Original Manuscript

Gerontology & Geriatric Medicine
Volume 7: 1–10
© The Author(s) 2021
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/23337214211038789
journals.sagepub.com/home/ggm
SAGE

A 16-Week Home-Based Progressive Resistance Tube Training Among Older Adults With Type-2 Diabetes Mellitus: Effect on Glycemic Control

Theng Choon Ooi[1], Arimi Fitri Mat Ludin[1,2], Seng Cheong Loke[3], Maria Antoinette Fiatarone Singh[4], Teck Wee Wong[5], Nathan Vytialingam[6], Muhammad Mikhail Joseph Anthony Abdullah[7], Ooi Chuan Ng[3], Norhaniza Bahar[8], Norliza Zainudin[9], and Leong Chen Lew[1,2]

Abstract

Research has proven that aerobic exercise improves glucose homeostasis among patients with type 2 diabetes mellitus (T2DM). Elastic resistance (tube or band) is suggested as a good alternative for home-based strength training among older adults including those with T2DM due to its low cost, simplicity, portability, and versatility. This study aimed to measure the effects of 16-week home-based progressive resistance training (PRT), using a resistance tube on glucose homeostasis and cardiovascular risk factors among older adults with T2DM. A total of 70 participants aged 61.68 (5.50) years with T2DM were assigned to the intervention (n = 35) and control (n = 35) groups in this quasi-experimental trial. The intervention group underwent 16 weeks of home-based PRT using a resistance tube. Significant improvements in HbA1c (−1.34% point, $p < 0.001$), fasting blood glucose (−1.30 mmol/L, $p < 0.001$), and systolic blood pressure (−1.42 mmHg, $p < 0.05$) were observed after 16 weeks of intervention. However, no significant changes were observed in lipid profile, diastolic blood pressure, resting heart rate, and ankle–brachial index. The finding suggests that 16 weeks of home-based PRT using a resistance tube has the potential to improve glycemic control and reduce systolic blood pressure among older adults with T2DM and caused no adverse events.

Keywords

glycemic control, older adults, progressive resistance training, resistance tube, type 2 diabetes mellitus

Manuscript received: June 18, 2021; **final revision received:** July 22, 2021; **accepted:** July 25, 2021.

Introduction

Diabetes mellitus (DM) has reached epidemic proportions and affects more than 170 million individuals worldwide and type 2 diabetes mellitus (T2DM) accounts for 90% of the total DM cases (World Health Organization, 2018). T2DM occurs due to insulin resistance and progressive reduction in insulin secretion (DeFronzo et al., 2015). Although there is no cure for T2DM to date, T2DM can be controlled via medications such as metformin, sulfonylureas, and insulin (Blair, 2016). Apart from the pharmacological approach, other diabetic care measures including practicing healthy dietary habits and exercises are beneficial to glycemic control as well and are considered as the basic parts of the treatment of T2DM patients (Blair, 2016). The treatment and management of T2DM are crucial to avoid the development of other complications such as diabetic nephropathy, retinopathy, neuropathy, cardiovascular diseases, and diabetic foot ulcer (DeFronzo et al., 2015).

Aerobic exercise (AE) and progressive resistance training (PRT) are two major forms of exercise that have been proved to be effective in T2DM management. Both AE and PRT have been reported to improve insulin sensitivity, glucose homeostasis, and other components of metabolic syndrome in T2DM

(Ferriolli et al., 2014). In general, AE improves cardiovascular fitness and significantly enhances peak oxygen consumption, with limited anabolic effects (Villareal et al., 2017). Meanwhile, PRT is an anabolic form of exercise, with the ability to induce muscle hypertrophy and improve the strength, power, and endurance of muscles without significantly changing the peak oxygen consumption (Pedersen & Saltin, 2006). However, AE is often limited by other comorbidities in the diabetic elderly (e.g., foot problems and osteoarthritis) (Ferriolli et al., 2014). In contrast to AE, PRT is safe and highly tolerable even in the frail diabetic elderly, making it feasible even when robust AE is impossible. Hence, PRT is particularly suitable for obese older individuals with diabetes and has been proposed as an alternative approach to the treatment of T2DM and metabolic syndrome. Furthermore, findings from a meta-analysis showed that high-intensity resistance exercise (75–100% of 1 repetitive maximum [RM]) is more prominent in reducing the HbA1c level than the low-to-moderate intensity (20–75% 1 RM) in T2DM patients (Liu et al., 2019).

Not every elderly person may have adequate access to weight training equipment that is usually found in health clubs, due to economic and physical constraints (Thiebaud et al., 2014). Besides, older adults may also lack confidence and knowledge on how to exercise using the instruments in the fitness center (Bethancourt et al., 2014). Another possible reason for this being that this group of individuals may be intimidated by the idea of exercising with younger people. With these limitations, less expensive and practical alternative modes of resistance exercise need to be developed and evaluated for their effectiveness. Elastic resistance (tube or band) has been used in rehabilitative medicine and also in the health and fitness industry to increase muscular strength. This method is commonly used for training because of its low cost, simplicity, portability, and versatility. In addition, it does not rely on gravity for resistance (Hughes & Page, 2003). Previously, older women who practiced resistance training using elastic tubes showed improvement in physical function and cardiovascular markers (Souza et al., 2019). Furthermore, home-based resistance training using elastic tubes showed increase in the strength and functional ability in older adults (Thiebaud et al., 2014). Thus, the elastic tube is a good alternative for home-based strength training among the elderly including those with T2DM. This study aimed to measure the effects of a 16-week home-based high-intensity PRT program, using a resistance tube on glucose homeostasis and cardiovascular health among older adults diagnosed with T2DM.

Methods

Ethics Approval and Informed Consent

Ethical approval was obtained from the Ministry of Health, Research and Ethics Committee (2)KKM/NIHSEC/08/0804/P09-385. The study was conducted in accordance with the Declaration of Helsinki. Potential candidates who met the inclusion criteria were interviewed on the day of their appointment and were briefed about the purposes, benefits, and potential risks of the study. At the end of the interview session, each person who agreed to participate was given a consent form to sign.

Sample Size Calculation

The sample size calculation was done by using G*power 3.1. The calculation was based on F test ANOVA repeated measures within-between interactions. Type I error rate was set at 5% (alpha-level 0.05), 5% type II error rate (95% power), and partial $\eta 2$ used for effect calculation was 0.06 (for medium effect size) which yielded the effect size (f) 0.25. Twenty-seven participants were needed in each group. As planned for a maximum 20% dropout, a total sample size of approximately 70 participants was recruited for this study to achieve adequate statistical power.

Participants

The inclusion criteria for this study are participants aged 50 years old and above, diagnosed with T2DM, HbA1c level between 8.0–12.0%, and were under any treatment regime regardless of diet alone, oral medication or insulin, or combination at the time of enrollment. Those participants with significant cognitive impairment, non-ambulatory status or lower extremities amputation other than toes, alcohol or other substance abuse, inability to comply with study requirements over the course of 6 months and specific contraindications to resistance training such as unstable cardiovascular diseases, aortic aneurysm, symptomatic hernias, proliferative diabetic retinopathy, retinal laser surgery within 6 weeks, chronic renal failure, or rapidly progressive illness were excluded from this study. Besides, participants with any changes in dosage or type of diabetic medications during the study period were excluded from this study as well to avoid any

[1]Center for Healthy Ageing and Wellness, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia
[2]Program of Biomedical Science, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia
[3]Department of Medicine, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Serdang, Malaysia
[4]Faculty Health Sciences, University of Sydney, Lidcombe, NSW, Australia
[5]IHEAL Medical Centre, Kuala Lumpur, Malaysia
[6]Perdana University School of Occupational Therapy, Serdang, Malaysia
[7]Perak Community Specialist Hospital, Ipoh, Malaysia
[8]Department of General Medicine, Serdang Hospital, Kajang, Malaysia
[9]Department of Medicine, Selayang Hospital, Batu Caves, Malaysia

Corresponding Author:
Arimi Fitri Mat Ludin, Centre for Healthy Aging and Wellness, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, UKM KL, Jalan Raja Muda Abdul Aziz, Kuala Lumpur 50300, Malaysia.
Email: arimifitri@ukm.edu.my

misinterpretation of outcome measurements since any changes in the treatment regimes may affect the glycemic control indicators. Furthermore, participants were among inactive individuals as they were not involved in any moderate to vigorous physical activity for more than 2 hours in a week as assessed by short-form International Physical Activity Questionnaires (IPAQ).

Lists of patients attending the medical specialist clinic were screened before the day of the appointment. Potential candidates who met the inclusion criteria were asked to do medical check-up by medical doctors involved in this study. Medical clearance form was provided and those with unsure risk of CVD complication were sent for a stress test. Once medical clearance was obtained, an appointment date was given for the baseline assessment.

Study Design and Training Protocol

A total of 70 older adults who met the inclusion and exclusion criteria were recruited in this quasi-experimental study. Participants in the intervention group ($n = 35$) were instructed to perform high-intensity PRT for 16 weeks at their respective homes using resistance tubes. On the other hand, the control group ($n = 35$) received no intervention and were instructed to continue their daily life as usual. A logbook was also given to each participant to record their daily physical activities.

The training protocol was based on recommendations from the American College of Sport Medicine (ACSM) and the American Heart Association (AHA) with some modifications (Nelson et al., 2007). This study adopted 12 exercises with 8–10 repetitions per set. The exercises were chest press, shoulder press, overhead pull-down, lateral shoulder raise, biceps curl, triceps extension, hip flexion, hip extension, calf raise, legs extension, squats, and seated row. For each exercise, participants were told to perform three sets of eight repetitions and to focus on the speed of the movement. Participants were told to perform fast concentric and slow eccentric phases. The rest between sets was set to be no longer than 60 seconds. The intensity of exercise was set to be at high intensity. Since no initial 1 repetition maximum measurement was done before the actual training, the intensity was determined by participant self-scoring using Borg Scale Rating Perceive of Exertion (Borg, 1998). The score must be within 16–18 to reach high-intensity level. Resistance was increased throughout the time course based on individual scores. Intensity progression was done by changing the tube to higher resistance. This was done once participants rated their difficulty level lesser than 16. Different participants started with different levels of resistance according to their initial muscle strength.

Exercise training was started with conditioning for 1 month. In the first and second week, participants were guided by the researcher on a one-to-one basis. They were asked to perform a single set of exercises with 8–10 repetitions each. The intensity was then increased to two sets with 8–10 repetitions each for the third and fourth week. The rest of the study period exercise was set to three sets with 8–10 repetitions each. Participants were allowed to perform the exercises on their own at their respective homes once the researcher was satisfied with the movement for each of the exercises. A complete exercise manual was provided to each participant as guidance. A logbook was also provided for monitoring purposes. Participants were asked to record the difficulty level of the exercise as well as any complications or adverse events that may have occurred. The logbook was evaluated during the monthly follow-up.

Biochemical Analysis

Venous blood samples were obtained from the participant's antecubital vein by a phlebotomist in the morning and after overnight fasting. The collected samples were sent to accredited medical laboratories for biochemical analysis, including the glucose homeostasis markers and lipid profile.

Glucose homeostasis markers. HbA1c and fasting blood glucose (FBG) were the two glucose homeostasis markers measured in this study. HbA1c level measurement was done on BioRad D10 automated diagnostic machine (BioRad California, USA), while FBG analysis was done using Architect ci8200 (Abbott Diagnostics, Wiesbaden, Germany).

Lipid profile. Biochemistry analyses for lipid profile including total cholesterol, triglycerides (TG), low-density lipoprotein (LDL), and high-density lipoprotein (HDL) were done as a part of the hospital routine by using the Architect ci8200 standardized automated diagnostic machine (Abbott Diagnostics, Wiesbaden, Germany).

Resting Blood Pressure and Heart Rate

The resting systolic BP, diastolic BP, and heart rate (HR) of the participants were measured using a stethoscope (Littman Classic II SE) and aneroid sphygmomanometer (DS48A, Welch Allyn, USA).

Ankle–Branchial Index (ABI)

The ABI was measured using an aneroid sphygmomanometer (DS48A, Welch Allyn, USA) and Doppler Ultrasound (SonoTraxII, EDAN, China). The leg-specific ABI was calculated as the ratio of the highest ankle pressure of each leg to average arm pressure. The average ABI equals to the average of the sum of right and left ankles' ABIs.

Statistical Analysis

Per-protocol analysis was adopted, and analyses were done only on participants with $\geq$ 75% compliance to exercise based on the individual logbook. All outcome measures were analyzed using the Statistical Package of Social Science

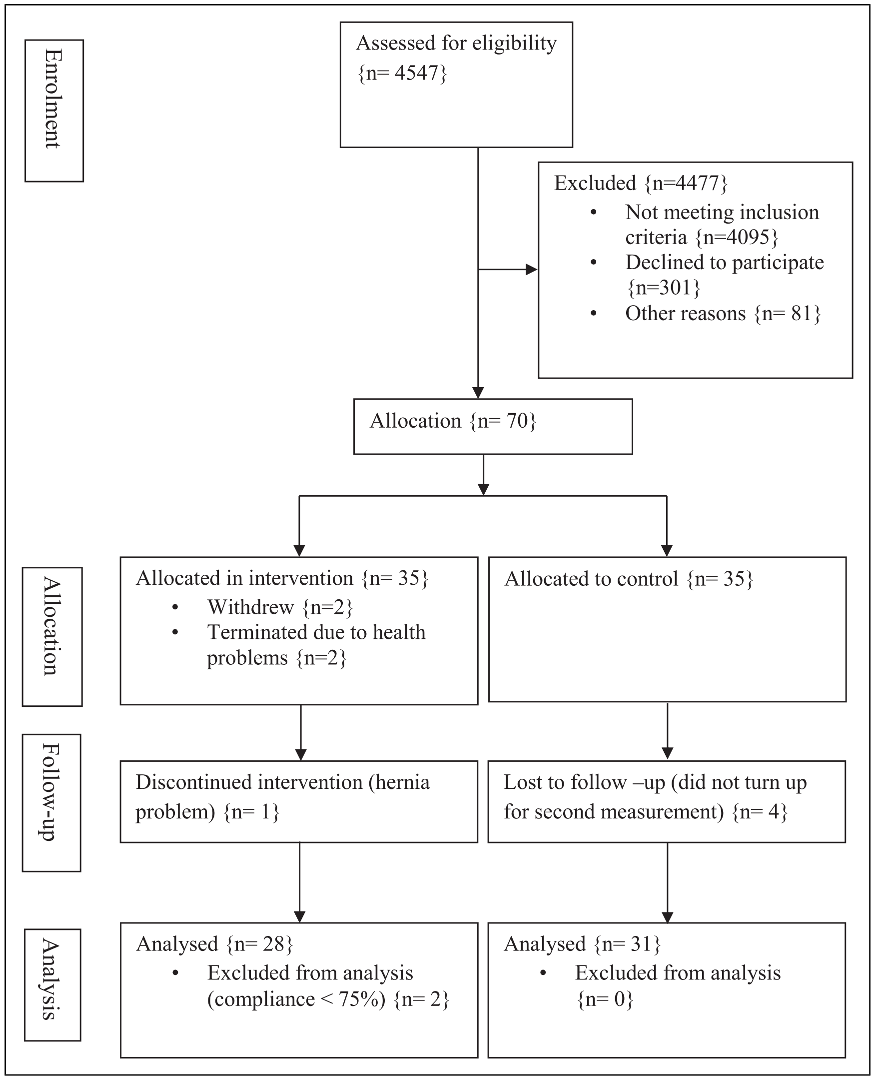

Figure 1. Study consort flow.

(SPSS), and statistical significance was assumed at $p < 0.05$. The independent t-test and chi-square test were used to compare the sociodemographic characteristics between the control and intervention groups at baseline. The standardized differences between the intervention and control groups were computed to evaluate the magnitude of the difference at baseline. Then, the mix-split design ANOVA was employed to analyze the interaction effects for all the dependent variables. The effect size of each analysis was reported as partial eta squared. All the outcome measurements were statistically adjusted with the type of treatment regimens received by each participant during baseline.

Results

A total of 4547 patients were assessed for eligibility based on the lists of patients attending the medical specialist clinic. Out of 452 eligible patients, a total of 70 patients agreed to participate in this study, as shown in the study consort flow (Figure 1). Within the intervention group, two participants withdrew from the study due to relocating reasons. During baseline measurement, another two participants were terminated because their BP was greater than 160 mmHg. Both of them were referred back to the hospital. Of the 31 participants who started the conditioning period, one participant withdrew after the first week due to a recurring hernia problem, leaving a total of 30 participants to continue the exercise training. Another two participants were excluded from analysis due to the compliance < 75%. From the control group, four out of 35 participants did not turn up for the post-intervention measurement. No reason was given for their non-attendance. A total of 28 and 31 participants from intervention and control groups, respectively, were included in the final analysis.

Baseline Data

The mean age for the total study cohort was 61.68 (5.50) years. The majority of the participants were women (54.2%). No

Table 1. Baseline Data Difference Between Control and Intervention Groups.

Parameter	Total cohort N = 59	Intervention (n = 28)	Control (n = 31)	Standardized difference
Age (years)	61.68 (5.50)	61.79 (5.11)	61.58 (5.92)	0.04
Gender				
Men (%)	45.8	42.9	48.4	0.11
Women (%)	54.2	57.1	51.6	
Ethnicity				
Malay (%)	54.2	60.7	48.4	−0.30
Chinese (%)	21.4	25.0	25.8	
Indian (%)	17.1	14.3	25.8	
Education background				
Primary (%)	10.2	14.3	6.5	0.23
Secondary (%)	59.3	50.0	67.7	
Tertiary (%)	23.7	21.4	25.8	
Post grad (%)	6.8	14.3	0.0	
Athropometry				
Height (cm)	1.61 (0.08)	1.62 (0.08)	1.61 (0.09)	0.12
Weight (kg)	69.31 (10.71)	68.79 (11.56)	69.78 (1.80)	−0.12
BMI (kg/m^2)	26.5 (4.03)	26.0 (3.81)	26.9 (4.23)	−0.22
Lipid profile				
TC (mmol/L)	4.74 (1.19)	4.52 (1.08)	4.94 (1.27)	−0.36
TG (mmol/L)	1.52 (0.55)	1.47 (0.54)	1.57 (0.57)	−0.18
LDL (mmol/L)	2.80 (0.13)	2.59 (0.99)	2.98 (0.99)	−0.39
HDL (mmol/L)	1.14 (0.18)	1.17 (0.20)	1.11 (0.15)	0.34
Glucose homeostasis				
FBG (mmol/L)	9.13 (2.09)	9.24 (1.89)	9.02 (2.28)	0.11
HbA1c (%)	9.42 (0.80)	9.40 (0.79)	9.44 (0.83)	−0.05
Cardiovascular risk factors				
Systolic BP (mmHg)	140.66 (19.89)	134.14 (16.42)	146.56 (21.13)*	−0.60
Diastolic BP (mmHg)	79 (7)	79 (5)	78 (8)	0.07
Heart rate (bpm)	75 (10)	73 (7)	78 (11)	−0.53
Left ABI	1.13 (0.08)	1.13 (0.06)	1.13 (0.09)	< 0.01
Right ABI	1.19 (0.08)	1.20 (0.06)	1.19 (0.10)	0.12

Data were presented as mean (SD) or %. Independent T-test and Mann–Whitney U test were used for normally distributed and non-normally distributed continuous data, while the chi-square test was used for categorical data.
ABI: ankle–brachial index; BMI: body mass index; BP: blood pressure; FBG: fasting blood sugar; HbA1c: glycated hemoglobin; HDL: high-density lipoprotein; LDL: low-density lipoprotein; TC: total cholesterol; TG: triglycerides.
*Significant at p < 0.05 when comparing the intervention and control groups.

significant differences between intervention and control groups in all the baseline measurements included age, gender, ethnicity, educational background, height, weight, body mass index (BMI), total cholesterol, TG, LDL and HDL, HbA1c, FBG, diastolic BP, resting HR, and ABI except for systolic BP ($p < 0.05$) (Table 1). Systolic BP was used as a covariate in the subsequent analysis since it is the only variable that shows significant differences between intervention and control groups during baseline measurements.

Post-Intervention Outcomes

Table 2 shows the interaction effect of glucose homeostasis markers and cardiovascular risk factors from baseline to post-intervention. The ANOVA analysis showed significant interaction effect (p < 0.05) in HbA1c [F (1,57) = 44.92, partial n^2 = .45], FBG [F (1,56) = 14.63, partial n^2 = .21], and systolic BP [F (1,57) = 5.62, partial n^2 = .09]. However, no significant interaction effects were observed in total cholesterol, TG, LDL and HDL, diastolic BP, resting HR, and ABI.

Discussion

Resistance training (RT) using resistance tubes has shown promising findings in various studies. Previously, Lima et al. (2018) reported that RT using resistance tubes is equally effective in promoting the peripheral muscle force and functional exercise capacity as compared to RT using weight machines in middle-aged to older adults. Meanwhile, Souza et al. (2019) demonstrated that RT using resistance tubes can improve the physical and cardiovascular function in older

Table 2. Group by Time Effect of Glucose Homeostasis Markers and Cardiovascular Risk Factors.

Biochemical analysis	Mean (SD)		Group-by-time interaction effect
	Pre-int.	Post-int.	
HbA1c (%)			
Intervention	9.40 (0.79)	8.06 (0.79)	F (1,57) = 52.65, partial η^2 = 0.48***
Control	9.44 (0.83)	9.68 (1.13)	
FBG (mmol/L)			
Intervention	9.24 (1.89)	7.94 (1.39)	F (1,57) = 7.25, partial η^2 = 0.23***
Control	9.02 (2.28)	9.45 (2.05)	
TC (mmol/L)			
Intervention	4.52 (1.08)	4.26 (0.95)	F (1,57) = 2.43, partial η^2 = 0.48
Control	4.94 (1.27)	5.00 (1.17)	
TG (mmol/L)			
Intervention	1.47 (0.54)	1.48 (0.61)	F (1,57) = 0.35, partial η^2 = 0.01
Control	1.57 (0.57)	1.65 (0.57)	
LDL (mmol/L)			
Intervention	2.59 (0.90)	2.38 (0.94)	F (1,57) = 1.07, partial η^2 = .02
Control	2.98 (0.99)	2.95 (0.87)	
HDL (mmol/L)			
Intervention	1.17 (0.20)	1.13 (0.16)	F (1,57) = 1.07, partial η2 = .02
Control	1.10 (0.15)	1.12 (0.25)	
Systolic BP (mmHg)			
Intervention	134.14 (16.42)	132.72 (16.62)	F (1,56) = 5.62, partial η2 = .09*
Control	146.56 (21.13)	147.25 (19.75)	
Diastolic BP (mmHg)			
Intervention	78.90 (5.36)	78.91 (5.98)	F (1,57) = 3.09, partial η2 = .05
Control	78.41 (8.26)	75.56 (10.30)	
Heart rate (bpm)			
Intervention	71 (5)	72 (6)	F (1,57) = 2.29, partial η^2 = .04
Control	75 (7)	78 (5)	
Left-ABI			
Intervention	1.13 (0.06)	1.15 (0.06)	F (1,57) = 0.48, partial η^2 < .01
Control	1.13 (0.09)	1.13 (0.09)	
Right-ABI			
Intervention	1.20 (0.06)	1.20 (0.06)	F (1,57) = 0.23, partial η^2 < .01
Control	1.19 (0.10)	1.18 (0.09)	

ABI: ankle–brachial index; BP: blood pressure; bpm: beat per minute; FBS: fasting blood glucose; HbA1c: glycated hemoglobin; HDL: high-density lipoprotein; LDL: low-density lipoprotein; Pre-Int.: pre-intervention; Post-Int.: post-intervention; TC: total cholesterol; TG: triglycerides.
*Significant at $p < 0.05$. ***Significant at $p < 0.001$.

women. In this present study, significant improvement in terms of glycemic control was observed in older adults with T2DM who performed the 16-week home-based PRT using resistance tubes. In agreement with our current findings, Park et al. (2016) reported that 12 weeks of RT using resistance tubes showed significant reductions in HbA1c, fasting, and postprandial glucose levels.

The present study showed a 1.34% point of HbA1c reduction in the intervention group. A recent study achieved a significant 0.9% point of reduction in HbA1c after 4 months of RT (Amnas et al., 2018). Another 8-week RT also showed a significant reduction (−0.4%) in HbA1c (Eskandary & Rahimi, 2017). Dunstan et al. (2002) suggested that the mean 1.2% reduction in HbA1c offers a prognostic advantage in older T2DM patients. Pesta et al. (2017) and Schwingshackl et al. (2014) reported that RT-induced physiological stimuli and/or specific molecular signaling cascade are important in promoting physiological adaptations such as increased insulin sensitivity of T2DM participants to the exercise regime. This study observed a higher reduction of HbA1c, which was 1.34% point. This result also confirmed that the intensity of the exercise implemented was sufficient to yield a positive impact on glycemic control. However, it is noted that the HbA1c level after 16 weeks of intervention (8.06 ± 0.79%) was still higher than the target in T2DM management as suggested by the American Diabetes Association (2020a, 2020b), which is HbA1c < 7.0% for most of the non-pregnant adults and < 7.5% for older adults.

Amnas et al. (2018) and Eskandary and Rahimi (2017) also found a significant reduction in FBG in the RT group. Although Amnas et al. (2018) implemented a home-based RT using elastic bands, the age range of participants was wider as compared to the present study which was between 18- to 65-year-olds. Contrary to our study, Eskandary and Rahimi (2017) implemented a supervised RT using the weight-lifting method, and the study participants were all diabetic men. In terms of feasibility, the present study seemed more practical to be implemented to the public especially the elderly. Nevertheless, Bweir et al. (2009) suggested RT is associated with significantly better glycemic control in adults with T2DM compared to aerobic exercise.

It is common to find T2DM patients to have impaired lipid profiles. On top of high LDL, patients were often found with elevated TG and low HDL (Chew et al., 2012). Marques et al. (2009) reported no significant changes in all lipid profile parameters where the participants were prescribed with an 8-month home-based RT. This result is similar to the present study, which also applied the home-based resistance training only. Ferrer-García et al. (2011) reported that there were no significant reductions in lipid profile parameters except for total cholesterol in a 24-week combined aerobic exercise and RT. In the same study, they reported no significant changes in BP in the intervention group. Contrary to the present study, when a 9-month multi-component exercise consisting of aerobic, resistance, balance, and flexibility exercise were prescribed to participants with T2DM, a significant interaction effect was observed in lipid profile (Mendes et al., 2017). Hamasaki et al. (2015) reported that a 12-week low-intensity resistance training significantly increased HDL levels in obese patients with T2DM. The different modes of exercise and the duration of the study were the main reasons why different lipid profile results were observed.

Dobrosielski et al. (2012) reported no significant changes in BP following a 26-week supervised combination of aerobics and RT. This is also reflected in the study of Barone Gibbs et al. (2012) and Tan et al. (2012) where no significant changes in both systolic and diastolic BP were observed after 6 months' exercise training. Nevertheless, both studies also implemented a combination of RT or weight training and aerobic exercise. The lack of change in arterial stiffness suggests resistance to exercise-induced BP reduction in persons with T2DM (Dobrosielski et al., 2012). On contrary, Jorge et al. (2011) reported a significant reduction in systolic BP among participants with T2DM assigned with RT. Chen et al. (2010) reported a significant reduction in systolic BP among the hypertensive group who underwent 12 weeks of PRT. Our result is also in accordance with the previous study, which concluded that RT was more effective in reducing systolic BP as compared to aerobic training (Morais et al., 2011).

The present study observed no significant changes in resting HR, and this finding is similar to the study of Kang et al. (2016), which focused on the effects of 12 weeks of combined aerobics and RT on HR variability in patients with T2DM. In contrast, a study on the impact of combined aerobic and RT found a significant reduction in resting HR (Hordern et al., 2011). The non-significant changes in resting HR could be attributed to the HR measurement itself. Ideally, resting HR measurement should be done on three consecutive early mornings following undisturbed sleep. In the present study, it was impossible to ask the participants to measure their resting HR as the majority of them were not familiar with the procedure.

ABI is a simple and non-invasive diagnostic test that has been validated to diagnose peripheral arterial disease (PAD) (Aboyans et al., 2012). Diabetes and smoking are the strongest risk factors for PAD (American Diabetes Association, 2003). Advanced age, hypertension, and hyperlipidemia are also well-known risk factors for PAD, and they are strongly related to T2DM (Resnick & Foster, 2005). The normal range for ABI is from 0.91 to 1.30, and all participants in the present study had normal ABI scores throughout the intervention period (Potier et al., 2011). The non-significant finding of ABI was in line with the study of Jani et al. (2017), Parr et al. (2009), and Tebbutt et al. (2011). On the contrary, ABI increased among T2DM patients with baseline ABI < 1.0 after a 6-month supervised aerobics and RT (Barone Gibbs et al., 2013).

The strengths and limitations of this study should be considered. The strength of this study is the use of home-based PRT with elastic materials, which allows older individuals to train privately at their convenience since resistance tubes are light, cheap, and easy to store and transport. This study was subjected to few limitations. First, the study design was a quasi-experimental design. Participants were recruited through the purposive sampling method and were not randomized into control or intervention groups. Thus, a selection bias exists. Second, habitual physical activity and dietary intake were not accessed in this study. However, the participants were asked and reminded not to change their dietary patterns and habitual physical activity throughout the study duration. These components warrant further scrutiny in the future.

Conclusion

In conclusion, there is a significant improvement in glucose homeostasis and systolic BP of the older adults with T2DM following a 16-week home-based high-intensity PRT using resistance tube. It has the potential to be implemented as a method for lifestyle intervention among the elderly with T2DM. Further study is pursued to elucidate the beneficial effect of the high-intensity PRT on the quality of life and other psychological aspects of life.

Acknowledgments

The authors thank the participants of the study.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Ministry of Health Malaysia [MRG-2010-25].

ORCID iD

Arimi Fitri Mat Ludin https://orcid.org/0000-0003-1517-2115

References

Aboyans, V., Criqui, M. H., Abraham, P., Allison, M. A., Creager, M. A., Diehm, C., Fowkes, F. G. R., Hiatt, W. R., Jönsson, B., Lacroix, P., Marin, B., McDermott, M. M., Norgren, L., Pande, R. L., Preux, P.-M., Stoffers, H. E. J., & Treat-Jacobson, D. (2012). Measurement and interpretation of the ankle-brachial index: a scientific statement from the American Heart Association. *Circulation*, *126*(24), 2890-2909. https://doi.org/10.1161/CIR.0b013e318276fbcb

American Diabetes Association. (2003). Peripheral arterial disease in people with diabetes. *Diabetes Care*, *26*(12), 3333-3341. https://doi.org/10.2337/diacare.26.12.3333

American Diabetes Association. (2020a). 12. Older adults: Standards of medical care in diabetes- 2020. *Diabetes Care*, *43*(Supplement 1), S152-S162. https://doi.org/10.2337/dc20-S012

American Diabetes Association. (2020b). 6. Glycemic targets: Standards of medical care in diabetes-2020. *Diabetes Care*, *43*(Suppl 1), S66-S76. https://doi.org/10.2337/dc20-S006

Amnas, S. A. M. F., Wijetunga, W. M. U. A., Dissanayake, H. A., & Katulanda, P. (2018). Home-based resistance training improves glycemic control and body fat content in patients with type 2 diabetes mellitus: Experience from a tertiary care hospital in Sri Lanka. *Clinical Research in Diabetes and Endocrinology*, *1*(1), 1-4. https://pdfs.semanticscholar.org/34b2/37e84acdb7bab6f6f36ce452b11477d0c979.pdf

Barone Gibbs, B., Dobrosielski, D. A., Althouse, A. D., & Stewart, K. J. (2013). The effect of exercise training on ankle-brachial index in type 2 diabetes. *Atherosclerosis*, *230*(1), 125-130. https://doi.org/10.1016/j.atherosclerosis.2013.07.002

Barone Gibbs, B., Dobrosielski, D. A., Bonekamp, S., Stewart, K. J., & Clark, J. M. (2012). A randomized trial of exercise for blood pressure reduction in type 2 diabetes: Effect on flow-mediated dilation and circulating biomarkers of endothelial function. *Atherosclerosis*, *224*(2), 446-453. https://doi.org/10.1016/j.atherosclerosis.2012.07.035

Bethancourt, H. J., Rosenberg, D. E., Beatty, T., & Arterburn, D. E. (2014). Barriers to and facilitators of physical activity program use among older adults. *Clinical Medicine & Research*, *12*(1-2), 10-20. https://doi.org/10.3121/cmr.2013.1171

Blair, M. (2016). Diabetes mellitus review. *Urologic Nursing*, *36*(1), 27-36. https://doi.org/10.7257/1053-816x.2016.36.1.27

Borg, G. (1998). *Borg's perceived exertion and pain scales.* Human Kinetics.

Bweir, S., Al-Jarrah, M., Almalty, A.-M., Maayah, M., Smirnova, I. V, Novikova, L., & Stehno-Bittel, L. (2009). Resistance exercise training lowers HbA1c more than aerobic training in adults with type 2 diabetes. *Diabetology & Metabolic Syndrome*, *1*, 27. https://doi.org/10.1186/1758-5996-1-27

Chen, V. C. W., Lee, C.-W., Lee, T. V, Chikani, G., Bui, S., & Riechman, S. E. (2010). Blood pressure is decreased after resistance training in stage 1 hypertensive but not normo- or pre-hypertensive elderly men and women. *Medicine and Science in Sports and Exercise*, *42*(5). https://journals.lww.com/acsm-msse/Fulltext/2010/05001/Blood_Pressure_is_Decreased_after_Resistance.1072.aspx

Chew, B. H., Ismail, M., Lee, P. Y., Taher, S. W., Haniff, J., Mustapha, F. I., & Bujang, M. A. (2012). Determinants of uncontrolled dyslipidaemia among adult type 2 diabetes in Malaysia: The Malaysian Diabetes registry 2009. *Diabetes Research and Clinical Practice*, *96*(3), 339-347. https://doi.org/10.1016/j.diabres.2012.01.017

DeFronzo, R. A., Ferrannini, E., Groop, L., Henry, R. R., Herman, W. H., Holst, J. J., Hu, F. B., Kahn, C. R., Raz, I., Shulman, G. I., Simonson, D. C., Testa, M. A., & Weiss, R. (2015). Type 2 diabetes mellitus. *Nature Reviews. Disease Primers*, *1*, 15019. https://doi.org/10.1038/nrdp.2015.19

Dobrosielski, D. A., Gibbs, B. B., Ouyang, P., Bonekamp, S., Clark, J. M., Wang, N.-Y., Silber, H. A., Shapiro, E. P., & Stewart, K. J. (2012). Effect of exercise on blood pressure in type 2 diabetes: A randomized controlled trial. *Journal of General Internal Medicine*, *27*(11), 1453-1459. https://doi.org/10.1007/s11606-012-2103-8

Dunstan, D. W., Daly, R. M., Owen, N., Jolley, D., De Courten, M., Shaw, J., & Zimmet, P. (2002). High-intensity resistance training improves glycemic control in older patients with type 2 diabetes. *Diabetes Care*, *25*(10), 1729-1736. https://doi.org/10.2337/diacare.25.10.1729

Eskandary, S., & Rahimi, E. (2017). Effects of eight weeks aerobic training, resistance training and concurrent training on the metabolic syndrome and HbA1c in men with type 2 diabetes. *Journal of Physical Activity & Health*, *1*(2), 51-64. http://jpah.iaushiraz.ac.ir/article_532184.html

Ferrer-García, J. C., Sánchez López, P., Pablos-Abella, C., Albalat-Galera, R., Elvira-Macagno, L., Sánchez-Juan, C., & Pablos-Monzó, A. (2011). [Benefits of a home-based physical exercise program in elderly subjects with type 2 diabetes mellitus]. *Endocrinologia y nutricion: organo de la Sociedad Espanola de Endocrinologia y Nutricion*, *58*(8), 387-394. https://doi.org/10.1016/j.endonu.2011.05.010

Ferriolli, E., Pessanha, F. P. A. S., & Marchesi, J. C. L. S. (2014). Diabetes and exercise in the elderly. *Medicine and Sport Science*, *60*(Dm), 122-129. https://doi.org/10.1159/000357342

Hamasaki, H., Kawashima, Y., Tamada, Y., Furuta, M., Katsuyama, H., Sako, A., & Yanai, H. (2015). Associations of low-intensity resistance training with body composition and lipid profile in obese patients with type 2 diabetes. *Plos One*, *10*(7), e0132959. https://doi.org/10.1371/journal.pone.0132959

Hordern, M. D., Marwick, T. H., Wood, P., Cooney, L. M., Prins, J. B., & Coombes, J. S. (2011). Acute response of blood glucose to short-term exercise training in patients with type 2 diabetes. *Journal of Science and Medicine in Sport*, *14*(3), 238-242. https://doi.org/10.1016/j.jsams.2010.11.003

Hughes, C., & Page, P. (2003). Scientific basis of elastic resistance. In P. Page, & T. S. Ellenbecker (Eds.), *Scientific and clinical application of elastic resistance* (pp. 3-9). Human Kinetics.

Jani, C. K., Thekdi, P. I., & Thakore, V. (2017). A comparative study of upper body strength training exercise vs. treadmill walking on patients with intermittent claudication. *Archives of Clinical and Experimental Surgery*, *7*(2), 77-83

Jorge, M. L. M. P., de Oliveira, V. N., Resende, N. M., Paraiso, L. F., Calixto, A., Diniz, A. L. D., Resende, E. S., Ropelle, E. R., Carvalheira, J. B., Espindola, F. S., Jorge, P. T., & Geloneze, B. (2011). The effects of aerobic, resistance, and combined exercise on metabolic control, inflammatory markers, adipocytokines, and muscle insulin signaling in patients with type 2 diabetes mellitus. *Metabolism: Clinical and Experimental*, *60*(9), 1244-1252. https://doi.org/10.1016/j.metabol.2011.01.006

Kang, S.-J., Ko, K.-J., & Baek, U.-H. (2016). Effects of 12 weeks combined aerobic and resistance exercise on heart rate variability in type 2 diabetes mellitus patients. *Journal of Physical Therapy Science*, *28*(7), 2088-2093. https://doi.org/10.1589/jpts.28.2088

Lima, F. F., Camillo, C. A., Gobbo, L. A., Trevisan, I. B., Nascimento, W. B. B. M., Silva, B. S. A., Lima, M. C. S., Ramos, D., & Ramos, E. M. C. (2018). Resistance training using low cost elastic tubing is equally effective to conventional weight machines in middle-aged to older healthy adults: A quasi-randomized controlled clinical trial. *Journal of Sports Science & Medicine*, *17*(1), 153-160.

Liu, Y., Ye, W., Chen, Q., Zhang, Y., Kuo, C.-H., & Korivi, M. (2019). Resistance exercise intensity is correlated with attenuation of HbA1c and insulin in patients with type 2 diabetes: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, *16*(1), 140. https://doi.org/10.3390/ijerph16010140

Marques, E., Carvalho, J., Soares, J. M. C., Marques, F., & Mota, J. (2009). Effects of resistance and multicomponent exercise on lipid profiles of older women. *Maturitas*, *63*(1), 84-88. https://doi.org/10.1016/j.maturitas.2009.03.003

Mendes, R., Sousa, N., Reis, V. M., & Themudo-Barata, J. L. (2017). Implementing low-cost, community-based exercise programs for middle-aged and older patients with type 2 diabetes: What are the benefits for glycemic control and cardiovascular risk? *International Journal of Environmental Research and Public Health*, *14*(9), 1057. https://doi.org/10.3390/ijerph14091057

Morais, P. K., Campbell, C. S. G., Sales, M. M., Motta, D. F., Moreira, S. R., Cunha, V. N. C., Benford, R. E., & Simões, H. G. (2011). Acute resistance exercise is more effective than aerobic exercise for 24h blood pressure control in type 2 diabetics. *Diabetes & Metabolism*, *37*(2), 112-117. https://doi.org/10.1016/j.diabet.2010.08.008

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., Macera, C. A., & Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: recommendation from the American college of sports medicine and the American heart association. *Medicine and Science in Sports and Exercise*, *39*(8), 1435-1445. https://doi.org/10.1249/mss.0b013e3180616aa2

Park, B.-S., Khamoui, A. V, Brown, L. E., Kim, D.-Y., Han, K.-A., Min, K.-W., & An, G.-H. (2016). Effects of elastic band resistance training on glucose control, body composition, and physical function in women with short- vs. long-duration type-2 diabetes. *Journal of Strength and Conditioning Research*, *30*(6), 1688-1699. https://doi.org/10.1519/JSC.0000000000001256

Parr, B. M., Noakes, T. D., & Derman, E. W. (2009). Peripheral arterial disease and intermittent claudication: Efficacy of short-term upper body strength training, dynamic exercise training, and advice to exercise at home. *South African Medical Journal = Suid-Afrikaanse Tydskrif Vir Geneeskunde*, *99*(11), 800-804.

Pedersen, B. K., & Saltin, B. (2006). Evidence for prescribing exercise as therapy in chronic disease. *Scandinavian Journal of Medicine & Science in Sports*, *16* Suppl 1, 3-63. https://doi.org/10.1111/j.1600-0838.2006.00520.x

Pesta, D. H., Goncalves, R. L. S., Madiraju, A. K., Strasser, B., & Sparks, L. M. (2017). Resistance training to improve type 2 diabetes: Working toward a prescription for the future. *Nutrition and Metabolism*, *14*(1), 24. https://doi.org/10.1186/s12986-017-0173-7

Potier, L., Abi Khalil, C., Mohammedi, K., & Roussel, R. (2011). Use and utility of ankle brachial index in patients with diabetes. *European Journal of Vascular and Endovascular Surgerys: The Official Journal of the European Society for Vascular Surgery*, *41*(1), 110-116. https://doi.org/10.1016/j.ejvs.2010.09.020

Resnick, H. E., & Foster, G. L. (2005). Prevalence of elevated ankle-brachial index in the United States 1999 to 2002. *The American Journal of Medicine*, *118*(6), 676-679. https://doi.org/10.1016/j.amjmed.2004.11.025

Schwingshackl, L., Missbach, B., Dias, S., König, J., & Hoffmann, G. (2014). Impact of different training modalities on glycaemic control and blood lipids in patients with type 2 diabetes: A systematic review and network meta-analysis. *Diabetologia*, *57*(9), 1789-1797. https://doi.org/10.1007/s00125-014-3303-z

Souza, D., Barbalho, M., Vieira, C. A., Martins, W. R., Cadore, E. L., & Gentil, P. (2019). Minimal dose resistance training with elastic tubes promotes functional and cardiovascular benefits to older women. *Experimental Gerontology*, *115*, 132-138. https://doi.org/10.1016/j.exger.2018.12.001

Tan, S., Li, W., & Wang, J. (2012). Effects of six months of combined aerobic and resistance training for elderly patients with a long history of type 2 diabetes. *Journal of Sports Science & Medicine*, *11*(3), 495-501.

Tebbutt, N., Robinson, L., Todhunter, J., & Jonker, L. (2011). A plantar flexion device exercise programme for patients with peripheral arterial disease: a randomised prospective feasibility study. *Physiotherapy*, *97*(3), 244-249. https://doi.org/10.1016/j.physio.2010.08.009

Thiebaud, R. S., Funk, M. D., & Abe, T. (2014). Home-based resistance training for older adults: A systematic review. *Geriatrics & Gerontology International*, *14*(4), 750-757. https://doi.org/10.1111/ggi.12326

Villareal, D. T., Aguirre, L., Gurney, A. B., Waters, D. L., Sinacore, D. R., Colombo, E., Armamento-Villareal, R., & Qualls, C. (2017). Aerobic or resistance exercise, or both, in dieting obese older adults. *New England Journal of Medicine*, *376*(20), 1943-1955. https://doi.org/10.1056/NEJMoa1616338

World Health Organization. (2018). *Diabetes*. https://www.who.int/news-room/fact-sheets/detail/diabetes