	-7.773	0.001
PBF	28.01 ±5.03	32.35 ±6.86	-5.793	0.001
LBM	40.01 ±6.17	45.61 ±6.36	-7.133	0.001
BFM	18.19 ±5.39	22.51 ±8.20	-4.993	0.001
SAME	42.71 ±22.59	24.59 ±13.50	7.722	0.001
DAME	19.45 ±8.96	12.88 ±1.17	6.445	0.001

Indicates significant difference at α = 0.05

Table 3

Independent t–test comparison of the general characteristics. anthropometric parameters and static and dynamic abdominal muscles endurance between primiparous and multiparous

Variables	Primiparae Mean±S.D (N = 41)	Multiparae Mean±S.D (N = 83)	t-cal	p-value
Age	26.95 ±6.80	37.17 ±10.14	-5.832	0.001
Height	1.65 ±0.07	1.63 ±0.06	1.589	0.115
Weight	65.85 ±12.00	69.18 ±12.79	-1.388	0.168
BMI	24.27 ±3.92	26.11 ±4.67	-2.177	0.031
PBF	29.64 ±6.28	33.69 ±6.77	-3.207	0.002
LBM	45.19 ±6.70	45.82 ±6.22	-0.516	0.606
BFM	20.79 ±7.85	23.36 ±8.28	0.511	0.101
SAME	30.10 ±13.10	21.87 ±12.46	0.381	0.001
DAME	16.05 ±7.98	11.31 ±6.20	0.036	0.001

Indicates significant difference at α = 0.05

Table 4

One way ANOVA and LSD post-hoc multiple comparison of the general characteristics. anthropometric variables and static and dynamic abdominal muscles endurance of the parous women grouped on the basis of number of births

Variables	1 birth Mean±S.D (N = 41)	2 births Mean±S.D (N = 36)	3 births Mean±S.D (N = 30)	≥4 births Mean±S.D (N = 17)	F-ratio	p-value
Age	26.95 ±6.80[a]	31.72 ±7.05[b]	39.50 ±10.31[c]	44.59 ±9.48[d]	24.822	0.001
Height	1.65 ±0.07	1.64 ±0.05	1.63 ±0.05	1.61 ±0.07	1.484	0.222
Weight	65.85 ±12.00	66.31 ±9.82	70.77 ±14.17	72.44 ±15.12	1.841	0.143
BMI	24.27 ±3.92[a]	24.74 ±3.40[a]	26.77 ±5.09[b]	27.85 ±5.61[b]	3.969	0.010
PBF	29.64 ±6.28[a]	32.49 ±5.31[b]	34.27 ±8.14[b]	35.24 ±6.84[b]	4.223	0.007
LBM	45.19 ±6.70	44.12 ±4.39	47.16 ±7.00	47.05 ±7.44	1.631	0.186
BFM	20.79 ±7.85	22.19 ±6.56	23.60 ±9.50	25.39 ±9.29	1.518	0.213
SAME	30.01 ±13.10[a]	25.14 ±11.50[b]	19.80 ±10.17[c]	18.59 ±16.58[c]	5.146	0.002
DAME	16.05 ±7.98[a]	14.00 ±7.27[b]	9.37 ±3.63[c]	9.06 ±5.36[c]	8.209	0.001

For a particular variable. mode means with different superscript are significantly (p<0.05) different. Mode means with same superscripts are not significantly (p>0.05) different. When only one contrast is significant. one of the cell means has no superscripts attached. A pair of cell means that is significant has different superscripts. BMI = Body mass index; PBF = Percentage body fat; LBM = Lean body mass; BFM = Body fat mass (fat weight); SAME = Static abdominal muscles endurance; DAME = Dynamic abdominal muscles endurance

the predictive equation for SAME is 26.6%.

The regression equation for predicting DAME from age, height, weight, BMI, PBF, LBM, BFM, number of births is: Y= -46.089 – 0.158 (Age) + 47.625 (Height) - 0.324 (Weight) + 1.272 (BMI) - 0.220 (PBF) - 0.379 (LBM) + 0.197 (BFM) + 1.684 (no. of births), where Y is the DAME; BO is a constant. The variability for the predictive equation for DAME is 25.6%.

DISCUSSION

This study quantified and investigated the predictors of static and dynamic abdominal muscles endurance of nulliparous and parous women. The results on the anthropometric characteristics of the participants revealed that the total body weight and the measures of adiposity (BMI, PBF and BFM) were significantly higher among the parous women compared with their nulliparous counterparts. In line with this result, previous investigators have found maternal weight gain and increase in general body fatness to be associated with pregnancy and parity[30-32]. Stamnes Koepp et al.[32] submitted that both pre-pregnant weight and weight gain in pregnancy are important predictors of babies' birth weight. However, optimal maternal weight-gain ranges in pregnancy are controversial and inconclusive[33]. Nonetheless, maternal weight gain outside certain recommended ranges is associated with various adverse maternal outcomes such as increased risk for pregnancy-associated hypertension, gestational diabetes, complications during labour and delivery, and postpartum weight retention and subsequent maternal obesity as well as an increased risk of unsuccessful breast-

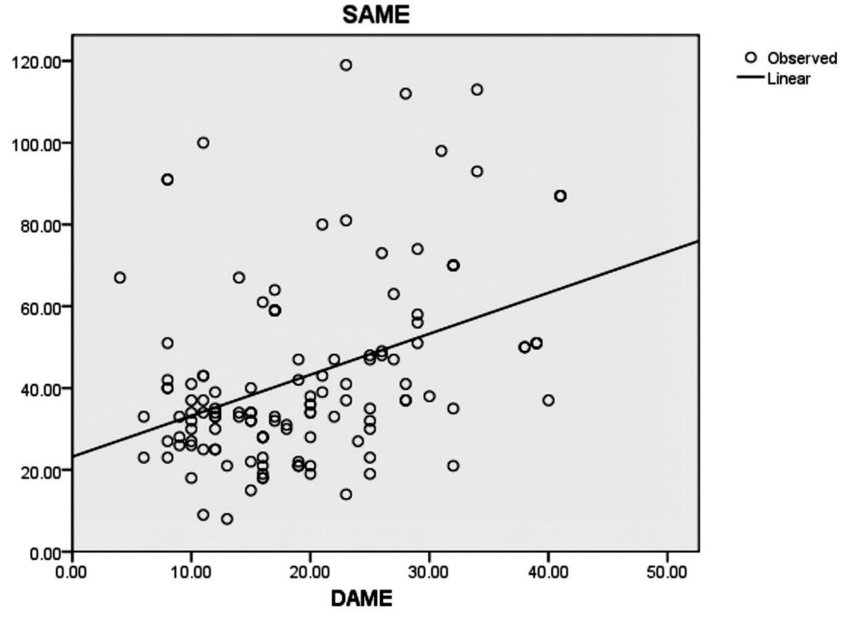

Figure 1
Relationship between SAME and DAME among the nulliparous women

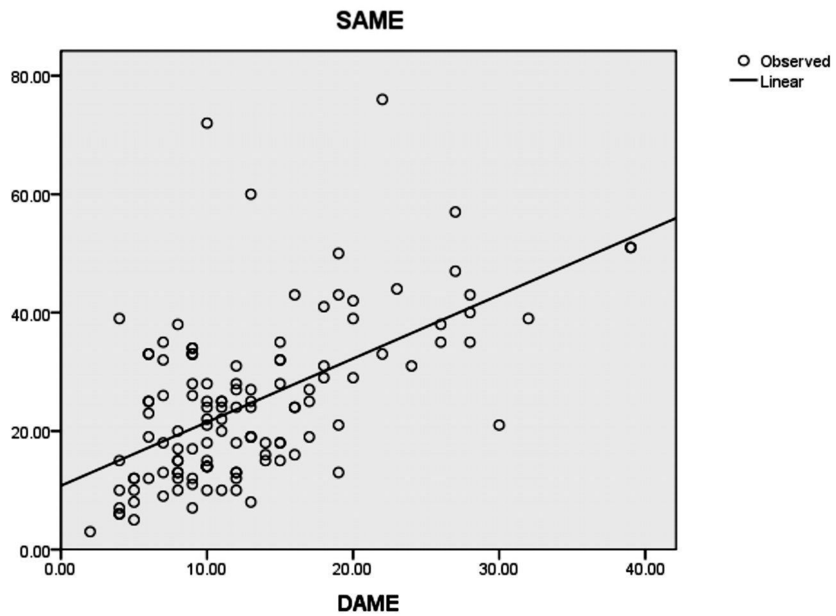

Figure 2
Relationship between SAME and DAME among the parous women

feeding[31]. Weight gain during pregnancy is more of fat gain than body water gain[30] and women tend to gain weight and fat with succeeding pregnancies[34]. This fat gain is preferentially deposited in the hips and thighs as it is often reflected by widening thighs and hip girth[35,36]. However, fat stores in the lower body are continuously mobilized as the pregnancy advances to meet the demands of the developing brain for essential fatty acids and energy during the time of peak growth of the foetus[34]. Lassek and Gaulin[34] submitted that when fat is regained after the postpartum period, relatively more is stored in central versus peripheral depots, resulting in a patterned change in body shape with parity.

The mean static and dynamic abdominal muscle endurance of the women in this study was 33.90 ±20.78 seconds and 16.26 ±8.76 repetitions respectively. Comparable with the mean values obtained in this study, Mbada et al.[37] in an earlier study found SAME and DAME of 34.8 ±20.1 seconds and 15.6 ±7.79 repetitions respectively among Nigerian women using the Partial Curl-Up Test of the Canadian Standardized Tests of Fitness. Other studies by Ito et al.[38] found the mean value of 85.1 ±44.8 seconds for static abdominal muscle endurance among women using a modified Kraus-Weber technique while Alaranta et al.[39] found a mean dynamic abdominal endurance of 19.0 ±14.0 repetitions among women using the repetitive sit-up test.

From this study, nulliparous women had significantly greater abdominal muscles endurance compared with their parous counterparts. Furthermore, among the parous group, it was shown that the ability of the abdominal muscles endurance to perform static hold or repetitions decreased with a higher number of births. Specifically, the women with ‘greater than or equal to four’ births had the lowest mean SAME and DAME of 18.59 ±16.58 seconds and 9.06 ±5.36 repetitions respectively. This study provides empirical data that parity is an important factor in abdominal muscles endurance in women. Gravidity and parity have been reported to alter abdominal muscles properties and motor performance including strength and endurance in women[3,16,40,41]. The physiologic stretching of the abdominal muscles during pregnancy to allow room for the developing foetus causes a rapid lengthening of the abdominal muscles with consequent loss of tone, elasticity, strength and endurance[9,10,42,43]. Gilleard and Brown[10] submitted that abdominal muscle function is affected by structural adaptations that occur during pregnancy. However, it is argued that it is not changes to the length of the abdominal muscles that primarily reduced their functional capabilities during pregnancy and postpartum[10]. This contention is based on research findings on animal subjects where it was found that skeletal muscle fibres add sarcomere to their length when stretched over periods such as 3 weeks[44]. Gilleard and Brown[10] postulated that the rectus abdominis muscle of humans, therefore, may increase in length and maintain maximum active tension in response to the long-term stretch of pregnancy. It is therefore adduced from this study that the incomplete musculoskeletal re-adaptation in the postpartum period[10,40,45,46], changes in the structural morphology of abdominal muscles complicated by an altered line of action rather than from overstretching and thinning[10], the divarication of the rectus muscles the midline[47] and consequently the occurrence of diastasis recti abdominis[10,40,45] possibly precipitate and perpetuate reduced post-partum abdominal muscles endurance capacity in women. Furthermore, women who had caesarean sections are prone to developing weak abdominal muscles which is as a result of the effect of anaesthesia[48-50] coupled with direct incisions on the abdominal muscles[47,51-53] or indirectly from transverse incision leading to the separation of the aponeurose and consequently the bruising and bloating that can disrupt the recruitment of transverse abdominus[54].

Consequent to the foregoing, it is adduced that the mobilization of fat from the lower extremities centrally to the abdomen during the advanced stage of pregnancy and post-partum reduces abdominal muscles performance capacity. Studies have shown an inverse association between high abdominal fat and abdominal muscles strength and endurance[55-57]. However, it is not clear whether central abdominal fat deposit from each pregnancy resolves thereafter, and if not, there may be a negative accumulated effect with successive pregnancies on the endurance of the abdominal muscles. This assertion is speculated based on this study's finding that the different measures of adiposity were significantly higher among parous women with a high number of births; however, this is still subject to empirical verification. A direct relationship between static and dynamic abdominal muscles endurance capacity was found in this study. This finding was consistent with some previous reports[37,58]. It is implied that good performance of the abdominal muscles in a dynamic task may translate into the capacity to perform static activities such as postural balance of the trunk. Therefore, training abdominal muscles for dynamic tasks may translate to similar effects on static performance capacity. However, Wohlfahrt et al.[58] suggested that if curl-up is being taught with the aim of developing abdominal muscles stability capacity, then curl-up should be performed at a slow controlled rate.

The prediction equation model derived from this study revealed that factors such as age, weight, height, BMI, PBF, LBM, BFM and number of births are significant predictors of static and dynamic abdominal muscles endurance capacity among nulliparous and parous women. This finding is consistent with most studies that have reported that age[59-62], anthropometric parameters such as body weight and height[37,63,64], measures of body adiposity[37,57,65] and differences in body morphology and geometry such as trunk and leg length[37,66] are significant determinants of the endurance capability of the trunk muscles test results. However, these variables did not significantly influence the endurance capability of the trunk muscles test results in some other studies[67-69]. From this study, it is opined that the tests results of abdominal muscles endurance are influenced by many factors which may be mutually exclusive or in association with each other. Therefore, the prediction equation obtained in this study may be a swift method to diagnose abdominal muscles endurance impairment and also serve as a useful tool in the post-partum rehabilitation of abdominal muscles. However, it is important to note that simple demographic and anthropometric measures may not accurately predict abdominal muscles endurance without significant errors as indicated by the level of variability of the equations in this study (25.6 to 26.6%).

Clinical Implications of Findings

The effect of the developmental changes that women undergo in the endurance capability of their abdominal muscles secondary to pregnancy, parity and menopause are still not well investigated. Previous research underscores the need and importance of a better understanding of women's trunk muscles performances after child birth as this may lead to better utilization of physical therapy in treating related dysfunctions associated with pregnancy[10]. Sanya and Famuyide[3] recommended that obstetricians in charge of ante and postnatal women should refer them to physiotherapy for abdominal muscle strengthening programmes. Mbada et al.[46] corroborated that physical therapy has a widening role in the field of obstetrics and gynaecology and this should include prenatal education on the importance of abdominal muscles endurance and a postpartum exercise programme to retrain abdominal muscles endurance. To this effect, physicians, midwives and other health practitioners in the field of obstetrics and gynaecology will need to be sensitized on the importance of post-partum care involving abdominal muscle endurance training. Physical therapists should work in synergy with nurses and midwives to provide pre- and post-natal education for the women stressing the importance of exercises on tone and tautness of the abdominal muscles; and prevention of bad posture, poor body image and musculoskeletal pain. It is essential to document reference mean values in order to identify any departure of the abdominal muscles endurance from what is considered physiologic for either the nulliparous or parous women. This study provided reference mean data for static and dynamic abdominal muscles endurance among apparently healthy nulliparous and parous women which can be used to compare a patient's score at intake or as an outcome measure in post-partum rehabilitation of the abdominal muscles. The information presented in this article indicates the legitimacy of applying specialist exercises for women in the prenatal period, during pregnancy itself as well as after giving birth. It is adduced that decreased abdominal muscles endurance in women may be precipitated and perpetuated by parity. Thus, the study reinforces the need to educate women to engage in an abdominal muscle endurance programme to avert the untoward effects of musculoskeletal impairments caused by pregnancy on their posture, body image and health.

The psychometric limitations of trunk curl-up tests constitute a significant shortcoming to the outcome of this study[29]. Other limitations of this study includes the inability to ascertain the health status of the participants with regards to reports on the last episode of low-back pain, and also the possible influence of an individual's motivation in physical performance testing. Furthermore, there is a lack of information on the mode of delivery with regards to Spontaneous Vaginal Delivery versus Caesarean section which is adduced as an important mediating variable on the static and dynamic endurance of the abdominal muscles within the dimension of pregnancy and childbirth.

CONCLUSION

This study provided reference mean data for static and dynamic abdominal muscles endurance for nulliparous and parous women. Parity was associated with a significant decrease in the static and dynamic endurance capacities of the abdominal muscles. Age, high level of adiposity and the number of births were significant predictors of decreased abdominal muscles endurance. A significant direct relationship was found between the static and dynamic abdominal muscles endurance capability of nulliparous and parous women.

Competing interests

The authors declare no competing interest.

Authors' contributions

CEM conceived the idea for this study, participated in the design of methodology and data collection and analysis and prepared the final manuscript for publication. OGS participated in the design of methodology and data collection and analysis and drafted the manuscript. ABA and OEJ participated in the design of the study's methodology, participated in the interpretation of data and drafted the manuscript. AEO, AFF and JOF participated in the design of the study's methodology and drafted the manuscript. All the authors read and approved the final manuscript.

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Address for correspondence

Chidozie E. Mbada BMR Ph.D
Department of Medical Rehabilitation
College of Health Sciences
Obafemi Awolowo University
Ile-Ife, Nigeria
e-mail:doziembada@yahoo.com