ORIGINAL ARTICLE

The 400-Meter Walk Test to Evaluate Walking Performance between Diabetics and Healthy Females

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ABSTRACT

Objective: to evaluate walking performance in female with type 2 diabetes mellitus (DM2) with the 400-meters walk test (400-MWT) compared to healthy individuals.
Methods: two groups of female subjects with DM2 and healthy individuals were matched by the age. The 400-MWT parameters to be compared were walking speed (WS) and predicted maximum oxygen consumption (pVO2max). Baseline examination included body mass index (BMI), random blood glucose (RBG), and ankle-brachial index (ABI). All subjects performed 2 minutes warm up before the test. Heart rate (HR) was recorded every 30 seconds, and blood pressure (BP) was measured before warm up and within 60 seconds after test. The test was performed twice on a different day.
Results: Nineteen subjects on each group participated in the study. The mean WS was significantly different ($p<0.0001$) between the study group (1.26 ± 0.19 and 1.31 ± 0.17 m/s) and the control group (1.70 ± 0.20 and 1.78 ± 0.24 m/s) for the first and second tests respectively. There was a significant difference of mean pVO2max ($p<0.0001$) between the study group (17.22 ± 2.94 and 17.99 ± 2.36 ml/kg/min) and the control group (23.68 ± 3.79 and 24.44 ± 3.74 ml/kg/min).
Conclusion: the 400-MWT demonstrated lower walking performance in female subjects with DM2 compared to healthy individuals.

Keywords: *Type 2 DM, healthy individuals, 400 meter walk test, walking speed,* VO_{2max}.

INTRODUCTION

Walking performance is a representation of cardiopulmonary capacity and fitness level of an individual with type 2 DM (DM2). In women with DM2 a decrease in cardiopulmonary capacity may be related to increased C-reactive protein (CRP) level and reduced fasting blood glucose control.[1] Reduced cardiopulmonary capacity and fitness level may lead to further macrovascular and microvascular complications of DM2.[2]

The standard test to evaluate walking performance is treadmill exercise test.[3] However treadmill test has a technical disadvantages that it must be performed in certain institution that provide such facility. With the increasing needs to evaluate fitness level in DM2 patients, an exercise test that provide technical flexibility and easy to perform become a major issue.

The corridor walk test has been an alternative methods to evaluate cardiopulmonary performance. The most common corridor walk

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tests used widely were the 6 minutes and the 12 minutes walk tests. Long distance corridor walk test is a relatively new methods to evaluate walking performance. The 400 meter walk test (400 MWT) is an example of distance-targeted exercise test.[4]

The 400 MWT was initially developed by Simonsick et al.[4] to evaluate walking performance in geriatric patients. In several studies, inability to walk 400 meters in 15 minutes has been defined as disability in mobility.[4-6] In a comparative study by Simonsick et al,[7] the 400 MWT demonstrated better achievements compared to the 6 minutes walk test. In this study, subjects accomplished higher walking speed when given targeted distance compared to targeted time.

In women with DM2, the 400 meters distance has been used as a threshold value to determine walking disability.[5,8] However, evaluation of walking performance in women with DM2 using the 400 MWT has not been used earlier. The objective of this study is to evaluate walking performance in women with DM2 using the 400 MWT compared with healthy female individuals. The parameters used in this study includes walking speed (WS) and predicted maximum oxygen consumption (pVO2max).

METHODS

Design

The design is a comparative cross-sectional study between 2 paired groups.

Subjects

The subjects in this study were enrolled from Medical Rehabilitation Polyclinic and Metabolic-Endocrine Polyclinic in Cipto Mangunkusumo Hospital, Jakarta. The time of this study was between July – September 2007. All subjects were female matched by the age group, and divided into the study and control groups.

The inclusion criteria of the study group subjects include: had type 2 DM without a complication of peripheral arterial disease, able to walk without using any assistive device, and controlled blood glucose level with appropriate medications. For the control groups the inclusion criteria were healthy individuals, no history of DM2 or other hyperglycemia-related metabolic syndrome, able to walk without assistive device, normal RBG, resting BP, and ABI values.

The exclusion criteria include: indication of peripheral arterial disease with ABI score <0.9, RBG $\geq$300 mg/dl or $\leq$80 mg/dl, resting HR >120x/minutes, history of stroke or any other conditions that may cause paresis of the lower extremity, history of diabetic foot ulcer, recent heart disease within 6 month prior to the test, uncontrolled hypertension, and complication of diabetic retinopathy and/or nephropathy.

Subjects will be classified as drop out if hypoglycemia presents during the test and/or unable to finish all of the test sessions.

Informed Consent and Ethical Clearance

All subjects was given oral and written explanation about the procedure. Subjects that agreed to participate in the study were asked to signed written Informed Consent form before the study.

This study has passed an ethical clearance issued by the Ethical Committee for Research from the Faculty of Medicine, University of Indonesia.

Materials used in this study includes: sphygmomanometer (Riester-Nova ™), stethoscope (Littmann ™), hand-held Doppler Ultrasound (Minidop FS-100VX) with 5 MHz probe, road cones and an indoor 20-meters tract, glucometer (Super Glucocard II GT-1640 series), pedometer (JS-208 model), measuring tape, weight and height scales, stopwatch (Casio ™), pulse Monitor (Opto-Electronics PU-711 model), portable oxygen tank with masks (for emergency), and sweets or candies (if hypoglycemia presents).

All subjects that agreed to participate this study had been given written explanation and signed an informed consent form. Subjects were matched by the age group, and divided into two groups: the study and control groups. All subjects undergone thorough medical history taking, physical examination, blood glucose levels, and ankle-brachial index measurement using hand held Doppler. The body mass index was calculated to further ensure homogeneity between subjects.

The 400 MWT was taken twice on two random days to minimize learning effect. Each test session was taken exclusively for 1 subject to reduced the possibility of a bias. The 400 MWT protocol used in this study was based on the design by Simonsick et.al.[4,7]

Prior to the test the RBG, resting BP and HR were measured. All subjects were ask to perform 2 minutes of warm up in a 20-m tract. Each end of the tract was marked by a road cone, and subjects were asked to go about each of the road cones forming a continuous path. Subjects were asked to maintain an even walking speed and covered the ground as much as possible. Standardized encouragement was given on each turn and subjects were given signs before the warm up time stopped. Heart rate was recorded every 30 seconds from the beginning, and blood pressure was recorded before and immediately after warm up.

The exercise test was performed within 60 seconds after warm up. All subjects were to walk as fast as possible, covering 400 meters distance in 10 rounds. Standard encouragements were given on every round. The heart rate and blood pressure were recorded as in the warm up. Two parameters were calculated in this study, the WS and pVO2max.

Calculation of Predicted Maximum Oxygen Consumption

The pVO2max formula used in this study was developed by Simonsick et al.:[7]

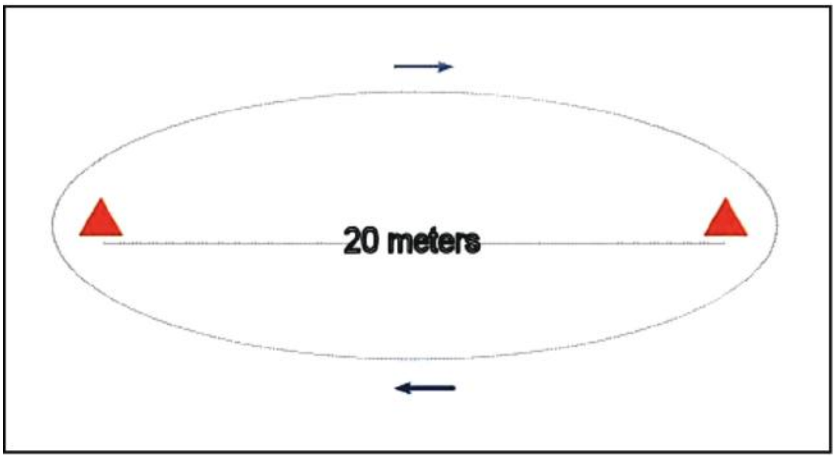
$$\mathbf{pVO_{2max} = 39.431 - (0.054 \times t_{400m}) + (2.832 \times LS) - (0.031 \times SBP_{60}) - (0.064 \times CF)}$$

with

- pVO2max = predicted maximum oxygen consumption (ml/kg/min)
- t_{400m} = elapsed time after 400-m walk completed (seconds).
- LS = longstride score: if the stride length <1.2 steps/meter

(total steps <24 steps/20 meter) the score = 1, other than that = 0.

- CF = correction factor: if the $t_{400m} \geq 240$ seconds, the score = 0.
  If the t_{400m} <240 seconds, then:
  CF = t_{400m} (seconds) – 240 (seconds) X (– 0.064).
  The (– 0.064) value is the estimation parameter.
- SBP_{60} = systolic blood pressure taken within 60 seconds after the 400-meter laps completed.



Picture 1. 20-meters Tract

Picture 2. (A) Doppler Minidop-FS-100VX. (B) Glucometer (Super Glucocard II, GT-1640). (C). Pedometer JS-208. (D). Pulse Monitor Opto-Electronics PU-711

Picture 3. Pedometer and Pulse Monitor Application

Statistical Analyses

Statistical analysis was performed using SPSS v. 13.0 software. Data analysis was categorized into

1. Descriptive Study:
   - Numerical variables: age, SBP_{60}, t_{400m}, longstride, WS, and pVO2max, presented in mean value (Standard Deviation).
   - Categorical variable was age group, presented in precentage (%).
2. Analytic Study: paired t-test will be used if data distribution was normal, or the Wilconxon analysis if the data distribution non-normal.

RESULTS

From July to September 2007, there were 38 subjects participated in the study, nineteen on each group. For the study group, subjects were taken from Medical Rehabilitation Poylclinic and Metabolic-Endocrine Polyclinic. All subjects were patients with DM2. For the control group, all subjects were healthy volunteer who agreed to participate in the study.

Subject Characteristics

All subjects were divided into 3 age groups: 40-49, 50-59, and 60-69 years old. Age range in the study group was 43-68 years of age (mean 54.5 $\pm$ 7.752, and for the control group 41-68 years of age (mean 54 $\pm$ 8.266). Subject distribution between the two groups was normal.

Table 1 shows general characteristics of all subjects. The majority of subjects in the study group were housewives (52.6%), while the occupation in the control group were governor employee (68.4%). Average level of education was college level on both groups.

Table 1. Subject Distribution Based on Age, Occupation, and Education Level Between the Study and Control Groups

Parameters	Study (N = 19)		Control (n = 19)	
	n	%	n	%
Age Classification (years)				
40 – 49	7	36.8	7	36.8
50 – 59	7	36.8	7	36.8
60 – 69	5	26.4	5	26.5
Occupation				
Governor employee	4	21.1	13	68.4
Private employee	1	5.3	0	0
Housewive	10	52.6	0	0
Retired	4	21.1	5	26.3
Others	0	0	1	5.3
Education Level				
College / university	7	36.8	9	47.4
High school	6	31.6	8	42.1
Elementary school	6	31.6	2	10.5

From 19 subjects in the study group, 14 patients had an onset of DM2 less than 10 years (73.7%), while 5 patients had DM2 for 11 years or more (26.3%). Most common comorbidities in the study group was hypertension and dyslipidemia (n = 12, 63.2% on both comorbidities) and in the control group was dyslipidemia (n = 6, 31.6%). All of the subjects had received proper medications for their conditions. Other comorbidities on both groups was knee osteoarthritis and past history of cardiovascular events. However, none of the subjects on both groups had recent cardiovascular diasese within the past 6 months. Signs of neuropathy such as paresthesia and numbness were found in 10 subjects of study group (52.6%) and in 5 subjects in the control group (26.3%). However all subjects had normal gait pattern without history of walking difficulty.

Ankle brachial index on both groups were normal. In the study group ABI was 1.08 $\pm$ 0.161, and in the control group 1.09 $\pm$ 0.134. No significant difference in ABI value between the 2 groups ($p = 0.717$).

Mean BMI on the study group was 27.58 $\pm$ 5.78 kg/m^2 with normal distribution ($p = 0.200$). In the control group mean BMI was 24.61 $\pm$ 3.38 kg/m^2 also showing normal distribution ($p = 0.200$). The difference in BMI values among the 2 groups was not significant ($p = 0.063$).

Walking Speed

Mean WS in the study group was 1.28 ± 0.17 m/s ($p = 0.085$), while in the control group 1.74 ± 0.21 m/s ($p = 0.200$). Walking speed distribution on both groups was normal.

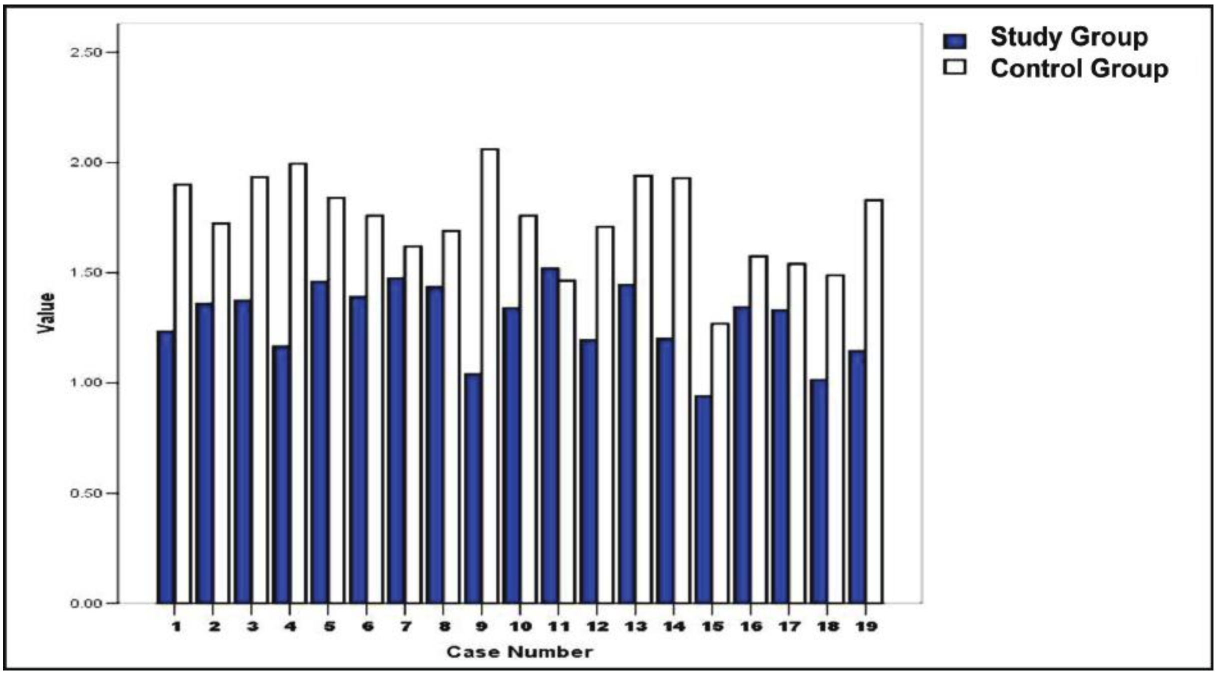
Table 2 displayed a comparison of WS from the first and second tests on both groups. There is no significant difference in mean WS between the first and second tests in the study group ($p = 0.121$). In the control group, mean WS between the first and second tests showed a significant difference ($p = 0.037$). However the difference was not significant when compared within the age groups.

Table 2. Mean Walking Speed from the First and Second Tests in Study and Control Groups

Age Clasification (years)	Study (N = 19)			Control (n = 19)		
	Mean (m/s)	SD	p+	Mean (m/s)	SD	p+
Mean						
Test 1	1.26	0.19		1.70	0.20	
Test 2	1.31	0.17	0.121	1.78	0.24	0.037*
40 – 49						
Test 1	1.33	0.16		1.77	0.13	
Test 2	1.37	0.11	0.567	1.88	0.19	0.175
50 – 59						
Test 1	1.27	0.17		1.73	0.21	
Test 2	1.35	0.20	0.222	1.86	0.21	0.054
60 – 69						
Test 1	1.14	0.218		1.55	0.23	
Test 2	1.17	0.15	0.476	1.53	0.18	0.456

Note: + = p value after paired t-test
* = significant p value ($p < 0.05$)

Mean WS difference between the study and control groups are shown in Picture 4. There was a significant difference on mean WS between the study and control groups (p <0.0001. The result was consistent within age group comparison (Table 3).



Picture 4. Comparison of Mean Walking Speed in Study and Control Groups

Table 3. Mean Walking Speed Comparison Between Study and Control Groups Based on the Age Classification

Age Classification (Year)	Paired Differences				
	Δ§	SD	t	df	p^{*+}
General	-0.453	0.258	-7.684	18	<0.0001
40 – 49	- 0.474	0.227	-5.509	6	0.002
50 – 59	- 0.483	0.341	-3.751	6	0.009
60 – 69	- 0.386	0.197	-4.374	4	0.012

Note: § = mean group differences: control group – study group (m/s)
+ = p value after paired t-test
* = significant p value ($p < 0.05$)

Predicted Maximum Oxygen Consumption

The mean value of pVO2max in the study group was 17.61 ± 2.54 ml/kg/min (p = 0.118), and in the control group 24.06 ± 3.62 ml/kg/min (p = 0.200). Distribution of the mean value of both group was normal.

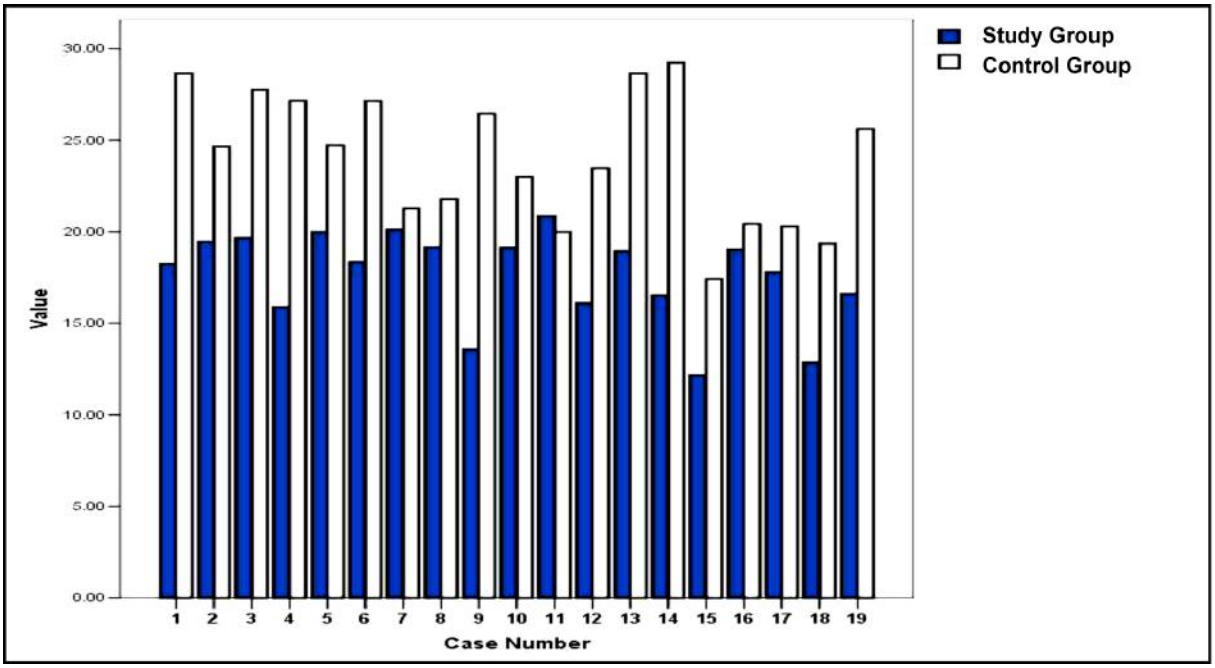
The mean value pVO2max comparison between study and control group from the first and second tests was shown in Table 4. No significant difference was found between the first and second test results.

Table 4. Mean pVO2max from the First and Second Tests in Study and Control Groups

Age Clasification (years)	Study (N = 19)			Control (n = 19)		
	Mean (ml/kg/ menit)	SD	p+	Mean (ml/kg/menit)	SD	p+
Mean						
Test 1	17.22	2.94		23.68	3.79	
Test 2	17.99	2.36	0.055	24.44	3.74	0.133
40 – 49						
Test 1	18.58	2.09		25.14	3.18	
Test 2	19.05	1.23	0.496	26.67	2.38	0.142
50 – 59						
Test 1	17.33	2.42		24.26	3.94	
Test 2	18.21	2.81	0.212	25.05	3.44	0.392
60 – 69						
Test 1	15.19	3.88		20.81	3.41	
Test 2	16.20	2.21	0.261	20.46	2.73	0.478

Note: $^{+}$ = p value after paired t-test

There was a significant differences on the mean value of pVO2max between the study and control groups (p<0.0001. The comparison of mean pVO2max on both groups are shown in Picture 5. The result was also consistent within the age groups (Table 5).



Picture 5. Comparison of Mean pVO2max between Study and Control Group

Table 3. Mean Walking Speed Comparison Between Study and Control Groups Based on the Age Classification

Age Classification (Year)	Paired Differences				
	Δ§	SD	t	df	p*+
General	-6.452	4.059	-6.928	18	<0.0001
40 – 49	-7.094	3.579	-5.243	6	0.002
50 – 59	-6.888	5.266	-5.243	6	0.013
60 – 69	-4.942	3.070	-3.599	4	0.023

Note: § = mean group differences: control group – study group (ml/kg/min)
\+ = p value after paired t-test
* = significant p value ($p < 0.05$)

Parameters Affecting pVO2max Calculations

Other parameters affecting the pVO2max calculations include total elapsed time (t_{400m}), longstride, and post test systolic blood pressure (SBP_{60}). The characteristics of these parameters are shown in Table 6.

Table 6. Parameter Characteristics Affecting pVO2max Calculations on Study and Control Groups

Parameter	Study			Control (n = 19)		
	Age Classification	Mean	SD	Mean	SD	p+
t400m (seconds)	General	317.03	45.56	233.66	30,44	<0.0001
	40-49	298.43	28.25	209.36	11,09	0.001
	50-59	310.21	42.38	229.93	14,86	0.003
	60-69	352.60	56.41	272.90	25,91	0.055
Longstride (steps / 20 meters)	General	30.32	2.91	24.45	1,69	<0.0001
	40-49	29.29	2.27	24.00	1,63	0.003
	50-59	29.64	3.16	24.14	1,18	0.005
	60-69	32.70	2.36	25.50	2,21	<0.0001
SBP60 (mmHg)	General	151.84	18.29	153.29	19,33	0.807
	40-49	145.36	19.06	138.57	15,20	0.562
	50-59	158.57	14.92	154.64	16,48	0.551
	60-69	151.50	21.77	172.00	10,37	0.138

Note: + = p value after paired t-test
* = significant p value (p<0.05)

Elapsed time (ET) in the study group was 317.03 ± 45.56 seconds. In the control group, ET was 233.66 ± 30.44 seconds. The ET was significantly different between the study and control groups (P<0.0001). Longstride was significantly different (p<0.0001) between the study (30.32 ± 2.91 steps/20m) and control groups (24.45 ± 1.69 steps/20m).

On SBP_{60} measurement, mean SBP on the study group was 151.84 ± 18.29 mmHg, while the control group was 153.29 ± 19.33 mmHg. Using a paired t-test analysis, no significant difference found between the two groups (p=0.807).

DISCUSSION

To the date this study was conducted, the 400 MWT has been exclusively used to evaluate walking performance in geriatric populations, and has not been used before in diabetic subjects. In this study, walking performance characterized by walking speed (WS) and predicted maximum oxygen consumption (pVO2max) were significantly lower in female diabetics subjects, compared to healthy individuals (Table 2 and Table 4). Walking performance is also affected by several factors including: fitness level, fatigue threshold, learning effect, and motivational effect.[2,4,9-11]

Reduced walking capacity in DM2 has been associated with a decrease in cardiopulmonary function. In a study by McGavock et al., female diabetics subjects showed significantly lower maximum oxygen consumtion (VO_{2max}), and predicted VO_{2max} compared with healthy subjects (15.7±2.0 ml/kg/min and 21.9± 3.0 ml/kg/min), despite the heart rate and systolic blood pressure differences between the two groups were not significant. The test demonstrated an increase in C-reactive protein level in diabetics subjects (6.3±4.3 mg/l and 4.1±4.0 mg/l), that ilustrates a decrease in aerobic capacity.[1]

Lower limb dysfunction that leads to disability is a progressive state, related to a decrease in aerobic capacity. Volpato et al[12] applied several exercise test including 4-meter walk test, five-chair stand test, and graded balance test to evaluate lower limb function in geriatric female with DM2. The study demonstrated significant decrease on lower limb function in diabetics subjects compared to the control group. This study also revealed walking disability in diabetics subjects marked by inability to walk 400 meters. The decrease in walking performance due to reduced aerobic capacity was also found in studies by Johnson et al,[13] and Bjørgaas et al.[14]

In this study, subjects with DM2 showed a significantly slower walking speed compared to healthy individuals (Picture 4). Mean difference between the study and control groups was 0.45 ± 0.26 m/s ($p<0.0001$). This findings was consistent when analyzed within the 3 age groups (Table 3). Lowest mean difference was found in the age 60-69 years group ($\Delta = 0.39 \pm 0.20$ m/s, p=0.012). Lowest walking speed in geriatric group (age >60 years) is consistent with several studies that demonstrated age influence to the functional walking ability that may also related to changes in gait pattern biomechanics.[4,6,10]

Several other factors may be responsible in reducing walking capacity in DM2 subjects, those include: vascular endothelium glycation and hemoglobin glycation,[15-17] changes in musculoskeletal structure and function of the lower limbs,[18,19] and decreased insulin vasodilatory effect and glucose uptake of the lower limb muscles.[20,21] However these factors were not analyzed in our study.

The predicted VO_{2max} in the study group was also significantly lower compared to the control group (17.61 ± 2.54 ml/kg/min and 24.06 ± 3.62 ml/kg/min). Mean difference of pVO2max value between study and control group was 6.45±4.06 ml.kg.min ($p<0.0001$). Previous study by Walker et al. found similar findings in female subjects with DM2 compared to normoglycemic female subjects prior to a 12-week exercise program. In this study, the VO_{2max} in the study group was significantly lower to the control group (18.7 $\pm$ 3.2 ml/kg/min and 20.7 $\pm$ 5.4 ml/kg/min), before the traininig period.[22] Lower pVO2max findings were consistent within the 3 age groups (Table 5). Lowest mean difference was found on the geriatric groups ($\Delta = 4.942 \pm 3.07$ ml/kg/min; p = 0,023), with mean pVO2max value of 20.64 ± 3.07 ml/kg/min. The result is consistent with previous study by Simonsick et al.[7]

There are two other parameters directly influence the pVO2max result, the elapsed time (ET) and longstride (LS). These parameters was calculated based on the equation developed by Simonsick et al. in the 400 MWT study.[7]

In previous study by Simonsick, if the Åstrand estimation was applied to the 400 MWT, minimum or suboptimal oxygen consumption will reduced ET to 6 minutes 48 seconds – 7 minutes 40 seconds to cover the 400-m tract. The prediction VO_{2max} in this condition lies between 12 – 18 ml/kg/min. From this estimation, Simonsick stated that functional walking disability can be determined if ET is greater than 5 minutes 30 seconds to walk the 400 meters course.[7]

Our study showed that the mean ET in the control group was 3 minutes 53 ± 30.4 seconds. In contrast to the study group, mean ET was 5 minutes 17 ± 45.6 seconds (Table 6). This finding was close to the threshold value in the Simonsick study. The longest ET on the study was found in the age 60-69 years group (5 minutes 52 ± 56.4 seconds). The result demonstrated an indication of walking disability in this group. As a comparison, in earlier study by Simonsick, the ET in healthy geriatric subjects was 5 minutes 11 seconds.[4]

The influence of stride length in VO_{2max} measurement was introduced by Åstrand. In this study, stride length will affect energy economy in exercise test. According to Åstrand, greater stride lenght will result in greater speed, hence greater oxygen consumption.[23] Simonsick et al. showed that stride length was an important adjustment factor in predicting VO_{2max}. The term *longstride* (LS) in Simonsick's equation is a dichotomous variable to categorize subjects into those who had a long stride and those who had a short stride. Subjects with stride length <24 steps / 20 meters were categorized as longstride, with a score = 1 and adjustment coefficient of 2.832. Whereas subjects with stride length $\geq$24 steps / 20 meters were categorized as shortstride with a score = 0.[7]

The stride length in our study was significantly differed between the study and control groups (30.3 ± 2.9 steps/20m and 24.5 ± 1.7 steps/20m; $p<0.0001$). However only 7 subjects in the control group had a stride length <24 steps/20m (mean value = 22.6 steps/20m), which put the majority of the subjects as a shortstrider. These findings may indicate that the dichotomous category in Simonsick study may not be appropriate in our study, and may become a bias in this study. It may be the race differences that influence the anthropometric factor in Asian population that give rise to the dyscrepancy. However this asumption will need further investigation.

CONCLUSIONS

Walking capacity was found significantly lower in female with DM2 compared to healthy female subjects, characterized by slower walking speed and lower predicted maximum oxygen consumption. There is a need to further investigate the use of the 400 MWT as an alternative exercise test to determine walking ability in various population and medical conditions. The validity of the test as an alternative measurement is also needs to be compared and standardized with the treadmill exercise test.

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