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SELECTED PHYSICAL FITNESS PARAMETERS IN INDIVIDUALS WITH TYPE 2 DIABETES MELLITUS AND APPARENTLY HEALTHY CONTROLS: A COMPARATIVE CROSS-SECTIONAL STUDY

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Abstract
Objective: The study aimed to compare the physical fitness of subjects with type 2 diabetes mellitus (ST2DM) and apparently healthy non-diabetic controls (NDC).
Methods: Thirty-two ST2DMs and 32 NDCs were recruited for a comparative cross-sectional study. Flexibility, balance, power, and strength were assessed using sit-up and sit and reach (SR), one leg stand, horizontal jump (HJ), and hand grip tests, respectively. Cardiovascular endurance was assessed using Vo2max estimated with a 6-minute walk test. Also, body composition was estimated using body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-hip ratio (WHR), and percent body mass. Data were analyzed using descriptive and inferential statistics. The alpha level was set at $p < 0.05$.
Results: Static balance was significantly higher in the NDCs (11.1 ± 12.6 vs 5.5 ± 5.0 sec; $p = 0.047$) than in the ST2DMs. Hand (34.6 ± 19.9 vs 23.6 ± 12.7 kg; $p = 0.001$) and leg (122.4 ± 42.8 vs 26.5 ± 43.9 cm; 0.001) strength/power were significantly higher in the NDC group compared with the ST2DM. The SR test, a measure of flexibility, was significantly higher in the NDC (SDM = 12.2 ± 19.8cm, NDC = 35.3 ± 8.8cm, $p = 0.001$). BMI (28.7 ± 4.3 vs 26.4 ± 41kgm-2; $p = 0.048$), WC (104.2 ± 8.0 vs 94.2 ± 8.7cm; $p = 0.001$) and WHR (1.0 ± 0.6 vs 0.9 ± 0.7; $p = 0.001$) were significantly higher in the ST2DM than in the NDC. There was no significant difference in the estimated VO2max between the subject group and the control group.
Conclusion: Balance, flexibility, and strength were significantly lower, while measures of adiposity are significantly higher in subjects with type 2 diabetes mellitus compared with non-diabetic controls.
Key words: *diabetes, physical fitness, evaluation, cardio-respiratory*

Introduction

Diabetes mellitus (DM) is characterized by hyperglycemia and carbohydrate, fat, and protein metabolism disturbances associated with absolute or relative deficiencies in insulin action or secretion [1]. There is a rising prevalence of diabetes worldwide, with type 2 diabetes (T2DM) accounting for 90-95% of all diagnosed diabetes cases [2]. Diabetes is associated with micro-vascular complications which result in retinopathy, nephropathy, and neuropathy [2]. Optimal management of diabetes involves appropriate diet, exercise, and use of medications. Exercise helps patients with diabetes achieve a variety of goals, including improved cardiorespiratory fitness, vigor, glycemic control, lipid profile, decreased blood pressure (BP) and insulin resistance, as well as maintenance of weight loss [3–5]. Physical activity is also an effective therapeutic tool for the prevention of type 2 diabetes mellitus because it affects the metabolism of glucose and other intermediate substrates in healthy subjects and subjects with diabetes mellitus [6]. However, a low level of physical fitness among individuals with T2DM may hinder their adherence to exercise prescription and physical activity [7].

The ability to exercise may be dependent on how physically fit a person is. Physical fitness is the ability to perform daily activities willingly and actively, and it involves cardio-respiratory fitness, muscle endurance, strength, flexibility, and body composition.

These components of physical fitness have been shown to be significantly impacted by diabetes mellitus. Diabetics have decreased cardiorespiratory fitness as measured by VO2 peak compared to similarly obese and or sedentary subjects [8]. Diabetes is strongly associated with an increased risk of falling - an indication of impaired balance function - because diabetics are susceptible to balance, gait, and cognitive impairments [9, 10]. It is also commonly associated with premature loss of muscle function and ankle dorsiflexion, while body composition has been shown to increase in diabetics [11, 12]. Patients with T2DM usually present with common symptoms such as frequent thirst, frequent urination, extreme fatigue, blurred vision, and neuropathies. Neuropathy can result in a sensory loss in the lower extremities, an increase in plantar pressures, and fatigue in muscles stimulated by the peroneal and tibial nerves. These all impair motor function and thus the physical fitness of diabetics [3]. Other barriers to physical activity among people with diabetes mellitus include body mass index, age, income, gender, education level, and psychosocial factors [13].

Studies on Turks and Caucasians have shown that physical fitness was lower in type 2 diabetic patients than in non-diabetics [13, 14], however, physical fitness differs with race. For example, African Americans have lower physical fitness than Caucasians [15, 16]. Similarly, compared to British men, south-east Asian men have lower physical fitness [17]. The racial variations noted above may be due to genetic, biological, and environmental factors, and these observations have led to the concept of individualized race-specific exercise prescription [18, 19].

There is, however, a paucity of studies on physical fitness among patients with diabetes in Nigeria, and it is unclear if the diabetes-associated decline in physical fitness reported among other races is applicable in the Nigerian population. It will also be of interest to establish the main domains of physical fitness that describe fitness status in diabetics and non-diabetics since identification of these sub-domains of physical fitness may be useful in ensuring optimal physical fitness in patients with T2DM. The present study aims to compare physical fitness in patients with type 2 diabetes mellitus (T2DM) and apparently healthy non-diabetic controls (NDC).

Methods

Study population and design

A comparative cross-sectional study involved age and sex-matched subjects that have been clinically diagnosed with T2DM according to the WHO criteria [1]. The control group comprised individuals without symptoms of diabetes and with random blood sugar <140mg/dl. A minimum sample size of 64 (32 per group) was calculated using a-priori sample size for Student's t-tests [20] with an anticipated effect size of 0.8 in a 6 min-walk test as reported in Awotidebe et al. [21] between the two groups, and power of 80% while anticipating a 20% attrition rate. Subjects with type 2 diabetes were recruited from the medical outpatient clinic of the Endocrinology Unit of the Department of Internal Medicine, Federal Medical Centre, Abeokuta, Ogun State, Nigeria. The controls were apparently healthy individuals who were staff members of the same institution. Subjects were invited to participate in the research based on a sample of convenience. Inclusion criteria were that participants with diabetes must not be acutely ill and must be able to walk independently without pain or walking aids. Potential participants were excluded, if they had diabetic foot, congestive heart failure, history of heart attack, gestational diabetes, and type 1 diabetes. Informed consent was obtained from participants and ethical approval was secured from the Health Research Committee of the Federal Medical Centre in Abeokuta.

Selected tests from the Eurofit Physical Fitness Test Battery [22] were carried out to assess physical fitness covering flexibility, balance, power and strength, cardiorespiratory fitness, and body composition. Body height, body weight, body mass index (BMI), waist and hip circumference (WHC), and percentage body fat (PBF) were used for measuring body composition. Body weight (kg) was measured with a standard weighing scale. Body height (m) was measured in standing in an erect posture using a stadiometer. Body mass index was calculated as a ratio of body weight and square of body height in meters (kgm-2). Waist circumference (WC) (cm) was measured at the narrowest circumference between the bottom of the rib cage and the top of the iliac crest after normal respiration. Hip circumference (HC) (cm) was measured at the maximum circumference over the buttocks. The waist-to-hip ratio (WHR) is the ratio of the circumference of the waist to that of the hip. Percentage body fat (PBF) was measured with an Omron bioelectric impedance fat monitor. The participants with specified body height and sex were required to stand barefoot on the Omron fat estimator, which expressed total body fat as a percentage of body fat in kg.

The 6 min-walk test was used to estimate VO2max (cardio-respiratory fitness). Pre- and post-exercise systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and respiratory rate (RR) were measured. VO2max was determined using the formula: 0.2 x distance (m) - 0.191 x age (year) – 0.07 x body weight (kg) + 0.09 x body height (cm) 0.26 x RPP (rate pressure product) (10-3) + 2.45 [23]. The Borg RPE scale was used to assess the perceived exertion level of the 6 min-walk test of participants. The single-leg stance test was used to assess the balance of individuals with eyes opened and closed (in seconds). Flexibility was evaluated with the sit-and-reach (SR in cm) and sit-up tests (in repetitions per seconds), while handgrip in elbow flexion (HG flex) and extension (HG ext) (kg), and horizontal jump (cm) were used to quantify lower limb strength.

Sit-up and horizontal jump tests results were stratified by age and sex and were interpreted as excellent, good, above average, average, below average, poor, and very poor [24–26]. A sit-and-reach test score of > 30 cm was rated as excellent, 20–30 cm as good, 10–19 cm as average, and < 10 cm as poor [27], while the results of the single-leg stance test of 29.8 seconds and 4.9 seconds as good with open and closed eyes, respectively [28]. Handgrip dynamometer norms were interpreted based on age- and gender-specific published values [29, 30].

Data analysis

Data analysis was performed with the use of SPSS for Windows 21.0. Descriptive statistics of frequency distribution tables and percentage was used to summarize participants' socio-demographic and individual characteristics. Inferential statistics of independent t-test was used to determine the significant differences in variables measured between the two groups, and comparisons were considered significant at < 0.05.

Results

The participants were not significantly different in their demographic characteristics of age (ST2DM = 52.3 ± 9.8 years, NDC = 48.1 ± 8.8 years, p = 0.094) and sex (men = 10, women = 22 in each group, p = 0.525). The clinical characteristics of the ST2DM group are shown in Table 1. The result of the 6-min walk test are given in Table 2. SBP (post-exercise), DBP (pre and post-exercise) RR, distance walked, and the Borg scale scores differed non-significantly between the two groups ($p > 0.05$). Pre-exercise SBP and pre- and post-exercise HR were significantly greater in the ST2DM ($p < 0.05$) than the NDC.

Table 1. Laboratory test results of subjects with type 2 diabetes mellitus (ST2DM)

TEST	ST2DM MEAN ± SD (RANGE)
Fasting blood glucose (mmol/l)	8.5 ± 0.7 (5.5 - 15.8)
Total cholesterol (mmol/l)	7.4 ± 1.6 (4.6 - 7.7)
Low density lipoprotein	2.9 ± 1.0 (2.3 - 7.5)
High density lipoprotein (mmol/l)	0.9 ± 0.5 (0.8 - 1.9)
Triglycerides	1.5 ± 0.3 (0.7 - 4.1)
HbA_{1c} (%)	7.9 ± 2.4% (6 - 11.5)

Note: HbA1c - glycated hemoglobin; ST2DM - subjects with type 2 diabetes mellitus

Table 2. Comparison of 6-minute walk test results in participants with and without diabetes

Variable	ST2DM	NDC	p-value
6-min walk test distance	308.5 ± 61.7m	305 ± 43.5m	0.802
SBP pre-exercise	142 ± 14.7mmHg	129.4 ± 16.1mmHg	0.04
SBP post-exercise	143.2 ± 19.3mmHg	134.6 ± 20.3mmHg	0.115
DBP pre-exercise	81.2 ± 15.5mmHg	77.4 ± 9.3mmHg	0.254
DBP post-exercise	80.6 ± 8.7mmHg	76.8 ± 13.8mmHg	0.246
HR pre-exercise	86.3 ± 12.2b/min	72.7 ± 10.7b/min	0.00
HR post-exercise	90.4 ± 10.0b/min	77.7 ± 13.0b/min	0.00
RR pre-exercise	23.3 ± 5.0/min	21.7 ± 4.2/min	0.183
RR post-exercise	26.7 ± 5.5/min	26.4 ± 6.7/min	0.183
Borg scale	9.0 ± 1.9	10.1 ± 2.8	0.111

Note: SBP - systolic blood pressure; DBP - diastolic blood pressure; HR - heart rate; RR - respiratory rate

Table 3 shows the results of selected physical fitness tests between the ST2DM and NDC groups. BMI was significantly higher (p = 0.048) in ST2DM than NDC, WHR was significantly higher in ST2DM, and PBF was similar in the two groups. In the single leg stance test with closed eyes (one legec) the standing time was significantly shorter in the ST2DM ($p = 0.047$), while it was not significantly different in the single leg stance test with open eyes (one legeo) ($p = 0.155$). In the lower limb strength test the distance covered during the broad jump was significantly lower in the ST2DM compared to the NDC ($p < 0.0001$) (Tab. 3). Trunk/hip flexibility and grip strength in extension (HG ext and SR) were significantly reduced ($p < 0.05$) amongst the ST2DM. There was no significant difference in grip strength during elbow flexion ($p = 0.061$) and in cardiorespiratory fitness ($p = 0.782$) between the two groups.

Table 3. Comparison of selected physical fitness scores among participants with and without diabetes

Variable	ST2DM	NDC	*p*-value
Body weight (kg)	78.3 ± 11.8	74.3 ± 11.1	0.202
Body height (m)	1.6 ± 0.8	1.8 ± 0.8	0.810
BMI (kg/m^2)	28.7 ± 4.3	26.4 ± 4.1	0.048
WC (cm)	104.2 ± 8.0	94.2 ± 8.7	0.000
HpC (cm)	110.0 ± 5.2	107.1 ± 7.9	0.509
WHpR	1.0 ± 0.6	0.9 ± 0.70	0.000
Body fat (%)	33.3 ± 10.4	31.9 ± 9.1	0.615
One legeo	31.0 ± 22.5 sec	39.6 ± 21.5 sec	0.15
One legec	5.5 ± 5.0 sec	11.1± 12.6 sec	0.047
Sit and reach (SR)	12.2 ± 19.8cm	35.3 ± 8.8cm	0.00
Sit up (reps/sec)	7.1 ± 7.4	6.7 ± 5.8	0.805
Horizontal broad jump	26.5 ± 43.9cm	122.4 ± 42.8cm	0.00
HG flexion	21.7 ± 10.4	28.2 ±14.9	0.074
HG extension	23.6 ± 12.7	34.6 ± 19.9	0.022
estimated $VO_{2\,MAX}$	48.7±12.7ml/min/kg	47.9±9.0ml/min/kg	0.782

Note: BMI - body mass index; WC - waist circumference; HpC - hip circumference; WHpR – waist-to-hip ratio; One legeo – single leg stance with open eyes; One legec – single leg stance with eyes closed; HG - hand grip; ST2DM - subjects with diabetes mellitus; NDC - non-diabetic controls

Discussion

The present study compared the physical fitness of subjects with type 2 diabetes mellitus against age- and sex-matched non-diabetic controls. The study revealed no significant differences in the percentage of body fat between the NDC and ST2DM groups. However, several studies have reported that increased body fat percentage is significantly associated with type 2 diabetes mellitus [31, 32]. The outcome of this study indicates that subjects with diabetes mellitus have a significantly higher body mass index in tandem with several other studies [32–34] which reported that ST2DMs had a significantly higher BMI than NDCs. However, Mohammed [31] reported no significant difference in the body mass index between the ST2DM and NDC groups. Both constructs measure body fat, however, BMI does not distinguish fat mass from muscle, whereas body fat percentage focuses on fat mass. Thus, body fat percentage is a more accurate measure of body composition than BMI. Increased fat mass has been associated with the development and presence of type 2 diabetes mellitus [31]. The lack of significant differences in the body fat percentage between the two groups in the present study may be an indication of the inadequacy of the modality of measurement of body fat percentage. We made use of the electrical bio-impedance method (which has been shown to exhibit an error rate as high as 8%), whereas a total lipid profile through haematological analysis may provide more clinically plausible information in respect to the correlation between the presence of increased body fat and type 2 diabetes mellitus [31, 32].

WC was also greater in the ST2DM than NDCs. It has been reported that WC and its change are more associated with the risk of type 2 diabetes than general adiposity indicators, BMI, and changes in body weight among adults [35]. In the present study waist/hip ratio was significantly higher in ST2DM than NDC. This is consistent with other studies [36, 37] showing that increased truncal obesity is significantly associated with DM. Increased waist/hip ratio has been described as a predictor of cardiovascular morbidity [38, 39]. This suggests that body composition should be monitored and controlled in addition to routine management of diabetes mellitus.

In this study, the standing time with eye closed in the single-leg stance test was significantly shorter in ST2DM than NDC, signifying problems with proprioception or other sensory pathways which may play a role in the ability of individuals to maintain a one-leg stance. Balance impairment is usually associated with lower limb motor weakness or, sometimes, with impairment of sensory pathways. These are commonly seen in patients with diabetes [40, 41]. However, the standing time with open eyes in the single-leg stance test was not significantly different between ST2DM and NDC. In this study, the controls covered a significantly longer distance in their jump test, which indicates that the subjects with T2DM may have had impaired lower limb motor strength. Authors of some earlier studies found that balance was impaired among people with diabetes [40, 42].

Hip/trunk flexibility was significantly reduced amongst the ST2DM, which suggests that diabetics may not be able to exercise as they expect, and they would have a higher risk of injury. There are many benefits of being flexible and of regular performance of flexibility exercises. It has been reported that flexibility exercises help to maintain balance, and that performance of aerobic exercises [4] contributes to a reduction in blood glucose (especially post-meal) [4, 43], and is effective as resistance exercise in lowering post-meal blood glucose [43]. Reduction in the joint range of motion and muscular extensibility, which are synonymous with reduced flexibility, may be indicative of the presence/onset of musculoskeletal complications in diabetes mellitus [44]. This may explain the reduced flexibility observed among the ST2DM in the present study. Flexibility in the non-diabetic population may be reduced with age, but the presence of diabetes mellitus enhances the possibilities of patients to develop diabetic cheiroarthropathy (stiff hand syndrome) or limited joint mobility syndrome, diabetic muscle infarction, and several other musculoskeletal complications [44]. Our results revealed no significant differences in the sit-up test between the two groups of participants. Sit-up exercises as measured with the Eurofit test battery were rated by the participant's ability to complete curl up exercises within a specified period [22]. The fact that this test is difficult for most apparently healthy individuals may explain the lack of significant difference in the ability of the two groups to complete it. The Eurofit test battery was initially designed as a standard test for school-aged children [22], who may not find it difficult completing five sit-up exercises in 30 seconds. The sit-up exercises as measured with the test battery do not accurately assess the strength of the abdominal muscles among adult subjects because of the ceiling effect.

The distance covered during the horizontal jump test was significantly higher in NDC than in ST2DM, which could be explained by motor impairments in the latter [45, 46]. A shorter horizontal jump distance may be a reflection of lower limb weakness. Lower and upper limb muscles strength in patients with diabetes has been reported to be reduced, and it is usually associated with impaired mobility [45]. Some studies [46, 47] also revealed a reduction in motor strength due to the presence and severity of peripheral neuropathy. Our data suggest significant differences in handgrip strength during elbow extension between the two groups. This is in tandem with Tayyari [48] who reported that the greatest handgrip strength is attained when the elbow is in a fully extended position. However, in our study, there was no significant difference in handgrip strength during elbow flexion between the two groups of participants. Again, Tayyari [48] suggests that the real test of grip strength is carried out with the elbow extended, and this can be noted in our study with the higher grip strength during elbow extension in NDC than ST2DM. Although we did not measure lower limb strength, the horizontal jump results reflect lower limb muscle strength in ST2DM. Tsai et al. [42] reported that muscle strength was not only reduced in ST2DM, but it also determined balance in patients with diabetes. Hence, the musculoskeletal health of people with diabetes should receive adequate attention during rehabilitation.

No significant differences in cardio-respiratory fitness (CRF) between the two groups were found in the present study. This is contrary to the observation that the CRF of diabetics was significantly lower compared with age- and sex-matched non-diabetic controls [13, 40]. However, people with high CRF have been shown to have a lower incidence of T2DM compared with those with low CRF [49], which is associated with reduced diabetes-related mortality among women [50]. We estimated CRF with a 6-minute walk test, indicating exercise capacity. A lower exercise capacity estimated with a 6-minute-walk test has been reported among Nigerians with T2DM [21, 51]. In our study, the mean 6-minute walk distance covered by the two groups was significantly lower than the reference data for this age group [52]. This may be due to the differences in procedural specifics adopted in our research. We used a single trial instead of the best of the three trials recommended by the American Thoracic Society Guidelines for 6MWT [53]. Bohannon [54] revealed that in some studies subjects were allowed to complete the test twice using the highest value with verbal incentives to encourage subjects to walk at a faster pace; hence, variations in procedural specifics for the 6MWT are not uncommon. This variation in procedural specifics may have reduced the external validity of CRF estimation in the present study; however, CRF data obtained from the 6MWT are estimates and may all be subject to similar or other inaccuracies. The present study revealed no significant differences in the cardiorespiratory fitness in the two groups of participants. It is also likely that the lack of differences in cardio-respiratory fitness as reported in our study may be attributed to the lower and similar age of the participants, or better still because both groups were overweight, as suggested by our data, and thus may contribute to lower CRF. Loprinzi and Pariser [55] found that obesity and sedentary lifestyle contributed to lower cardio-respiratory fitness among patients with diabetes.

This study is limited as it did not explore other determinants of physical fitness such as socioeconomic status, history of involvement in physical activities, and lower limb dynamometry. Also, some of the Eurofit tests, especially the sit-up test, were meant for children/adolescents, and a 6-minute walk test may pose limitations on our results. Despite these limitations, the outcome of our study is consistent with the fact that flexibility and motor strength are reduced in subjects with type II diabetes mellitus compared with non-diabetic controls. Participants with diabetes mellitus had similar cardio-respiratory fitness levels when compared with apparently healthy age- and sex-matched controls.

Conclusion

Balance, flexibility, and strength were significantly lower, while measures of adiposity were significantly higher in subjects with type 2 diabetes mellitus compared with non-diabetic controls.

Reduced motor strength and flexibility in diabetics may be indicative of the development of diabetes–associated neuromuscular pathologies. To ensure optimal physical fitness, exercise prescription for patients with diabetes should be targeted at improving motor strength and flexibility.

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