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Review

Optimal strategies for exercise intervention in older people diabetic patients: The impacts of intensity, form, and frequency on glycemic control An exercise prescription for older people with diabetes

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HIGHLIGHTS

- The first exercise prescription for middle-aged and elderly patients with diabetes mellitus.
- Comparing intensity and form of exercise for diabetes improvement.
- The best time to exercise for older people with diabetes.

ARTICLE INFO

Keywords:
Diabetic older people
Exercise intensity
Exercise form;EXercise time;MEta-analysis

ABSTRACTS

Objective: This study aims to investigate the optimal exercise intensity, type, and weekly duration for improving glycated haemoglobin (HbA1c) and fasting blood glucose (FBG) levels in older people individuals with diabetes.
Materials and Methods: PubMed, EMBASE, Web of Science and other databases were searched to identify randomised controlled trials (RCTs) starting from January 2000 to February 2024 that reported improved effects on fasting glucose and glycated haemoglobin after different exercises in middle-aged and elderly diabetic patients. Meta-analyses Review Manager V.5.3 was used.
Results: Meta-analysis showed that moderate- and high-intensity exercise had a significant effect on HbA1c levels, with a mean difference (MD) of -0.34 (95 % CI: -0.44 ~ -0.24, $p < 0.01$) for moderate-intensity exercise and -0.54 (95 % CI: -0.78 ~ -0.3, $p < 0.001$) for high-intensity exercise.. Both moderate-intensity and high-intensity exercise demonstrated statistical significance in lowering fasting blood glucose levels ($p < 0.001$). Additionally, there was no significant difference between aerobic and resistance exercise forms (p= 0.72). Furthermore, for reducing HbA1c levels, engageing in weekly exercise for at least 2.5 hours showed a MD of-0.44(95 % CI:-0.63~0.25;p<0.001).
Conclusions: In summary, in terms of exercise intensity, medium and high-intensity exercise can significantly reduce HbA1c and FBG levels in middle-aged and older people diabetic patients; in terms of exercise form, the effects of different exercise forms within medium and high-intensity on HbA1c and FBG are not statistically significant; and in terms of exercise time, in moderate-intensity aerobic exercise, older people exercising for more than 2.5 h per week are more beneficial.

1. Introduction

As the global economy continues to develop and medical science advances, the life expectancy of the population is increasing, leading to a global trend of ageing. With this trend, chronic diseases have become a significant threat to the health and well-being of middle-aged and older people, placing a heavy burden on economies worldwide. According to a report from the World Health Organization, diabetes is a major contributor to loss of healthy life years World Health Organizatio (2023). The Report on Nutrition and Chronic Disease Status of the

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Chinese Population (2020) indicates that the prevalence of diabetes among Chinese residents aged 18 years and above is 11.9 %, with type 2 diabetes being predominant, especially among adults aged 50 years and above Report on nutrition and chronic disease status of chinese residents (2020). Diabetes has emerged as a risk factor affecting quality of life in middle-aged and older people individuals.

Exercise, as an environmentally friendly and healthy lifestyle choice, is increasingly recognized for its role in actively intervening in diabetes mellitus.Oliveira's (Oliveira, Trelha and Lima, 2019) cross-sectional study of 970 older adults in Brazil demonstrated that sociodemographic variables and health status were associated with physical activity levels in older adults. Older adults with higher levels of physical activity had a lower risk of diabetes and osteoporosis. Aerobic exercise (AT) not only reduces cardiovascular risk factors but also improves glycemic status in diabetic patients Papagianni et al. (2023). Kargarfard et al (Kargarfard et al., 2022) discovered that AT can have favorable effects on pre-diabetic patients by improving glycemic control. Additionally, AT improves glycemic control in patients with type 2 diabetes mellitus (T2D), insulin resistance, pancreatic β-cells dysfunction, and dyslipidemia Qadir, Sculthorpe, Todd and Brown (2021), Sayer et al. (2005), Wewege, Desai and Honey (2022). Recent findings have highlighted the importance of resistance exercise (RT) in effectively manageing diabetes.The Kobayashi trial demonstrated (Kobayashi, Long and Dan, 2023) that RT alone was superior to AT alone in lowering levels of glycated hemoglobin (HbA1c) in normal-weight T2D patients.Moreover, Rt can be performed indoors making it more suitable for sedentary older people T2D patients with poor muscle strength (Qadir et al., 2021), While resistance training (RT) intervention can enhance muscle strength and improve muscle weakness in older adults with diabetes, thus reducing the risk of injury in their daily lives. A meta-analysis conducted by Liu (Liubaoerjijin et al., 2016) revealed that increasing the intensity of aerobic exercise can lead to a reduction in HbA1c levels in patients with type 2 diabetes mellitus. However, it was also found (Botton, Umpierre and Rech, 2018, Promsrisuk, Kongsui and Sriraksa, 2023) that low-intensity exercise has a beneficial effect on older people individuals with diabetes.

Currently,many studies on exercise interventions for diabetes have focused on adult diabetics, but there is currently a lack of scientific and systematic analysis regarding exercise modalities and intensity for older people diabetics. The trials included in this study consisted of randomized controlled trials of exercise training lasting 12 weeks or more, whether supervised or unsupervised, involving older people patients with T2D. We analyzed the changes in two outcome indicators following different exercise interventions: HbA1c and FBG. These findings will assist clinicians in designing personalized programs for middle-aged and older people patients with diabetes while providing a scientific basis for doing so.

2. Materials and methods

2.1. Protocol and registration

The study protocol was registered with the International Registry of Prospective Systematic Reviews, which is an international registry (PROSPEROID: CRD42024533159). A systematic literature search was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines Liberati et al. (2009).

2.2. Sources of information and access to books

The keywords "middle-aged and older people" were searched in the Pubmed, Web of Science, The Cochrane Library, Embase, Wanfang, and Zhi.com databases. The search also included terms such as "type 2 diabetes" or "T2D", "exercise intervention", "aerobic training", "resistance training" or "strength training", and "randomised controlled trial". There was no limitation on the language of the literature. The search strategy utilized a combination of subject terms and free words and systematically tracked references related to the cited literature. Additionally, the year of publication was restricted to 2000–2024.

2.3. Inclusion and exclusion criteria

Prior to inclusion, the titles and abstracts of search articles were screened for relevance. The full text of the articles was then obtained and reviewed for inclusion criteria. In order to be included, the following criteria were followed: (1) all patients were definite T2D patients in the middle-aged or older age group (age >45), with age determined according to WHO criteria (World Health Organizatio, 2023) for screening; (2) the studies were randomised controlled trials (RCTs); (3) exercise duration was 12 weeks or more, either aerobic training (AT) or resistance training (RT) alone, not combined; (4) all interventions in the control group were identical to those in the RT group except for exercise; and all studies provided mean values of diabetes markers before and after the RT intervention. Studies were excluded based on the following criteria: (1) clinical trials without controls; (2) studies that did not measure fasting blood glucose (FBG) or HbA1c were excluded; (3) controlled trials that did not involve diabetic patients; 4 research papers with duplicate reports, poor quality, or insufficient information; and 5 papers in which changes in glucose or HbA1c before and after analysis focused solely on amount of change.

2.4. Subgroup division and observational indicators

Subgroup category criteria are based on the exercise testing and prescription guidelines of ACSM Liguori (2021). The included ATs were classified according to intensity as follows: for VO2max, <46 % as low intensity, 46 %–63 % as moderate intensity, and >63 % as high intensity; for HRmax, <40 % as low intensity, 40 %-59 % as moderate intensity, and >59 % as high intensity; and for RPE, <12 as low intensity, 12–13 as moderate intensity, and >13 for high strength. Strength classification of RT is determined by 1RM with strength below 50 % considered low strength, 1RM with strength between 50%-69% considered medium strength, and 1RM with strength between 70 %–100 % considered high strength. In middle-aged people, absolute strength (MET) <4.0 is considered low strength, 4.0–5.9 is considered medium strength, and >5.9 is considered high intensity; in older adults absolute intensity (MET) <3.2 is considered low intensity,3.2–4.7is considered moderateintensity,and>4 .7isconsideredhighintensity.Changesinthekey markersFBGandHbA1c in T2D were included in the Meta-analysis. Where the unit conversion of HbA1c is according to HbA1c(%) =0.0915 × HbA1c(mmol/mol)+2.15 %(applicable range:4 % HbA1c~12%HbA1c) Donghuan, Wenxiang and Chuanbao (2013)

2.5. Statistical analysis

The data were analyzed using Review Manager 5.4. The effect sizes of the studies were expressed as weighted mean difference (WMD) and 95 % confidence intervals were calculated. Heterogeneity of the study was measured by the coefficient of heterogeneity I^2. If the results showed $I^2 \leq 50$ %, indicating homogeneous group of studies, a fixed-effects model was used for analysis; if not, a random-effects model was chosen. Subgroup analyses compared different training modalities with varying exercise durations. Sensitivity analyses were conducted to eliminate the effect of bias on the overall effect of individual studies that differed. In cases where there was statistical rather than clinical heterogeneity between study groups, random-effects model was used for analysis. Descriptive analyses were employed to address situations where study heterogeneity made it difficult to determine the cause. Inverted funnel plots were utilized to analyze for publication bias.

3. Results

3.1. Search results and article selection

Through a systematic search, a total of 2548 articles were identified from all databases. Initially, 1321 duplicate articles were excluded. After screening the titles of the remaining 1227 articles, 44 were selected for abstract and full text assessment. Among these, 29 met the inclusion criteria. Of the 44 articles, 15 were excluded for various reasons: 5 did not have a control group, 4 had mean differences or no post-training data, 1 had insufficient details of exercise intensity, 2 involved combined exercises, and 3 did not have a training period of at least 12 weeks or involve patients in the middle-aged or older people stage. The final number of papers included in the Meta-analysis was determined to be 29 (Abdullah et al., 2023, AminiLari, Fararouei and Amanat, 2017, An, Min and Han, 2005, Banitalebi, Kazemi and Faramarzi, 2019, Botton, Umpierre and Rech, 2018, Brooks, Layne and Gordon, 2007, Cassidy, Thoma and Hallsworth, 2016, Chen, Qin and Tao, 2023, Cheung et al., 2009, Emerenziani et al., 2015, Hwang, Lim and Yoo, 2019, K L Way, Sabag and Sultana, 2020, K L Way, Sabag and Sultana, 2020, Karstoft et al., 2013, Kim and Lim, 2022, Ku et al., 2010, Kwon et al., 2010, Kwon et al., 2011, Lam et al., 2008, Mavros et al., 2013, Melo et al., April 2020, Mendes, Sousa and Themudo-Barata, 2019, Plotnikoff et al., 2010, Promsrisuk, Kongsui and Sriraksa, 2023, Sigal et al., 2007, Tapehsari et al., 2020, Terathongkum and Kittipimpanon, 2023, Wycherley, Noakes and Clifton, 2010, Yavari et al., 2012).(Fig. 1)

3.2. Description of included articles

The present meta-analysis includes 29 trials with a total of 1592 participants (802 in the experimental group and 790 in the control group). The selected studies were conducted in various countries, such as Australia, Portugal, Indonesia, Brazil, Canada, China, Korea, Iran, the United Kingdom, Finland, and the United States. According to the inclusion criteria, these trials were published between 2000 and 2023. Among them, 7 trials enrolled only female patients, 1 trial enrolled only male patients, 21 trials included both genders, and 1 trial did not provide gender information. The mean age of the patients ranged from 45 – 71 years old. The baseline HbA1c levels were measured at 7.7 % for control group patients and at post-intervention it was found to be at a level of approximately around or equal to that of exercise trial patients which is about or near abouts at a level of around or equal to that of approximately around or close to being about or near abouts at a level of around or equal to that which is equivalent to being roughly similar within an approximate range value percentage point difference compared with each other respectively . Furthermore,the duration of diabetes varied from more than six months up until thirteen years according based on data collected from these trials as shown in Table one (Table 1).

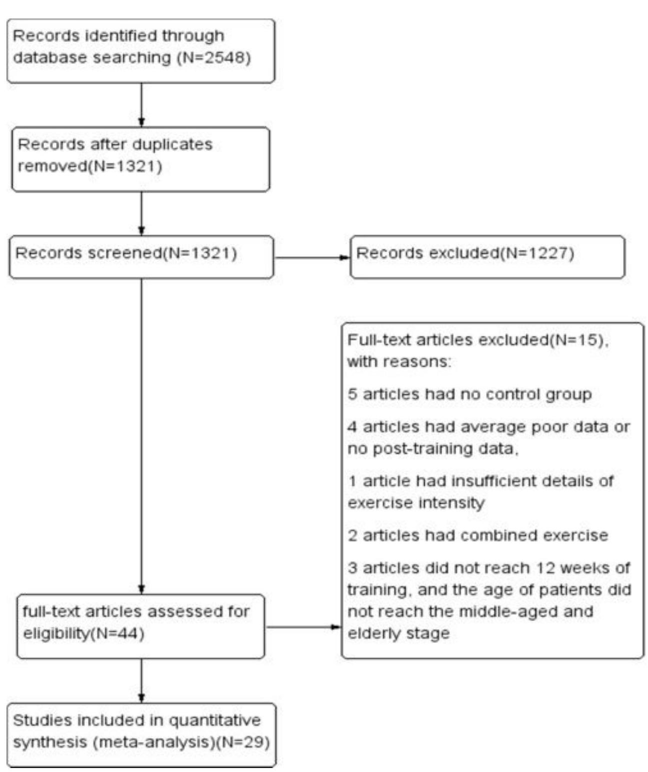

Fig. 1. Flow chart for study selection according to PRISMA declaration 2009.

3.3. Moderate to high intensity exercise has a more pronounced effect on HbA1c and FBG in middle-aged and older people diabetes mellitus

Of the 31 articles included, 22 studies used HbA1c as an indicator of glycaemic control in patients with T2D, with data from a total of 1337 patients included in the analysis.Based on intensity, we categorised the 22 trials into low-intensity (5), moderate-intensity (12) and high-intensity (5) subgroups and assessed the effect of intensity on the change in HbA1c.Meta-regression analyses showed that in moderate-intensity (Abdullah et al., 2023, An, Min and Han, 2005, Banitalebi, Kazemi and Faramarzi, 2019, Chen, Qin and Tao, 2023, Emerenziani et al., 2015, Huang et al., 2016, Hwang, Lim and Yoo, 2019, K L Way, Sabag and Sultana, 2020, Karstoft et al., 2013, Kim and Lim, 2022, Ku et al., 2010, Kwon et al., 2011, Lam et al., 2008, Melo et al., April 2020, Terathongkum and Kittipimpanon, 2023, Yavari et al., 2012, Ahn and Song, 2012) (MD = -0.34; I^2 = 36%; 95% CI:-0.44 ~ -0.24, $p < 0.001$) and high intensity (Cassidy, Thoma and Hallsworth, 2016, Hwang, Lim and Yoo, 2019, K L Way, Sabag and Sultana, 2020, Mavros et al., 2013, Sigal et al., 2007, Wycherley, Noakes and Clifton, 2010)(MD =-0.54; I^2=41 %,95 % CI: -0.78 ~ -0.3,p< 0.001) under was statistically significant for reducing HbA1c levels in diabetic patients. Whereas in the low-intensity subgroup (Botton, Umpierre and Rech, 2018, Cheung et al., 2009, Kwon et al., 2010, Kwon et al., 2011, Promsrisuk, Kongsui and Sriraksa, 2023) did not show statistical significance (MD = -0.33;I^2 =0%;95 %CI:-0.71~ 0.05,p = 0.09) (Fig. 2).Diabetic patients, especially the elderly, have lower muscle strength in the elbow flexors and knee extensors Singer, Nathan and Anderson (1992). This decrease in muscle strength is related to the presence and severity of diabetic neuropathy. In Ahn's study, although the completion rate was not as high as in other articles, the participants in Ahn's study were a special group of diabetic patients with neuropathy. Previous studies have found that Tai Chi exercise has a more significant effect on diabetic patients with neuropathy. Long-term adherence to Tai Chi exercise is helpful for restoring foot sensation and improving balance Park, Goodpaster and Strotmeyer (2006).

There were 16 studies using FBG as an indicator of glycaemic control in patients with T2D, with a total of 977 patients, on moderate intensity [(AminiLari, Fararouei and Amanat, 2017- (Chen, Qin and Tao, 2023, Huang et al., 2016, Hwang, Lim and Yoo, 2019, K L Way, Sabag and Sultana, 2020, Karstoft et al., 2013, Ku et al., 2010) (Tapehsari et al., 2020, Yavari et al., 2012)] The effect on FBG was statistically significant under (MD = -0.66; I2 =50 %; 95 % CI: -0.87 ~ -0.46, $p < 0.001$), and at high intensities (Cassidy, Thoma and Hallsworth, 2016, Hwang, Lim and Yoo, 2019, K L Way, Sabag and Sultana, 2020, Mendes, Sousa and Themudo-Barata, 2019, Wycherley, Noakes and Clifton, 2010) .The effect on FBG decline was similarly statistically significant under (MD = -0.86; I2 =26 %; 95% CI:-1.38 ~ -0.34, p = 0.001); however, under low-intensity (Botton, Umpierre and Rech, 2018, Promsrisuk, Kongsui and Sriraksa, 2023) under FBG (MD = 0.97; I2 = 0 %; 95 % CI: -1.36 ~ 0.59, $p < 0.001$). This suggests that the effect on FBG decline is more pronounced at moderate or high intensity. In addition, the difference between the subgroups reached statistical significance (p< 0.001),

Table 1
Characteristic table.

study	country	Participants	Duration year	Participants (E/C)		drop	MeanAge		Diabetes Duration(Y)		forms of sport	Intensity	concrete content
Brooks,2007	Spain	male and female	16 weeks	31	31	NA	66 ± 2	66 ± 1	NA	NA	resistance training	middle to high	Upper back, chest press, leg press, knee extension and flexion
Nuttamonwarakul, 2012	Thailand	male and female	12 weeks	20	20	NA	>60	>60	NA	NA	aerobic exercise	moderate intensity	swim
Tapehsari, 2020	Iran	male and female	3 Months	47	48	5	45.85 ±6.85	46.58 ±5.31	NA	NA	aerobic exercise	moderate intensity	walking
Plotnikoff, 2010	Canada	male and female	16 weeks	27	21	7	55±12	54±12	NA	NA	resistance training	middle to High Intensity	Execute a structured exercise plan for three non consecutive days per week. Each session consists of eight exercises, four of which are core exercises (i.e. squatting, sitting rowing, chest pushing, shoulder pushing), and four are auxiliary exercises (i.e. lunge, lateral pull down, standing triceps extension, standing pulley abdominal twist, bicep curl, triceps press, reverse diamond shaped bird, lateral pulley deltoid lift, and pulley abdominal curl).
Mavros , 2013	Australia	male and female	48 weeks	36	48	3	≥ 60	≥ 60	RE:7 ± 5	C:9 ± 7	resistance training	high intensity	Seated row, chest press, leg press, knee extension, hip, flexion, hip extension and hip abduction
Yavari, 2012	Iran	male and female	52 weeks	20	20	15	48.2 ± 9.2	51.5 ± 6.3	> 1	> 1	aerobic training	middle intensity	treadmill, elliptical machine, or bicycle dynamometer
Wycherley, 2010	Australia	male and female	16 weeks	16	17	NA	56 ± 7.5	56 ± 7.5	NA	NA	resistance training	high intensity	Leg press, knee extension,chest press, shoulder press,lat pull down, seated row,tricep press, and sit-ups
Sigal, 2007	Canada	male and female	6 months	64	63	0	54.7 ± 7.5	54.7 ±7.5	6.1 ± 4.7	5.0 ± 4.5	resistance training	high intensity	Group A: Abdominal crunches, seated row, seated biceps curls, supine bench press, leg press, shoulder press, leg

(*continued on next page*)

Table 1 (*continued*)

study	country	Participants	Duration year	Participants (E/C)		drop	MeanAge		Diabetes Duration(Y)		forms of sport	Intensity	concrete content
													extension. Group B: abdominal crunches, lateral pulldown, triceps push-down, sitting chest press, leg press, upright row, leg curls
Ku, 2010	Korea	male and female	12 weeks	15	16	NA	55.7 ± 7.0	57.8 ±8.1	5.7 ± 4.8	5.8 ± 6.1	aerobic training	moderate intensity	walking
AnK, 2005	Korea	male and female	12 weeks	10	7	NA	59.2 ±2.7	52.3 ±3.3	7.8 ±1.7	6.6 ±1.4	resistance training	moderate intensity	Resistance exercise group elastic band
Cheung, 2009	Korea	male and female	16 weeks	20	17	NA	59±8.7	62±6.7	NA	NA	resistance training	low intensity	The resistance exercises performed were chest press, seated back rows, leg abductions, leg extension, seated leg press, triceps extensions, and biceps curls. Leg abduction and leg extension were performed using body weight as resistance.
Kwon, 2010	Korea	male and female	12 weeks	13	15	NA	55.7 ± 6.2	57.0 ±8.0	5.7 ± 4.8	6.1 ± 6.3	resistance training	low intensity	bicep curls, triceps extensions, upright rows, shoulder presses, chest presses, and seated rows to work the upper body. Lower body exercises included leg presses, hip flexion, leg flexion, and leg extensions.
Kwon, 2011b	Korea	male and female	12 weeks	13	15	NA	55.5 ±8.6	58.9 ±5.7	6.6 ±6.7	4.9 ±4.7	aerobic training	moderate intensity	walking
Kwon, 2011a	Korea	male and female	12 weeks	12	15	NA	56.3 ±6.1	58.9 ±5.7	4.6 ±2.7	4.9 ±4.7	resistance training	low intensity	Upper body exercises included bicep curls, tricep extensions, upright rows, shoulder chest press, and seated rows. Core exercises included trunk side bends, and lower body exercises included a leg press, hip flexions, leg flexions, and leg extensions.
Abdullah, 2023	Indonesia	male and female	3 Months	30	30	0	56.13 ±9.145	58.73 ±6.772	NA	NA	aerobic exercise	moderate intensity	walking

(*continued on next page*)

Table 1 (*continued*)

study	country	Participants	Duration year	Participants (E/C)		drop	MeanAge		Diabetes Duration(Y)		forms of sport	Intensity	concrete content
Karstoft, 2013	Denmark	male and female	4 Months	12	8	4	60.8 ±2.2	57.1 ±3.0	NA	NA	aerobic exercise	moderate intensity	walking
Lam,2008	Australia	male and female	6 Months	28	25	10	63.2 ±8.6	60.7 ±12.2	NA	NA	aerobic exercise	moderate intensity	tai chi
Mendes, 2019	Portugal	male and female	12 weeks	15	15	0	60.25 ± 3.14	60.25 ± 3.14	5.33 ± 2.31	5.33 ± 2.31	aerobic exercise	High Intensity	walking protocols
Way KL, 2020a	Australia	male and female	12 weeks	12	10	3	56.9 ±2.1	51.9 ±1.4	9.3 ±7.3	6.9 ±6.2	aerobic exercise	high intensity	HIIT;1 × 4 min high intensity bout at a workload designed to elicit 90% VO2peak
Way KL, 2020b	Australia	male and female	12 weeks	10	10	3	54.8 ±2.4	51.9 ±1.4	8.2 ±5.8	6.9 ±6.2	aerobic exercise	moderate intensity	MICT;45 minutes of continuous cycling on the ergometer
Promsrisuk,2023	Thailand	male and female	3 Months	20	20	0	66.50 ± 3.65	66.20 ± 4.37	NA	NA	aerobic exercise	low intensity	BETY for 1 hour, 5 days a week, for 3 consecutive months
AminiLari,2017	Iran	females	12 weeks	12	15	3	aged 45 to 60 years	aged 45 to 60 years	At least 2	At least 2	resistance training	moderate intensity	leg extension, prone leg curl, abdominal crunch, biceps, triceps, and seated calf
Hwang, 2018a	Korea	male and female	8 weeks	18	16	5	65±2	61±2	7.8 ±1.3	8.2 ±1.5	aerobic exercise	high intensity	treadmill
Hwang, 2018b	Korea	male and female	8 weeks	18	16	1	62±2	61±2	8.3 ±1.5	8.2 ±1.5	aerobic exercise	moderate intensity	treadmill
Banitalebi, 2019	Iran	females	10 weeks	17	18	10	54.14± 5.43	55.71± 6.40	NA	NA	aerobic exercise	moderate intensity	readmill or cycle
Melo, 2020	Brazil	women	12 weeks	11	11	NA	65.5 ±5.5	67.5 ±6.3	9.9 ±8.5	6.7 ±3.4	aerobic exercise	moderate intensity	Pilates
Kim, 2022a	Korea	females	12 weeks	12	9	NA	72.25 ± 5.07	67.78 ± 2.33	NA	NA	resistance training	moderate intensity	squat, lunge, chest press, vertical fly, lat pull down, long pull, and crunch
Kim, 2022b	Korea	females	12 weeks	15	9	NA	70.47 ± 5.57	67.78 ± 2.33	NA	NA	aerobic exercise	moderate intensity	vine step, manbo, twist, bumb, love repeat, love trick, and walking
Cassidy, 2015	UK	male and female	12 weeks	12	11	3	61±9	59±9	5±3	4±2	resistance training	high intensity	arm resistance bands, face pull, horizontal push,horizontal pull and 30°push
Botton, 2018	Brazil	male and female	12 weeks	13	13	16	70.6 ± 6.7	68.6 ± 7.06	10.7 ± 7.9	11.31 ± 7.4	resistance training	low intensity	squat and steps up and down
Emerenziani, 2015	Italy	male and female	3 Months	15	15	NA	66.7 ±4.9	66.9 ± 4.2	NA	NA	aerobic exercise	moderate intensity	Bicycle dynamometer or treadmill
Chen, 2023a	china	male and female	24 weeks	101	99	6	67.56 ±4.99	67.62 ±5.35	9.82 ±5.58	10.9 ±7.2	aerobic exercise	moderate intensity	tai chi chuan
Chen, 2023b	china	male and female	24 weeks	103	99	7	67.46 ±4.73	67.62 ±5.35	10.7 ±7.49	10.9 ±7.2	aerobic exercise	moderate intensity	walking

suggesting that there is a correlation between intensity and the degree of change in FBG and that the forest plot shows a greater decrease in FBG levels in the moderate intensity subgroup(Fig. 3).In the forest plot, Melo's research appears to have a significant overall impact. This may be due to the relatively small sample size of 11 individuals in the experimental group, as well as the notably higher severity of diabetes in the experimental group compared to the control group.

3.4. There was no difference between AT and RT at moderate to high intensity in terms of lowering HbA1c, FBG

Among the factors affecting HbA1c, the correlation between intensity and lower HbA1c index was not evident from the previous set of subgroup analyses. The following was a further breakdown from the different exercise modalities, AT versus RT, at moderate to high intensity. In the subgroup of AT a total of 14 relevant papers were included

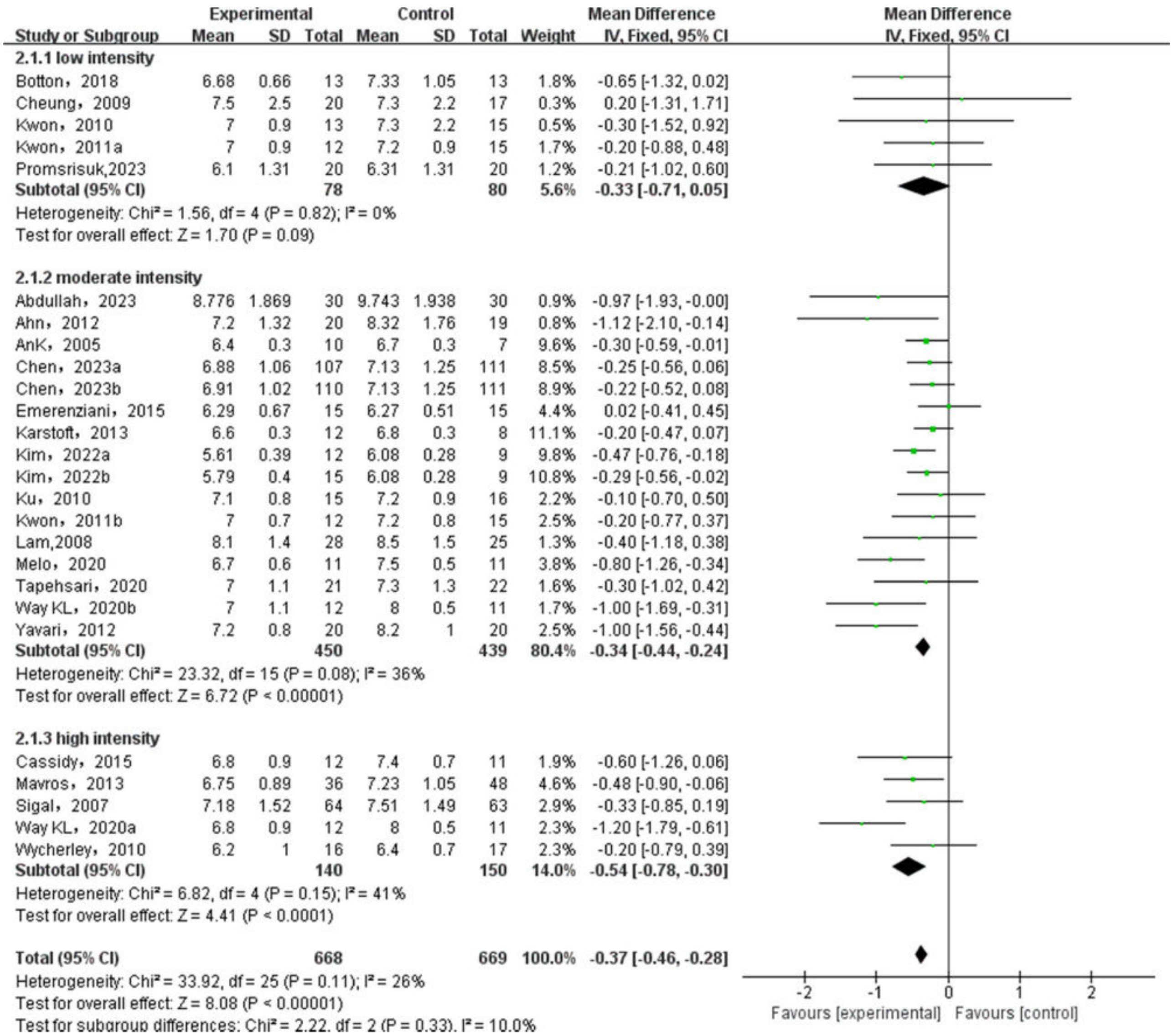

Fig. 2. Effect of different exercise intensities on HbA1C.

and a total of 585 patients were enrolled, the results of the study showed that moderate to high intensity experiments (Abdullah et al., 2023, Banitalebi, Kazemi and Faramarzi, 2019, Chen, Qin and Tao, 2023, Emerenziani et al., 2015- (Kwon et al., 2010, Kwon et al., 2011, Lam et al., 2008, Mavros et al., 2013, Melo et al., April 2020, Terathongkum and Kittipimpanon, 2023, Yavari et al., 2012) exhibiting a significant decrease in HbA1c (MD = -0.36; $I^2 = 53\%$; 95 % CI:–0.47 ~-0.25; p<0.00001); six papers were included in the RT, with a total of 150 patients enrolled, and the study results showed that a moderate to high-intensity trials [23, 27, 33, 38, 43. 46].A significant decrease in HbA1c was demonstrated (MD = -0.39; $I^2 = 0$ %; 95 % CI:-0.55 ~-0.23; p< 0.001). However, the test for subgroup differences between the AT and RT subgroups was not significant (p = 0.71), which emphasizes that there is no correlation between the effects of RT or AT on HbA1c in moderate to high intensity (Fig. 4).

The same results were seen in FBG. The effect of AT or RT on FBG was statistically significant (p<0.001) at moderate to high intensity. However, the test between the two subgroups was not significant (p=0.16). In summary, moderate-intensity versus high-intensity exercise has an effect on both HbA1c and FBG, but there is no significant difference between the effects of different exercise forms on the two indicators (Fig. 5).

3.5. *In moderate-intensity exercise, older adults who exercise for 2.5 h or more per week have more beneficial effects on the reduction of HbA1c indexes*

It has been demonstrated in the literature that low to moderate intensity aerobic training (AT) is more achievable for older adults H Ismail, McFarlane and Dieberg (2014). Additionally, it has been found that low- and medium-intensity AT can have a protective effect on knee cartilage Huizhen, Wei and Haitao (2024). Therefore, in this paper, we conducted a subgroup analysis of weekly exercise time at moderate intensity and excluded articles that did not meet the requirements for subgroup analysis. A total of eight experiments (466 participants) were included in the Meta-analysis of HbA1c data. We reviewed the eight articles to summarize the exercise time and determined that they could be divided into two groups using 2.5 hours as a dividing criterion. Meta-regression analyses were performed, and the results showed that weekly exercise time was statistically significant in reducing HbA1c whether or not it reached 2.5 hours; however, there was a statistically significant difference between the two groups (p=0.05). Furthermore, there was a negative correlation between exercise time and HbA1c reduction, indicating that reaching an exercise time of 2.5 hours or more is more beneficial in reducing the HbA1c index. This provides guidance

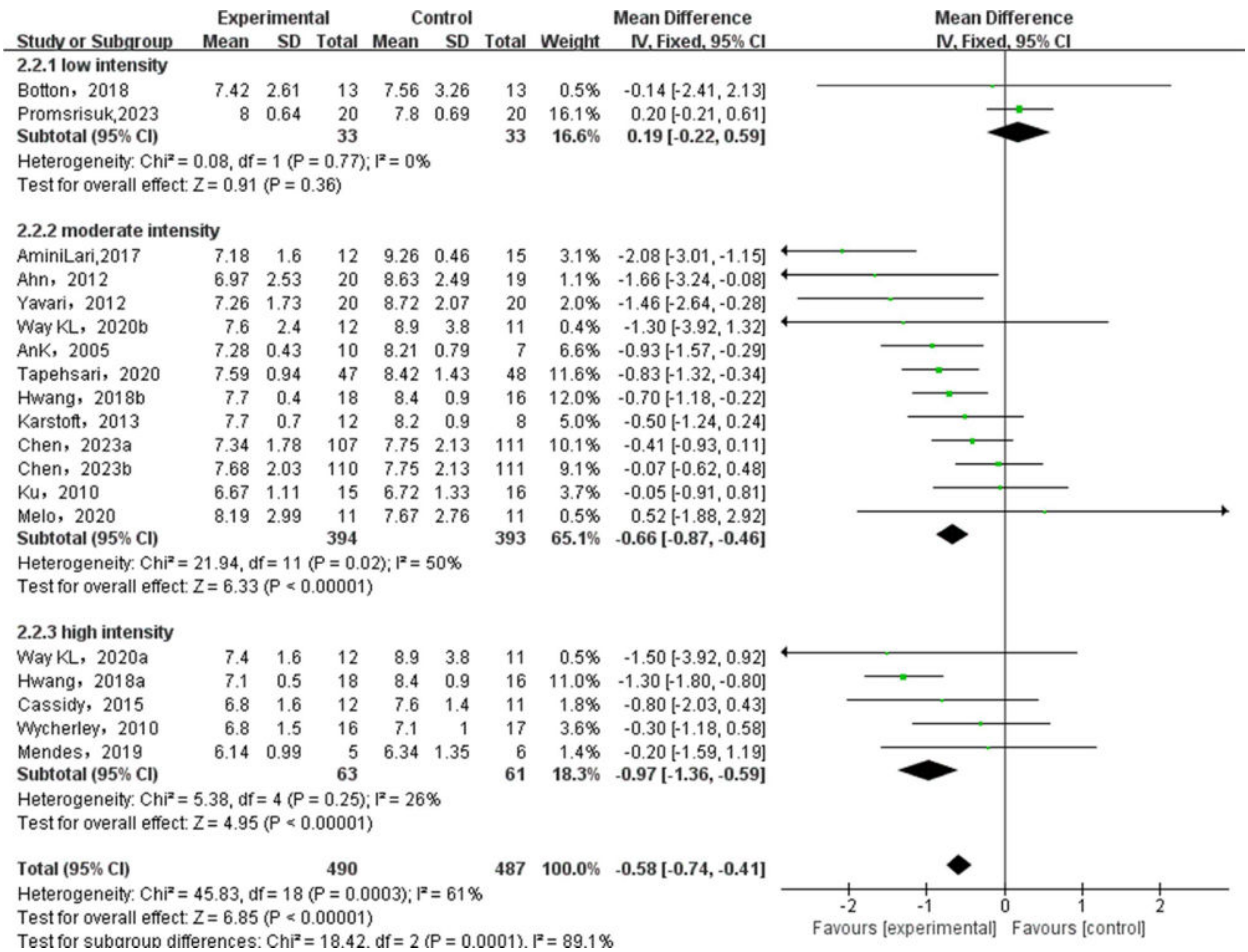

Fig. 3. Effect of different exercise intensities on FBG.

regarding exercise duration to reduce HbA1c levels in older people diabetic patients (Fig. 6).

3.6. Results of the quality assessment of included literature

The risk of bias in this study was assessed using the Cochrane Collaboration methodology. The extent of bias in the articles included in the analysis is shown in Fig. 7, with a detailed description provided in Fig. 8. Regarding selection bias, all trials included in the analysis reported randomised sequence generation, and twenty reported allocation concealment. As for performance bias, most trials were judged to be at high risk of bias for blinding patients to the intervention. This is due to the nature of exercise interventions, which involved testing all participants for physical indicators and psychological conditions; thus, double-blinding between participants and testers was not feasible. However, it should be noted that reporting such a high risk of bias does not necessarily compromise the quality of the study.

Other variables affecting study quality include detection bias (found in only two trials), wear and tear bias (present in nine trials), and reporting bias (reported by eight articles). Incomplete outcome data and selective reporting are also common problems associated with a high risk of bias Bourke, Smith and Steed (2016).

4. Discussion

Currently, many studies are exploring which type of exercise - aerobic exercise, resistance exercise, or combined exercise - is most beneficial for lowering blood sugar. However, in reality, elderly diabetes patients may not be able to adhere to the prescribed forms of exercise due to various physical conditions. Therefore, this article proposes for the first time that when the intensity of exercise reaches a certain level, the specific form of exercise may not be necessary.This paper represents the first meta-analysis and systematic evaluation comparing the effects of aerobic training (AT) and resistance training (RT) on diabetes indicator levels in middle-aged and older people patients with diabetes. The aim is to provide a more effective exercise prescription for this population.Diabetes mellitus is diagnosed by FBG, HbA1c, and 2 h post glucose load blood glucose.Therefore, this meta-analysis focused on analyzing HbA1c and FBG, specifically looking at experiments lasting 12 weeks or longer to ensure meaningful changes in HbA1C among diabetic patients Selig, Levinger and Williams (2010, Smart and Fang (2003). It has been suggested that a frequency of training twice a week for 14 weeks can prevent or reduce physical and psychological disorders in older women de Oliveira, dos Santos Campos and Antunes (2019). All of this suggests that the effects of exercising for more than 12 weeks can be emphasized.It has been demonstrated that low to moderate intensity AT is easier and safer for older adults H Ismail, McFarlane and Dieberg (2014). Thus, the primary objective of this study was to assess the effect of different exercise modalities, intensities, and durations on HbA1c and FBG in middle-aged and older adults with T2D when exercise was performed for 12 weeks or more. The analysis mainly focused on moderate intensity exercises to provide a targeted exercise prescription for middle-aged and older people with diabetes. The study concluded that higher intensity exercises have a greater improvement effect for middle-aged and older people diabetic patients; however, exercising up to two and a half hours per week at a moderate intensity is favorable for

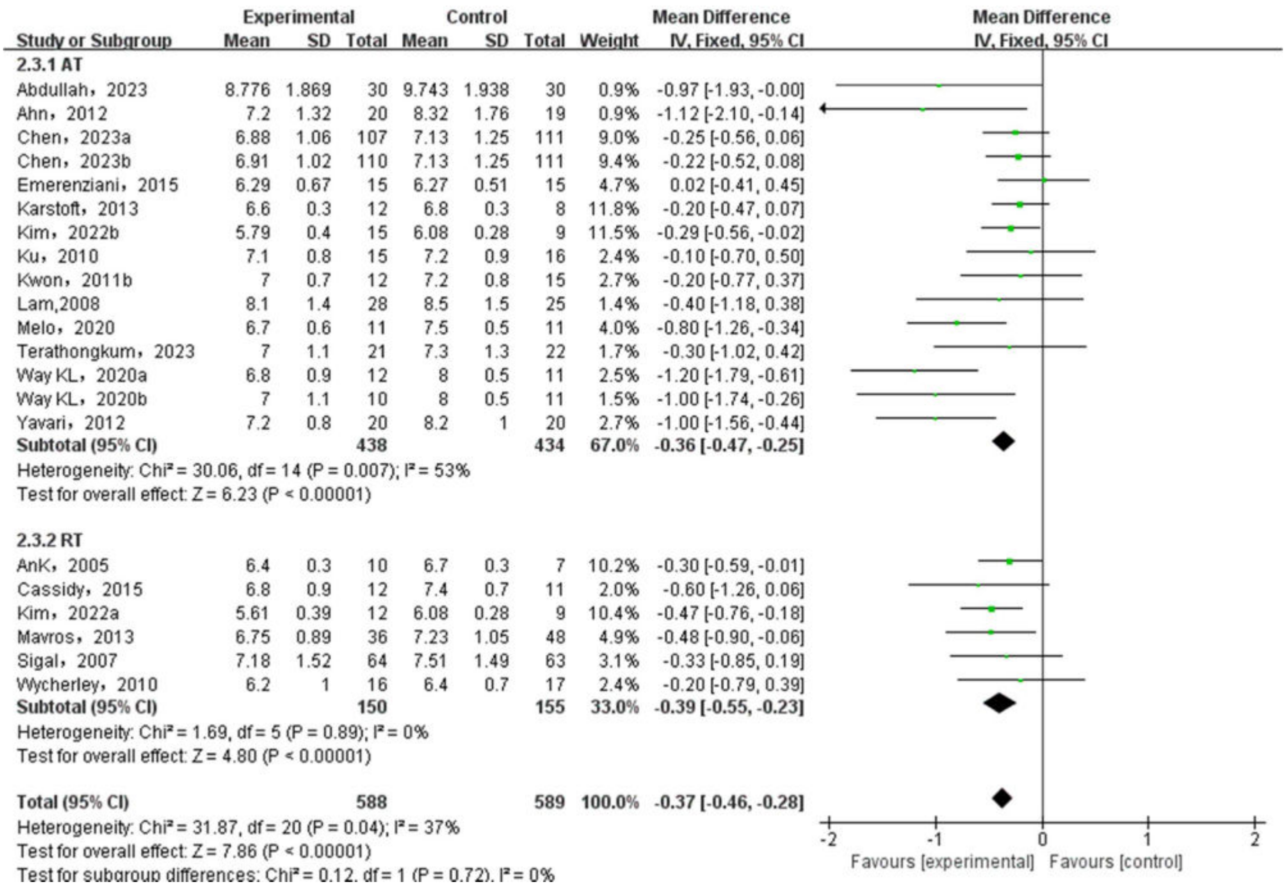

Fig. 4. Effect of different exercise types on HbA1C.

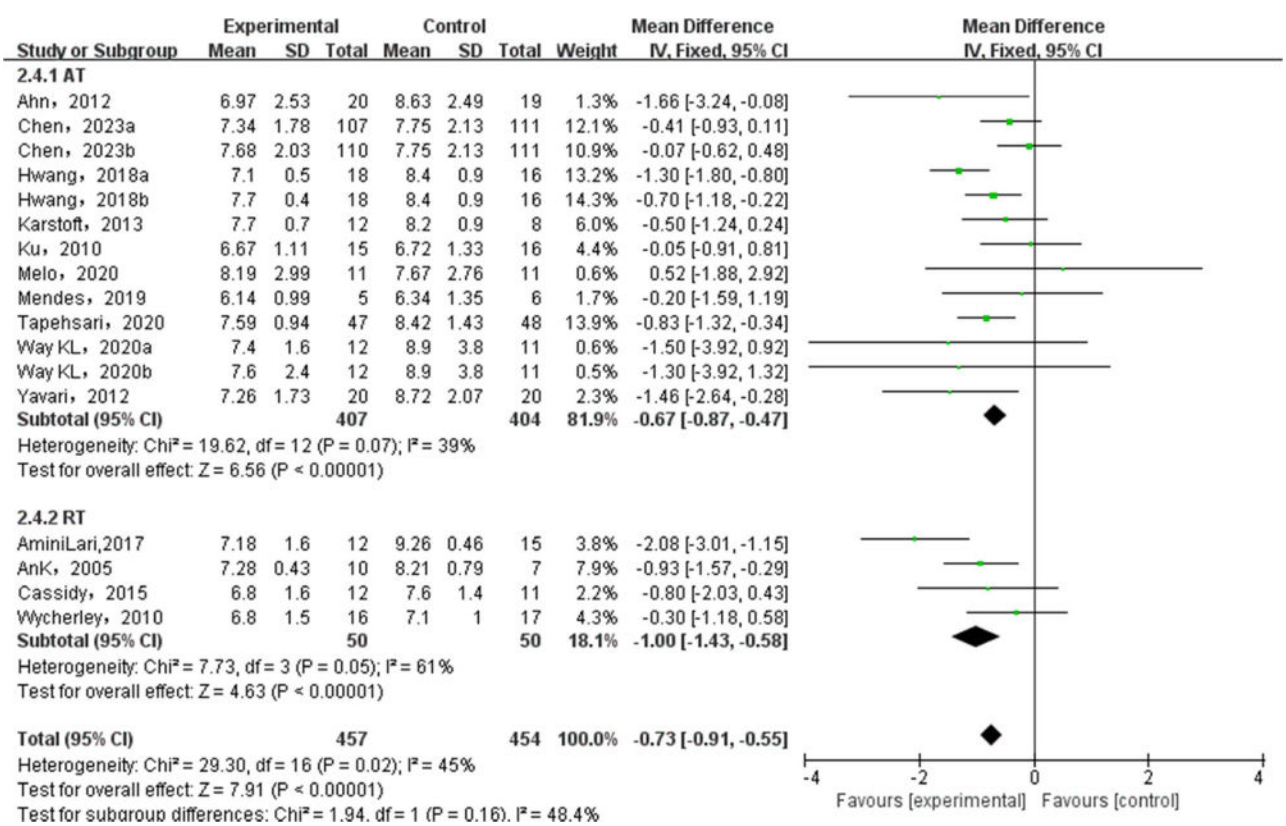

Fig. 5. Effect of different exercise types on FBG.

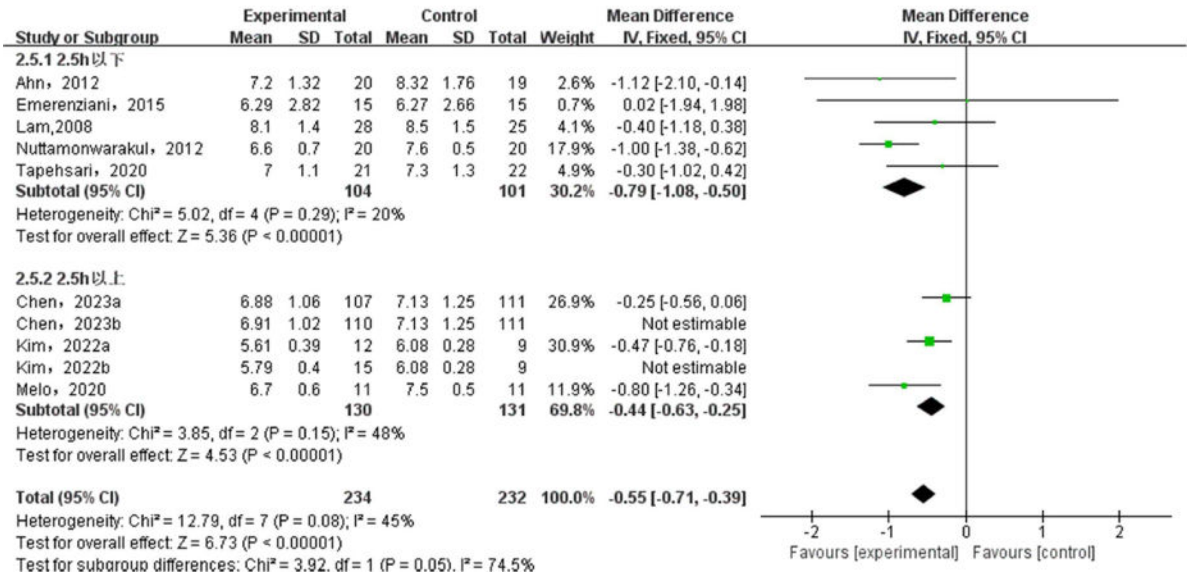

Fig. 6. Effect of different exercise times on HbA1C.

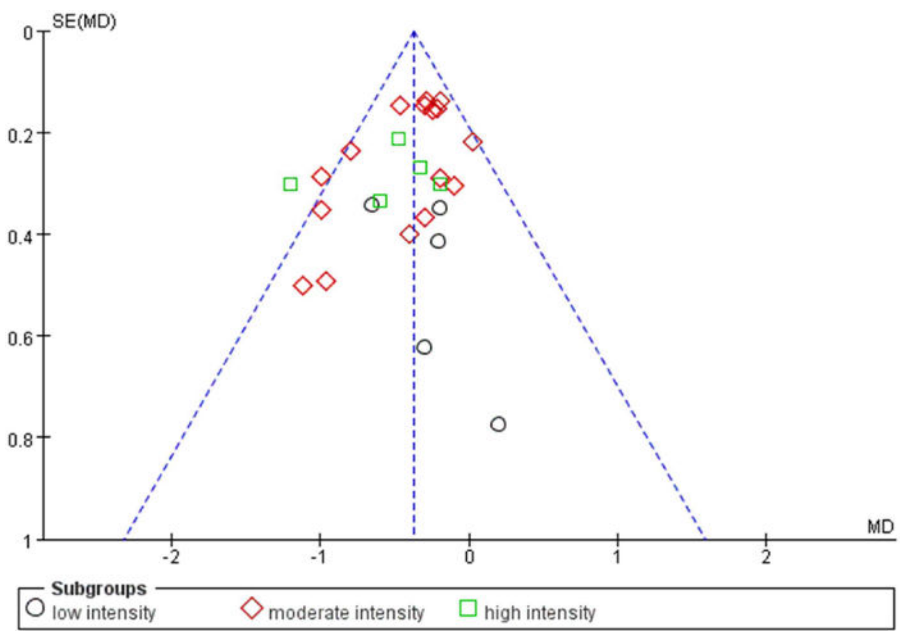

Fig. 7. Funnel diagram.

decreasing HbA1c levels in older people diabetic patients.

4.1. Lowering HbA1c will also have a positive effect on other diseases

Research has shown a correlation between elevated blood glucose levels, reduced muscle strength, and impaired physical function in diabetic patients Sayer et al. (2005). Reduced blood supply can lead to peripheral nerve disease, exacerbating muscle atrophy and further impairing insulin sensitivity and glycaemic control. As a result, diabetic patients often have lower muscle strength compared to their peers. Studies have indicated that skeletal muscle is the primary site for glucose uptake DeFronzo and Tripathy (2009). Low-intensity aerobic exercise can increase glucose uptake in active leg muscle fibers of healthy young individuals, potentially improving glycaemia in people with type 2 diabetes Singer, Nathan and Anderson (1992). It has been noted that skeletal muscle plays a major role in achieving systemic insulin resistance (Merz and Thurmond, 2020 Jul 8). Repairing insulin resistance in the muscles alone may be sufficient to restore whole-body glucose homeostasis.Exercise can accelerate glucose uptake in skeletal muscles, reducing glucose binding to hemoglobin and lowering HbA1c levels, ultimately leading to hypoglycemia. While insulin also plays a role, diabetic patients are often accompanied by insulin resistance. Some studies have suggested that ageing may be related to defects in the receptors for insulin action, resulting in reduced sensitivity of systemic tissues to insulin Rowe et al. (1983).A meta-analysis by Marson (Marson et al., 2016) showed that aerobic, resistance, and combined exercise were associated with a reduction in insulin resistance indices in obese children. Ha's study demonstrated that 12 weeks of combined exercise helped improve insulin resistance and stimulate the secretion of ageing-related hormones in older women Ha and Son (2018). However, there is currently no definitive proof for older adults with diabetes. In addition to this, the Oliveira de Oliveira, da Silva and Scherer (2019)

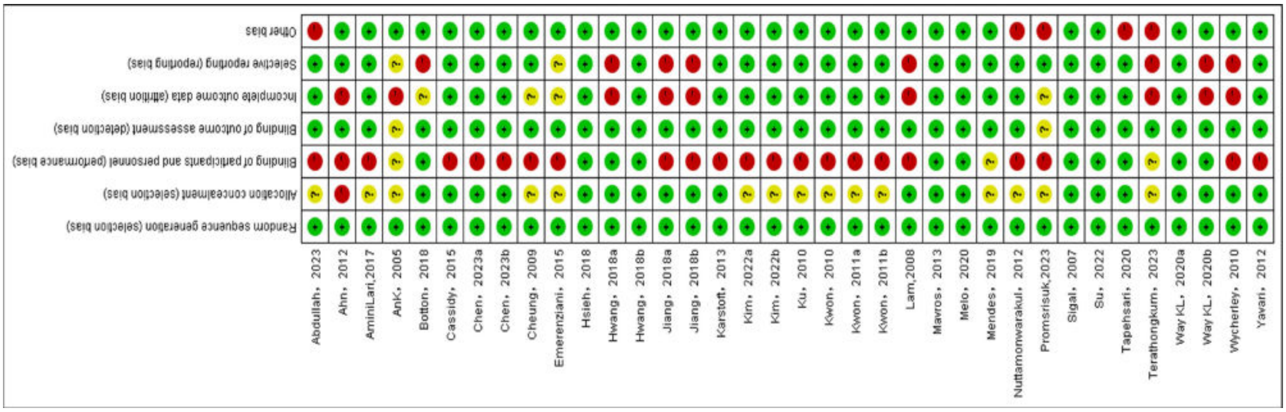

Fig. 8. Summary of risk of bias for trials included in this meta-analysis. Green indicates low risk of bias, yellow indicates unclear, and red indicates high risk of bias. Summary of risk of bias for trials included in this meta-analysis. Green indicates low risk of bias, yellow indicates unclear, and red indicates high risk of bias.

study found that aerobics in older people had better health benefits than water aerobics and long-term exercise. However, further experiments are needed to prove whether or not this exercise in elderly diabetic patients will help improve their condition.

4.2. Possible mechanisms of action of exercise to reduce HbA1c

Church (Church, Blair and Cocreham, 2010) A nine-month randomized controlled trial of 186 individuals demonstrated that combined exercise (aerobic training with resistance training) was more effective than aerobic training alone or resistance training alone in reducing HbA1c levels. However, the trial did not further subdivide the age of the subjects, and it remains to be explored whether this combined exercise has the same effect on middle-aged and older adults. The trial found a correlation between lower HbA1c levels and increased lean body mass and decreased fat mass.Chao (Chao et al., 2018)'s meta-analysis found that aerobic exercise improved visceral fat area and HbA1c levels in middle-aged and older people obese type 2 diabetic patients, as well as improving lipid metabolism, body composition, and cardiorespiratory function, resulting in effective control of blood glucose levels. Additionally, Singer (Singer, Nathan and Anderson, 1992) found a significant association between HbA1c levels and the prevalence of cardiovascular disease in women, as well as with hypertension and the ratio of total cholesterol to HDL cholesterol levels.Furthermore, a quantitative relationship was found between HbA1c levels and plaque texture in ultrasound images of patients with atherosclerosis Huang et al. (2016). Lowering HbA1c levels can also improve atherosclerosis due to glucose reacting with various proteins to produce advanced glycosylation end products, ultimately leading to cellular dysfunction and damage. Individuals with diabetes are in a hyperglycaemic state which increases their susceptibility to other diseases even further .

5. Conclusion

For middle-aged and older people patients with diabetes, engageing in exercise of moderate to high intensity has been shown to be more effective in reducing HbA1c and FBG levels. In the case of older people individuals with diabetes, participating in moderate-intensity exercise for more than 2.5 hours per week has been found to have a significant impact on lowering their HbA1c levels.

Ethical approval

not applicable

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Data availability and sources

The data in this paper are all from published experimental articles, and the data are available.

CRediT authorship contribution statement

Xueru Yan: Writing – review & editing, Writing – original draft. **Yujuan Lu:** Writing – original draft. **Haoda Zhang:** Writing – review & editing. **Chen Zhu:** Writing – original draft. **Lan Tian:** Data curation. **Jishuai Chen:** Writing – original draft. **Enpeng He:** Writing – review & editing. **Yingying Li:** Writing – review & editing.

Declaration of competing interest

No human subjects were involved in this study and therefore, no consent was necessary.There is no conflict of interest in this article

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Respect in heart, not in vain

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