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RESEARCH

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Psychophysiological effects of a supervised home-based resistance band exercise program in pre-frail older patients with type 2 diabetes mellitus: a randomized controlled trial

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Abstract

Background Frailty is a syndrome as with aging in the population of type 2 diabetes mellitus (T2DM) and exercise has become an essential non-pharmacological tool especially in the pre-frail stage. Notably, the form of supervised home-based exercise program has been strongly recommended in recent years. This study aimed to verify the potential effects of the supervised home-based elastic band exercise in pre-frail older T2DM patients in China.

Methods A total of 100 participants were included and randomly divided into intervention group (IG) ($n=50$) and control group (CG) ($n=50$). The CG received a routine care, while the IG received an extra home-based elastic band training under online and offline supervisions sustaining 12-weeks. The glycosylated hemoglobin (HbA1c), blood lipids, body composition, physical function, scales of Diabetes specificity quality of life scale (DSQL), Pittsburgh sleep quality index (PSQI) and short form geriatric depression scale (GDS-15) of the participants were evaluated before and after intervention.

Results The average age of the participants were 66.01 ± 4.76 with 55% male and average BMI 24.75 ± 3.51 kg/m^2. The clinical characteristics of the two groups were comparable. After 12 weeks' training, muscle mass of the limbs ($P<0.05$), physical function indicators including grip strength, chair stands (both $P<0.05$), walking time ($P<0.01$), HbA1c ($P<0.05$), frailty score ($P<0.05$), subjective sleep quality ($P<0.05$), total DSQL scores ($P<0.01$) and the depressive status ($P<0.01$) improved significantly in IG when compared with CG.

Conclusion Supervised home-based elastic band exercise could improve limb muscle mass, physical fitness, glucose and lipid control and quality of life in pre-frail older T2DM patients.

Trial registration number ChiCTR2300070726; Registration date: 21/04/2023.

Keywords Frailty, Home-Based Exercise, Elastic Band Training, Pre-Frail Older Adults, Diabetes Mellitus

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Introduction

Frailty is a discernible geriatric clinical syndrome characterized by a noticeable decline in physiological vigor, muscular endurance, and overall physiological functionality [1]. The geriatric population affected by frailty was predisposed to a range of adverse outcomes, including falls, disability, cognitive decline, psychological abnormalities, and even mortality [2]. Type 2 diabetes mellitus (T2DM) played a significant role as a contributing factor in the etiology of frailty among the geriatric population. Previous reports have indicated a concerning prevalence of frailty among older individuals with T2DM, estimated at 20.1% [3]. The geriatric population dealing with both frailty and T2DM experienced a noticeable increase of approximately 6–7% in their reliance on medical interventions compared to non-frail T2DM peers [4, 5]. The pre-frail stage was in a state between health and frailty, with partial functional decline or physiological deterioration, and T2DM older patients in pre-frail stage have been more susceptible to external pressures and diseases such as cardiovascular disease, osteoporosis, infections when compared to the non-frail T2DM. Hence, it is very essential to implement early and effective interventions to prevent or delay the onset of frailty in the geriatric T2DM.

The home-based exercise programs have been reported as a useful strategy to facilitate the practice of exercises especially during and after periods of social isolation experienced by the Corona Virus Disease 2019 pandemic because of their advantages such as easy accessibility, inexpensive, and organizational flexibility [6–8]. However, previous studies showed that the participation and adherence to home-based exercise programs often remained low. As an alternative, supervised home-based exercise programs could significantly improve patient compliance, ensure proper execution of exercises, and provide timely feedback [9], which had been recently reported associating with significant benefits for example in the cardiometabolic, functional, and psychosocial effects in T2D patients [10] and in the mental health and quality of life [11], reducing risk of falling in older people [12]. Besides, several tele- assessment tools have been developed and proven highly reliable in monitoring physical changes in performance over time in T2D patients [13]. However, past literature was few regarding studies verifying the results in pre-frail older T2D individuals.

Resistance exercise, a form of anaerobic exertion, commonly involves the use of external resistance to stimulate muscle contractions. This approach encompasses various modalities, including elastic band exercises, weight-bearing routines, equipment-based training, and similar methodologies [14, 15]. Contemporary clinical practice guidelines [16] have strongly advocated for the use of resistance exercise as a potent strategy to prevent frailty in older individuals with T2DM. Moreover, the multifaceted benefits of resistance exercise include increased muscle strength, improved bone mineral density, blood pressure regulation, enhancement of blood lipid profiles, and improved insulin sensitivity in the geriatric T2DM population [17–20].

While equipment training and weight-bearing exercise may be popular among professional sports trainers, their acceptance among the geriatric population was often hindered by limitations such as the lack of professional guidance and financial resources. Consequently, the geriatric group showed relatively lower acceptance due to these constraints. Colado et al. [21] reported a significant attrition rate of 50% within the first year of initiating free weight training among the geriatric cohort. As a noteworthy alternative, elastic band resistance exercise has emerged as a practical solution, characterized by its cost-effectiveness, ease of use, and enhanced user-friendliness [22, 23]. This modality engaged various anatomical regions through a range of movements. Furthermore, previous reports have confirmed that the effects of elastic band resistance exercise were comparable to those of conventional equipment-based regimens, especially in terms of strength improvement [24]. Importantly, the suitability of elastic band exercise was enhanced for the geriatric population due to its ability to impose a modest load, thus reducing the risk of injuries and enhancing safety measures [25].

Contemporary investigations had proffered evidence delineating the salutary impact of elastic band resistance exercise upon the enhancement of muscle function and concomitant augmentation of quality of life, both within the cohort of frail older individuals [26] and the patients with T2DM [27]. However, most existing studies have focused on either the general frail population or elderly individuals without diabetes, while research targeting pre-frail elderly patients with T2DM was very limited. Besides, the combination of the flexibility of home-based exercise and professional supervision is an innovative intervention model that has seldomly reported. In this study, we conducted a randomized controlled study, focusing on the changes on physical function, body composition and quality of life before and after the intervention of supervised home-based elastic band resistance exercise, in order to provide the new insights of its effects on the pre-frail T2DM patients.

Methods

Participants

This study recruited pre-frail older participants with T2DM, through giving out leaflets, posting leaflets on the bulletin board in the inpatients from the Department of Endocrinology in ZhongDa Hospital about to be discharged and it was a continuous recruitment between 2022 April and August. All participants were informed that they would receive a new intervention before the study began, but the specific group assignments were kept confidential from them. Patients were assigned to either the intervention or control group based on random numbers generated using the random number function within the Excel spreadsheet. The odd numbers indicated the intervention group (IG) and even numbers indicated the control group (CG). If both the IG and CG were from the same ward, such patients were excluded from the study. This study was a single-blind trail which referred to a situation where the participants did not know whether they were in the IG or the CG, while the researchers were aware. Informed consent was obtained from the patient for publication. The sample size was calculated using the formula for comparing the means of two independent samples. The significance level (α) was set at 0.05, and the desired statistical power ($1-\beta$) was 0.90, corresponding to a β value of 0.1. To calculate the effect size (δ), a small-scale pilot study was carried out. Generally, we recruited 20 elderly participants who underwent the same intervention and assessment procedures as in the formal study. The frailty of the participants was assessed using the Fried frailty score system, and comparisons were made before and after the intervention. The effect size used in the calculation was $\delta = 1.77$ (based on the pilot study), with an assumed standard deviation (σ) of 2.00. The effect size parameters "uα" and "uβ" represent the minimum effect sizes associated with the significance level and statistical power, respectively. A sample size of 45 participants were generated for each group. Given the missing rate, the sample size increased by 20% to 110. Planning and reporting were guided by the CONSORT 2010 checklist.

Totally, 110 participants were randomly divided into IG or IG, 55 in each group. The average age of the participants were 66.01 ± 4.76 with 55% male and average BMI 24.75 ± 3.51 kg/m^2. The compliance rate in IG was 96.36% and the compliance rate in CG was 98.18%. 5 participants in IG and 5 participants in CG were lost for change of contact information or house moving. Finally, there were 50 participants in IG and 50 in CG. The whole flowchart could be seen in the Fig. 1. This study was approved by the Ethics Committee of ZhongDa Hospital, Southeast University and as a retrospective registration, it had been registered on the website of Chinese Clinical Trial Registry (trial registration number: ChiCTR2300070726; date of registration: 21/04/2023; https://www.chictr.org.cn/showproj.html?proj=186796). The details of the process of randomization could been obtained from the above webpage.

Inclusion and exclusion criteria

The inclusion criteria were aimed T2DM participants who met 1–2 criteria based on the Fried frailty phenotype [28] (seen in Supplementary Table 1), aged between 60 and 80 years old, could walk independently without assistance and follow general commands, and had no understanding/hearing/visual impairment or vestibular/cerebellar dysfunction. The diagnostic criteria for T2DM were typical symptoms of diabetes (polydipsia, polyuria, polyphagia, and weight loss) plus at least one of the following: (1) random blood glucose ≥ 11.1 mmol/L; (2) fasting blood glucose (FBG) ≥ 7.0 mmol/L; (3) 2 h blood glucose ≥ 11.1 mmol/L during an oral glucose tolerance test (OGTT); (4) hemoglobin A1c (HbA1c) ≥ 6.5% [29]. And if participants without typical symptoms of diabetes need to repeat the above check another day. Participants were excluded if they had serious diseases (e.g. heart, lung, liver, and kidney), mental illness, severe cognitive impairment, autoimmune diseases, malignant tumors, knee or hip joint surgery history, or unwilling to participate in the study.

Intervention

The CG maintained normal daily activity and did not receive extra professional intervention. For the IG, a personalized group was firstly established including a therapist who would generate a personal maximum exercise intensity (50% ~ 65% of the maximum heart rate) and teach participants how to do elastic band training during the hospitalization, and a nurse who was responsible for guiding participants' home exercise after discharge. Besides, week 1 was considered form the moment participant received the training lesson from the study nurses.

The follow-up management included both online and offline approaches which were shown in Supplementary Table 2. For both groups, participants could access elastic band exercise videos through the endocrinology department's official WeChat account. These videos included complete exercise routines, along with explanations of exercise precautions, rest intervals, and rhythmic cues. Besides, they were not controlled engage in additional exercise. Exercise reminders were received three times a week through WeChat app prompting to engage in physical activity. For the participants in IG, once the participants completed their exercises, they send exercise videos and confirm their completion through WeChat. Monthly telephone follow-ups were conducted to inquire about their exercise progress and any discomfort they might be experiencing. For the offline management, a home visit was conducted to provide one-on-one guidance to patients regarding exercise and to assess their exercise workload monthly. A follow-up hospital appointment was scheduled for both groups after three months. This comprehensive follow-up approach combined online reminders, instructional videos, monitoring, and offline interactions to ensure patients in IG adhere to their exercise routines and to assess their progress over the course of three months.

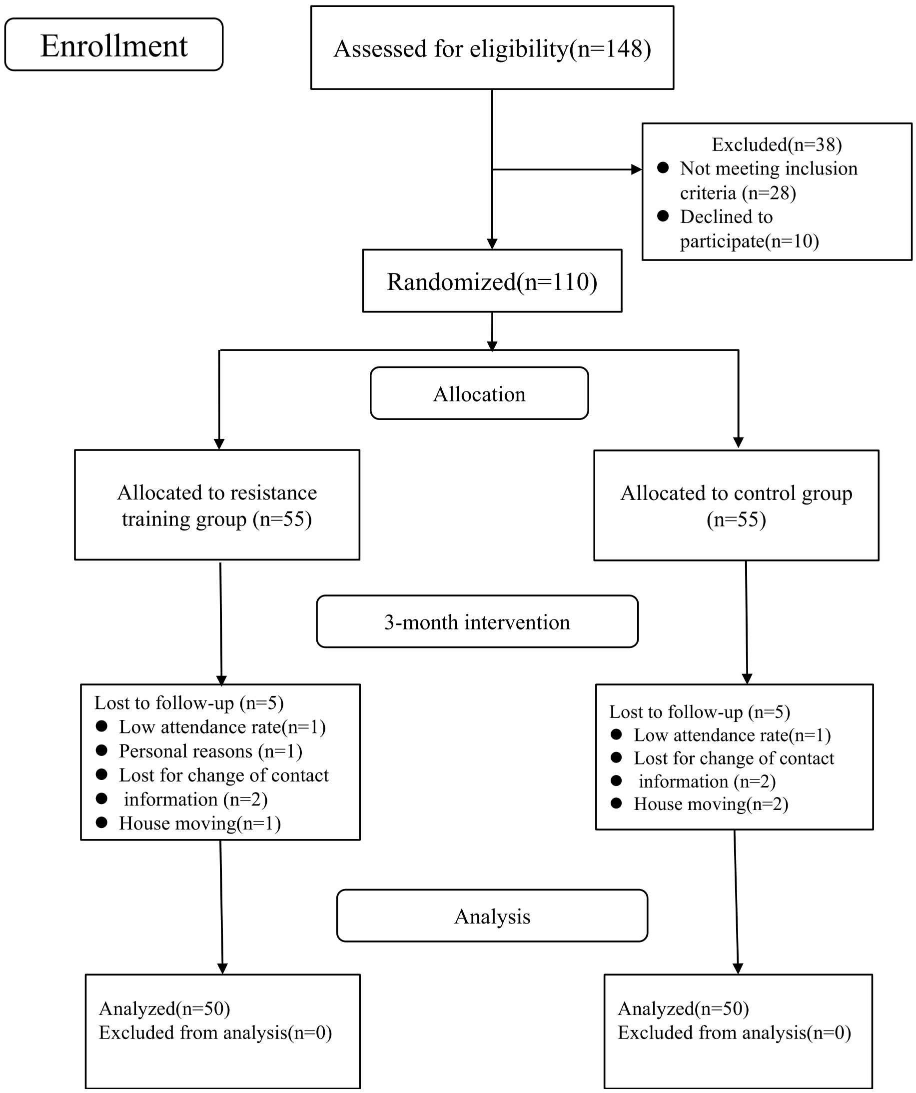

Fig. 1 Flowchart of this study

The total elastic band exercise cost 45 min including 9 sessions, and each session was 5 min. The participants were required to perfume at least one set count three times a week. Eight exercise movements were listed in Supplementary Fig. 1. Besides, for the safety of the training, the participants' family members were required to accompany during the training. The exercise time was selected as 1 h after meals. Once there was panic, cold sweat, fatigue, asthma, dizziness, exercise would be stopped immediately; If there was a strong hunger and other hypoglycemia syndrome, the participants were also required to stop immediately and replenish sugary items in time. The elastic band used in this study is Thera-Band® which was selected respectively according to the patient's height, weight, and maximum heart rate. The participants' feelings about exercise were inquired monthly offline to make sure they could endure the training with the resistance bands. The band resistance levels were not changed once set at the beginning.

Data collection and measurements

The primary outcome of this study was body composition. Secondary outcome included body strength, biochemical indicators, and frailty scores. Generally, information on sex, age, duration of diabetes, history of present illness, and previous drinking and smoking history of the participants were collected. Weight and height measured without shoes were gathered. BMI (kg/m^2) were calculated by weight in kilogram (kg) dividing by the square of height in meters (m). The narrowest part of the body between the inferior ribs and the iliac crest and the widest part of the hip was measured with a tapeline as the waist circumference and hip circumference respectively, after a participant exhaled naturally. Blood pressure was measured in a seated position using a hemomanometer (Yamasu, Tokyo, Japan) after ten minutes' rest. Body composition analyzer (Donghuayuan, Jilin, China, model: DBA-210) was used for assessing body composition. Serum samples for fasting concentrations were drawn in the morning after an overnight fast. Fasting plasma glucose (FPG), triglyceride (TG), total cholesterol (TC), low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C) and glycosylated hemoglobin (HbA1c) were determined by an oxidase method, and fasting C-peptide (FCP) were determined by radioimmunoassay. For the walling test, the patients began the test from a stationary position at the starting point and walked 6 m at their usual pace. Timing commenced when the patient's toe crossed the starting line and concluded when the toe crossed the finish line of the testing area. The walking time was recorded for two trials, and the average walking time was calculated to determine the walking speed. Disease-specific quality of life, sleep quality and depressive symptoms were evaluated by using Diabetes Specific Quality of Life scale (DSQL) [30], Pittsburgh Sleep Quality Index (PSQI) [31] and short form geriatric depression scale (GDS-15) [32], respectively at preintervention, and 12 weeks after the intervention.

Statistical analyses

All statistical analyses were conducted using SPSS version 25.0. Continuous variables were descripted as mean ± standard deviation (SD) if they were followed by normal distribution and median (25% quartile, 75% quartile) if they were skewed. Categorical variables were reported as count and percentage. Values estimated as (12 weeks-baseline)/baseline in each group were used to do the comparation test between IG and CG. Mixed designed ANOVA was used for continuous normally distributed data, while Friedman test was used for non-parametric equivalent. A significance level of 0.05 was set, and a P-value of ≤ 0.05 was considered statistically significant.

Results

Clinical characteristics of the participants

As shown in Table 1, there were no significant differences in average age, sex, WHR, duration of DM, BMI, comorbidity, drinking and smoking history between IG and CG. Basal SBP and DBP levels were also similar. The indicators of liver and kidney function and metabolic indicators including FPG, PPG, FCP, PCP, TC, TG, HDL-C, LDL-C and HbA1c were comparable between two groups.

Table 1 Baseline characteristics

Characteristic	IG (n = 50)	CG (n = 50)	P value	Normal range
Age (years)	65.50 ± 4.5	66.52 ± 5.0	0.287	-
Sex (male, %)	28 (56%)	27 (54%)	0.841	-
WHR (U)	0.95 ± 0.08	0.94 ± 0.07	0.794	-
BMI (kg/m^2)	25.17 ± 3.30	24.3 ± 3.68	0.227	-
DM duration (years)	9.04 ± 8.21	9.36 ± 7.62	0.840	-
Comorbidity			0.216	-
n = 1 (%)	31 (62%)	23 (46%)		-
n = 2 (%)	13 (26%)	21 (42%)		-
n ≥ 3 (%)	6 (12%)	6 (12%)		-
Smokers (%)	33(66%)	36(72%)	0.385	-
Drinkers (%)	33(66%)	37(74%)	0.519	-
SBP (mmHg)	130.9 ± 20.75	131.2 ± 19.27	0.940	-
DBP (mmHg)	72.8 ± 10.77	72.7 ± 13.53	0.974	-
ALT (U/L)	22.4 ± 15.04	19.7 ± 14.58	0.357	9–50
AST (U/L)	19.12 ± 6.40	18.32 ± 7.12	0.556	15–40
BUN (pmol/L)	6.78 ± 1.89	6.54 ± 1.95	0.549	3.6–9.5
Cr (umol/L)	68.88 ± 19.34	72.32 ± 24.07	0.433	57–111
FPG (mmol/L)	10.98 ± 5.69	9.93 ± 4.54	0.314	3.90–6.10
PPG (mmol/L)	17.73 ± 5.27	16.38 ± 5.43	0.211	< 7.80
FCP (nmol/L)	0.61 ± 0.27	0.52 ± 0.27	0.301	0.37–1.47
PCP (nmol/L)	1.97 ± 1.35	1.94 ± 1.06	0.904	-
TC (mmol/L)	4.72 ± 1.38	4.81 ± 1.05	0.714	0.00–6.20
TG (mmol/L)	2.03 ± 1.69	2.05 ± 1.91	0.958	0.00–2.26
HDL-C(mmol/L)	1.08 ± 0.24	1.12 ± 0.34	0.545	> 1.00
LDL-C (mmol/L)	2.64 ± 0.95	2.71 ± 0.93	0.691	0.00–3.40
HbA1c (%)	9.13 ± 2.18	8.71 ± 2.16	0.338	4.00–6.00

Normally distributed variables in the table are presented as mean ± SD

WHR Waist-to-hip ratio, *BMI* Body mass index, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure, *ALT* Alanine transaminase, *AST* Aspartate transaminase, *BUN* Blood urea nitrogen, *Cr* Creatinine, *FPG* Fasting plasma glucose, *PPG* Postprandial plasma glucose, *FCP* Fasting c-peptide, *PCP* Postprandial c-peptide, *TC* Total cholesterol, *TG* Triglyceride, *HDL-C* High density lipoprotein cholesterol, *LDL-C* Low density lipoprotein cholesterol, *HbA1c* Glycosylated hemoglobin

Changes in body composition

The comparison of anthropometric parameters and body composition was presented in Table 2 per assessment (baseline and 12 weeks) and per group. Before intervention, the anthropometric parameters and body composition were comparable between IG and CG. The within-group comparison showed that the IG had decreased levels in the BFM (P < 0.01), VFA(P < 0.05), and PBF(P < 0.01), and increased in muscle mass including SMM, RULMM, LULMM, TMM, RLLMM, LLLMM (all P < 0.01) significantly over time. When compared with CG, indicators of the RULMM, LULMM, RLLMM, and LLLMM (all P < 0.05) showed statistically improvements in IG.

Table 2 Changes in body composition, body strength, biochemical parameters and frailty score

	IG ($n=50$)			CG ($n=50$)			95%CI	Effect sizes	[a]P value
	Baseline	12 weeks	P value	Baseline	12 weeks	P value			
Body composition									
WHR (U)	0.94 ± 0.03	0.94 ± 0.03	0.073	0.94 ± 0.02	0.93 ± 0.03	0.052	0.007 [-0.006,0.022]	0.011	0.230
BFM (kg)	20.51 ± 5.72	19.29 ± 5.41	< 0.001	19.03 ± 5.92	18.58 ± 6.06	0.159	0.711 [-1.569,2.993]	0.004	0.336
VFA (cm^2)	130.54 ± 20.99	127.47 ± 19.60	0.005	123.94 ± 22.22	121.59 ± 21.61	0.028	5.882[-2.308,14.072]	0.020	0.137
PBF (%)	29.26 ± 6.07	27.70 ± 6.10	0.001	33.97 ± 4.17	33.07 ± 4.19	0.060	-5.366[-17.269,6.537]	0.008	0.401
SMM (kg)	25.49 ± 5.25	26.58 ± 5.17	0.001	25.39 ± 5.05	25.36 ± 5.07	0.923	1.227[-0.807,3.261]	0.014	0.510
RULMM (kg)	2.53 ± 0.68	2.98 ± 0.97	< 0.001	2.47 ± 0.63	2.48 ± 0.63	0.961	0.500[0.173,0.827]	0.086	0.04
LULMM (kg)	2.53 ± 0.69	2.98 ± 0.95	< 0.001	2.48 ± 0.62	2.47 ± 0.63	0.965	0.506[0.183,0.828]	0.090	0.047
TMM (kg)	21.10 ± 4.09	22.03 ± 4.08	0.001	20.78 ± 4.01	20.97 ± 3.90	0.481	1.227[-0.807,3.261]	0.018	0.377
RLLMM (kg)	6.94 ± 1.54	7.68 ± 1.42	< 0.001	7.24 ± 1.99	7.07 ± 1.51	0.481	0.607[0.025,1.189]	0.042	0.037
LLLMM (kg)	6.92 ± 1.51	7.67 ± 1.42	< 0.001	7.06 ± 1.45	7.02 ± 1.48	0.696	0.649[0.072,1.225]	0.049	0.026
Body strength									
Grip strength (kg)	20.85 ± 8.21	27.29 ± 7.66	< 0.001	20.28 ± 8.57	21.91 ± 7.62	0.111	5.377[2.341,8.412]	0.112	0.041
Chair stands (rep)	12.94 ± 2.29	9.94 ± 1.72	< 0.001	12.50 ± 1.61	12.06 ± 2.61	0.247	-2.125[-3.007,-1.244]	0.190	0.011
Walking time (s)	12.49 ± 3.55	7.17 ± 1.22	< 0.001	12.14 ± 3.38	11.41 ± 3.30	0.201	-4.235[-5.225,-3.245]	0.424	< 0.001
Biochemical parameters									
TC (mmol/L)	4.72 ± 1.38	4.05 ± 1.15	< 0.001	4.81 ± 1.05	4.57 ± 1.07	0.421	-0.506[-0.950,-0.634]	0.050	0.445
TG (mmol/L)	2.03 ± 1.69	1.41 ± 0.84	< 0.001	2.05 ± 1.91	1.83 ± 0.85	0.741	-0.432[-1.005,0.140]	0.022	0.739
HDL-C(mmol/L)	1.08 ± 0.24	1.14 ± 0.30	0.011	1.12 ± 0.34	1.15 ± 0.32	0.945	-0.012[-0.137,0.112]	0.000	0.484
LDL-C (mmol/L)	2.64 ± 0.95	2.24 ± 0.82	< 0.001	2.71 ± 0.93	2.53 ± 0.92	0.166	-0.295[-0.642,0.052]	0.028	0.632
HbA1c (%)	8.13 ± 2.18	7.28 ± 1.47	< 0.001	8.71 ± 2.16	7.55 ± 1.37	0.322	-0.277[0.849,0.294]	0.109	0.034
Frailty score									
Non frailty (0 point)	0	31		0	13		-	-	0.041
Pre-frailty I (1–2 points)	50	19		50	37		-	-	

Normally distributed variables in the table are presented as mean ± SD

BFM Body fat mass, *VFA* Visceral fat area, *PBF* Percentage of body fat, *SMM* Skeletal muscle mass, *RULMM* Right upper-limb muscle mass, *LULMM* Left upper-limb muscle mass, *TMM* Trunk muscle mass, *RLLMM* Right lower-limb muscle mass, *LLLMM* Left lower-limb muscle mass

[a] *P* values for comparisons of change values at 12 weeks between IG and CG

Changes in body strength and frailty states

As shown in Table 2, after 12 weeks, there were 31 participants returned to non-frailty from prefrailty in elastic band group while only 13 participants in CG, which showed significant difference ($P<0.05$). We further compared three indicators between two groups, including grip strength, chair stands, and walking time which represented upper and lower body strength of the participants respectively. Before intervention, the between-group differences of grip strength, chair stands, and walking time were comparable. After 12-week intervention, there showed significant differences of grip strength ($P<0.05$), chair stands (i < 0.05), and walking time ($P<0.01$) in the IG when compare with CG.

Changes in blood glucose and lipids

HbA1c and blood lipid parameters including TG, TC, LDL-C, HDL-C were presented in Table 2. After 12 weeks, the IG showed statistically significant improvements in HbA1c, TG, TC, and LDL-C (all $P<0.01$). When compared with CG, the IG group showed statistically significant improvements in HbA1c ($P<0.05$).

Changes in DSQL, PSQI and GDS-15

Scales of the DSQL were compared between CG and IG as shown in Table 3, which indicated total scores of DSQL, and especially the social relations domain had significant improvements after elastic band exercise ($P<0.01$). Notably, Scales of the sleep quality were compared between CG and IG as shown in Table 4, which indicated no significant changes expect the improvement of subjective sleep quality ($P<0.01$) and daytime dysfunction ($P<0.05$) after elastic band exercise. As shown in Fig. 2, after 12 weeks, the IG had significant improvements in depressive status ($P<0.01$).

Table 3 Changes in Diabetes specificity quality of life scale

	IG (*n* = 50)			CG (*n* = 50)			95%CI	Effect sizes	[a]*P* value
	Baseline	12 weeks	*P* value	Baseline	12 weeks	*P* value			
Total scores	72.62 ± 10.74	47.00 ± 10.88	< 0.001	73.16 ± 10.70	57.86 ± 9.73	< 0.001	-11.120[-15.290,-6.949]	0.222	0.004
Interference domain	36.08 ± 5.64	21.40 ± 5.44	< 0.001	34.32 ± 7.02	26.64 ± 7.36	< 0.001	-5.240[-7.811,-2.668]	0.143	0.893
Psychology domain	22.82 ± 4.98	15.14 ± 5.91	< 0.001	25.24 ± 6.85	18.34 ± 6.06	< 0.001	-3.200[-5.578,-0.821]	0.165	0.050
Social relations domain	7.32 ± 3.20	5.78 ± 2.43	< 0.001	7.10 ± 3.59	6.94 ± 3.13	< 0.001	-1.320[-2.538,-0.101]	0.045	0.009
Treatment domain	6.40 ± 1.84	5.34 ± 1.72	< 0.001	6.00 ± 1.77	5.94 ± 1.75	0.701	-1.380[-2.003,-0.756]	0.068	0.060

Normally distributed variables in the table are presented as mean ± SD

[a] *P* values for comparisons between IG and CG

Table 4 Changes in Pittsburgh sleep quality index (PSQI)

	IG (*n* = 50)			CG (*n* = 50)			95%CI	Effect sizes	[a]*P* value
	Baseline	12 weeks	*P* value	Baseline	12 weeks	*P* value			
PSQI subscales	5(3,7)	2(4,5)	< 0.001	5(3,7)	2(1,3)	1.000	0.0[-1.0,1.0]	0.067	0.497
Subjective sleep quality	1(0,1)	0(0,1)	0.010	1(0,1)	1(0,1)	0.317	0.5[0.0,1.0]	0.071	0.002
Sleep latency	1(1,2)	1(1,2)	0.025	1(0,2)	1(0,2)	0.106	0.0[0.0,0.0]	0.059	0.443
Sleep duration	0(0,0.25)	0(0,0)	0.059	0(0,0)	0(0,0)	1.000	0.0[0.0,1.0]	0.253	0.554
Habitual sleep efficiency	0(0,0)	0(0,0)	0.527	0(0,0)	0(0,0)	0.120	0.0[0.0,0.0]	0.152	0.095
Sleep disturbances									
Use of sleep medication	0(0,1)	0(0,1)	0.200	0(0,1)	0(0,1)	0.157	0.0[0.0,1.0]	0.025	0.100
Daytime dysfunction	1(0.75,1)	1(0,1)	0.083	1(0,1.25)	1(0,1)	0.117	0.0[-1.0,0.0]	0.210	0.041

[a] *P* values for comparisons between IG and CG

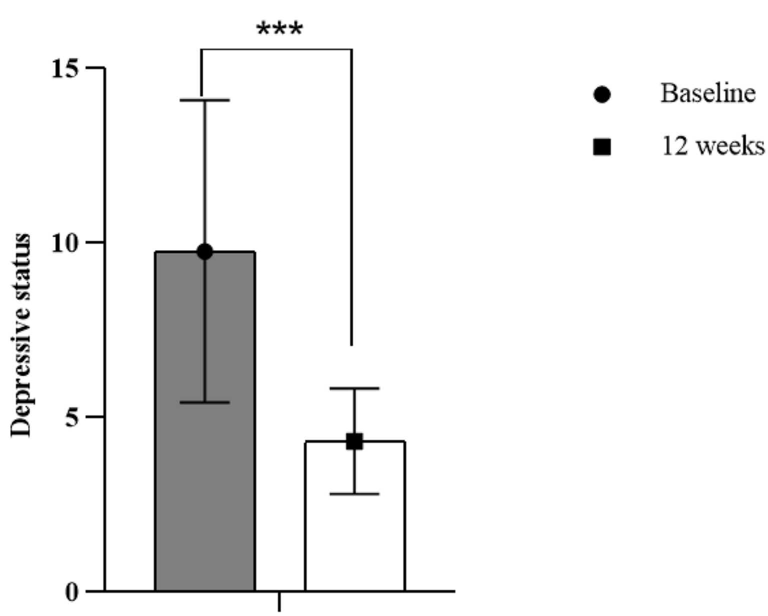

Fig. 2 Depressive states in IG at baseline and 12 weeks. Note: *** < 0.001

Disscussion

Advancing age precipitates a cascade of age-related physiological transformations within the geriatric demographic, encompassing diminished volume and count of skeletal muscle cells, elevated adipose content, and attenuated muscular potency [33]. These changes were characterized by muscle loss and strength decline, leading to symptoms such as weakness, decreased physical activity, and falls. Previous studies had suggested muscle mass and strength were important indicators for measuring muscle function [34]. Furthermore, the positive influence of exercise regimens on the augmentation of both muscle mass and strength in the older stratum stands substantiated within extant literature [14, 35]. Although a previous meta-analysis of randomized controlled trials concluded that no benefits were found for the physical fitness measures including handgrip strength of resistance training in community-dwelling older adults [36], we found these studies were conducted in an unsupervised home-based way. And multiple recent studies have shown the great benefits of supervised home-based sports [37–41]. Thus, we conducted a supervised home-based elastic band exercise, and found following 12 weeks of training, wherein discernible improvements in muscle mass and body strength levels surfaced in stark juxtaposition to the CG. The possible key reason was a tight adherence using both online and offline approaches in the follow up stages to ensure the completion degree of training. With the supervision of timely online reminders and frequently offline home visit, the participants accepted the training quickly and easily and completed training with high standard.

Maintaining good control of blood sugar and lipid levels was crucial for T2DM patients. Previous study had found that [27, 42] that HbA1c, FPG and PPG were significantly improved after elastic band resistance training, regardless of the length of T2DM course. Lee et al. [43]found that the levels of TC decreased in T2DM older females after elastic band resistance exercise. Consistent with previous study, our study also found the HbA1c in the IG were improved significantly when compared to the CG. It was possibly because that the elastic band exercise consumed excess energy in the body to avoid long-term accumulation of glucose [44]. Besides, the increased skeletal muscle mass also enhanced the ability to take up glucose into muscle, thus increased insulin sensitivity of the body [45]. However, the blood lipids in the IG showed no significant changes when compared to the CG which might because of the relevant short exercise time.

To assess the effect of diabetes management on the health status of an individual DSQL is an essential measure [46]. In this study, the total DSQL scores was significantly decreased especially the social relations domain which indicated that elastic band exercise could improve the quality of life of older pre-frail patients with T2DM. The possible reasons are as follows. First, before the training, our study conducted a personalized evaluation of participants to understand their needs for diabetes and debilitating knowledge, and correctly guided participants with diabetic sports knowledge and skills. After the evaluation, the researchers followed up the participants' mastery of relevant sports knowledge and skills so as to enhance the rehabilitation confidence and improve the training compliance of older participants with T2DM. This professional rehabilitation training guidance could improve the enthusiasm of older participants for exercise. In addition to persisting in training, participants possibly could also correct their other bad habits and maintain a healthy lifestyle, thus improving their quality of life. Secondly, after the intervention, the muscle mass and strength of participants increased, the activity ability and the physiological reserve ability were subsequently improved. The improvement of physiological reserve capacity induced the ability of participants to deal with adverse health outcomes increases. Thirdly, multi-mode, multi-information and multi-channel training mode enabled participants to face difficulties and try their best to solve them. Through personal experience, verbal persuasion, emotional support, training compliance and enthusiasm were improved. This was conducive to the formation of stable healthy behavior of participants, thus improving the quality of life of patients.

Depression is a common mental illness among older adults, and multiple studies had shown that old adults with T2DM were more susceptible to depression, anxiety, cognitive impairment, and other psychological problems due to the long duration of illness or the coexistence of other chronic organ diseases [47, 48]. In addition, depression and frailty was highly connected [49]. Sanchez-Garcia et al. [50] randomly selected 1,933 community-dwelling older adults aged 60 and above from the SADEM study and found that the rate of depression was higher in pre-frail older compared to non-frail older patients. A cross-sectional study of centenarians in Portugal also indicated that the risk of depression was significantly increased in frail older adults compared to non-frail older adults [51]. Woods et al. collected frailty data from 40,657 women aged 65–79 years old, followed up with 28,181 women without frailty at baseline after 3 years, and found that the incidence of frailty significantly increased in women with higher depression scores [52]. For the inner pathogenesis of T2DM, frailty and depression, there were some shared risk factors such as cerebrovascular diseases, chronic inflammation, oxidative stress, mitochondrial dysfunction, hypothalamus–pituitary–adrenal axis imbalance, and cerebral white matter lesions [53–55]. And long-term regular resistance exercise had been found effectively correcting the above psychological factors, thereby improving T2DM, frailty and depression [56–58]. Our study was consistent with previous studies and found that the depression level of T2DM patients during the prefrail stage significantly decreased after intervention with elastic band exercise.

Sleep disorders, inefficient sleep, and daytime sleepiness are the main sleep problems that plague the frail older patients, and studies have shown that the degree of influence of these sleep problems would gradually increase with age [59, 60]. Although taking hypnotic drugs can temporarily alleviate sleep problems, the ensuing problems of drug dependence and abuse, the impact on liver and kidney function and the long-term effect were not significant, making it less applicable in the older population, while non-drug intervention methods such as elastic band exercise intervention have the advantages of simplicity, economy, safety and effectiveness, making it a good application prospect in the older population [61–67]. Our study showed that the subjective sleep quality in the pre-frailty T2DM older patients decreased after the intervention, indicating that exercise improve the sleep quality in some extent. And this finding might be one of causes which explained the above depression states' improvement in our study. However, more longer studies need to be performed to see the effectiveness as there other PSQI subscales showed no significant changes.

This study was underpinned by several inherent limitations, which warrant due consideration. Primarily, the CG, characterized by its maintenance of the status quo, stands in contrast to the IG, where the participants may have nurtured anticipatory expectations of experiential amelioration. This inherent anticipation introduces the potential for the Hawthorne effect, thereby confounding the interpretation of intervention-related enhancements [68]. Furthermore, the influence of this effect on the observed improvements cannot be definitively excluded. Secondly, there might be a selection bias as the participants were recruited from the inpatients of the hospital. Thirdly, the intervention period of 12 weeks may not be sufficient to observe the long-term effects of elastic band training. As a result, the enduring sustenance of the observed ameliorative effects over the long term eludes observation within our study design. Fourthly, given that our study participants were primarily from China, our results may be influenced by specific cultural and social contexts. future research designs could incorporate more heterogeneous participants, including participants from various ethnicities, cultural backgrounds, and health statuses. Finally, the intervention measures were based on individualized customization, which poses certain difficulties for the reproducibility of the study. Future research will consider adopting a standardized exercise protocol to address these issues.

Conclusion

In generally, our study indicated that supervised home-based elastic band exercise could effectively enhance body muscle mass, prevent frailty states progression and improve glucose control in pre-frail older T2DM patients. Besides, quality of life, depression state and sleep quality were meanwhile improved which indicated that elastic band resistance exercise restored the health not only physically but also mentally in pre-frail T2DM older patients.

Abbreviations

T2DM	Type 2 diabetes mellitus
CG	Control group
IG	Intervention group
DSQL	Diabetes specificity quality of life scale
PSQI	Pittsburgh sleep quality index
GDS-15	Short form geriatric depression scale
WHR	Waist-to-hip ratio
BMI	Body mass index
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
ALT	Alanine transaminase
AST	Aspartate transaminase
BUN	Blood urea nitrogen
Cr	Creatinine
FPG	Fasting plasma glucose
PPG	Postprandial plasma glucose
FCP	Fasting c-peptide
PCP	Postprandial c-peptide
TC	Total cholesterol
TG	Triglyceride
HDL-C	High density lipoprotein cholesterol
LDL-C	Low density lipoprotein cholesterol
HbA1c	Glycosylated hemoglobin
SD	Standard deviation
BFM	Body fat mass
VFA	Visceral fat area
PBF	Percentage of body fat
SMM	Skeletal muscle mass
RULMM	Right upper-limb muscle mass
LULMM	Left upper-limb muscle mass
TMM	Trunk muscle mass
RLLMM	Right lower-limb muscle mass
LLLMM	Left lower-limb muscle mass

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13102-025-01105-6.

Supplementary Material 1: Supplementary Table 1: Fried frailty phenotype. Supplementary Table 2: Interventions between the two groups. Supplementary Figure 1: Flowchart of this study. Supplementary Figure 2: Exercise movements of elastic band exercise.

Supplementary Material 2.

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Consort statement

The study adheres to CONSORT guidelines.

Authors' contributions

Yumin Zhang, Lin Hu and Haixia Feng designed the study. Lin Hu, Qing Han and Jing Han performed the data acquisition. Yumin Zhang and Lin Hu performed the data analysis and wrote the main manuscript text.

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Data availability

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of ZhongDa Hospital, Southeast University and as a retrospective registration, it had been registered on the website of Chinese Clinical Trial Registry (trial registration number: ChiCTR2300070726; date of registration: 2023–04-21; https://www.chictr.org.cn/showproj.html?proj=186796)4, 20. Informed consent was obtained from all subjects involved in the study.

Consent for publication

Written consent for publication has been obtained from the patient shown in Supplementary Fig. 1.

Competing interests

The authors declare no competing interests.

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