

## TITLE PAGE

# Volume of supervised exercise training and metabolic, anthropometric outcomes and body composition in patients with type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials

Running title: Exercise training, metabolism & anthropometry

#Xingyun Zhu<sup>1</sup>, MD, E-mail: [xingyunzhu427@gmail.com](mailto:xingyunzhu427@gmail.com)

#Fang Zhang<sup>1</sup>, MD, E-mail: [zhangfang@bjmu.edu.cn](mailto:zhangfang@bjmu.edu.cn)

Jing Chen<sup>1</sup>, MD, E-mail: [cnncj@sina.com](mailto:cnncj@sina.com)

Yingxi Zhao<sup>2</sup>, MPH, E-mail: [yingxi.zhao@ndm.ox.ac.uk](mailto:yingxi.zhao@ndm.ox.ac.uk)

Tianhao Ba<sup>1</sup>, MD, E-mail: [batianhao@pku.edu.cn](mailto:batianhao@pku.edu.cn)

Chu Lin<sup>1</sup>, MD, E-mail: [chulin@bjmu.edu.cn](mailto:chulin@bjmu.edu.cn)

Yingli Lu<sup>3</sup>, E-mail: [luyingli@ciss.cn](mailto:luyingli@ciss.cn)

Tao Yu<sup>3</sup>, E-mail: [yutao@ciss.cn](mailto:yutao@ciss.cn)

\*Xiaoling Cai<sup>1</sup>, MD, E-mail: [dr\\_junel@sina.com](mailto:dr_junel@sina.com)

\*Linong Ji<sup>1</sup>, MD, E-mail: [jiln@bjme.edu.cn](mailto:jiln@bjme.edu.cn)

\*Li Zhang<sup>3</sup>, E-mail: [zhangli@ciss.cn](mailto:zhangli@ciss.cn)

# Xingyun Zhu and Fang Zhang contributed equally to this manuscript.

\* Corresponding authors

### Author affiliation:

1 Department of Endocrinology and Metabolism, Peking University People's Hospital, Beijing, China

2 Nuffield Department of Medicine, University of Oxford, Oxford OX2 6NN, United Kingdom

3 China Institute of Sport Science, Beijing, China

### Corresponding to

Xiaoling Cai, MD

Department of Endocrinology and Metabolism

Peking University People's Hospital

No.11 Xizhimen South Street, Xicheng District  
Beijing  
China, 100044  
E-mail: dr\_junel@sina.com

Linong Ji, Professor  
Department of Endocrinology and Metabolism  
Peking University People's Hospital  
No.11 Xizhimen South Street, Xicheng District  
Beijing  
China, 100044  
E-mail: jiln@bjmu.edu.cn  
Tel: 8610-88324108  
Fax: 8610-88325534

Li Zhang  
China Institute of Sport Science  
No.11 Tiyyuguan Road, Dongcheng District  
Beijing  
China, 100763  
E-mail: [zhangli@ciss.cn](mailto:zhangli@ciss.cn)

**Manuscript details:**

Manuscript word count: 3583  
Figure number: 2  
Table number: 1  
References: 40  
Supplementary Materials to be published online: 3

**ABSTRACT**

**BACKGROUND**

The effect of different types of exercise training on metabolic outcomes remains

controversial, and few studies investigated the dose-response relationship.

## **PURPOSE**

To assess the metabolic effect of different types of supervised exercise training in patients with type 2 diabetes (T2DM), and explore the dose-response relationship between exercise volume and duration and changes in metabolic, anthropometric and body composition outcomes.

## **DATA SOURCES**

PubMed/MEDLINE, Embase, and Cochrane database were searched for studies between January 1980 and June 2019.

## **STUDY SELECTION**

Randomized controlled trials (RCTs) in T2DM patient with supervised exercise training versus control were included. Eligible RCTs were required to report detailed exercise plans and change in any of the 12 metabolic, anthropometric and body composition outcomes.

## **DATA EXTRACTION**

We extracted data on the standardized mean difference between the exercise and control groups in change from baseline level of included outcomes.

## **DATA SYNTHESIS**

42 RCTs including 3,625 patients with T2DM were included. Exercise training reduced body weight, WC, WHR, total body fat, LDL-C, TG, TC, SBP, DBP, HbA1c and FFB, meanwhile increased HDL-C. Higher volume of aerobic exercise decreased body weight, LDL-C and HbA1c as well as increased HDL-C. Lower volume of aerobic exercise was superior in reducing WHR and TG. Higher volume of resistance exercise showed more ability to reduce body weight and SBP, while low-volume-resistance-exercise was associated with significant reduction in LDL-C and TC.

**LIMITATIONS**

Information we extracted was sometimes dynamic throughout the studies, and some unavailable baseline characters might be confounding factors.

**CONCLUSIONS**


Supervised exercise training shows positive effect on metabolic outcomes, while different types and volume of exercises have their own merits.

Abstract word count: 250

## INTRODUCTION


Exercise training interventions have been proved to improve glycemic control, reduce cardiovascular risk factors, contribute to weight loss and improve well-being in general population(1-3). Compared to healthy individuals, patients with type 2 diabetes (T2DM) have higher risk of cardiovascular death due to the metabolic complexity and underlying comorbidities including obesity, dyslipidemia and hypertension(4-5). Therefore, exercise is recognized as one key non-pharmaceutical strategy for T2DM patients in most international and national guidelines(6-8).

Several systemic reviews and meta-analysis were conducted to evaluate the effect of exercise on metabolic and anthropometric outcomes including glycemic control(9-13), lipid profile(9,13-15), anthropometric data(9,12,16) and blood pressure(9,14,17). However, the results of those studies were still conflicting. Besides, limited evidence was found in terms of the relationship between exercise volume and the improvement of metabolic and anthropometric outcomes in patients with T2DM (9-11,17).

Therefore in this study, we addressed the gap on the association between supervised exercise training (aerobic, resistance or combined) on metabolic outcomes (lipid profile, blood pressure and glycemic control), anthropometric outcomes and body composition, specifically focusing on the effect of different exercise training volume  those outcomes, by a systematic review and meta-analysis of randomized controlled trials (RCTs) .

## METHODS

This systematic review and meta-analysis was conducted according to the Cochrane


Handbook for Systematic Reviews of Interventions and followed a registered protocol with PROSPERO (CRD42019152282). A PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist was created (see Supplementary Appendix PRISMA Checklist). 

We used Abstrackr for literature management including study selection (18), Microsoft excel for data extraction, STATA (version 14.0, Stata Corp, College Station, Texas, USA) and the Review Manager statistical software package (version 5.3, Nordic Cochrane Centre, Copenhagen, Denmark) for statistical analyses.

### ***Data Sources and Searches***

We performed systematic searches in MEDLINE (accessed by PubMed), EMBASE, and Cochrane Central Register of Controlled Trials for studies of exercise training intervention published between January 1980 and June 2019. Electronic searches were supplemented with manual searches of references from included studies and other review articles. The search strategy is available in Supplementary Appendix Protocol.

### ***Study Selection***

We included RCTs that have at least one arm of supervised exercise training (aerobic, resistance and/or a combination of both) in participants aged over 18 and with T2DM, compared with a control group  be included, studies had to be  $\geq 12$  weeks in duration, and reported change in any of the following as outcome variables: weight (kg), waist circumference (WC, cm), waist hip ratio (WHR), total body fat percentage (%), low-density lipoprotein cholesterol (LDL-C, mmol/L or mg/dl), high-density lipoprotein cholesterol (HDL-C, mmol/L or mg/dl), triglyceride (TG, mmol/L or

mg/dl), total cholesterol (TC, mmol/L or mg/dl), systolic blood pressure (SBP, mmHg), diastolic blood pressure (DBP, mmHg), HbA1c (%), fasting plasma glucose (FPG, mmol/L or mg/dl). We only included trials with supervised exercise training with pre-determined frequency, duration and intensity as those were more likely to have had strict control of the variables of interest. We excluded trials with a follow-up period shorter than 12 weeks; included patients with type 1 diabetes or gestational diabetes; and duplicate publications.

Three authors (XZ, YZ and TB) independently screened titles, abstracts and full texts for eligibility, with each title/abstract/full text reviewed by two authors, and any discrepancies were resolved through discussion with additional authors (FZ and CL).


### **Data Extraction and Quality Assessment**

Data were extracted in duplicate by two authors XZ and YZ including publication detail (first author, year of publication, country of study), population characteristics (sample size, age, sex, duration of diabetes), exercise training type (aerobic, resistance and/or a combination of both), exercise training duration (total weeks and minutes per session), exercise training frequency (sessions or sets per week), exercise training intensity (percentages of maximum heart rate [HR<sub>max</sub>] or percentages of the peak oxygen uptake [VO<sub>2max</sub>] for aerobic exercise; percentages of 1-repetition maximum [1-RM] for resistance exercise) and outcome changes (in any of the outcome variables of interest [weight, WC, WHR, total body fat percentage, LDL-C, HDL-C, TG, TC, SBP, DBP, HbA1c, FPG]).

The risk of bias was evaluated using the Cochrane risk of bias tool (RoB 2)(19). The

quality of included evidence was evaluated by GRADE Working Group grade(20). Any discrepancies during data extraction and quality assessment were resolved by discussion with an additional author (CL).

### ***Data Synthesis and Analysis***

We defined the volume of exercise as exercise training duration per week (minutes) multiply by intensity (%) for aerobic exercise, and total sets per week multiply by intensity (%) for resistance exercise. We categorized exercise volume into XXX groups based on XXXX. Similarly, we categorized study duration into three groups XXXX.  outcomes in analyses were continuous outcomes and evaluated by computing the weighted mean differences (WMDs) and 95% confidence intervals (CIs).

Between-study heterogeneity were evaluated by Higgins  $I^2$  statistics, with an  $I^2$  value >50% indicating high level of heterogeneity. Fixed effects model was used for low level of heterogeneity while random effects model was used for high level of heterogeneity. Z test were used to compare the mean difference of effect sizes between independent subgroups. Meta-regression analyses were conducted to evaluate the associations between different potential influencing indicators (including age, sex, disease duration, weekly exercise volume, total exercise volume, program duration and baseline level of analyzed outcome) in outcomes. Publication bias was assessed via Egger's test. Statistical significance was considered at  $P < 0.05$ .

## **RESULTS**

### ***Study selection and study characteristics***

Of 3240 citations, 2600 were excluded based on titles and abstracts. 640 eligible




studies underwent full text review, and a total of 42 RCTs met the inclusion criteria including 28 RCTs in aerobic exercise training group, 16 RCTs in resistance exercise training group and 12 RCTs in combined exercise training group. **Fig. 1** summarizes the results of the systematic review process. Baseline characteristics of each included RCT were summarized in supplementary material **Supplementary Table S1**.

### ***Risk of bias and quality of evidence***

The overall risk of bias and selective reporting bias was low, while no significant publication bias was found (**Supplementary Table S2**). The quality of included trials in each outcome was ranked low to moderate according to GRADE Working Group grade (**Supplementary Table S3**).


### ***Effect on anthropometric outcomes and body composition***

In total, compared with non-exercise control group, exercise training led to significant reduction in body weight (WMDs, -1.10 kg; 95% CI, -1.58 to -0.62 kg,  $P<0.01$ ), WC (WMDs, -2.51 cm; 95% CI, -3.25 to -1.77 cm,  $P<0.01$ ), WHR (WMDs, -0.03; 95% CI, -0.05 to -0.02,  $P<0.01$ ) and percentage of total body fat (WMDs, -1.16%; 95% CI, -1.57 to -0.75%,  $P<0.01$ ). Compared with the control group, WC was reduced by aerobic exercise, resistance exercise and combined exercise in an undifferentiated way, body weight was decreased in aerobic exercise group and combined exercise group, while WHR was only lessened by aerobic exercise. Percentage of total body fat was reduced by all types of exercise, with significant difference between aerobic exercise and resistance exercise ( $P=0.02$ ), and significant difference between combined exercise and resistance exercise ( $P<0.01$ ) (**Fig. 2**).

In terms of exercise volume, compared with the control group, high-volume of aerobic exercise ( $P < 0.01$ ) and high-volume of resistance exercise ( $P < 0.01$ ) led to significant weight reductions, but not in the low-volume exercise group and medium-volume exercise group. Compared with non-exercise control group, WHR was improved in low-volume ( $P < 0.01$ ) and in medium-volume aerobic exercise subgroup ( $P = 0.01$ ), but not in high-volume aerobic exercise subgroup. No difference was found between low-volume exercise group and high-volume exercise group in terms of WC and percentage of total body fat (**Table 1**). 

Results from the subgroup analysis that stratified by study duration were shown in **Table 1**. Data from meta-regression analyses indicated that patients with longer disease duration enjoyed larger total body fat reduction after aerobic exercise (coefficient = -0.407, 95% CI -0.650, -0.161,  $P = 0.007$ ). Studies with longer program duration tended to show more WC reduction in resistance exercise group (coefficient = -0.082, 95% CI -0.117, -0.048,  $P = 0.002$ ). No association between exercise volume and weight change, WC, total body fat or WHR reduction was observed (**Supplementary Table S4**).

### ***Effect on glycemic control***

Overall, the levels of HbA1c and FPG significantly decreased after exercise intervention when compared with non-exercise control group (WMDs, -0.47%  -0.61 mmol/L, respectively; both  $P < 0.01$ ). All three types of exercise reduced HbA1c level without distinction, but only aerobic exercise could reduce FPG (WMDs, -0.86 mmol/L;  $P < 0.01$ ) (**Fig. 2 and Table 1**).

When compared with control group, reduction of HbA1c was significant in high-volume ( $P < 0.01$ ) and medium-volume ( $P < 0.01$ ) aerobic exercise group, but not in low-volume aerobic exercise group (**Table 1**). Our result didn't suggest any relationship between resistance exercise volume and HbA1c reduction or any relationship between exercise volume and FPG change (**Table 1 and Supplementary Table S4**).

When stratified by program duration, HbA1c level decreased in all three subgroups without significant difference (**Table 1**). However, FPG only showed significant reduction in studies with short program duration ( $P < 0.01$ ) (**Table 1**).

### *Effect of exercise on blood pressure*

On a whole, compared with control group, exercise training was associated with significant reductions on both SBP (WMDs, -4.65mmHg; 95% CI, -6.90 to -2.39mmHg,  $P < 0.01$ ) and DBP (WMDs, -1.84mmHg; 95% CI, -2.75 to -0.93 mmHg,  $P < 0.01$ ). When compared with control group, aerobic exercise resulted in the reductions on both SBP and DBP, resistance exercise only reduced the level of DBP, while blood pressure decreased without significance in combined exercise group (**Fig. 2 and Table 1**).


When compared with controls, SBP was significantly decreased in high weekly resistance volume subgroup with low heterogeneity ( $P < 0.01$ ,  $I^2=0\%$ ), but not in low weekly resistance volume subgroup (**Table 1**). We didn't observe any relationship between aerobic exercise volume and SBP reduction or any relationship between exercise volume and DBP reduction in both subgroup analysis and meta-regression

analysis (**Table 1 and Supplementary Table S4**).

Results from subgroup analysis that stratified by baseline blood pressure level and study duration was demonstrated in **Table 1 and Supplementary Figure S1-S4**. Meta-regression indicated that patients with higher baseline DBP level had more decline in DBP after aerobic exercise (coefficient=-0.350, 95% CI -0.521, -0.178,  $P=0.001$ ) (**Supplementary Table S4**).

### ***Effect of exercise on blood lipid profile***

Intervention with exercise resulted in significant decrease in LDL-C (WMDs, -0.22 mmol/L; 95% CI, -0.34 to -0.11mmol/L,  $P<0.01$ ), TG (WMDs, -0.11 mmol/L; 95% CI, -0.19 to -0.03mmol/L,  $P<0.01$ ), and TC (WMDs, -0.24 mmol/L; 95% CI, -0.39 to -0.09mmol/L,  $P<0.01$ ), and significant increase in HDL-C (WMDs, 0.08 mmol/L; 95% CI, 0.04 to 0.12mmol/L,  $P<0.01$ ), when compared with control group. Aerobic exercise improved lipid profile by raising the level of HDL-C while decreasing the level of LDL-C and TC. Resistance exercise reduced the level of TG and TC. Combined exercise did not improve lipid profile (**Fig. 2 and Table 1**).


When stratified by aerobic exercise volume, the reduction of TG was significant in low weekly aerobic exercise volume subgroup with low heterogeneity ( $P=0.04$ ,  $I^2=0\%$ ), but insignificant in high weekly aerobic volume subgroup and medium weekly aerobic volume subgroup (**Table 1**). Only high-volume of aerobic exercise could significantly increase HDL-C ( $P < 0.01$ ). We didn't find any relationship between aerobic exercise volume and TC or any relationship between aerobic exercise volume and LDL-C (**Table 1 and Supplementary Table S4**). When stratified by

resistance exercise volume, TC ( $P < 0.01$ ) and LDL-C ( $P < 0.01$ ) was significantly lessened by exercise in low weekly resistance exercise volume subgroup, but not in high weekly resistance exercise volume subgroup (**Table 1**). No relationship between exercise volume and lipid profile improvement was observed in the analysis of TG or HDL-C in resistance exercise group (**Table 1 and Supplementary Table S4**).

When stratified by program duration, the levels of HDL-C and TC were improved in the group with medium study duration ( $P=0.02$  and  $P < 0.01$  respectively) and short study duration ( $P=0.01$  and  $P < 0.01$  respectively), but not in group with long study duration (**Table 1**). The level of LDL-C and TG were only significantly decreased in the groups with short study duration ( $P=0.02$  and  $P < 0.01$  respectively), with insignificant reduction in groups with medium study duration and long study duration (**Table 1**).

By meta regression analysis, lower total resistance exercise volume was associated with larger reduction of TC (coefficient=0.00015, 95% CI 0.000035, 0.00027,  $P=0.018$ ). In addition, patients with longer disease duration had greater change in LDL-C level after aerobic exercise intervention (coefficient=-0.737, 95% CI -1.412, -0.062,  $P=0.036$ ) (**Supplementary Table S4**).

## DISCUSSION

This systematic review and meta-analysis provided the effect of different volume  exercise training on metabolic outcomes in patients with type 2 diabetes. Overall, supervised exercise training contributed to weight loss, improved lipid profile, blood

pressure and glycemic control in T2DM patients. High-volume of exercise training was associated with greater BP reduction, better glycemic control and more weight loss. Low volume of exercise training was associated with larger lipid profile improvement and WHR reduction.

In previous studies, physical exercise has been suggested to augment post-receptor insulin signal(21), increase the transcription and translation of glucose transporter(22), higher clearance and lower release of free fatty acid as well as stimulate the release of nitrogen oxide from endothelial(23-24). Those mechanisms would explain the result that physical activities improved glycemic control, blood pressure control and lipid profiles.

According to this meta-analysis, we found that high-volume of exercise was associated with more weight loss, BP reduction and blood glucose control, when compared with control group, which was not observed in low-volume exercise or medium-volume exercise group. However, low-volume of aerobic exercise resulted in greater reductions of WHR and TG, and low-volume of resistance exercise was associated with better improvement of LDL-C and TC, when compared with non-exercise group. The above results may reflect the diversity and complexity of the metabolic mechanisms of exercise training intervention. Some glucose-raising hormones, for instance glucocorticoids and glucagon, may be upregulated during high volume exercise and impair metabolism(25-26). So far, few guidelines have set up an upper limit for the volume of exercise(7-8,27), and our findings partly challenged the assumption that the more exercise the patients did, the healthier they would be. Although the specific amount of exercise volume needed to be explored by further

experiments, the current result suggested that we should be careful and act according to our ability in exercise planning to keep exercise volume in an exact range.

Previous studies evaluated the relationship between exercise time(11,28) or exercise intensity(11,28-29) and the effect on metabolic outcomes. A meta-analysis by Umpierre et al. (11), concluded that the reduction in HbA1c was associated with exercise frequency in supervised aerobic training and was associated with resistance exercise volume in combined exercise. Our results also suggested that the level of HbA1c was improved with high-volume of aerobic exercise, but no relationship was observed between glycemic improvement and the volume of resistance exercise. Moreover, as few previous studies evaluated the effect of exercise time and exercise intensity as a whole on the metabolic outcomes, therefore, to answer this question, we combined exercise time, exercise frequency and exercise intensity together as a whole, for the analyses of exercise volume, and the effect on the metabolic outcomes.

In this study, we found that the effect of aerobic exercise was superior to that of resistance exercise in reducing total body fat, which might probably be associated with the fully burning of fat by beta-oxidation during aerobic exercise. We also found that only aerobic exercise might decrease WHR in patients with T2D, which was supposed to be caused by better belly fat burning effect with aerobic exercise. Aerobic exercise also showed a potential effect of improving cholesterol metabolism, while resistance exercise could lessen the level of TG, which were reported in some previous researches (30-31). Previous experiments suggested that aerobic exercise may promote the uptake of LDL-C by liver through up-regulating the activity of LDL-R (32-33), while resistance exercise might increase the activity of skeletal

muscle lipase (34-35), which further promoted the uptake of TG from serum and low serum TG level. All the above biological mechanisms may give some explanations of our results, but further researches were needed to establish a comprehensive theory. Interestingly, we also observed a bidirectional regulation effect of DBP with aerobic exercise, which might be explained by the ability of improving vascular elasticity in aerobic exercise(36). Our study did not show any difference in glycemic control between different types of exercise, consisting with previous observations(9,11).


Another important observation from our study was that compared with longer duration of the exercise program, shorter duration of the exercise program was associated with better outcomes in lipid profile and glycemic control in patients with T2DM, which suggested that there might be an “exercise inertia phenomenon” in exercise training, similar to the “therapy inertia” in hypoglycemic treatment (37-38). Since we included RCTs with supervised exercise intervention, this kind of exercise inertia was unlikely to be caused by the poor adherence of participants. Of course, other confounding factors, such as state of diet and baseline comorbidities, were not taken into consideration in analyses due to the inconsistency in the reporting of relevant information in primary trials. Besides, we also hypothesized that “homeostasis of metabolism” might participate in the process of inertia. Though exercise training has positive effects on those metabolic outcomes, the improvements seemed to be eventually compensated by complex metabolic mechanisms, and therefore to achieve homeostasis in the long-term. Yet this theory has not been proved, given the degenerative nature of T2DM and the evidence that exercise intervention alone can hardly benefit cardiovascular outcome in T2DM (39), exercise alone could not be the only management of T2DM patients.




A net-work meta-analysis by Pan et al. (9) evaluating the effect of different types of exercise on change in weight, BP, LDL-C, HDL-C, TG and TC in T2DM patients, drew a similar conclusion with our results. According to our study, we additionally found that exercise training could also improve the levels of total body fat, WC and WHR as abdominal obesity in patients with T2DM, which was considered to be associated with insulin resistance (40-41). Besides, we explored a lot in the relationship between exercise volume and effect of exercise, which was poorly evaluated in the previous studies.

#### *Limitation of this study*

Several limitations should be considered when interpreting these results. First, information we extracted was sometimes dynamic throughout the studies, for example trials with progressive exercise intensities and durations (42-46). For these trials, we extracted the average intensity and duration though there could be a potential bias caused by thus. Additionally, we excluded trials with considerably imprecise data where we could not extract the detail exercise training plan. Second, considerable baseline characteristics, such as medication usage, comorbidities (e.g. systemic inflammation disease, cardiovascular disease, trauma), and dietary interventions etc., might interfere with the metabolism outcomes and act as confounding factors in the analyses. Despite our attempt to extract and adjust for these potential confounding variables, there were not commonly and consistently reported in the published trials. Therefore, we only adjusted for age, sex, disease duration, and baseline level of analyzed outcome in our meta-analysis. Third, though 12 RCTs was included in combined exercise group, usually only 4-5 trials were available in each outcome

analysis, made it difficult to conduct subgroup analysis in combined exercise group. Related analyses need to be supplemented in the future to improve exercise physiology theory and establish comprehensive exercise planning methods for T2DM patients.  ally, unlike drug therapy, which has well-defined pharmacological mechanism predictable medication effect, the mechanisms by which exercise affects metabolism are complex and unclear, and the effect of exercise on metabolic even cardiovascular outcomes can be varies from person to person, depending on personalized baseline situation. In this study, the heterogeneity in the pool result was high, which might due to the diversity of the population. Hence, it is very arbitrary to conclude whether exercise training is useful or not to an independent individual. During future clinical practice, characteristics of patients' age, comorbidities and exercise ability etc. should be taken in to account during the formulation of exercise training plan, and physicians should work with patients to develop personalized plans.

## CONCLUSIONS

In conclusion, exercise training has a positive effect on metabolic, anthropometric and body composition outcomes including reduced anthropometrics, lipid profile improvement, blood pressure control and glycemic control. While resistance exercise was superior in reducing serum TG level, aerobic exercise showed a greater potential for lessening body fat, WHR, FPG,  BP and improving cholesterol metabolism. Moreover, our study suggested that higher volume of exercise was associated with more weight loss, more BP reduction and better blood pressure control. Meanwhile, lower volume of exercise was related to greater reduction of WHR and larger improvement in lipid profile. Furthermore, we found that exercise alone is not suitable for long duration of exercise course, suggesting that, the choosing of exercise

regimens for diabetics should be carefully and personalized.

## **ACKNOWLEDGEMENTS**

We thank the doctors, nurses and technicians for their practical work during the study at Department of Endocrinology and Metabolism in Peking University People's Hospital.

## **CONTRIBUTORS**

XZ and FZ conceptualized this study and designed the systematic review protocol; XZ, YZ, FZ and TB performed the study selection and data extraction; CL and XZ performed the statistical analyses; CL and XZ prepared the outlines and wrote the manuscript. All authors contributed to the critical revision of manuscript drafts.

## **FUNDING**

This work was supported by....

除我们的项目外，体育总局的老师希望加入此资助项目：Project 15-22 supported by the Fundamental Research Funds for the China Institute of Sport Science

## **ETHICAL APPROVAL**

Not applicable.

## **DATA SHAREING STATEMENT**

All data relevant to the study are included in the article or uploaded as supplementary information. No more additional data are available.



## REFERENCE

1. Committee PAGA. Washington, DC: US Department of Health and Human Services; 2008. J Physical activity guidelines advisory committee report 2008
2. Lin X, Zhang X, Guo J, Roberts CK, McKenzie S, Wu WC, Liu S and Song Y. Effects of Exercise Training on Cardiorespiratory Fitness and Biomarkers of Cardiometabolic Health: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *J J Am Heart Assoc* 2015;4(7)
3. Zhao M, Veeranki SP, Magnussen CG and Xi B. Recommended physical activity and all cause and cause specific mortality in US adults: prospective cohort study. *J BMJ* 2020;370:m2031.
4. Saydah SH, Eberhardt MS, Loria CM and Brancati FL. Age and the burden of death attributable to diabetes in the United States. *J Am J Epidemiol* 2002;156(8):714-9.
5. Grieb P. [Impaired glucose tolerance and the risk of cardiovascular death]. *J Pol Merkur Lekarski* 2004;16(94):394-7.
6. Colberg SR, Sigal RJ, Yardley JE, Riddell MC, Dunstan DW, Dempsey PC, Horton ES, Castorino K and Tate DF. Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *J Diabetes Care* 2016;39(11):2065-79.
7. Cosentino F, Grant PJ, Aboyans V, Bailey CJ, Ceriello A, Delgado V, Federici M, Filippatos G, Grobbee DE, Hansen TB, Huikuri HV, Johansson I, Juni P, Lettino M, Marx N, Mellbin LG, Ostgren CJ, Rocca B, Roffi M, Sattar N, Seferovic PM, Sousa-Uva M, Valensi P, Wheeler DC and Group ESCSD. 2019 ESC Guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD. *J Eur Heart J* 2020;41(2):255-323.
8. Diabetes Canada Clinical Practice Guidelines Expert C, Sigal RJ, Armstrong MJ, Bacon SL, Boule NG, Dasgupta K, Kenny GP and Riddell MC. Physical Activity and Diabetes. *J Can J Diabetes* 2018;42 Suppl 1:S54-S63.
9. Pan B, Ge L, Xun YQ, Chen YJ, Gao CY, Han X, Zuo LQ, Shan HQ, Yang KH, Ding GW and Tian JH. Exercise training modalities in patients with type 2 diabetes mellitus: a systematic review and network meta-analysis. *J Int J Behav Nutr Phys Act* 2018;15(1):72.
10. Umpierre D, Ribeiro PA, Kramer CK, Leitao CB, Zucatti AT, Azevedo MJ, Gross JL, Ribeiro JP and Schaan BD. Physical activity advice only or structured exercise training and association with HbA1c levels in type 2 diabetes: a systematic review and meta-analysis. *J JAMA* 2011;305(17):1790-9.
11. Umpierre D, Ribeiro PA, Schaan BD and Ribeiro JP. Volume of supervised exercise training impacts glycaemic control in patients with type 2 diabetes: a systematic review with meta-regression analysis. *J Diabetologia* 2013;56(2):242-51.
12. Yang Z, Scott CA, Mao C, Tang J and Farmer AJ. Resistance exercise versus aerobic exercise for type 2 diabetes: a systematic review and meta-analysis. *J Sports Med* 2014;44(4):487-99.
13. Yoo JS and Lee SJ. [A meta-analysis of the effects of exercise programs on glucose and lipid metabolism and cardiac function in patients with type II diabetes mellitus]. *J Taehan Kanho Hakhoe Chi* 2005;35(3):546-54.
14. Hayashino Y, Jackson JL, Fukumori N, Nakamura F and Fukuhara S. Effects of supervised exercise on lipid profiles and blood pressure control in people with type 2 diabetes mellitus: a meta-analysis of randomized controlled trials. *J Diabetes Res Clin Pract* 2012;98(3):349-60.
15. de Oliveira VN, Bessa A, Jorge ML, Oliveira RJ, de Mello MT, De Agostini GG,

Jorge PT and Espindola FS. The effect of different training programs on antioxidant status, oxidative stress, and metabolic control in type 2 diabetes. *J Appl Physiol Nutr Metab* 2012;37(2):334-44.

16. Boule NG, Haddad E, Kenny GP, Wells GA and Sigal RJ. Effects of exercise on glycemic control and body mass in type 2 diabetes mellitus: a meta-analysis of controlled clinical trials. *JAMA* 2001;286(10):1218-27.

17. Igarashi Y, Akazawa N and Maeda S. Regular aerobic exercise and blood pressure in East Asians: A meta-analysis of randomized controlled trials. *J Clin Exp Hypertens* 2018;40(4):378-89.

18. Wallace BC, Small K, Brodley CE, Lau J and Trikalinos TA. Deploying an interactive machine learning system in an evidence-based practice center: abstractcr. Proceedings of the 2nd ACM SIGHIT international health informatics symposium, 2012:819-24.

19. Higgins JP, Altman DG, Gotzsche PC, Juni P, Moher D, Oxman AD, Savovic J, Schulz KF, Weeks L, Sterne JA, Cochrane Bias Methods G and Cochrane Statistical Methods G. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *J BMJ* 2011;343:d5928.

20. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, Schunemann HJ and Group GW. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *J BMJ* 2008;336(7650):924-6.

21. Dela F, Handberg A, Mikines KJ, Vinten J and Galbo H. GLUT 4 and insulin receptor binding and kinase activity in trained human muscle. *J J Physiol* 1993;469:615-24.

22. Dela F, Mikines KJ, Sonne B and Galbo H. Effect of training on interaction between insulin and exercise in human muscle. *J J Appl Physiol* (1985) 1994;76(6):2386-93.

23. Ivy JL, Zderic TW and Fogt DL. Prevention and treatment of non-insulin-dependent diabetes mellitus. *J Exerc Sport Sci Rev* 1999;27:1-35.

24. McAllister RM, Hirai T and Musch TI. Contribution of endothelium-derived nitric oxide (EDNO) to the skeletal muscle blood flow response to exercise. *J Med Sci Sports Exerc* 1995;27(8):1145-51.

25. Sellers TL, Jaussi AW, Yang HT, Heninger RW and Winder WW. Effect of the exercise-induced increase in glucocorticoids on endurance in the rat. *J J Appl Physiol* (1985) 1988;65(1):173-8.

26. Ferlazzo A, Cravana C, Fazio E and Medica P. The different hormonal system during exercise stress coping in horses. *J Vet World* 2020;13(5):847-59.

27. American Diabetes A. 5. Facilitating Behavior Change and Well-being to Improve Health Outcomes: Standards of Medical Care in Diabetes-2020. *J Diabetes Care* 2020;43(Suppl 1):S48-S65.

28. Wewege MA, Thom JM, Rye KA and Parmenter BJ. Aerobic, resistance or combined training: A systematic review and meta-analysis of exercise to reduce cardiovascular risk in adults with metabolic syndrome. *J Atherosclerosis* 2018;274:162-71.

29. Stoner L, Beets MW, Brazendale K, Moore JB and Weaver RG. Exercise Dose and Weight Loss in Adolescents with Overweight-Obesity: A Meta-Regression. *J Sports Med* 2019;49(1):83-94.

30. Igarashi Y, Akazawa N and Maeda S. Effects of Aerobic Exercise Alone on Lipids in Healthy East Asians: A Systematic Review and Meta-Analysis. *J J Atheroscler Thromb* 2019;26(5):488-503.

31. Kim KB, Kim K, Kim C, Kang SJ, Kim HJ, Yoon S and Shin YA. Effects of

Exercise on the Body Composition and Lipid Profile of Individuals with Obesity: A Systematic Review and Meta-Analysis. *J J Obes Metab Syndr* 2019;28(4):278-94.

32. Seelbach JD and Kris-Etherton PM. The effect of vigorous treadmill exercise on plasma lipoproteins and hepatic lipoprotein production in Zucker rats. *J Atherosclerosis* 1985;57(1):53-64.

33. Young IR and Stout RW. Effects of insulin and glucose on the cells of the arterial wall: interaction of insulin with dibutyryl cyclic AMP and low density lipoprotein in arterial cells. *J Diabetes Metab* 1987;13(3 Pt 2):301-6.

34. Pedersen SB, Bak JF, Holck P, Schmitz O and Richelsen B. Epinephrine stimulates human muscle lipoprotein lipase activity in vivo. *J Metabolism* 1999;48(4):461-4.

35. Bosma M. Lipid homeostasis in exercise. *J Drug Discov Today* 2014;19(7):1019-23.

36. Seals DR, Nagy EE and Moreau KL. Aerobic exercise training and vascular function with ageing in healthy men and women. *J J Physiol* 2019;597(19):4901-14.

37. Phillips LS, Branch WT, Cook CB, Doyle JP, El-Kebbi IM, Gallina DL, Miller CD, Ziemer DC and Barnes CS. Clinical inertia. *J Ann Intern Med* 2001;135(9):825-34.

38. Reach G, Pechtner V, Gentilella R, Corcos A and Ceriello A. Clinical inertia and its impact on treatment intensification in people with type 2 diabetes mellitus. *J Diabetes Metab* 2017;43(6):501-11.

39. Look ARG, Wing RR, Bolin P, Brancati FL, Bray GA, Clark JM, Coday M, Crow RS, Curtis JM, Egan CM, Espeland MA, Evans M, Foreyt JP, Ghazarian S, Gregg EW, Harrison B, Hazuda HP, Hill JO, Horton ES, Hubbard VS, Jakicic JM, Jeffery RW, Johnson KC, Kahn SE, Kitabchi AE, Knowler WC, Lewis CE, Maschak-Carey BJ, Montez MG, Murillo A, Nathan DM, Patricio J, Peters A, Pi-Sunyer X, Pownall H, Reboussin D, Regensteiner JG, Rickman AD, Ryan DH, Safford M, Wadden TA, Wagenknecht LE, West DS, Williamson DF and Yanovski SZ. Cardiovascular effects of intensive lifestyle intervention in type 2 diabetes. *J N Engl J Med* 2013;369(2):145-54.

40. Verboven K, Wouters K, Gaens K, Hansen D, Bijnen M, Wetzels S, Stehouwer CD, Goossens GH, Schalkwijk CG, Blaak EE and Jocken JW. Abdominal subcutaneous and visceral adipocyte size, lipolysis and inflammation relate to insulin resistance in male obese humans. *J Sci Rep* 2018;8(1):4677.

41. Castro AV, Kolka CM, Kim SP and Bergman RN. Obesity, insulin resistance and comorbidities? Mechanisms of association. *J Arq Bras Endocrinol Metabol* 2014;58(6):600-9.

42. Cuff DJ, Meneilly GS, Martin A, Ignaszewski A, Tildesley HD and Frohlich JJ. Effective exercise modality to reduce insulin resistance in women with type 2 diabetes. *J Diabetes Care* 2003;26(11):2977-82.

43. Abdelaal AA and Mohamad MA. Obesity indices and haemodynamic response to exercise in obese diabetic hypertensive patients: Randomized controlled trial. *J Obes Res Clin Pract* 2015;9(5):475-86.

44. Sigal RJ, Kenny GP, Boule NG, Wells GA, Prud'homme D, Fortier M, Reid RD, Tulloch H, Coyle D, Phillips P, Jennings A and Jaffey J. Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: a randomized trial. *J Ann Intern Med* 2007;147(6):357-69.

45. Shenoy S, Arora E and Jaspal S. Effects of progressive resistance training and aerobic exercise on type 2 diabetics in Indian population. *J Int J Diabetes Metab* 2009;17(1):27-30.

46. Wycherley TP, Noakes M, Clifton PM, Cleanthous X, Keogh JB and Brinkworth GD. A high-protein diet with resistance exercise training improves weight loss and body composition in overweight and obese patients with type 2 diabetes. *J Diabetes Care* 2010;33(5):969-76.

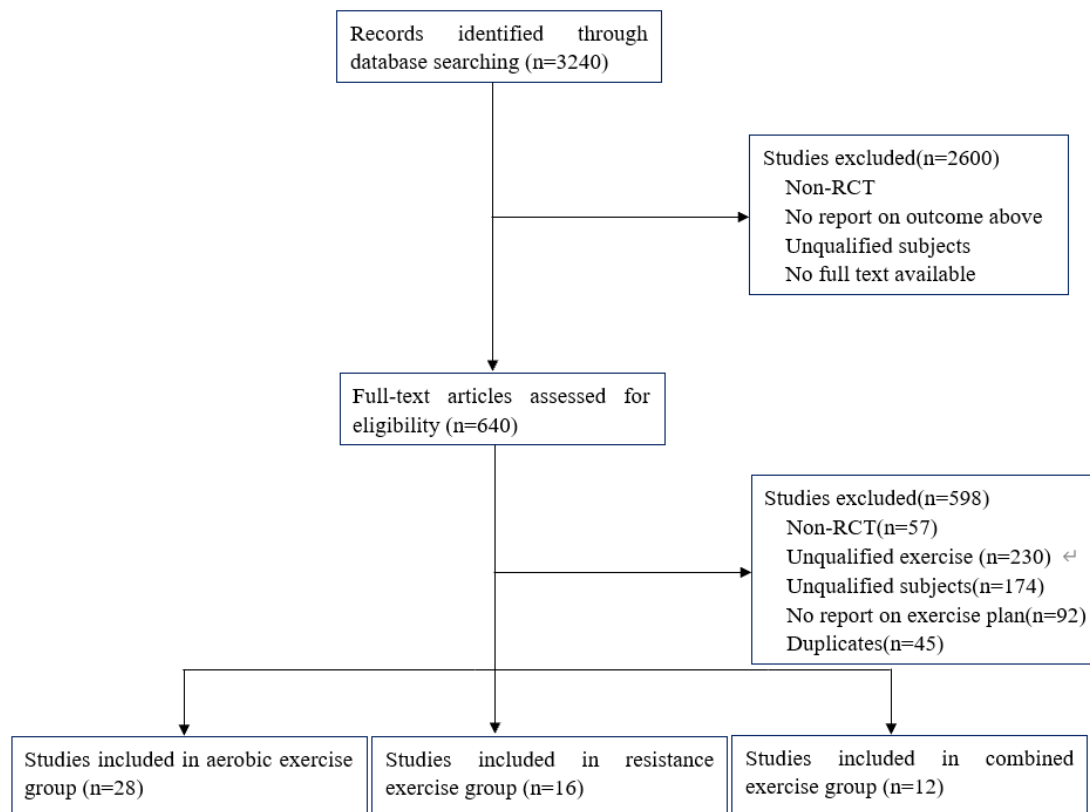


**Figure legends**

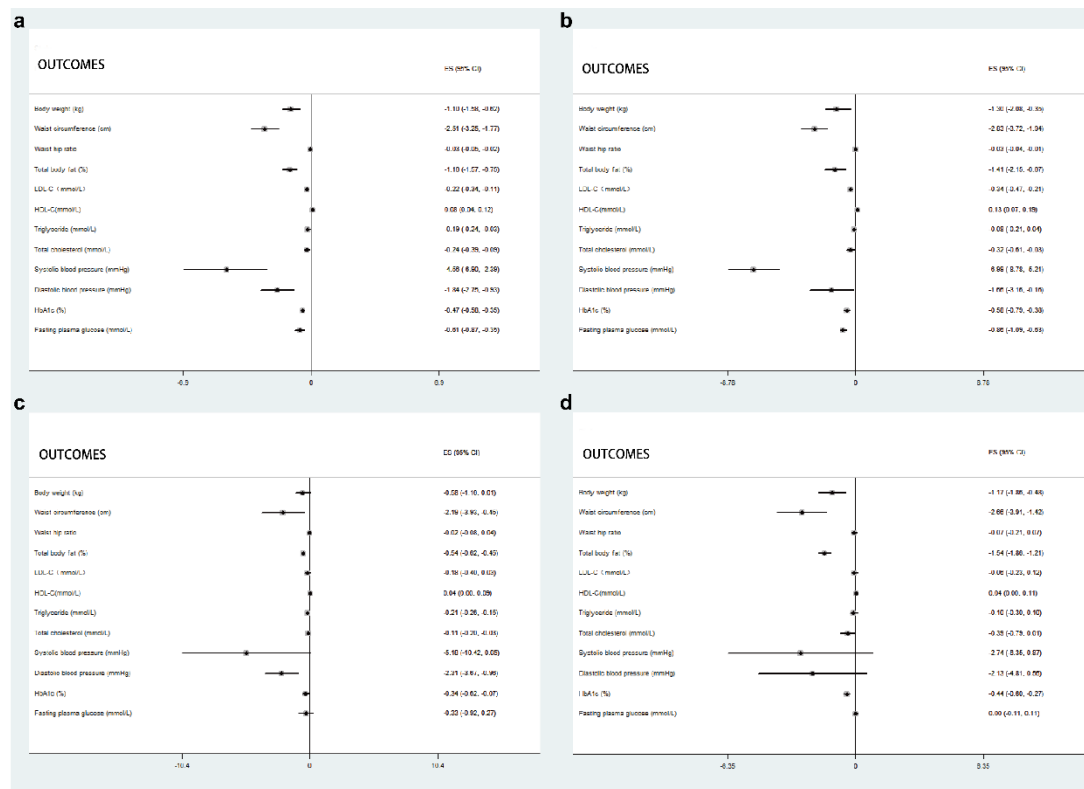
Figure 1. Flow chart of included randomized controlled trial

Figure 2. Summary of pooled effects from included RCTs

Table 1. Effect of exercise on metabolic outcomes in patients with T2DM



**Figure 1. Flow chart of included randomized controlled trial**



**Figure 2. Summary of pooled effects from included RCTs**

a: Overall summary of pooled effects of different outcomes ; b: Summary of pooled effects of different outcomes in aerobic exercise intervention group. c: Summary of pooled effects of different outcomes in resistance exercise intervention group. d: Summary of pooled effects of different outcomes in combined exercise intervention group ; Weighted mean difference (WMD) and 95% CI were calculated for a change from baseline to the study endpoint for exercise group vs non-exercising control group.

Subgroup	Outcomes	No. of participants (exercise/control)	WMDs	95% CI	P value	Heterogeneity $I^2$
Overall effect of						

exercise by		exercise types				
<i>Aerobic</i>						
	body weight	314/295	-1.30	-2.08, -0.35	<b>0.001</b>	97%
	waist circumference	190/168	-2.83	-3.72, -1.94	<b>&lt;0.00001</b>	88%
	waist-hip ratio	165/173	-0.03	-0.04, -0.01	<b>0.0005</b>	99%
	total body fat (%)	168/172	-1.41	-2.15, -0.67	<b>0.0002</b>	97%
	LDL-C	271/286	-0.34	-0.47, -0.21	<b>&lt;0.00001</b>	89%
	HDL-C	270/285	0.13	0.07, 0.19	<b>&lt;0.00001</b>	93%
	TG	353/374	-0.08	-0.21, 0.04	0.18	93%
	TC	210/221	-0.32	-0.61, -0.03	<b>0.03</b>	96%
	SBP	357/374	-6.99	-8.78, -5.21	<b>0.003</b>	88%
	DBP	357/374	-1.66	-3.16, -0.16	<b>0.003</b>	96%
	HbA1c	400/384	-0.58	-0.79, -0.38	<b>&lt;0.00001</b>	90%
	FPG	299/313	-0.86	-1.09, -0.63	<b>&lt;0.00001</b>	88%
<i>Resistance</i>						
	body weight	185/148	-0.58	-1.16, 0.01	0.33	27%
	waist circumference	169/133	-2.19	-3.93, -0.45	<b>0.01</b>	13%
	waist-hip ratio	83/81	-0.02	-0.08, 0.04	0.49	98%
	total body fat (%)	93/82	-0.54	-0.62, -0.45	<b>&lt;0.00001</b>	0%
	LDL-C	234/229	-0.18	-0.40, 0.03	0.10	82%
	HDL-C	234/229	0.04	-0.00, 0.09	0.07	62%
	TG	267/261	-0.21	-0.26, -0.15	<b>&lt;0.00001</b>	0%
	TC	179/175	-0.11	-0.20, -0.03	<b>0.007</b>	5%
	SBP	234/229	-5.18	-10.42, 0.05	0.05	98%

<i>Combined</i>	DBP	234/229	-2.31	-3.67, -0.96	<b>0.0008</b>	85%
	HbA1c	348/306	-0.34	-0.62, -0.07	<b>0.01</b>	93%
	FPG	176/170	-0.33	-0.92, 0.27	0.28	67%
	body weight	180/147	-1.17	-1.86, -0.48	<b>0.0009</b>	86%
	waist	459/426	-2.66	-3.91, -1.42	<b>&lt;0.0001</b>	97%
	circumference					
	waist-hip ratio	32/36	-0.07	-0.21, 0.07	0.431	99%
	total body fat	114/116	-1.54	-1.86, -1.21	<b>&lt;0.00001</b>	76%
	(%)					
	LDL-C	425/416	-0.06	-0.23, 0.12	0.66	86%
	HDL-C	425/416	0.04	-0.0, 0.11	0.28	92%
	TG	489/479	-0.10	-0.30, 0.10	0.32	93%
	TC	415/403	-0.39	-0.79, 0.01	0.05	98%
	SBP	517/522	-2.74	-6.35, 0.87	0.14	97%
	DBP	469/473	-2.13	-4.81, 0.56	0.12	98%
	HbA1c	607/652	-0.44	-0.60, -0.27	<b>&lt;0.00001</b>	86%
	FPG	383/385	0.00	-0.11, 0.11	0.98	0%

Overall effect of  
exercise by study  
duration

*Long study  
duration\**

body weight	351/252	-0.99	-1.50, -0.48	<b>0.0001</b>	89%
waist	614/516	-2.49	-3.43, -1.56	<b>&lt;0.00001</b>	97%
circumference					
total body fat	132/120	-0.69	-1.43, 0.04	0.06	96%
(%)					

<i>Medium duration** study</i>	LDL-C	615/625	-0.19	-0.38, 0.01	0.06	97%
	HDL-C	603/612	0.05	-0.01, 0.1	0.01	97%%
	TG	626/638	-0.08	-0.26, 0.09	0.35	95%
	TC	415/420	-0.22	-0.58, 0.14	0.22	99%
	SBP	747/766	-4.17	-7.01, -1.33	<b>0.004</b>	98%
	DBP	699/717	-1.69	-3.04, -0.34	<b>0.01</b>	97%
	HbA1c	704/595	-0.29	-0.43, -0.15	<b>&lt;0.0001</b>	92%
	FPG	476/485	-0.47	-1.05, 0.10	0.11	98%
	body weight	142/142	-1.46	-2.36, -0.56	<b>0.002</b>	73%
	waist circumference	80/79	2.19	-3.93, -0.45	<b>0.01</b>	40%
	waist-hip ratio	135/136	-0.06	-0.11, -0.02	<b>0.01</b>	100%
	total body fat (%)	135/136	-1.10	-1.74, -0.47	<b>0.0006</b>	96%
	LDL-C	100/91	-0.26	-0.52, 0.00	0.05	89%
	HDL-C	100/91	0.05	0.01, 0.1	<b>0.02</b>	89%
	TG	257/249	-0.08	-0.23, 0.07	0.30	89%
<i>Short duration*** study</i>	TC	164/154	-0.13	-0.18, -0.09	<b>&lt;0.00001</b>	2%
	SBP	139/130	-6.12	-12.78, 0.55	0.07	93%
	DBP	139/130	-2.09	-4.56, 0.37	0.10	88%
	HbA1c	427/428	-0.59	-0.84, -0.34	<b>&lt;0.00001</b>	91%
	FPG	150/141	-0.31	-0.98, 0.37	0.38	88%
	body weight	186/196	-1.10	-2.19, -0.01	<b>0.05</b>	97%
	waist circumference	124/132	-2.66	-3.91, -1.42	<b>&lt;0.0001</b>	72%

waist-hip ratio	145/154	-0.01	-0.02, -0.00	<b>0.02</b>	93%
total body fat (%)	108/114	-1.52	-2.55, -0.50	<b>0.0004</b>	96%
LDL-C	215/215	-0.23	-0.43, -0.04	<b>0.02</b>	80%
HDL-C	226/227	0.15	0.03, 0.28	<b>0.01</b>	80%
TG	226/227	-0.22	-0.36, -0.08	<b>0.002</b>	51%
TC	216/215	-0.33	-0.47, -0.19	<b>&lt;0.00001</b>	23%
SBP	222/229	-7.72	-9.25, -6.19	<b>&lt;0.00001</b>	65%
DBP	200/208	-1.52	-3.55, 0.51	0.14	95%
HbA1c	224/229	-0.45	-0.69, -0.22	<b>0.0002</b>	70%
FPG	232/242	-0.87	-1.18, -0.57	<b>&lt;0.00001</b>	78%

Overall effect of  
exercise by  
aerobic weekly  
volume

*High aerobic  
weekly volume<sup>£</sup>*

body weight	122/91	-1.83	-2.61, -1.05	<b>&lt;0.00001</b>	79%
waist-hip ratio	77/81	-0.04	-0.11 to 0.02	0.20	100%
total body fat (%)	85/85	-0.97	-1.66, -0.27	<b>0.0006</b>	93%
LDL-C	115/117	-0.42	-0.57, -0.27	<b>&lt;0.00001</b>	84%
HDL-C	115/117	0.14	0.03, 0.24	<b>0.009</b>	94%
TC	115/117	-0.44	-0.80, -0.08	<b>0.02</b>	94%
TG	123/129	-0.07	-0.50, 0.36	0.76	91%
SBP	129/32	-8.46	-11.02, -5.89	<b>&lt;0.00001</b>	82%
DBP	129/132	-1.09	-3.62, -1.43	0.40	94%
HbA1c	102/105	-0.67	-1.16, -0.18	<b>0.007</b>	94%

<i>Medium aerobic weekly volume</i> £ £	FPG	89/89	-1.57	-2.15, -0.99	<0.00001	68%
	body weight	77/77	-0.24	-0.72 to 0.25	0.34	84%
	waist-hip ratio	37/37	-0.00	-0.01 to -0.00	<b>0.03</b>	0%
	total body fat (%)	32/33	-0.53	-0.85, -0.20	<b>0.001</b>	0%
	LDL-C	54/63	-0.32	-0.72, 0.08	0.12	96%
	HDL-C	42/50	0.08	-0.01, 0.17	0.09	96%
	TC	42/50	0.08	-0.08, 0.23	0.33	26%
	TG	72/71	-0.05	-0.25, 0.15	0.64	98%
	SBP	97/96	-7.27	-9.99, -4.55	<0.00001	91%
	DBP	97/96	-3.66	-5.73, -1.59	<b>0.0005</b>	96%
	HbA1c	156/122	-0.58	-0.93, -0.23	<b>0.001</b>	95%
	FPG	87/87	-0.92	-1.24, -0.60	<0.00001	94%
<i>Low aerobic weekly volume</i> £ £	body weight	104/115	-1.76	-4.41 to 0.90	0.19	98%
	waist-hip ratio	40/43	-0.03	-0.03 to -0.03	<0.00001	0%
	total body fat (%)	40/42	-2.17	-3.68, -0.67	<b>0.005</b>	98%
	LDL-C	102/106	-0.15	-0.31, 0.00	0.05	0%
	HDL-C	102/106	0.32	-0.23, 0.86	0.26	62%
	TC	42/42	-0.42	-0.73, 0.11	<b>0.007</b>	0%
	TG	124/136	-0.20	-0.39, -0.01	<b>0.04</b>	0%
	SBP	110/124	-5.23	-11.29, 0.82	<b>0.009</b>	89%
	DBP	110/124	0.85	-1.02, 2.73	0.37	76%
	HbA1c	106/119	-0.48	-1.05, 0.09	0.10	74%



	FPG	64/73	-1.29	-2.44, -0.15	<b>0.003</b>	87%
Overall effect of exercise by resistance weekly volume						
<i>High resistance weekly volume<sup>c</sup></i>						
	body weight	128/93	-0.63	-0.98, -0.29	<b>0.003</b>	0%
	waist circumference	128/93	-2.49	-2.91 to -2.08	<b>0.00001</b>	11%
	LDL-C	75/70	-0.09	-0.31, 0.13	0.44	23%
	HDL-C	75/70	-0.05	-0.02, 0.12	0.19	27%
	TG	75/70	-0.18	-0.40, 0.04	0.10	0%
	TC	75/70	0.07	-0.16, 0.30	0.57	0%
	SBP	65/60	-4.39	-4.85, -3.94	<b>&lt;0.00001</b>	0%
	DBP	65/60	-0.94	-4.75, 2.68,	0.63	85%
	HbA1c	179/137	-0.13	-0.34, 0.08	0.22	75%
	FPG	71/65	-0.13	-0.21, 0.94	0.81	69%
<i>Low resistance weekly volume</i>						
	body weight	185/148	-0.58	-1.16, 0.01	0.05	62%
	waist circumference	185/48	-2.71	-4.47 to -0.95	<b>0.003</b>	42%
	LDL-C	170/165	-0.33	-0.58, -0.09	<b>0.007</b>	69%
	HDL-C	170/165	-0.05	-0.04, 0.13	0.32	76%
	TG	139/134	-0.22	-0.47, 0.04	0.10	29%
	TC	95/95	-0.13	-0.19, -0.08	<b>0.0001</b>	0%
	SBP	95/95	-4.91	-14.36, 4.55	0.31	94%
	DBP	95/95	-0.86	-3.45, 1.73	0.51	61%

HbA1c	95/95	-0.38	-0.84, 0.09	0.11	90%
FPG	166/160	-0.34	-1.17, 0.50	0.43	67%

**Table 1. Effect of exercise on metabolic outcomes in patients with T2D**

\* >24 weeks in analyses of bodyweight, waist circumference, total body fat (%), HbA1c; ≥24 weeks in analyses of LDL-C, HDL-C, TG, TC, SBP, DBP and FPG

\*\* ≥24 weeks & ≥12 weeks in analyses of bodyweight, waist circumference, total body fat (%), HbA1c; <24 weeks & ≥12 weeks in analyses of LDL-C, HDL-C, TG, TC, SBP, DBP and FPG

\*\*\* 12 weeks in analyses of all outcomes

£ Weekly aerobic volume ≥90 min/weeks in analyses of bodyweight, waist circumference, total body fat (%), LDL-C, HDL-C, TC, SBP, DBP; ≥100 min/weeks in analyses of HbA1c and TG; ≥95 min/weeks in analyses of FPG; Tertiles were selected as cutoff points.

£ £ Weekly aerobic volume 70min/weeks -90 min/weeks in analyses of bodyweight, waist circumference; 65min/weeks -90 min/weeks in analyses of LDL-C, HDL-C, TC, SBP, DBP, total body fat (%); 70min/weeks -100 min/weeks in analyses of HbA1c and TG; 70min/weeks -95 min/weeks in analyses of FPG; Tertiles were selected as cutoff points.

£ £ £ Weekly aerobic volume ≤70min/weeks in analyses of bodyweight, waist circumference, HbA1c, TG and FPG; ≤65min/weeks in analyses of LDL-C, HDL-C, TC, SBP, DBP, total body fat (%); Tertiles were selected as cutoff points.

° ≥400 sets/week in analyses of bodyweight, waist circumference, LDL-C, HDL-C, TG, TC, FPG; ≥350 sets/week in analyses of SBP; ≥380 sets/week in analyses of DBP; ≥500 sets/week in analyses of HbA1c. Median was selected as cutoff point