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Relationships among exercise capacity, dynamic balance and gait characteristics of Nigerian patients with type-2 diabetes: an indication for fall prevention

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This study investigated the relationships among exercise capacity (EC), dynamic balance (DB), and gait characteristics (GCs) of patients with type-2 diabetes (T2D) and healthy controls (HCs). This observational controlled study involved 125 patients with T2D receiving treatment at a Nigerian university teaching hospital and 125 apparently healthy patients' relatives and hospital staff recruited as controls. EC maximum oxygen consumption (VO_{2max}) was estimated following a 6-min walk test. DB and GC were assessed using the Time Up to Go Test and an accelerometer (BTS G-Walk) assessing gait speed, step length, stride length, and cadence respectively during a self-selected walk. Data were analyzed using descriptive and inferential statistics. Alpha level was set at $P<0.05$. The mean ages of patients with T2D and HCs were 57.6±6.6 and 60.0±7.0 years, respectively. All physical characteristics were comparable ($P>0.05$). There were significant differences in the VO_{2max} and DB between patients with T2D and HCs; 7.6±0.6 mL/kg/min vs. 9.6±0.6 mL/kg/min (t=-16.6, P=0.001) and 14.2±2.1 sec vs. 10.4±1.5 sec (t=-6.37, P=0.001), respectively. Furthermore, significant differences were found in GC between patients with T2D and HCs; gait speed: 0.7±0.1 m/sec vs. 1.2±0.1 m/sec (t=-16.60, P=0.001), step length: 0.6±0.2 m vs. 0.9±0.3 m (t=-7.56, P=0.001) and stride length: 0.9±0.1 m vs. 1.1±0.5 m (t=-6.09, P=0.001). There were significant correlations between EC and gait speed in both groups (T2D: r=-0.26, P=0.032 and HCs: r=0.51, P=0.003). In conclusion, patients with T2D demonstrated lower EC, unstable DB, and altered GCs compared with HCs. Exercise interventions to improve EC and gait balance are recommended.

Keywords: Type-2 diabetes, Exercise capacity, Stability, Gait parameters, Fall prevention

INTRODUCTION

Chronic noncommunicable diseases (NCDs) are the leading causes of morbidity and mortality globally of which low and middle income countries are mostly plagued (Mather et al., 2001; World Health Organization, 2011). Of all NCDs, the prevalence of type-2 diabetes (T2D) is rapidly on the rise due to an increased prevalence of overweight and obesity, lifestyle changes, poor dietary intake, and physical inactivity (BeLue et al., 2009; World Health Organization, 2011). In sub-Sahara Africa, it is estimated that undiagnosed T2D accounts for 60% of those with the disease in Cameroon, 70% in Ghana and over 80% in Tanzania (Hall et al., 2011). In Nigeria, more than 1.2 million people were affected with an estimation of about 3.8 million people having impaired glucose tolerance (Awotidebe et al., 2016a).

The most common symptoms of T2D include hyperglycaemia, polyuria, muscle weakness and diabetic peripheral neuropathy resulting to numbness, tingling sensation in the extremities and

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consequent severe muscle impairment, neuromuscular systems dysfunction, easy fatigability and poor exercise tolerance (Kumar et al., 2005; Kumar et al., 2008). Furthermore, T2D has been reported to have negative impact on locomotory systems functioning due to poor blood leg flow, muscular weakness, and joint proprioceptive dysfunction in the lower extremities which may affect gait characteristics (Fulk et al., 2010).

Gait characteristics connotes walking pattern and could be described as the manner of walking style in relation to body sways during ambulation (Kirtley, 2006). It is a complex process of transformation of a series of controlled and coordinated motions occurring simultaneously at various joints of the lower extremities and as well as cerebral and spinal coordination which can be normal, antalgic or unsteady (Baker, 2006; Wolfson et al., 1990). Although gait parameters including gait speed, step length, stride length, and cadence can be measured during walking, they differ from one person to the other (Lee and Grimson, 2002). Furthermore, altered gait parameters have been documented as important determinants of stability or fall during ambulation (Ostrosky et al., 1994).

Physical therapists often prescribe walking as a form of exercise for improving cardiorespiratory endurance and plasma blood glucose control (Allet et al., 2010; Colberg et al., 2010). Regular walking has also been documented to contribute to improvement in muscular strength, joint flexibility and a protective mechanism for preventing secondary complications commonly seen in patients with T2D (Guyatt et al., 1985; Warburton et al., 2006). More importantly, walking enhances exercise tolerance thereby effectively improving oxygen consumption (Ozdirenç et al., 2003). However, it is not known whether oxygen utilization is related to walking pattern in patients with T2D. Furthermore, unsteady or imbalance gait pattern has been reported as a risk factor for falling in patients with T2D (Allet et al., 2010). However, only a few studies have examined exercise capacity, dynamic balance and their relationships with gait parameters in patients with T2D and compared with healthy controls. Investigating exercise capacity, dynamic balance and gait parameters in patients with T2D could help to understand the mechanism contributing to increased risk of falling among this population. The aim of this study was to assess exercise capacity, dynamic balance and relationships with spatiotemporal gait parameters of patients with T2D and compare the parameters with that of healthy controls.

MATERIALS AND METHODS

Participants

The participants were patients with T2D who were attending the Medical Out-Patient Department, Endocrinology and Metabolism Unit of the Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC), Ile-Ife, Nigeria. They were included in the study following a clinical diagnosis of T2D, regular use of anti-diabetic medications and with ability to ambulate without any assistive device. They were excluded from the study if presented with poor glycaemic control, concomitant foot ulcer, orthopaedic or surgical problems affecting walking ability. Furthermore, patients with comorbidity such as diabetic peripheral neuropathy, uncontrolled hypertension or stroke were excluded. The controls were age and sex-matched apparently healthy individuals recruited among patients' relatives and hospital staff using purposive sampling technique. The minimum sample size for the study was calculated using the formula: $n = Z^2(p\ (1-p)/e^2$ where, n = required sample size, Z = z-value (z-value for 95% confidence level (1.96), p = the estimated proportion of an attribute that is present in the population, and e = the desired level of precision (i.e., confidence interval, expressed as decimal [0.05]) (Kasiulevičius et al., 2006). The prevalence (p) of any functional disability (defined as inability to independently perform any function) is 9.2% (Gureje et al., 2006). Hence, a minimum of 125 patients with T2D and 125 healthy controls resulting to a total of 250 participants were recruited for this study.

Protocol design

This is an observational, controlled study involving 125 patients with T2D and 125 apparently healthy controls. Ethical approval for this study was obtained from the Ethics and Research Committee of the Obafemi Awolowo University Teaching Hospitals Complex (OAUTHC) (ERC/2016/03/14), Ile-Ife, Nigeria. Permission to recruit patients with T2D from the Medical Out-Patient Department, Endocrinology and Metabolism Unit of the OAUTHC was sought and obtained. Patients with T2D were approached, the purpose of the study was explained and an informed consent form was given to those who volunteered to participate in the study. Data on socio-demographic and anthropometric characteristics, clinical profile including fasting blood glucose (FBG) and cardiovascular parameters were recorded.

Tests

The tests were carried out in the Gymnastic section of the Physiotherapy Department of the OAUTHC, Ile-Ife, Osun State, Nigeria.

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Assessment of FBG

The FBG was assessed using a portable glucometer (One Touch Lifescan Glucometer; Johnson-Johnson Company Product, Inc., Milpitas, CA, USA) in order to determine the plasma blood glucose level using the standard procedure (American Diabetes Association, 2012). A day prior to the assessment of FBG, participants were informed not to eat any food or drink for a minimum of 8 hours before coming their appointment. All measurements were taken between 7:00 a.m. to 9:00 a.m. A FBG greater than 5.6 mmol/L confirms the presence of diabetes.

Assessment of cardiovascular parameters

Cardiovascular parameters including heart rate, systolic and diastolic blood pressure were assessed using an electronic blood pressure device (Omron M6 Comfort IT Intellisense, Osaka, Japan) after 5 min of quiet sitting.

Assessment of exercise capacity

Exercise capacity was assessed using the 6-min walk test according to the procedure advanced by the American Thoracic Society. Participant was instructed to walk from the starting point to the end at their own selected pace along a 30-m walkway while attempting to cover as much ground as possible in 6 min. They were encouraged every 30 sec in a standardized manner by saying: "You are doing well" or "Keep up the good work." Participants were reminded of the time remaining for the completion (Adedoyin et al., 2010). At the end of 6-min walk distance (6-MWD), participant's heart rate, systolic and diastolic blood pressures were recorded immediately. The distance covered was recorded to the nearest meter while exercise capacity (maximum oxygen consumption, VO_2max) was estimated using the American College of Sport Medicine (1995) predictive equation during level ground walking (Adedoyin et al, 2010; Awotidebe et al., 2016b).

Computation

$VO_2max = speed (m/min) \times 0.1 (mL/O_2/kg) + 3.5$ (American College of Sport Medicine, 1995).

Assessment of dynamic balance

Dynamic balance was assessed using the Timed Up and Go (TUG) Test. Participants were allowed to sit on a standard and comfortable chair after resting for 5 min. Participant was instructed to get up and walk as quickly as possible on a 3 m level ground without running. Thereafter, participant was allowed to return to sitting position on the chair. The total duration taken to complete the task was recorded in seconds. The higher the value the poorer the dynamic balance (Wall et al., 2000).

Assessment of gait parameters

The spatiotemporal gait parameters including gait speed, step length, stride length, and cadence were assessed using an accelerometer; the BTS G-Walk, a locomotory analysis tool software (BTS SpA, Via della Croce Rossa, 11 Padova, Italy; SN: 0213-0378) during a self-selected walk along an 8-m pathway (Pau et al., 2014). The G-walk is a wireless system consisting of an inertial sensor composed by a triaxial accelerometer, a magnetic sensor, and a triaxial gyroscope. It was positioned at the 5th lumbar spine and wrapped around the waist level of each participant with a semielastic belt during a self-selected walk. The G-walk has a G-sensor with a Bluetooth device which was used to transfer signal motions during the self-selected walk to a computer (HP model) for which BTS G-walk software has been installed. The gait parameters generated by the BTS G-walk device was sent to the laptop computer via a small Bluetooth device fixed on the laptop. The selected gait parameters during the level corridor walk were recorded, analyzed, and retrieved from the laptop computer.

Statistical analysis

Data were summarized using descriptive statistics of frequency, percentage, mean and standard deviation. Inferential statistics of paired t-test was used to compare male and female patients with T2D as well as healthy controls. Pearson moment correlation was used to determine the relationship among exercise capacity, dynamic balance and gait parameters. Alpha level was set at $P < 0.05$. The IBM SPSS Statistics ver. 19.0 (IBM Co., Armonk, NY, USA) was used to perform statistical analyses.

RESULTS

Table 1 shows the socio-demographic characteristics of patients with T2D and healthy controls. There were more women than men in both groups and a majority were in the middle age. Less than a fifth of the respondents had monthly income greater than ₦100,000 while more than half, 69 of the patients with T2D (55.2%) had onset of diagnosis of diabetes less than 5 years. The mean ages of patients with T2D and healthy controls were 57.6 ± 6.6 and 60.0 ± 7.0 years, respectively and they were comparable in all physical characteristics ($P > 0.05$). There were significant differences in clinical profile between patients with T2D and

Table 1. Socio-demographic characteristics of participants (n=250)

Variable	Patients (n=125)	Control (n=125)
Sex		
Male	57 (45.6)	55 (44.0)
Female	68 (54.4)	70 (56.0)
Age group (yr)		
40–60	71 (56.8)	80 (64.0)
>60	54 (43.2)	45 (36.0)
Occupation		
Artisan/farmer	68 (54.4)	12 (9.6)
Civil servant	21 (16.8)	88 (70.4)
Retiree	36 (28.8)	25 (20.0)
Marital status		
Married	78 (62.4)	64 (51.2)
Divorced	13 (10.4)	28 (22.4)
Widow/widower	34 (27.2)	33 (26.4)
Level of education		
Nonformal /primary	30 (24.0)	22 (17.6)
Secondary	73 (58.4)	62 (49.6)
Tertiary	22 (17.6)	41 (32.8)
Monthly income		
<₦50,000	46 (36.8)	44 (35.2)
₦50,000–100,000	63 (50.4)	59 (47.2)
>₦100,000	16 (12.8)	22 (17.6)
Onset of diagnosis		
<5 yr	69 (55.2)	-
≥5 yr	56 (44.8)	-

Values are presented as number (%).
₦=Naira (Nigerian currency).

healthy controls in FBG and systolic blood pressure: 7.6±1.4 mmol/L vs. 5.5±1.1 mmol/L (t=-14.4; P=0.001) and 128.6±5.6 mmHg vs. 122.3±7.5 mmHg (t=-2.58, P=0.043).

There were significant differences between patients with T2D and healthy controls in 6-MWD and estimated VO_{2max} were 6-MWD: 237.1±34.8 m vs. 361.0±35.1 m (t=-15.39, P=0.001) and VO_{2max}: 7.6±0.6 mL/kg/min vs. 9.6±0.6 mL/kg/min (t=-16.16, P=0.001), respectively. Furthermore, significant differences were observed between patients with T2D and healthy control in gait parameters; gait speed: 0.7±0.1 m/sec vs. 1.2±0.1 m/sec (t=-16.60, P=0.001), step length: 0.6±0.2 m vs. 0.9±0.3 m (t=-7.56, P=0.001), stride length: 0.9±0.1 m vs. 1.1±0.5 m (t=-6.09, P=0.001). Significant higher duration of dynamic balance test was observed in patients than healthy controls: 14.2±2.1 sec vs. 10.4±1.5 sec (t=-6.37; P=0.001), respectively (Table 2).

Table 3 shows comparison of physical characteristics between male and female patients with T2D. There was no significant difference between male and female patients in age and all physical characteristics except height; 1.7±0.1 m vs. 1.6±0.1 m (t=4.66, P=0.001), respectively. There was no significant difference in 6-MWD, VO_{2max}, gait parameters and dynamic balance between male and female patients with T2D (P>0.05). There were significant correlations in both patients with T2D and healthy controls between exercise capacity (VO_{2max}) and each of gait parameters; speed (patient: r=0.26, P=0.032 and control: r=0.51, P=0.003).

Table 2. Comparison of age, physical characteristics, gait parameters, clinical profile, and exercise capacity of patients with type-2 diabetes and healthy controls

Variable	Patient (n=125)	Control (n=125)	t-cal	*P*-value
Age (yr)	57.6±6.6	60.0±7.0	-1.60	0.118
Weight (kg)	70.3±10.2	68.5±10.4	0.77	0.448
Height (m)	1.7±0.1	1.7±0.1	-0.30	0.976
BMI (kg/m^2)	25.6±4.3	24.8±4.1	0.67	0.505
FBG (mmol/L)	7.6±1.4	6.5±1.1	-14.4	0.001*
SBP (mmHg)	128.6±5.6	122.3±7.5	-2.58	0.043*
DBP (mmHg)	82.6±4.6	80.7±7.0	-0.19	0.617
HR (bpm)	82.1±5.7	81.6±7.0	-0.05	1.248
6-MWD (m)	237.1±34.8	361.0±35.1	-15.39	0.001*
Est.VO_{2max} (mL/kg/min)	7.6±0.6	9.6±0.6	-16.16	0.001*
DB (sec)	14.2±2.1	10.4±1.5	-6.37	0.001*
Gait speed (m/sec)	0.7±0.1	1.2±0.1	-16.60	0.001*
Step length (m)	0.6±0.2	0.9±0.3	-7.56	0.001*
Stride length (m)	0.9±0.1	1.1±0.5	-6.09	0.001*
Cadence (step/min)	97.8±15.6	101.7±8.4	-1.07	0.292

Values are presented as mean±standard deviation.
BMI, body mass index, FBG, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate, 6-MWD, 6-min walk distance, Est.VO_{2max}, estimated maximum oxygen consumption; DB, dynamic balance.
*P<0.05.

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Table 3. Comparison of age, physical characteristics, clinical profile, gait parameters, and exercise capacity of male and female patients with type-2 diabetes

Variable	Male (n=57)	Female (n=68)	t-cal	*P*-value
Age (yr)	57.0±7.5	58.2±5.8	-0.62	0.542
Weight (kg)	71.3±11.7	69.4±8.5	0.58	0.566
Height (m)	1.7±0.06	1.6±0.1	4.66	0.001*
BMI (kg/m^2)	24.6±4.3	26.5±3.5	-1.59	0.126
FBG (mmol/L)	7.3±1.3	7.4±1.6	-0.26	0.451
SBP (mmHg)	129.4±4.7	128.3±6.6	-0.26	0.152
DBP (mmHg)	81.6±3.4	80.5±6.0	-0.24	0.421
HR (bpm)	82.5±7.5	81.8±6.2	-1.05	0.129
6-MWD (m)	238.2±34.9	242.7±36.3	-0.49	0.851
Est.VO_{2max} (mL/kg/min)	7.5±0.6	7.6±0.82	-0.49	0.851
DB (sec)	13.2±1.8	13.3±1.6	-0.42	0.382
Gait speed (m/sec)	0.7±0.1	0.7±0.1	-0.55	0.589
Step length (m)	0.7±0.4	0.8.6±0.3	0.36	0.721
Stride length (m)	1.1±0.4	1.0±0.3	1.39	0.180
Cadence (step/min)	99.6±14.8	98.2±12.8	-0.13	0.900

Values are presented as mean±standard deviation.
BMI, body mass index, FBG, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate, 6-MWD, 6-min walk distance, Est.VO_{2max}, estimated maximum oxygen consumption; DB, dynamic balance.
*P<0.05.

Similarly, there was significant correlations between exercise capacity (VO_{2max}) and 6-MWD in both groups; patient (r=0.75, P=0.001 and healthy controls: (r=0.86, P=0.001). However, significant negative correlation was found between exercise capacity and body mass index in both in groups; patients: (r=-0.25, P=0.014 and healthy control: (r=-0.32, P=0.002) (Table 4).

DISCUSSION

This study investigated the relationship among exercise capacity, dynamic balance and gait characteristics of patient with T2D and compared with apparently healthy controls. Findings from our study showed that the 6-MWD between patients with T2D and healthy controls varied considerably with significant statistical difference. This is consistent with the findings of some previous study that patients with T2D have reduced walking capacity (Adeniyi et al., 2010; Awotidebe et al., 2014). Reasons for the differences in the 6-MWD between patients and controls may be as a result of underlying pathologies associated with T2D which may include effects of hyperglycemia on supra-spinal activities, easy fatigability, poor blood leg supply and proprioceptive dysfunction in the lower limbs during ambulation (Petrofsky et al., 2005; Wallace et al., 2002). However, comparison of 6-MWD in our study with that of patients with heart failure showed that the 6-MWD is far less than what is obtained in patients with cardiac challenges (Adedoyin et al., 2010; Cahalin et al., 2013). Perhaps, it implies that patients with T2D may have lower cardiopulmonary endurance compared to other patients with chronic diseases. Although reference values for 6-MWD in healthy individuals provided wide range of values, several factors but not limited to age, sex, weight, height, disability, and test familiarization may possibly influence the result of 6-MWD in patients with chronic diseases including T2D (Adeniyi et al., 2010; McKelvie et al., 2002).

Table 4. Relationships between exercise capacity and gait characteristics of patients with type-2 diabetes and healthy controls

Variable	Exercise capacity	
	Patients	Control
Step length (cm)	-0.10 (0.546)	-0.16 (0.215)
Stride length (cm)	-0.20 (0.202)	-0.11 (0.308)
Cadence (step/min)	-0.11 (0.495)	-0.42 (0.031)*
Gait speed (m/sec)	0.26 (0.032)*	0.51 (0.003)*
DB (sec)	0.31 (0.051)	0.43 (0.060)
6-MWD (m)	0.75 (0.001)**	0.86 (0.001)**
BMI (kg/m^2)	-0.25 (0.014)*	-0.32 (0.002)*

Values are presented as r (*P*-value).
DB, dynamic balance; 6-MWD, 6-min walk distance; BMI, body mass index.
*P<0.05. **P<0.01.

Exercise capacity (VO_{2max}) is a function of cardiorespiratory fitness and a strong determinant of survival in chronic diseases including T2D. Findings from our study showed that the estimated VO_2max is lower in patients with T2D compared to healthy controls. This is in agreement with findings of some previous studies that patients with T2D have lower exercise capacity (Awotidebe et al., 2014; Fang et al., 2005). The reduction in exercise capacity of patients with T2D may be linked to poor glucose metabolism. A study provided laboratory evidence that the transporter protein GLUT4 expression at the plasma membrane is related to fibre volume in human skeletal muscle fibres (De Rekeneire et al., 2003). Similarly, poor glycemic control in patients with T2D has been associated with increased stiffness of large conduit vessels. The compliance of the aorta plays significant role in modulating coronary artery blood flow which has important consequences for myocardial work capacity and, therefore, leading to reduced exercise capacity (Fang et al., 2005). Furthermore, there is growing body of evidence to suggest that body's capability to utilize oxygen in patients with T2D is compromised due to poor blood perfusion of muscles at cellular level and consequent reduction in exercise capacity (Awotidebe et al., 2014; Kingwell et al., 2003). It is possible that low exercise capacity impacted negatively on muscular functioning causing an increased muscle weakness and progressive deconditioning in patients with T2D resulting to an unprecedented abnormal gait performance and consequently higher risk of falling during ambulation.

Gait speed is one of the most widely reported spatiotemporal gait parameters involving gait studies (Allet et al., 2010). Findings from our study show that patients with T2D demonstrated slower gait speed than healthy controls. This finding corroborates the reports of previous studies that gait speed and functional capacity decline occurred more in patients with T2D compared to healthy individuals (Mantovani et al., 2015; Volpato et al., 2012). Furthermore, there is evidence to suggest that development of joint stiffness and poor sensory perception in patients with T2D contributes to increased gait abnormality (Guimaraes and Isaacs, 1980; Maki, 1997). Our study also found that both step and stride length, and cadence were lower in patients with T2D compared to healthy controls. It is believed that whenever the systems regulating gait are dysfunctional, movement control may be impaired leading to reduced step and stride lengths (Hausdorff, 2005). Gait parameters like most physiological parameters are not often constant but rather fluctuate with time and change from one stride to the next. This may explain why there is increased risk of falling in patients with T2D who are known to demonstrate frequent altered gait parameters.

Several changes in gait characteristics such as slower gait speed, shorter stride length, and increased gait variability and postural instability have been related to an increased risk of falling in older individuals as well as patients with T2D (Guimaraes and Isaacs, 1980; Mecagni et al., 2000). Moreover, gait characteristics in older adults have been linked to gray matter atrophy and white matter hyper-intensities (Callisaya et al., 2013; Rosano et al., 2007). It is possible that the gray matter atrophy have stronger effect on locomotor control in those with T2D compared to apparently healthy individuals (Manor et al., 2012). Similarly, the interaction between the vestibular system and cerebellum in patients with T2D probably altered the body balance and further increases the risk of falling. Our study detected that the duration to complete the TUG test was higher in patients than healthy controls which implies probable reduced dynamic balance. More importantly, diabetic neuropathy increases fall risk rate up to 1.5 times higher in patients than normal individuals due to balance and postural instability (Ijzerman et al., 2012).

Worthy of note is the relationship between exercise capacity and gait characteristics. It is not surprising that only gait speed demonstrated significant correlation with exercise capacity in both patients with T2D and healthy controls. Several studies have reported that gait speed is an important determinant of exercise capacity in patients with T2D (Ble et al., 2005; Volpato et al., 2012). Exercise plays significant role in falls reduction but patients with inadequate gait stability or who experience a fall related injury, may consequently not be able to meet the recommendations for effective exercise regimen leading to an increased risk of diabetic complications and decreased musculoskeletal function. Furthermore, fall-related injuries are often assumed to trigger a vicious circle because of potentially detrimental influence on patients' physical activity level (Allet et al., 2008). Currently, the public health guidelines for patients with T2D management recommend that patients should perform at least 30 min of physical activity a day, 6 times a week, requiring adequate gait security and balance.

Balance control, muscle strength and joint mobility are also important fall risk factors and are salient measures that may be influenced by exercise (Barnett et al., 2003; Volpato et al., 2012). There is growing evidence that exercise intervention involving lower limbs resistance training, gait re-education and cardiorespiratory endurance training play important role for fall prevention and improving quality of life in patients with T2D (Allet et al., 2010; Barnett et al., 2003; Lee et al., 2013). Emphasis should be laid on regular assessment of exercise capacity, gait balance and specific exercise interventions to prevent recurrent falls among patients with T2D. Notable limitations in our study include the design of the study being a cross sectional study. This may limit the generalizability of our findings to other patients with T2D. Furthermore, the physical activity level of our participants was not assessed prior to this study and it may confound the outcome of this study, hence, caution should be exercised in interpreting this results.

In conclusion, patients with T2D demonstrated lower exercise capacity, reduced dynamic balance and altered gait characteristics compared to healthy controls. There was significant relationship between exercise capacity and gait speed in both groups but significantly correlated with cadence only among healthy controls. Interventions to improve exercise capacity, balance and gait training program in patients with T2D should be incorporated into plan of treatment to reduce risk of falling among this population.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

Adedoyin RA, Adeyanju SA, Balogun MO, Akintomide AO, Adebayo RA, Akinwusi PO, Awotidebe TO. Assessment of exercise capacity in African patients with chronic heart failure using six-minute walk test. Int J Gen Med 2010;3:109-113.

Adeniyi AF, Uloko AE, Sani-Suleiman I. Relationship between the 6-minute walk test and correlates of type 2 diabetes: indication for caution in exercise prescription. Afr J Physiother Rehabil Sci 2010;2:21-24.

Allet L, Armand S, de Bie RA, Golay A, Monnin D, Aminian K, Staal JB, de Bruin ED. The gait and balance of patients with diabetes can be improved: a randomised controlled trial. Diabetologia 2010;53:458-466.

Allet L, Armand S, Golay A, Monnin D, de Bie RA, de Bruin ED. Gait characteristics of diabetic patients: a systematic review. Diabetes Metab Res Rev 2008;24:173-191.

American College of Sport Medicine. Prediction of maximum oxygen consumption VO2 max during level walking. Indianapolis (IN): American College of Sport Medicine; 1995.

American Diabetes Association. Standards of medical care in diabetes--2012. Diabetes Care 2012;35 Suppl 1:S11-63.

Awotidebe TO, Adedoyin RA, Oke KI, Ativie RN, Opiyo R, Ikujeyisi EO, Ikem RT, Afolabi MA. Relationship between functional capacity and health-related quality of life of patients with type-2 diabetes. Diabetes Metab Syndr 2016a Jun 8 [Epub]. http://dx.doi.org/10.1016/j.dsx.2016.06.004.

Awotidebe TO, Adedoyin RA, Yusuf AO, Mbada CE, Opiyo R, Maseko FC. Comparative functional exercise capacity of patients with type 2-diabetes and healthy controls: a case control study. Pan Afr Med J 2014;19:257.

Awotidebe TO, Adeyeye VO, Adedoyin RA, Oke KI, Ativie RN, Ogunyemi SA, Ajulo SM, Balogun MO. Assessment of functional capacity in patients with hypertension using the six minute walk test. West Indian Med J 2016b Aug 28. http://dx.doi.org/10.7727/wimj.2016.099.

Baker R. Gait analysis methods in rehabilitation. J Neuroeng Rehabil 2006;3:4.

Barnett A, Smith B, Lord SR, Williams M, Baumand A. Community-based group exercise improves balance and reduces falls in at-risk older people: a randomised controlled trial. Age Ageing 2003;32:407-414.

BeLue R, Okoror TA, Iwelunmor J, Taylor KD, Degboe AN, Agyemang C, Ogedegbe G. An overview of cardiovascular risk factor burden in sub-Saharan African countries: a socio-cultural perspective. Global Health 2009;5:10.

Ble A, Volpato S, Zuliani G, Guralnik JM, Bandinelli S, Lauretani F, Bartali B, Maraldi C, Fellin R, Ferrucci L. Executive function correlates with walking speed in older persons: the InCHIANTI study. J Am Geriatr Soc 2005;53:410-415.

Cahalin LP, Arena R, Labate V, Bandera F, Lavie CJ, Guazzi M. Heart rate recovery after the 6 min walk test rather than distance ambulated is a powerful prognostic indicator in heart failure with reduced and preserved ejection fraction: a comparison with cardiopulmonary exercise testing. Eur J Heart Fail 2013;15:519-527.

Callisaya ML, Beare R, Phan TG, Blizzard L, Thrift AG, Chen J, Srikanth VK. Brain structural change and gait decline: a longitudinal population-based study. J Am Geriatr Soc 2013;61:1074-1079.

Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, Chasan-Taber L, Albright AL, Braun B; American College of Sports Medicine.; American Diabetes Association.. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. Diabetes Care 2010;33:e147-167.

De Rekeneire N, Resnick HE, Schwartz AV, Shorr RI, Kuller LH, Simonsick EM, Vellas B, Harris TB; Health, Aging, and Body Composition study. Diabetes is associated with subclinical functional limitation in nondisabled older individuals: the Health, Aging, and Body Composition study. Diabetes Care 2003;26:3257-3263.

Fang ZY, Sharman J, Prins JB, Marwick TH. Determinants of exercise capacity in patients with type 2 diabetes. Diabetes Care 2005;28:1643-1648.

Fulk GD, Robinson CJ, Mondal S, Storey CM, Hollister AM. The effects of diabetes and/or peripheral neuropathy in detecting short postural perturbations in mature adults. J Neuroeng Rehabil 2010;7:44.

Guimaraes RM, Isaacs B. Characteristics of the gait in old people who fall. Int Rehabil Med 1980;2:177-180.

Gureje O, Ogunniyi A, Kola L, Afolabi E. Functional disability in elderly Nigerians: Results from the Ibadan Study of Aging. J Am Geriatr Soc 2006;54:1784-1789.

Guyatt GH, Thompson PJ, Berman LB, Sullivan MJ, Townsend M, Jones NL, Pugsley SO. How should we measure function in patients with chronic heart and lung disease? J Chronic Dis 1985;38:517-524.

Hall V, Thomsen RW, Henriksen O, Lohse N. Diabetes in Sub Saharan Africa 1999-2011: epidemiology and public health implications. A systematic review. BMC Public Health 2011;11:564.

Hausdorff JM. Gait variability: methods, modeling and meaning. J Neuroeng Rehabil 2005;2:19.

IJzerman TH, Schaper NC, Melai T, Meijer K, Willems PJ, Savelberg HH. Lower extremity muscle strength is reduced in people with type 2 diabetes, with and without polyneuropathy, and is associated with impaired mobility and reduced quality of life. Diabetes Res Clin Pract 2012;95:345-351.

Kasiulevičius V, Šapoka V, Filipavičiūtė R. Sample size calculation in epidemiological studies. Gerontologija 2006,7:225-231.

Kingwell BA, Formosa M, Muhlmann M, Bradley SJ, McConell GK. Type 2 diabetic individuals have impaired leg blood flow responses to exercise: role of endothelium-dependent vasodilation. Diabetes Care 2003;26:899-904.

Kirtley C. Clinical gait analysis: theory and practice. Edinburgh: Elsevier Churchill Livingstone; 2006.

Kumar V, Abbas AK, Fausto N, Robbins SL, Cotran RS. Robbins and Cotran pathologic basis of disease. 7th ed. Philadelphia (PA): Elsevier Saunders; 2005.

Kumar V, Fausto N, Abbas AK, Mitchell RS. Robbins basic pathology. 8th ed. Philadelphia (PA): W.B. Saunders; 2008.

Lee L, Grimson WE. Gait appearance for recognition. In: Lecture notes in computer science, Proceedings of the International ECCV 2002 Workshop Copenhagen on biometric authentication; 2002 Jun 1; Copenhagen, Denmark. 2002;2359:143-154.

Lee K, Lee S, Song C. Whole-body vibration training improves balance, muscle strength and glycosylated hemoglobin in elderly patients with diabetic neuropathy. Tohoku J Exp Med 2013;231:305-314.

Maki BE. Gait changes in older adults: predictors of falls or indicators of fear. J Am Geriatr Soc 1997;45:313-320.

Manor B, Newton E, Abduljalil A, Novak V. The relationship between brain volume and walking outcomes in older adults with and without diabetic peripheral neuropathy. Diabetes Care 2012;35:1907-1912.

Mantovani AM, Pinto MC, Lourenconi RM, Palma MR, Ribeiro FE, Fregonesi CE. Risk of falls in people with diabetes mellitus. Int J Diabetes Clin Res 2015;2:040.

Mathers CD, Lopez C, Stein D, Ma Fat C, Rao M, Inoue A. Deaths and disease burden by cause: global burden of disease estimates for 2001 by World Bank country groups. In: World Bank. Disease control priorities project working paper 18. Washington DC: World Bank; 2001.

McKelvie RS, Teo KK, Roberts R, McCartney N, Humen D, Montague T, Hendrican K, Yusuf S. Effects of exercise training in patients with heart failure: the Exercise Rehabilitation Trial (EXERT). Am Heart J 2002;144:23-30.

Mecagni C, Smith JP, Roberts KE, O'Sullivan SB. Balance and ankle range of motion in community-dwelling women aged 64 to 87 years: a correlational study. Phys Ther 2000;80:1004-1011.

Ostrosky KM, VanSwearingen JM, Burdett RG, Gee Z. A comparison of gait characteristics in young and old subjects. Phys Ther 1994;74:637-644.

Ozdirenç M, Biberoğlu S, Ozcan A. Evaluation of physical fitness in patients with Type 2 diabetes mellitus. Diabetes Res Clin Pract 2003;60:171-176.

Pau M, Leban B, Collu G, Migliaccio GM. Effect of light and vigorous physical activity on balance and gait of older adults. Arch Gerontol Geriatr 2014;59:568-573.

Petrofsky J, Lee S, Bweir S. Gait characteristics in people with type 2 diabetes mellitus. Eur J Appl Physiol 2005;93:640-647.

Rosano C, Aizenstein HJ, Studenski S, Newman AB. A regions-of-interest volumetric analysis of mobility limitations in community-dwelling older adults. J Gerontol A Biol Sci Med Sci 2007;62:1048-1055.

Volpato S, Bianchi L, Lauretani F, Lauretani F, Bandinelli S, Guralnik JM, Zuliani G, Ferrucci L. Role of muscle mass and muscle quality in the association between diabetes and gait speed. Diabetes Care 2012;35:1672-1679.

Wall JC, Bell C, Campbell S, Davis J. The Timed Get-up-and-Go test revisited: measurement of the component tasks. J Rehabil Res Dev 2000;37:109-113.

Wallace C, Reiber GE, LeMaster J, Smith DG, Sullivan K, Hayes S, Vath C. Incidence of falls, risk factors for falls, and fall-related fractures in individuals with diabetes and a prior foot ulcer. Diabetes Care 2002;25:1983-1986.

Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. CMAJ 2006;174:801-809.

Wolfson L, Whipple R, Amerman P, Tobin JN. Gait assessment in the elderly: a gait abnormality rating scale and its relation to falls. J Gerontol 1990;45:M12-19.

World Health Organization. Global atlas on cardiovascular disease prevention and control. Geneva: World Health Organization; 2011.