

Clinical guideline

Clinical guidelines on physical activity and exercise therapy for Chinese adults with type 2 diabetes: A clinical practice guideline from the Chinese Society of Endocrinology

Fang Zhang^{a,†}, Jiajun Zhao^{b,†}, Yuwei Zhang^a, Zhenjun Tian^c, Jing Li^a, Qingguo Lü^a, Weiqing Wang^d, Tianpei Hong^e, Zhongyan Shan^f, Li Yan^g, Yongde Peng^h, Nanwei Tong^{a,*}

^a Department of Endocrinology and Metabolism, Center for Diabetes and Metabolism Research, West China Hospital of Sichuan University, Chengdu 610041, China

^b Department of Endocrinology, Shandong Provincial Hospital Affiliated with Shandong First Medical University, Jinan 250021, China

^c Institute of Sports Biology, College of Physical Education, Shaanxi Normal University, Xi'an 710062, China

^d Department of Endocrine and Metabolic Diseases, Shanghai Institute of Endocrine and Metabolic Diseases, Ruijin Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai 200025, China

^e Department of Endocrinology and Metabolism, Peking University Third Hospital, Beijing 100191, China

^f Department of Endocrinology and Metabolism, Institute of Endocrinology, National Health Commission (NHC) Key Laboratory of Diagnosis and Treatment of Thyroid Diseases, The First Affiliated Hospital of China Medical University, China Medical University, Shenyang 110801, China

^g Department of Endocrinology, Sun Yat-sen Memorial Hospital of Sun Yat-sen University, Guangzhou 510120, China

^h Department of Endocrinology and Metabolism, Shanghai General Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai 200080, China

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Abstract

Diabetes, a leading global chronic disease, poses a significant health threat, with physical inactivity being a major risk factor for its development and progression. This guideline, developed by the Chinese Society of Endocrinology, synthesizes the latest evidence and expert insights to provide evidence-based recommendations for physical activity and exercise therapy in adults with type 2 diabetes (T2D). It is generally recommended that all adult patients with T2D engage in at least 150–300 min of moderate-intensity aerobic exercise per week, or a minimum of 75–150 min of vigorous-intensity exercise, or an equivalent combination of moderate- and vigorous-intensity exercise (with a total exercise volume of at least 450 metabolic equivalent-min per week). For patients with T2D who are capable, moderate over-exercise and a combination of different forms of exercise (aerobic, resistance, flexibility, and/or balance training) are encouraged. The guideline also underscores the necessity of targeting specific subgroups of patients with T2D, including the elderly, individuals with obesity or pre-obesity, cardiovascular disease, hypertension, chronic kidney disease, metabolic dysfunction-associated steatotic liver disease, and/or diabetic foot and its high-risk populations. The guideline provides a scientific basis for clinicians to develop personalized exercise guidance and recommendations, with the goal of improving the disease prognosis of the relevant population.

Keywords: Adult; Exercise; Physical activity; Type 2 diabetes; Therapy principle

1. Introduction

Diabetes, one of the most prevalent chronic noncommunicable diseases (NCDs) worldwide, poses a significant threat to

global public health. A substantial body of research has identified physical inactivity as one of the primary risk factors for the development and progression of NCDs, including type 2 diabetes (T2D) and cardiovascular disease (CVD). The 10th edition of the International Diabetes Federation (IDF) Diabetes Atlas estimated that in 2021, there would be 537 million people (uncertainty interval: 424–612 million) aged 20–79 years living with diabetes across 215 countries and

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* Corresponding author.

E-mail address: tongnw@scu.edu.cn (N. Tong).

† These both authors contributed equally to this work.

regions,¹ indicating an increase of 74 million compared with 2019 (463 million).² An analysis published by the World Health Organization (WHO) in 2023 estimated that if the current widespread lack of physical activity remains unchanged, there will be 499.2 million new cases of NCDs globally from 2020 to 2030.³ Among these, projections indicate that T2D will account for 11.2 million new cases, constituting 2% of all new NCD cases, with direct healthcare costs of USD4.681 billion accounting for 9% of the total increase in costs. China, a country with a high prevalence of diabetes, has experienced a continuous increase in diabetes rates over the past 30 years.⁴ The 8th national epidemiological survey on diabetes conducted between 2015 and 2017 revealed that the prevalence of diabetes among adults aged 18 years and above in China was 11.2%.⁵ Among these cases, T2D is the most prevalent, accounting for over 90% of the population with diabetes in the country.⁴

Physical activity (PA) is defined as any body movement or action produced by skeletal muscles that requires energy expenditure.⁶ In this guideline, PA also refers to any general, daily, or physical movement that is not specially designed or guided. Exercise, on the other hand, constitutes a more specific manifestation of PA, characterized by its structured and planned nature. Exercise has been demonstrated to have a positive impact on both physical health⁷ and mental and physical development, underscoring its role as an integral component of a health-promoting lifestyle. While the terms “PA” and “exercise” are often used interchangeably, there are distinct differences between them. It is imperative to note that all forms of exercise can be classified as PA but, conversely, not all PA can be considered exercise. Exercise offers a wide range of benefits, including but not limited to improving insulin sensitivity,⁸ skeletal muscle function, and lipid and protein metabolism,^{9,10} providing anti-inflammatory effects,¹¹ enhancing β -cell function,^{12,13} improving vascular and endothelial function,^{14–16} and regulating the gut microbiota.¹⁷ As an essential component of lifestyle intervention, exercise therapy exerts a pivotal role in both the prevention and management of diabetes throughout its course.

Therefore, healthcare and health management professionals need to have a comprehensive grasp on and emphasize to their patients the significance of exercise intervention in the management of T2D, and in the management of NCDs more broadly. In clinical practice, it is critical to consider multiple factors, including medical, social, cultural, and personal aspects, to provide patients with scientifically sound and personalized exercise guidance and recommendations. This guideline was initiated by the Chinese Society of Endocrinology (CSE) and has been registered bilingually on the Practice Guide Registration for TransPAREncy (PREPARE) (Registration No. PREPARE-2023CN186). This work aimed to compile the most recent evidence-based findings and integrate the expertise of relevant professionals to provide scientific recommendations and reference guidelines for PA and exercise therapy in adults with T2D, with a particular focus on clinical practitioners in China.

2. Methods

2.1. Target population of this guideline

The target population of this guideline is individuals aged 18 years and older who are living with T2D or who are deemed to be at high risk of developing T2D.

2.2. Development process

The development process of this guideline primarily involved the following key steps: (a) Establishment of the expert working group. Initiated by the CSE, a multidisciplinary working group was formed, including professionals from the fields of endocrinology and metabolic diseases, sports medicine, geriatrics, and methodology. The experts were drawn from various provinces, cities, and regions across the country, ensuring professional expertise and broad geographic representation. All members of the working group signed conflicts of interest declarations, thereby confirming the absence of any direct conflicts of interest related to this guideline. This approach was adopted to ensure the maintenance of fairness and transparency throughout the development process. (b) Identification of clinical questions. Clinical questions were identified through a systematic search of databases, such as Web of Science, PubMed, and Embase, focusing on clinical guidelines, consensus documents, randomized controlled trials (RCTs), systematic reviews, and cohort studies related to exercise therapy for diabetes. Additionally, expert consultations were conducted to gather clinical questions. Following discussions among the working group, a set of core issues to be addressed by the guideline was determined. Each clinical question was meticulously deconstructed employing the PICO framework: P (Population), adults living with T2D; I (Intervention), PA and/or exercise therapy; C (Comparison), no intervention or alternative interventions; O (Outcome), impacts on T2D prevention, glycemic control, cardiovascular benefits, weight management, and other related outcomes. (c) Evidence retrieval and screening. A comprehensive search strategy was developed on the basis of the identified clinical questions and the PICO framework. Various studies and literature were retrieved from the aforementioned databases, with the search covering publications from the database inception to December 2024. The evidence was evaluated via a method unanimously approved by the expert working group. (d) Formulation of recommendations. Preliminary recommendations were formulated by the core drafting group on the basis of evidence evaluations and expert opinions. These recommendations underwent a process of refinement through multiple rounds of expert meetings and discussions. During each round, the feasibility, applicability, and validity of each recommendation were thoroughly debated. For recommendations with significant controversy, additional literature and data were reviewed, and detailed discussions and validations were conducted to reach a consensus. The final recommendations were subsequently developed and endorsed by the group.

2.3. Search strategy and study selection

The search strategy employed combinations of keywords/phrases (“physical activity” OR “exercise” OR “sport”) AND “type 2 diabetes” AND “adult”) across the Web of Science, PubMed, and Embase databases. Study selection was guided by the PICO framework outlined previously, stipulating the necessity of complete information availability. Exclusion criteria were as follows: (a) studies not focused on T2D; (b) studies involving nonhuman subjects or nonadult populations; (c) inaccessible full-text articles; (d) interventions where PA/exercise was not the primary component; (e) non-English/Chinese publications; (f) studies unrelated to PA/exercise objectives; (g) study outcomes not within the scope of our concern; (h) methodologically flawed studies with significant bias risks; and (i) duplicate records. Notably, given that the most recent Chinese guidelines on diabetes and exercise available during our preparation period were the 2012 edition issued by the Chinese Diabetes Society,¹⁸ the majority of the included studies in our work were published after 2012 to ensure the representation of current evidence and advancements in the field. The literature screening process is illustrated in Fig. 1.

2.4. Evidence grading system

This guideline adopts the evidence grading system of the American Diabetes Association (ADA)¹⁹ (Table 1) to evaluate the quality of the included literature. Furthermore, it references the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system to classify the quality of evidence.¹⁹ The strength of recommendations is delineated by two levels,²⁰ as determined by the quality of the evidence, the results of the studies, and the feasibility of clinical practices (Table 2).

3. Profiles of recommendations and evidence

3.1. Clinical Question 1: What is the relationship between exercise and T2D?

Recommendation 1: Physical inactivity is closely associated with the onset of T2D. Increasing activity levels has the

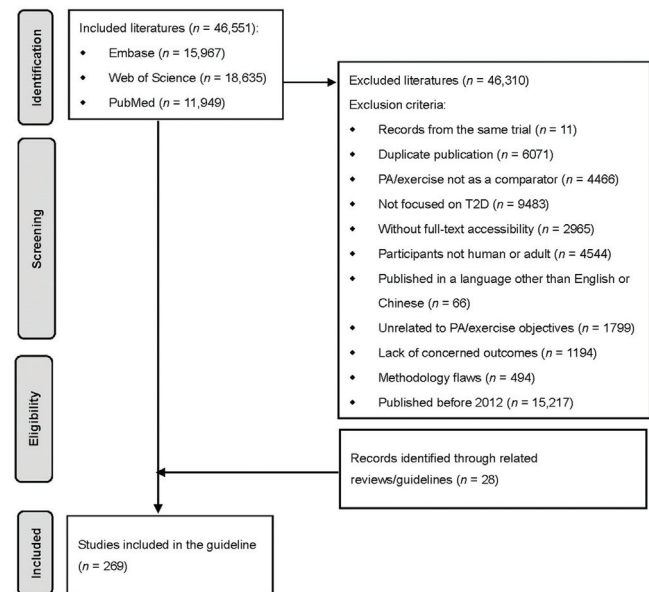


Fig. 1. The literature selection flowchart of this guideline. PA = physical activity; T2D = type 2 diabetes.

potential to reduce the risk of developing T2D and to help prevent or delay its progression (1A). In order to lower the likelihood of T2D, it is recommended that adults achieve a minimum of 4000 metabolic equivalent (MET)-min per week, encompassing the total amount of daily PA and exercise (2B). The optimal level of PA for the prevention of T2D in diverse populations remains to be elucidated.

Recommendation 1: Evidence and rationale

Physical inactivity is defined as the failure to meet current PA recommendations.^{21,22} Different studies quantify “physical inactivity” in various ways. To facilitate more precise measurement of PA levels, this guideline advocates for the utilization of METs as the unit for quantifying PA intensity, particularly for aerobic PA. MET refers to the ratio of the work metabolic rate to the standard resting metabolic rate.²³ One MET is defined as the resting metabolic rate, which represents the amount of oxygen consumed while sitting quietly, approximately 3.5 mL/kg/min. For instance, an activity with

Table 1
The evidence grading system of American Diabetes Association. (adapted from Elsayed et al.¹⁹).

Level of evidence	Description
A	Clear evidence from well-conducted, generalizable randomized controlled trials, including (a) well-conducted multicenter trials, and (b) meta-analysis evidence that incorporates quality ratings in the analysis
B	Supportive evidence from well-conducted randomized controlled trials, including (a) studies from well-conducted trials at 1 or more research sites, and (b) meta-analysis evidence that incorporates quality ratings in the analysis
C	Supportive evidence from well-conducted cohort studies, including (a) evidence from well-conducted prospective cohort studies or registry studies, and (b) evidence from a well-conducted meta-analysis of cohort studies
E	Supportive evidence from a well-conducted case-control study
	Supportive evidence from studies with inadequate controls or no controls, including (a) evidence from randomized clinical trials with one or more major or three or more minor methodological flaws, (b) evidence from observational studies with high potential bias (e.g., before-and-after case series), and (c) evidence from case series or case reports
	Conflicting evidence but overall supportive of the recommendation.
	Expert consensus or clinical experience.

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Table 2
Grading of recommendation strength.

Strength of recommendation	Description
1	Strong recommendation, clearly indicating that the benefits of an intervention outweigh the harms, or vice versa.
2	Weak recommendation, where the benefits and harms are uncertain, or where evidence of any quality shows that the benefits and harms are balanced.

an intensity of 2 METs indicates that the energy expenditure is twice that of resting. METs can be converted into kilocalories (kcal) or kilojoules (kJ), with 1 MET equivalent to 1 kcal/kg/h or 4.184 kJ/kg/h.²⁴ In previous studies, PA levels were often obtained through surveys, where each specific activity was assigned a corresponding MET value. For example, reference values for energy expenditure in physically active Chinese adults are provided in Table 3.²⁵ Activity levels are typically classified into quartiles on the basis of “MET-h per week”, with levels below the lowest quartile designated as “physical inactivity”.²⁶ The MET values and intensities for various daily PAs and exercises are illustrated in Fig. 2²⁷ and Table 4.^{28–31}

The robust association between physical inactivity and the development of T2D has garnered substantial recognition.^{4,18,22,32–36} Epidemiological studies have indicated a positive correlation between physical inactivity and the risk of developing T2D.³⁷ A sustained lack of PA for 6 months has been linked to varying degrees of increases in metabolic health markers such as body weight, waist circumference, and fat distribution, along with declines in insulin sensitivity and overall health index³⁸ (B). According to a WHO report,³⁹ one-quarter of the global population fails to meet the WHO’s recommended levels of PA. Increasing PA could potentially prevent 5 million deaths annually worldwide, whereas insufficient activity has been shown to elevate the risk of mortality by 20%–30%. A meta-analysis of 19 prospective observational cohort studies by Kivimäki et al.⁴⁰ (B) revealed that physical inactivity not only increases the 10-year risk of developing diabetes (hazard ratio (HR)=1.74, 95% confidence interval (95%CI): 1.53–1.98) but also sustains a higher risk beyond 10 years (HR=1.42, 95%CI: 1.25–1.61). Furthermore, physical inactivity may impose potential cumulative risks on the health of offspring⁴¹ (C).

It has been demonstrated that increasing PA can mitigate the risk of developing T2D, potentially aiding in the prevention or delay of its onset. Two separate reviews of several prospective studies lasting 5 years or longer by Reiner et al.⁴² (B) and Cleven et al.⁴³ (B) revealed that intentionally increased PA, including both structured exercise (e.g., playing soccer) and everyday activities (e.g., cycling, shopping), was associated with long-term reductions in the risk of obesity, diabetes, and coronary heart disease (CHD). Luo et al.⁴⁴ (B) analyzed data from the UK Biobank, involving 59,326 participants who were free of diabetes, CVD, and cancer at baseline. Participants were fitted with accelerometers to record daily moderate-to-vigorous-intensity PA (MVPA), low-intensity PA (LPA), sedentary behavior, and sleep. Total PA was measured using accelerometry and expressed in milligravity

units. Daily MVPA and LPA were defined as the total time spent during waking hours engaging in activities with METs ≥ 3.0 and 1.5–2.9, respectively, recorded in minutes per day. The researchers stratified participants into 4 groups based on percentiles of total PA, MVPA, or LPA: (a) Inactive group (P0–P10), total PA/MVPA/LPA activity levels at or below the 10th percentile of the respective measure; (b) Low activity group (>P10–P50), activity levels between the 10th and 50th percentiles; (c) Moderate activity group (>P50–P90), activity levels between the 50th and 90th percentiles; and (d) High activity group (>P90–P100), activity levels above the 90th percentile. After a median follow-up of 6.8 years, an increase in total PA was significantly associated with a lower risk of developing T2D. Compared with the inactive group (P0–P10, total PA ≤ 26.1 milligravity), the high activity group (>P90–P100, total PA > 54.3 milligravity) exhibited an 80% reduction in T2D risk (95%CI: 0.14–0.29). Even after adjusting for various risk factors, the association remained significant, with the high activity group having a 68% lower T2D risk (95%CI: 0.22–0.47) than the inactive group. Additionally, the low activity group (>P10–P50, total PA: 26.2–38.0 milligravity) and the moderate activity group (>P50–P90, total PA: 38.1–54.3 milligravity) presented significantly lower T2D risks than the inactive group. For MVPA, after adjusting for LPA and other variables, a strong inverse association with T2D risk was observed. Compared with the inactive MVPA group (P0–P10, MVPA ≤ 5.2 min/day), the high activity group (>P90–P100, MVPA > 68.4 min/day) had a 74% lower T2D risk (95%CI: 0.18–0.38). Similarly, the low activity group (>P10–P50, MVPA: 5.3–25.9 min/day) and the moderate activity group (P50–P90, MVPA: 26.0–68.4 min/day) demonstrated significant reductions in T2D risk after adjusting for confounding factors. For LPA, after adjusting for various risk factors, significant reductions in T2D risk were observed only in the high activity group (>P90–P100, LPA > 444 min/day) compared to the inactive group (P0–P10, LPA ≤ 202 min/day), with an HR of 0.64 (95%CI: 0.47–0.89).

A meta-analysis by Kyu et al.⁴⁵ (B) suggested that, for the general population, the most significant health benefits from PA are observed in the range of total PA ≤ 4000 MET-min/week, with diminishing returns for health benefits when PA exceeds 4000 MET-min/week. Regarding the risk of developing diabetes, compared with individuals with insufficient PA (<600 MET-min/week), those with low PA levels (600–3999 MET-min/week), moderate PA levels (4000–7999 MET-min/week), and high PA levels (≥ 8000 MET-min/week) experienced a 14%, 25%, and 28% reduction in diabetes risk,

Table 3

Reference values of energy expenditure from physical activity in healthy Chinese adults (aged 18–64 years, selected activities).²⁵

Activity type	Specific PA	MET	Intensity
Inactive/rest	Lying quietly	1.2	Static behavior
	Standing quietly	1.6	Light
	Sitting: reading	1.4	Static behavior
	Sitting: typing	1.7	Light
Walking	Walking: 3 km/h	2.9	Light
	Walking: 6 km/h	5.2	Moderate
	Walking: 9 km/h	9.9	Vigorous
	Walking downstairs: 90 steps/min	3.1	Moderate
	Walking upstairs: carrying a load of 1–5 kg, 70 steps/min	5.5	Moderate
	Walking upstairs: 90 steps/min	8	Vigorous
	Walking upstairs and downstairs: 6-min walk test	11.9	Vigorous
	Walking uphill: 5.5°, 5 km/h	7.1	Vigorous
	Walking with load: 4 kg on the back, 5 km/h	4.5	Moderate
	Walking with load: 4 kg on the leg, 5 km/h	6.1	Vigorous
	Walking with load: 25 kg on the back, 7 km/h	11.7	Vigorous
	Lunging	5.6	Moderate
	Crawling	8.3	Vigorous
Cycling	Outdoor cycling: 10 km/h	3.6	Moderate
	Outdoor cycling: 13 km/h	4.4	Moderate
	Outdoor cycling: 15 km/h	5.5	Moderate
	Outdoor cycling: 18 km/h	6.5	Vigorous
Household duties	Laundry: washing, folding and hanging clothes	2.2	Light
	Mopping	2.6	Light
	Making the bed: changing bed linens	2.7	Light
	Tidying up the room: desk and articles	2.7	Light
	Cleaning: wiping and sweeping the floor, and disposing of waste	2.8	Light
	Shopping: pushing a trolley	3.8	Moderate
	Shopping: carrying a basket	4.3	Moderate
Fitness training	Riding a cycle ergometer: 10 km/h	3.5	Moderate
	Riding a cycle ergometer: 18 km/h	6.1	Vigorous
	Resistance training: bent-over row, 12RM, 3 sets, 12 repetitions per set, with a 2-min rest between sets	4.1	Moderate
	Resistance training: dumbbell squat, 12RM, 3 sets, 12 repetitions per set, with a 2-min rest between sets	6.8	Vigorous
	Sports: table tennis	4.1	Moderate
	Sports: soccer	6.2	Vigorous
	Aerobics	7.3	Vigorous
Running	Running: 5 km/h	4.8	Moderate
	Running: 7 km/h	7.8	Vigorous
Sports activities	Table tennis	5.7	Moderate
	Soccer: goalkeeper	2.8	Light
	Soccer: frontline	9.1	Vigorous
	Mountaineering: slow pace, feeling slightly or a little tired	6.1	Vigorous
Traditional Chinese sports	Baduanjin exercise	3.2	Moderate
	Tai Chi softball	3.5	Moderate
	Martial arts: Chinese boxing	4.1	Moderate
	Tai Chi: breakdown (hand-pushing)	7.3	Vigorous
Occupational activities	Agricultural labor: cart pushing, fertilizing, rice transplanting, hoeing, and watering	3.9	Moderate
	Mining work: walking, pneumatic drilling, and drill rod holding	2.7	Light
	Mining work: ore dressing	6.4	Vigorous

Abbreviations: MET = metabolic equivalent; PA = physical activity; RM = repetition maximum.

respectively (Fig. 3, the green dashed line). In China, a prospective cohort study⁴⁶ (B) involving 127,540 participants (70,849 women and 56,691 men) demonstrated that insufficient PA (<2100 MET-min/week for men and <4500 MET-min/week for women) significantly increased the risk of diabetes among individuals aged 40–60 years. The association remained significant after adjusting for a variety of factors, such as age, occupation, income, family history of diabetes, energy intake, body mass index (BMI), alcohol consumption, smoking, high blood pressure (HBP), and menopause (for women).

This guideline recommends that adults engage in a minimum of 4000 MET-min of PA per week to mitigate the risk of developing T2D. The following provides a simple demonstration to calculate activity levels for different types of PAs on the basis of the *Physical activity energy expenditure reference value of healthy adults*.²⁵ (a) LPA: For example, walking at a speed of 3 km/h has an MET value of 2.9. If a single session lasts 60 min, the activity level for one session would be calculated as $2.9 \times 60 = 174$ MET-min. To achieve 4000 MET-min/week, it is necessary to walk at this intensity for approximately 23 h per week. Spread evenly across 7 days,

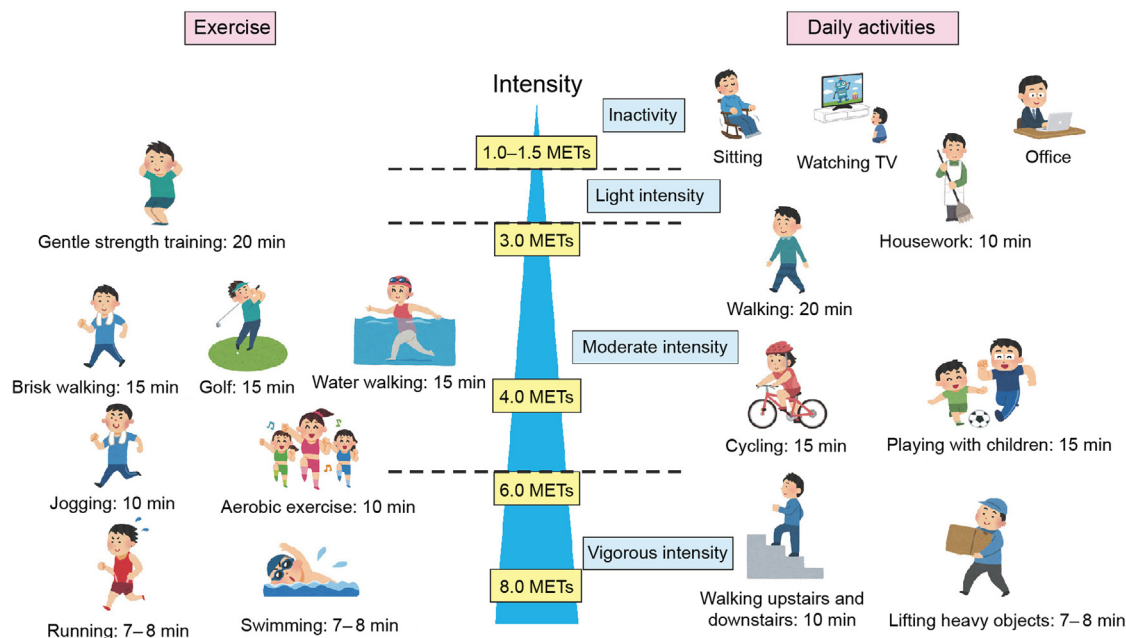


Fig. 2. Illustrative chart of physical activity and exercise intensity.²⁷ METs = metabolic equivalents.

this would require approximately 3 h of walking per day. (b) Moderate-intensity PA (MPA): For example, running at a speed of 5 km/h. To reach the minimum requirement of 4000 MET-min/week, it would require a run for approximately 14 h per week at this intensity. (c) High-intensity PA: For example, brisk walking at a speed of 9 km/h. Completing approximately 7 h of this activity per week would meet the 4000 MET-min/week requirement. Importantly, the PA or exercise we engage in during daily life typically consists of diverse types of activities and durations. If a more precise calculation of activity levels is needed, one can breakdown and perform calculations on the basis of the specific types of activities and the duration of each section throughout a single day.

Exercise can reduce the risk of developing diabetes by alleviating obesity and pre-obesity (since obesity is not solely defined by weight, the term “overweight” is not appropriate; instead, we use “pre-obesity” to better align with the definition of obesity). A Swedish study⁴⁷ (A) revealed that, following dietary and/or exercise interventions with a mean follow-up of 6 years, participants in the intervention group experienced a 2.3%–3.7% reduction in body weight, as well as improvements in blood pressure, blood lipids, and hyperinsulinemia. Additionally, 50% of individuals with impaired glucose tolerance (IGT) returned to normal glucose tolerance, and 50% of those with diabetes experienced remission. Further analysis indicated that improvements in glucose tolerance were associated with weight loss and enhanced physical fitness. The Finnish Diabetes Prevention Study (FDPS)⁴⁸ (A) implemented individualized dietary and exercise guidance in its lifestyle intervention group, suggesting at least 30 min of daily aerobic exercise and resistance training, along with a fat intake of less than 30% of total energy, with the goal of achieving a body weight reduction of more than 5%. After a mean follow-up of 7 years,⁴⁹ the intervention group showed a 43% reduction in

the risk of developing T2D. A follow-up study conducted over 13 years (median follow-up of 9 years)⁵⁰ further confirmed that a median of 4 years (range: 1–6 years) of lifestyle intervention continued to reduce diabetes risk (HR = 0.614, 95%CI: 0.478–0.789). A meta-analysis by Aune et al.⁵¹ (B) of 78 cohort studies and three randomized trials published before March 2015 revealed that, regardless of the type or intensity of exercise, PA reduced the risk of T2D by 35% (relative risk (RR) = 0.65, 95%CI: 0.59–0.71). Notably, exercise can independently lower the risk of diabetes, even without significant weight loss. In China, the Da Qing IGT and Diabetes Study⁵² (A) subgroup revealed that a 6-year exercise-only intervention reduced the risk of developing diabetes by 49% (hazard rate ratio = 0.51, 95%CI: 0.31–0.83) after 20 years. Additionally, a comparison of the lifestyle intervention group with the nonintervention group revealed no significant difference in the relative reduction of diabetes risk attributed to weight loss.

PA can help prevent the development of T2D, but the optimal forms of PA for different populations remain to be explored. A long-term cohort study from China with an 18-year follow-up (median of 10 years)⁵³ (B) found that occupational PA (OPA), which accounted for 68% of the total PA in the cohort, and domestic PA, which made up 25% of the total PA, were the most common forms of PA among the population. After adjusting for potential confounding factors, the study revealed that high-intensity PA (HR = 0.728, 95%CI: 0.570–0.929) and OPA (HR = 0.765, 95%CI: 0.596–0.982) were significantly associated with a reduced risk of diabetes compared with LPA (lowest quartile). However, domestic PA was not significantly associated with a reduced diabetes risk ($p > 0.05$). Hypoxic training refers to exercise performed in a low-oxygen environment where the oxygen levels in the tissues are lower than normal physiological levels, typically

Table 4
Classification of physical activity and exercise intensity.^{21–23,25,28–31}

Intensity of activity ^a	Issued by	Cardiorespiratory endurance exercise			Resistance exercise	Remarks
		Absolute intensity	Relative intensity		Relative intensity	
			MET ^b	%VO _{2max} , %HR _{max} , %HRR or %VO ₂ R	RPE ³¹	
Sedentary or static behavior	CSSS	≤1.5	- ^c	-	-	The Sedentary Behavior Research Network (SBRN) ²¹ recommends defining sedentary behavior as any waking behavior characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture; physical inactivity is defined as an insufficient PA level to meet specified exercise recommendations. The energy expenditure of resting quietly is 1.0 MET. ²³
	ACSM	-	-	-	-	The ACSM ²⁸ defines activity intensity below light intensity as very light (i.e., MET < 2, or <37% VO _{2max} , <57% HR _{max} and <30% HRR/VO ₂ R, or RPE < 9, or <30% RM).
	EAPC, ESC	-	-	-	-	The EAPC ²⁹ and ESC ³⁰ define the minimum activity intensity as light intensity.
Light-intensity PA or low intensity	CSSS	1.6–2.9	-	-	-	According to the WHO, ²² light-intensity activity is between 1.5 and 3 METs (i.e., activity with energy expenditure less than 3 times the expenditure at rest for that person). This can include slow walking, bathing, or other incidental activities that do not result in a substantial increase in heart rate or breathing rate.
	ACSM	2.0–2.9	37%–45% VO _{2max} 57%–63% HR _{max} 30%–39% HRR/VO ₂ R	9–11	30%–49%	
	EAPC, ESC	-	<40% VO _{2max} <55% HR _{max} <40% HRR	10–11	-	
Moderate-intensity PA or moderate intensity	CSSS	3.0–5.9	-	-	-	According to the WHO, ²² on an absolute scale, moderate intensity refers to PA/exercise that is performed between 3 and less than 6 times the intensity of rest.
	ACSM	3.0–5.9	46%–63% VO _{2max} 64%–76% HR _{max} 40%–59% HRR/VO ₂ R	12–13	50%–69%	
	EAPC, ESC	-	40%–69% VO _{2max} 55%–74% HR _{max} 40%–69% HRR	12–13	-	
Vigorous-intensity PA or high intensity	CSSS	≥6.0	-	-	-	According to the WHO, ²² on an absolute scale, vigorous intensity refers to PA/exercise that is performed at 6 or more METs.
	ACSM	6.0–8.7	64%–90% VO _{2max} 77%–95% HR _{max} 60%–89% HRR/VO ₂ R	14–17	70%–84%	Beyond vigorous intensity, the ACSM ²⁸ defines near-maximal to maximal intensity as MET ≥ 8.8, or >90% VO _{2max} , >95% HR _{max} and >89% HRR/VO ₂ R, or RPE > 17, or ≥85% RM.
	EAPC, ESC	-	70%–85% VO _{2max} 75%–90% HR _{max} 70%–85% HRR	14–16		Similarly, beyond vigorous intensity, the EAPC ²⁹ and ESC ³⁰ define near-maximal to maximal intensity as >85% VO _{2max} , >90% HR _{max} and >85% HRR, or RPE: 17–19.

Note: “-” signifies that the original text did not provide the relevant data.

^a Named mainly with reference to China’s *Physical Activity energy expenditure reference value of healthy adults*.²⁵

^b 1 MET = 1 Kcal/(kg × h) = 4.184 kJ/(kg × h).

Abbreviations: 1-RM = 1-repetition maximum; ACSM = American College of Sports Medicine; CSSS = China Sport Science Society; EAPC = European Association of Preventative Cardiology; ESC = European Society of Cardiology; HR_{max} = maximum heart rate; HRR = heart rate reserve; MET = metabolic equivalent; PA = physical activity; RPE = rating of perceived exertion; VO_{2max} = maximum oxygen consumption; VO_{2R} = oxygen consumption reserve; WHO = World Health Organization.

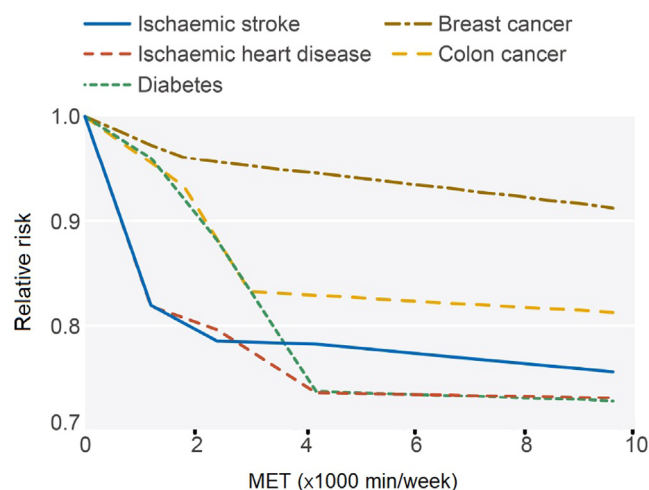


Fig. 3. The continuous risk curve between physical activity and related diseases.⁴⁵ MET = metabolic equivalent.

assessed by blood oxygen saturation (PO_2). Hypoxic training may improve glucose metabolism and overall health by activating specific signaling pathways, such as the peroxisome proliferator-activated receptor gamma coactivator-1 α (PGC1 α) and glucose transporter 4 (GLUT4). Among healthy individuals, hypoxic training may be more effective than normoxic training for improving glucose metabolism and health status. However, a narrative review by De Groote et al.⁵⁴ (C) analyzed the efficacy of hypoxic training for preventing diabetes among individuals at high risk for T2D and concluded that its preventive effects remain uncertain. High-risk populations for T2D were defined as individuals with obesity ($BMI > 30 \text{ kg/m}^2$), metabolic syndrome (as defined by NCEP ATP III,⁵⁵ Supplementary Table 1), advanced age (>65 years), and physical inactivity ($PA < 3 \text{ h/week}$) with a $BMI > 25 \text{ kg/m}^2$. Consequently, further research is necessary to explore the specific forms, frequencies, intensities, and other parameters of PA, as well as their effects on individuals at risk for T2D.

Recommendation 2: Exercise can reduce the risk of diabetes-related target organ damage and mortality (1B) while improving multiple health outcomes (1A).

Recommendation 2: Evidence and rationale

Even a PA with an intensity below the level recommended by the WHO is associated with a reduced risk of diabetes-related target organ damage⁵⁶ (B). A meta-analysis of RCTs¹¹ (A) in individuals with T2D confirmed that exercise improved glycosylated hemoglobin (HbA1c), fasting blood glucose (FBG), waist circumference, and BMI. Additionally, it induces changes in the levels of various exerkines, including increases in adiponectin, fibroblast growth factor-21 (FGF-21), and interleukin-10 (IL-10), as well as decreases in fetuin-A, interleukin-6 (IL-6), leptin, resistin, tumor necrosis factor- α (TNF- α), and visfatin. Another meta-analysis⁵⁷ (C) demonstrated that exercise improves heart rate variability in individuals with T2D, a parameter commonly used to assess cardiac autonomic neuropathy.

The MIDiab study⁵⁸ (B), which focused on the relationship between PA, sedentary behavior, and CVD risk among Chinese patients with T2D, categorized participants' self-reported PA levels into 3 groups based on the WHO-recommended minimum weekly MVPA duration (minimum defined as at least 150 min of MVPA per week; PA intensity levels are shown in Table 4). A low MVPA level was defined as $MVPA < 150 \text{ min/week}$ (below the recommended minimum weekly duration). A moderate MVPA level was defined as $MVPA$ of 150–450 min/week (1–3 times of the recommended minimum). A high MVPA level was defined as $MVPA \geq 450 \text{ min/week}$ (3 times and above of the recommended minimum). The MIDiab study revealed that 76.4% of Chinese patients with T2D did not meet the WHO-recommended minimum weekly MVPA duration. After adjusting for potential confounding factors, the study confirmed that a high MVPA level ($\geq 450 \text{ min/week}$) seemed to be associated with a reduced risk of CVD among Chinese patients with T2D (odds ratio (OR) = 0.825, 95%CI: 0.678–1.003). Increasing MVPA duration and reducing sedentary time have been shown to improve various health indicators, including blood pressure, BMI, low-density lipoprotein cholesterol (LDL-c), and HbA1c. A prospective cohort study from the UK Biobank⁵⁹ (B), which included 19,624 participants with T2D, measured PA duration and intensity over 7 days using accelerometers. After a median follow-up of 6.9 years, the study found that longer PA durations, regardless of intensity, were associated with an L-shaped relationship with all-cause and cancer mortality and a negative linear relationship with CVD mortality. Another prospective cohort study from the USA⁶⁰ (B) revealed a nonlinear, dose-dependent inverse relationship between MVPA (based on self-reported data) and diabetes-related mortality among American adults with T2D. Diabetes-related mortality was defined as death attributed to diabetes (International Classification of Diseases-10 (ICD-10) codes E10–E14), as recorded in the National Death Index. The study reported the following inverse associations between MVPA and diabetes-related mortality: (a) Compared with the inactivity group ($MVPA = 0 \text{ min/week}$), any level of MVPA was associated with a significantly lower risk of T2D-related mortality, with an insufficient activity group ($0 \text{ min/week} < MVPA < 150 \text{ min/week}$) with an HR of 0.71 (95%CI: 0.54–0.97), a sufficient activity group ($150 \text{ min/week} \leq MVPA \leq 300 \text{ min/week}$) with an HR of 0.68 (95%CI: 0.49–0.95), and a highly active group ($MVPA > 300 \text{ min/week}$) with an HR of 0.44 (95%CI: 0.32–0.60). (b) However, the reduction in diabetes-related mortality risk plateaued when MVPA exceeded 500 min/week, with no further significant decrease.

In recent years, the evidence supporting the role of exercise in preventing microvascular complications has steadily grown. The Diabetes Prevention Program Outcomes Study (DPPOS)⁶¹ (A) revealed that, although there was no significant difference in the risk of microvascular complications for the overall population, women who consistently engaged in lifestyle interventions had a significantly lower risk of developing microvascular complications than did those in the metformin (met) treatment group.

(RR_{vs. met} = 0.78, 95%CI: 0.62–0.96) and the placebo group (RR_{vs. placebo} = 0.79, 95%CI: 0.64–0.98).

Diabetic retinopathy (DR) is a common microvascular complication of diabetes and can lead to blindness in severe cases.⁶² Studies have shown that physical inactivity or low PA levels are risk factors for the development and progression of DR,^{63,64} whereas higher PA levels are associated with a reduced risk of DR onset,^{65,66} milder disease severity,⁶⁷ and slower disease progression.^{68,69} (B). A USA-based study⁷⁰ (C) explored the relationships among PA, a healthy diet, and moderate-to-severe nonproliferative diabetic retinopathy (NPDR). Using the Early Treatment Diabetic Retinopathy Study (ETDRS) grading system,⁷¹ moderate-to-severe NPDR was defined as having any of the following features (according to the 4-2-1 rule) without signs of proliferative retinopathy: more than 20 intraretinal hemorrhages in each of all four quadrants, venous beading in two or more quadrants, or prominent intraretinal microvascular abnormalities (IRMAs) in one or more quadrants. The study revealed no independent associations between PA or a healthy diet alone and the risk of moderate-to-severe NPDR. However, a combination of PA and a healthy diet had a synergistic effect. Compared with individuals with neither PA nor healthy dietary habits, individuals who had both PA and a healthy diet had a significantly lower likelihood of moderate-to-severe NPDR (OR = 0.03, $p = 0.02$). No significant associations were found between PA, diet, and mild NPDR (OR = 0.61, $p = 0.55$). A cross-sectional study by Frith and Loprinzi⁷² (C) indicated that MVPA (measured by accelerometry) but not resistance training (based on self-reported data) was associated with lower systemic inflammation, as measured by C-reactive protein (CRP) levels in patients (age = 56.3 ± 1.6 years (mean $\pm$ SEM)) with NPDR, either with (70.1%) or without (29.9%) diabetes. For every additional 30 min of MVPA per day, CRP levels decreased by 0.12 mg/dL.

A *post hoc* analysis of the Ongoing Telmisartan Alone and in Combination With Ramipril Global Endpoint Trial (ONTARGET) and Telmisartan Randomised Assessment Study in ACE-Intolerant Subjects with Cardiovascular Disease (TRANSCEND) studies⁷³ (C) revealed that, among patients with diabetes, engaging in physical exercise at least twice per week was significantly associated with a lower risk of progressing to end-stage renal disease (ESRD) and developing new-onset albuminuria compared to exercising ≤ 1 time per week (both $p < 0.0001$). Additionally, patients with diabetes who exercised daily experienced a significantly slower annual decline in the estimated glomerular filtration rate (eGFR) than did those who exercised ≤ 1 time per week ($p = 0.0004$). However, a meta-analysis by Nataraj et al.⁷⁴ (C), which included 4 RCTs, revealed that exercise did not significantly affect the serum creatinine level, eGFR, urinary albumin-creatinine ratio (UACR), urine protein-creatinine ratio (UPCR), or serum cystatin C level in adults with concomitant T2D and chronic kidney disease (CKD). This meta-analysis excluded studies with participants who had other confirmed kidney diseases, an eGFR of less than 15 mL/min/1.73 m², or who were receiving kidney replacement therapy, including dialysis. Studies involving

mixed groups of patients with hypertension or metabolic syndrome; studies without a control group or involving healthy controls without diabetes; studies assessing alternative therapies such as acupuncture, Tai Chi, dancing, or acupoint vibration; and studies reporting exercise-induced albuminuria or proteinuria were excluded. The included studies were limited in size. Further high-quality research is needed to clarify the effects of exercise on patients with coexisting T2D and CKD, including those receiving kidney replacement therapy.

Diabetes-related lower extremity complications (DRLECs) often begin with neuropathy, which is a key risk factor for foot ulcers. Foot ulcers, in turn, are critical risk factors for foot infections and amputations.^{75,76} It is estimated that up to 50% of individuals with diabetes develop neuropathy,⁷⁷ and as many as 34% may develop foot ulcers during their lifetime,⁷⁶ with 20% of those at risk of undergoing amputation.^{76,78,79} In China, multicenter studies have shown that the prevalence of lower-extremity arterial disease (LEAD) is 19.5% among individuals with diabetes over the age of 50 years,⁸⁰ whereas single-center studies have reported a prevalence of 35.4% among those over 60 years.⁸¹ The 1-year incidence of new foot ulcers among people with diabetes in China is 8.1%, and among those with existing foot ulcers, the 1-year recurrence rate is 31.6%.⁸² Globally, DRLECs account for more than 80% of all lower-extremity amputations, making them a significant cause of hospitalization in individuals with diabetes^{83–85} and severely reducing patients' quality of life.^{75,86} A systematic review and meta-analysis suggested that balance and muscle strengthening exercise have positive effects on static balance in patients with diabetic peripheral neuropathy (DPN)⁸⁷ (B). Combination exercise therapy, including strength training, range of motion (ROM), balance training, flexibility and stretching exercises, aerobic exercise, and gait training, has been shown to improve gait in patients with DPN⁸⁸ (B), enhance ankle ROM in patients with T2D, and reduce peak plantar pressure in the forefoot region⁸⁹ (B), thereby decreasing postural instability and the risk of falls. A meta-analysis by Fassora et al.⁹⁰ (A) demonstrated that exercise training significantly improves outcomes in symptomatic patients with lower-extremity peripheral artery disease (SLEPAD). Compared with no training, exercise increased the maximal walking distance (MWD) by 178 m (95%CI: 142–214, $p < 0.00001$), pain-free walking distance (PFWD) by 103 m (95%CI: 81–125 m, $p < 0.00001$), and cardiorespiratory fitness (peak oxygen uptake (VO_{2peak}) increased by 2.1 mL O₂/kg/min compared with controls, 95%CI: 1.3–2.8, $p < 0.00001$). For patients with ischemic or neuro-ischemic foot ulcers and intact skin, exercise was shown to improve walking distance and walking time in those with intermittent claudication⁹¹ (A). Compared with placebo or standard care, supervised exercise rehabilitation significantly improved MWD, PFWD, and 6-min walking distance in patients with LEAD. It also enhances functional metrics such as distance scores, speed scores, and stair-climbing scores on the Walking Impairment Questionnaire^{92,93} (A). However, there is no clear evidence that exercise reduces the risk of amputation or mortality in these patients⁹³ (C).

The relationship between PA and cognition is complex. Overall, PA is associated with a lower incidence of all-cause dementia and Alzheimer's disease, even over longer follow-up periods, suggesting that PA is a modifiable protective lifestyle factor^{94,95} (B). The cognitive benefits of long-term (more than 15 years) MVPA are particularly well established⁹⁶ (B). However, when different types of PAs are considered, higher levels of leisure-time PA (LTPA) are strongly associated with a reduced risk of cognitive impairment^{97–100} (B). In contrast, higher levels of OPA have been linked to an increased risk of dementia^{98,101,102} (B). The Nord-Trøndelag Health (HUNT) 470+ study¹⁰³ (B) further confirmed that higher levels of OPA increase the risk of mild cognitive impairment and dementia in late life.

Recommendation 3: Increased sedentary time is an independent risk factor for the development of T2D and CVD (1B). Regardless of the total amount of PA, reducing sedentary behavior and time at any given moment and frequently interrupting sedentary periods with PAs of any intensity or standing (1B) are recommended. It is advised to interrupt sedentary behavior at least every 30 min to gain blood glucose-related benefits (1C).

Recommendation 3: Evidence and rationale

Sedentary behavior is defined as any waking activity characterized by an energy expenditure ≤ 1.5 METs while in a sitting or reclining posture.²¹ The meta-analysis by Kivimäki et al.⁴⁰ (B) indicated that individuals who sat for more than 8 h per day had a significantly increased risk of CVD mortality compared with those who sat for less than 4 h per day. This risk is particularly pronounced in individuals with very low total PA levels. However, engaging in PA > 35.5 MET-h/week (equivalent to 2130 MET-min/week) may partially offset the increased risk of CVD mortality associated with prolonged sedentary behavior.

Modern lifestyles and environments have substantially increased sedentary time. A study on screen time (a common form of sedentary behavior due to the use of televisions, smartphones, computers, etc.) and quality of life among the Brazilian population¹⁰⁴ (B) revealed that screen time increased significantly over a 2-year follow-up period. The median daily screen time rose from 6.5 h to 8.0 h ($p < 0.001$). At the end of the 2-year follow-up, total screen time was negatively associated with social functioning.

According to a WHO report,²² American adults spend an average of 7.7 h per day engaging in sedentary behavior. The HUNT study¹⁰⁵ (B) indicated that, compared with sitting less than 4 h per day, self-reported sedentary behavior of ≥ 10 h per day was significantly associated with higher levels of CVD risk markers, including BMI, waist circumference, systolic blood pressure (SBP), diastolic blood pressure (DBP), triglycerides, and non-fasting blood glucose. Similar findings were corroborated by the Australian Diabetes, Obesity, and Lifestyle (AuSDiab) study¹⁰⁶ (B). Multiple studies^{107–109} (B) have demonstrated a positive correlation between sedentary behavior and increased risks of T2D, CVD events, CVD mortality, and all-cause mortality, regardless of the level of PA or exercise. A study on 6335 adults with diabetes in the

USA¹¹⁰ (B) with a median follow-up of 5.9 years reported that longer sedentary time was associated with higher risks of all-cause and cardiovascular mortality in those who were physically inactive (defined as MVPA < 10 min/week) or insufficiently active (MVPA: 10–150 min per week). However, this association was not observed in adults who engaged in sufficient PA (MVPA ≥ 150 min/week), suggesting that following guideline-recommended PA levels may offset the increased risk of prolonged sedentary behavior in adults with diabetes. A meta-analysis¹¹¹ (B) revealed that watching TV for more than 2 h per day was associated with a 20% increased risk of developing T2D (RR = 1.20, 95%CI: 1.14–1.27), and watching TV for 3 or more hours per day was linked to an increased risk of mortality. Conversely, engaging in 60–75 min of moderate-intensity PA per day (total PA ≥ 35.5 MET-h/week) could offset most of the health risks associated with sedentary behavior (HR = 1.04, 95%CI: 0.99–1.10). However, this level of PA could not completely eliminate the negative health impacts of prolonged TV watching (> 5 h/day)¹¹² (A). The MIDiab study⁵⁸ (B) further revealed that in Chinese patients with T2D, prolonged sedentary behavior (≥ 8 h per day) was independently associated with increased CVD risk (OR = 1.272, 95%CI: 1.013–1.597), regardless of weekly MVPA duration. When analyzing the combined effects of MVPA and sedentary time on CVD risk, the study found that patients who sat for ≥ 8 h per day had higher CVD risks in the moderate-MVPA group (defined as MVPA: 150–450 min/week; OR = 2.106, 95%CI: 1.043–4.255) and the low-MVPA group (MVPA < 150 min/week; OR = 1.437, 95%CI: 1.052–1.963). However, in the high-MVPA group (MVPA ≥ 450 min/week), there was no significant association between sedentary time and CVD risk, suggesting that high levels of MVPA may mitigate some of the negative health effects of prolonged sedentary behavior.

It has been demonstrated that even brief periods of sedentary behavior can negatively impact CVD risk factors. Studies have revealed that prolonged sitting for 3 h leads to significant increases in SBP and DBP¹¹³ and reduces endothelial function in the femoral artery. However, regularly interrupting sitting with light PA can prevent this decline in endothelial function¹¹⁴ (A). In individuals with pre-obesity/obesity and T2D¹¹⁵ (A), breaking up 7 h of prolonged sitting with light PA (e.g., walking) or simple resistance exercise has been associated with reduced levels of inflammation-related lipids, increased concentrations of lipids related to antioxidant capacity, and changes in molecules associated with platelet activation. Short-term interruptions to sedentary behavior may also have beneficial effects on postprandial lipid profiles in adults with T2D. Furthermore, sedentary behavior has been demonstrated to increase the risk of developing DR¹¹⁶ (B).

Interrupting prolonged sitting can improve cardiovascular risk markers in individuals, including those who are healthy, pre-obese, obese, or have impaired cardiovascular conditions.¹¹⁷ Specifically, avoiding sedentary periods longer than 15 min may help increase plasma levels of brain-derived neurotrophic factor (BDNF), which could positively impact the metabolic and cognitive functions of patients affected by

T2D, particularly those with low levels of MVPA.¹¹⁸ Breaking up sedentary time by walking may provide the most comprehensive benefits. Paing et al.^{119,120} (C) reported that taking 3-min light-intensity walking breaks for every 15 min of sitting improved FBG levels, the dawn phenomenon, and nighttime glycemic variability, suggesting that walking could be a simple therapeutic intervention to enhance glycemic control. As a result, reducing and interrupting sedentary behavior should be considered preventive and management strategies for CVD. Further research is needed to determine the long-term effectiveness of sedentary behavior interventions and to better inform CVD management guidelines.

Murtagh et al.¹²¹ conducted a meta-analysis of 13 RCTs involving individuals aged 18–59, focusing on interventions to reduce sedentary time outside of work (C). The findings indicate that there is currently insufficient evidence to determine which individual interventions (e.g., personal monitoring devices, informational or educational resources, or prompts to reduce sedentary behavior) are effective at decreasing sedentary time outside of work. Short-term follow-up (4 months) revealed that individual interventions had minimal effects on participants' sedentary time outside of work, and the medium-to long-term effects remain unclear. Future studies with high-quality evidence are needed to evaluate the impacts of interventions lasting at least 6–12 months on sedentary behavior.

3.2. Clinical Question 2: What pre-exercise assessment should be conducted for patients with T2D?

Recommendation 4: Exercise guidance should be provided by physicians or other healthcare professionals, with an emphasis on regular follow-ups and long-term management (1A).

Recommendation 5: Individuals with T2D are recommended to undergo a comprehensive, personalized exercise assessment at least once a year. Professional healthcare providers should collaborate with patients to develop and confirm the content of an exercise prescription (1E). The prescription should include details about the frequency, intensity, type, and duration of exercise, following the frequency, intensity, type, time/duration (FITT) model to describe exercise recommendations (1E).

Recommendation 6: Cardiovascular risk assessments are recommended for all patients with T2D before initiating an exercise prescription, particularly for those with CVD symptoms or microvascular diseases (1C).

Recommendation 7: For patients exhibiting signs or symptoms of CVD, a T2D duration of 10 years or more, aged over 40 years, or other diabetes-related organ damage, exercise tolerance testing is advised prior to commencing moderate-to-vigorous-intensity exercise (1E).

Recommendation 8: Educate and encourage patients with T2D who are at high risk for diabetic foot to regularly perform self-inspections of feet and monitor their condition, regardless of whether they have foot deformities, peripheral arterial disease, a history of foot ulcers, or toe/foot amputation (1E).

Recommendation 9: There are no absolute contraindications to exercise for individuals with diabetes. In the case of relative contraindications, exercise can be gradually resumed once the condition has stabilized. Before starting any exercise plan, it is advisable to consult a physician or a professional in sports medicine to ensure safety and suitability (1E).

Recommendations 4–9: Evidence and rationale

An exercise prescription¹²² is a personalized exercise plan developed by qualified professionals who are trained in exercise prescription techniques. It is based on an individual's basic health information, PA level, medical examinations and diagnoses, exercise risk screening, and fitness testing results. The prescription provides structured guidance on exercise, including type, frequency, intensity, duration, total weekly volume, progression, and precautions. It integrates both localized and whole-body exercises, as well as short- and long-term health promotion and disease prevention goals. As previously mentioned, healthcare professionals require clear and objective approaches to quantify elements of PA, such as intensity, duration, and type, to minimize misunderstandings. This guideline recommends the use of the FITT model to define exercise parameters.

The basic process for developing a fitness exercise prescription¹²² includes the following steps: gathering comprehensive health information → conducting a pre-exercise health screening → assessing cardiovascular and injury risks associated with exercise → evaluating health-related physical fitness → setting exercise goals → formulating the exercise prescription → explaining important precautions. The health information to be collected includes but is not limited to age, gender, height, weight, risk factors for chronic diseases, and health literacy.

The pre-exercise health screening process¹²² primarily includes the following steps: (a) identifying the individual's current PA level; (b) determining the presence of cardiovascular, metabolic, renal, and other diseases; (c) identifying any sign or symptom related to cardiovascular, metabolic, renal, and other diseases; and (d) assessing the intended intensity of exercise.

Exercise tolerance¹²³ refers to the maximum aerobic exercise load that can be endured without the occurrence of pathological symptoms and/or medical signs. It reflects the body's ability to extract oxygen from the air, transport it to muscle cells, and use it for mitochondrial energy production via ATPase. The gold standard for assessing cardiorespiratory endurance is maximal oxygen uptake (VO_{2max}). Although there is some debate regarding exercise tolerance testing in asymptomatic individuals with T2D,^{7,35} it is recommended to conduct such testing when patients with T2D meet 1 or more of the following criteria:³⁵ (a) over 40 years of age, regardless of whether other CVD risk factors coexist with T2D; or (b) over 30 years of age, with any of the following conditions lasting 10 years or more: T2D, HBP, smoking history, dyslipidemia, proliferative or pre-proliferative retinopathy, or kidney disease (including microalbuminuria); or (c) any age with T2D, if there is known or suspected CVD, coronary or peripheral artery disease, autonomic neuropathy, or ESRD.

Institutions with the necessary resources are encouraged to employ cardiopulmonary exercise testing (CPET)¹²⁴ to

comprehensively evaluate the overall function and reserve capacity of multiple organ systems (including the cardiopulmonary system) in patients with T2D. Although the 6-min walk test (6MWT) is less precise than the CPET, it serves as a submaximal exercise capacity assessment and can be used as the basis for developing endurance training exercise prescriptions in medical facilities where the CPET is unavailable.¹²⁵ Precautions for both the CPET and the 6MWT are detailed in [Supplementary Table 2](#).^{122,124–128} Australian exercise physiologists and physiotherapists¹²⁶ (E) have proposed seven indicators for evaluating individual cardiovascular (CV) functions in clinical practice. These include the resting and exercise heart rates; blood pressure before, during, and after exercise; the Borg rating of perceived exertion (RPE) ([Supplementary Table 3](#)³¹); and oxygen saturation during exercise.

Foot-related exercises are relatively easy to perform independently, cost-effective, and require minimal supervision. For patients with T2D who are at high risk for diabetic foot (defined as those with peripheral neuropathy but without foot ulcers, regardless of the presence of foot deformities, peripheral arterial disease, a history of foot ulcers, or previous amputation;^{129,130} see [Supplementary Table 4](#) for International Working Group on the Diabetic Foot (IWGDF) risk 1–2 criteria¹³¹), a pre-exercise foot assessment is recommended. Patients are especially encouraged to perform self-assessments. Patient education¹³² includes (a) maintaining proper foot hygiene¹³³ (E), which involves: inspecting the entire surface of both feet and the inside of shoes daily; washing feet daily and ensuring careful drying, especially between the toes; applying moisturizers to dry skin while avoiding the areas between toes; properly trimming toenails; and avoiding chemical agents, plasters, or any other methods for removing calluses or corns; (b) inspecting the feet for any cuts or sores; (c) wearing appropriate footwear; (d) regular communication and follow-ups with healthcare professionals are encouraged to monitor progress, provide training, and adjust plans as needed. According to the Cochrane reviews, foot care education can have short-term positive effects on patients' knowledge and self-reported behaviors. However, current evidence remains insufficient to demonstrate that patient education-oriented interventions and more frequent follow-ups can significantly reduce the incidence of ulcers and amputations^{134,135} (C). Patients with pre-ulcerative signs or active foot ulcers are advised not to participate in foot-loading PAs/exercises¹³³ (E). Furthermore, patients with coexisting T2D and poor glycemic control, neuropathy, retinopathy, CKD, and/or HBP should take extra precautions during exercise ([Table 5](#)^{35,136–139}).

Supervision and guidance from healthcare professionals or qualified exercise specialists can enhance the effectiveness of exercise interventions. The Italian Diabetes and Exercise Study (IDES)¹⁴⁰ (A) indicated that, within 12 months of receiving exercise counseling, patients reported increased levels of PA compared with baseline, with an 80.3% participation rate in aerobic and/or resistance exercises. In the intervention group, structured training programs were supervised in addition to exercise counseling, whereas the control group received counseling only. Compared with counseling alone, the combination of counseling and supervision significantly

improved the achievement of the HbA1c target (goal <6.5%). Other significantly improved metrics included the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), insulin levels, blood pressure, total cholesterol, high-density lipoprotein cholesterol (HDL-c), and LDL-c. Similarly, a meta-analysis of 47 RCTs¹⁴¹ (A) revealed that exercise counseling alone did not significantly improve HbA1c levels in patients with T2D. However, when combined with dietary advice, exercise counseling was associated with a reduction in HbA1c (an average decrease of 0.43%). Structured exercise training was even more strongly associated with a decrease in HbA1c (mean decrease of 0.67%). Furthermore, compared with structured exercise training of 150 min or less per week (mean HbA1c reduction of 0.36%), structured exercise programs exceeding 150 min per week (mean HbA1c decrease of 0.89%) can bring greater benefits.

Recommendation 10: Leveraging wearable devices and exercise apps to remotely monitor exercise interventions in patients with T2D may yield additional benefits (2A).

Recommendation 10: Evidence and rationale

An RCT conducted in China involving patients with T2D but without severe comorbidities or diabetes-related organ damage¹⁴² (A) demonstrated that, although the traditional exercise group reported longer exercise durations and higher adherence rates, the group using an App combined with a heart rate wearable device showed greater improvements in cardiorespiratory fitness and reductions in body fat percentage. Another prospective RCT in China involving patients with T2D aged 65 and older¹⁴³ (A) revealed that, after a 6-month intervention using a mobile telemedicine system, participants' postprandial plasma glucose (PPG) and HbA1c levels were lower than those of patients in the control group, who were managed through routine outpatient care. However, a 6-month RCT by St-Jules et al.¹⁴⁴ (A) involving patients with coexisting T2D and CKD reported no significant changes in body weight or urinary sodium and phosphorus excretion when comparing a mobile health intervention focused on self-monitoring diet and PA with a conventional behavioral counseling group. This highlights the necessity for further research to substantiate the application and benefits of different mobile health interventions in T2D management. International studies have provided preliminary evidence supporting the feasibility and acceptability of web-based weight loss interventions for men with obesity and T2D¹⁴⁵ (C), as well as comprehensive outpatient interventions aimed at breaking and reducing sedentary behavior. These interventions encompass a range of tools, including online education, self-monitoring techniques, wearable devices, smartphone apps, computer software, and health coaching¹⁴⁶ (A). Further large-scale studies are necessary to explore and confirm the effectiveness of these approaches in T2D management.

3.3. Clinical Question 3: What are the general exercise recommendations for adults with T2D?

Recommendation 11: To maintain metabolic health, it is recommended that adults with T2D engage in a minimum

Table 5
Special precautions for physical activity and exercise in adults with type 2 diabetes.^{35,136}

Health status	Precautions
Uncontrolled blood glucose	The optimal blood glucose concentration for exercise is 5.0–13.9 mmol/L. If a hypoglycemic event occurs within 24 h, it is advisable to postpone exercise to minimize the risk of experiencing hypoglycemia again. Avoid vigorous-intensity exercise when blood glucose levels exceed 16.7 mmol/L; if there is an increase in blood or urine ketones, exercise should be deferred.
Autonomic neuropathy	Be vigilant about the potential increase in hypoglycemia risk, abnormal blood pressure responses, impaired thermoregulation, elevated resting heart rate, and reduced maximal heart rate. It is advised to use the RPE scale to adjust exercise intensity appropriately. Implement strategies to prevent dehydration, hyperthermia, or hypothermia.
Peripheral neuropathy	Limit PA/exercise that might lead to foot injuries, such as long-distance hiking, jogging, or walking on uneven terrain. Non-weight-bearing exercises (such as cycling, chair exercises, and swimming) may be more suitable; however, aquatic activities should be avoided if plantar ulcers are unhealed. Check the feet daily for signs of injury and redness. Carefully select appropriate footwear and wear socks that maintain foot dryness.
Diabetic retinopathy	Refrain from selecting PA/exercise surpassing one's balance capabilities. For those with unstable proliferative and severe retinopathy, it is crucial to avoid vigorous-intensity PA/exercise, including breath-holding activities such as weightlifting and isometric training, as these could enhance the risk of vitreous hemorrhage. Patients with proliferative diabetic retinopathy should also steer clear of specific activities like high-altitude mountaineering and scuba diving. ^{137,138} Avoid engaging in PA/exercise that involve head-down positions (e.g., yoga, gymnastics) or those that cause head impacts (e.g., boxing). When maximal heart rate monitoring is unavailable, assess exercise intensity using the RPE scale, aiming for a rating of 10–12 on the 6–20-point scale. Exercise is contraindicated for individuals with unstable or untreated proliferative retinopathy, recent pan-retinal photocoagulation, or other recent surgical ophthalmic treatments. Seek advice from an ophthalmologist regarding specific PA/exercise options and limitations.
Diabetes combined with chronic kidney disease	Refrain from PA/exercise such as weightlifting or vigorous-intensity aerobic exercise that may excessively elevate blood pressure, and avoid breath-holding during activities. Elevations in blood pressure during physical activities are common; thus, LPA/exercise might be necessary to control blood pressure responses and prevent fatigue. If electrolytes are stable, low-to-moderate-intensity PA/exercise can be performed during dialysis treatment.
Hypertension ¹³⁹	Strengthen blood pressure monitoring. Avoid heavy lifting or breath-holding and ensure adequate relaxation after exercise. Engage large muscle groups through dynamic exercises such as low-to-moderate-intensity walking and cycling. Adhere to blood pressure guidelines to ascertain appropriate PA/exercise levels. Patients with comorbidities should undergo testing before selecting corresponding exercise training. When maximal heart rate monitoring is unavailable, assess exercise intensity using the RPE scale, aiming for a rating of 10–12 on the 6–20-point scale. Monitor the interactions between medications and PA/exercise.

Abbreviations: LPA = low-intensity physical activity; RPE = rating of perceived exertion; PA = physical activity.

of 450 MET-min/week of exercise (1B). For optimal glycemic control, 1100 MET-min/week of PA/exercise is suggested (1A).

Recommendation 12: It is recommended to aim for 150–300 min/week of moderate-intensity aerobic exercise (equivalent to a minimum of 450 MET-min/week or more), or 75–150 min/week of vigorous-intensity exercise (equivalent to at least 450 MET-min/week or more), or alternatively, an equivalent combination of moderate- and vigorous-intensity PA/exercise assessed in MET-min/week (1B). For optimal glycemic control, 245 min/week of moderate-intensity exercise or 160 min/week of vigorous-intensity exercise, both corresponding to 1100 MET-min/week of exercise, is recommended (1A).

Recommendation 13: For patients with T2D who are capable of engaging in more exercise, moderate overtraining can yield additional benefits. It is recommended to complete more than 300 min/week of moderate-intensity aerobic

exercise (equivalent to at least 900 MET-min/week or more), more than 150 min/week of vigorous-intensity aerobic exercise (equivalent to at least 900 MET-min/week or more), or an equivalent combination of moderate- and vigorous-intensity PA/exercise assessed in MET-min/week (2A).

Recommendation 14: Daily exercise or exercising at intervals no longer than 2 days is encouraged to enhance insulin sensitivity. For patients with T2D who cannot exercise daily or every other day, concentrating the weekly exercise volume within 1–2 days (e.g., weekends) can still offer comparable CV benefits (1B). Exercising for 30 min or more within 60 min after meals may provide greater benefits for postprandial and overall blood glucose control (2C).

Recommendation 15: A combination of aerobic and resistance exercise is recommended for optimal blood glucose and overall health outcomes (1A). It is further advised to incorporate strength/resistance training at least 2 days per week to maintain muscle, bone, and joint strength (1B).

Recommendations 11–15: Evidence and rationale

The current guideline recommendations for the minimum amount of exercise are not entirely consistent (Table 6^{7,18,35,39,147–149}). Overall, moderate to high levels of PA/exercise have been demonstrated to reduce the risks of CV and all-cause mortality in patients with T2D.^{150,151} Furthermore, MVPA is associated with a reduced incidence of CV events, microvascular complications, and all-cause mortality.¹⁵² A study by Yerramalla et al.¹⁵³ involving the Whitehall II cohort with an average follow-up of 27.1 ± 6.3 years (B) revealed that any duration of MVPA was associated with reduced all-cause mortality risk (HR = 0.61, 95%CI: 0.41–0.93, $p = 0.02$). However, a significant association was observed between PA aligning with or exceeding WHO recommendations³⁹ (≥ 150 min/week of MVPA or ≥ 75 min/week of vigorous-intensity PA) and a reduction in CV mortality risk among individuals with T2D (HR = 0.40, 95%CI: 0.16–0.96, $p = 0.04$). In light of these findings, this guideline adopts the WHO recommendations³⁹ for PA in patients with chronic conditions, including T2D. With respect to the conversion between moderate-intensity and vigorous-intensity PA/exercise, current guidelines³⁶ suggest that, for adults, 2 min of moderate-intensity PA/exercise is equivalent to 1 min of vigorous-intensity PA/exercise.

Nevertheless, achieving superior glycemic control through PA/exercise does require higher levels of activity. A meta-analysis encompassing 126 RCTs focused solely on exercise interventions (excluding studies with combined interventions such as exercise + dietary or short-term interventions lasting less than 4 weeks) involving 6718 participants with T2D (median age = 58 years, range: 39–73 years; mean diabetes duration = 7.66 ± 3.79 years; 46.19% male; median HbA1c level = 7.5%, range: 5.71%–11.14%)¹⁵⁴ (A) demonstrated a nonlinear, “J-shaped” dose–response relationship between exercise volume and HbA1c reduction. The most significant reduction occurred at 1100 MET-min/week, equivalent to 244 min/week of moderate-intensity exercise or 157 min/week of vigorous-intensity exercise. Specifically, for patients with poorly controlled blood glucose (HbA1c > 8.0%), the reduction in HbA1c ranged from 0.66% to 1.02%. For individuals with uncontrolled blood glucose ($7\% \leq \text{HbA1c} \leq 8\%$), the reduction ranged from 0.49% to 0.64%. For individuals with well-controlled blood glucose ($6.5\% \leq \text{HbA1c} < 7.0\%$), the reduction ranged from 0.4% to 0.47%. For patients with prediabetes (HbA1c < 6.5%), the reduction ranged from 0.24% to 0.38%. A study by Legaard et al.’s¹⁵⁵ team at Copenhagen University Hospital (A) further confirmed that, in patients with newly diagnosed T2D (mean age = 58.2 years, duration < 7 years; mean BMI = 33 kg/m²), combining diet-induced weight loss with 16 weeks of moderate- (3 sessions/week of aerobic and resistance exercise, 150–165 min total) or vigorous-intensity exercise (6 sessions/week of aerobic and resistance exercise, 300–330 min total) led to significant improvements in islet β -cell function (measured by the late-phase disposition index during a hyperglycemic clamp). The observed improvements exhibited a linear, dose-dependent relationship, indicating that an increase in exercise volume

resulted in more pronounced improvements. The MIDiab study⁵⁸ (B) also encouraged patients with T2D to exceed 450 min/week of MVPA to reduce medication use, improve multifactorial control, delay the onset and progression of CVD, and alleviate the disease burden. Similarly, a prospective cohort study from the UK Biobank⁵⁹ (B) revealed that light-, moderate-, and vigorous-intensity PA (VPA) were associated with a reduction in mortality risk among patients with T2D by 12.7%, 15.8%, and 22.3%, respectively. Consequently, this guideline strongly encourages adults with T2D to strive (within their capabilities) for higher levels of PA to maximize health benefits.

An analysis derived from UK Biobank data¹⁵⁶ (B) included 89,573 participants (3.1% of whom had diabetes) and used wrist-worn health monitoring devices to assess PA. The study revealed that regular exercise and weekend-focused exercise yielded comparable CV benefits when compared with a lack of exercise. Another nationwide prospective cohort study from the US National Health Interview Survey (NHIS)¹⁵⁷ (B) included 350,978 adults with an average age of 41.4 years. Participants self-reported their PA/exercise levels and were subsequently categorized into an inactive group (weekly MVPA < 150 min, $n = 190,080$) and an active group (at least 150 min/week of moderate-intensity PA/exercise or at least 75 min/week of vigorous-intensity PA/exercise, $n = 160,898$). The active group was further divided into 2 subgroups based on their exercise patterns: weekend warriors (1–2 sessions/week) and regular exercisers (≥ 3 sessions/week). After a median follow-up of 10.4 years, a total of 21,898 deaths were documented, with 4130 attributable to CVD and 6034 to cancer. Compared with the inactive group, the weekend warrior group had an HR of 0.92 for all-cause mortality (95%CI: 0.83–1.02), whereas the regular exerciser group had an HR of 0.85 (95%CI: 0.83–0.88). When the total MVPA volume was similar, the weekend warrior and regular exerciser groups exhibited comparable all-cause and cause-specific mortality rates. For weekend warriors compared with regular exercisers, the HR for all-cause mortality was 1.08 (95%CI: 0.97–1.20), for CVD mortality 1.14 (95%CI: 0.85–1.53), and for cancer mortality 1.07 (95%CI: 0.87–1.31). Thus, for patients with T2D who are unable to exercise regularly, allocating their weekly exercise regimen to 1–2 days (e.g., on weekends) may still offer CV benefits. However, further studies are needed to validate these findings.

Regarding the temporal aspect of exercise, a meta-analysis¹⁵⁸ (A) demonstrated that, in contrast to the absence of exercise after meals, postprandial exercise significantly reduced the 24-h mean glucose concentration and the postprandial glucose area under the curve (AUC) in individuals with obesity and T2D. The exercise, whether completed within 60 min or after 60 min post-meal, exhibited a comparable effect on the postprandial glucose AUC. However, when exercise was performed within 60 min post-meal, a more substantial reduction in the 24-h mean glucose concentration was observed. Additionally, individuals who engaged in exercise for 30 min or more after meals experienced a lower postprandial glucose AUC compared with those exercising for less

Table 6

Minimum exercise recommendations for adults with type 2 diabetes in selected national and international guidelines/consensus statements.

Title	Issued by	Year of publication	Minimum exercise recommendations
Chinese guidelines for exercise in diabetes ¹⁸	Chinese Diabetes Society	2012	Exercise prescriptions for individuals with diabetes should emphasize moderate-intensity aerobic exercises, with an aim to include diversity and enjoyment, performed at least 3 sessions a week for a minimum of 20 min per session.
Physical activity fact sheet ³⁹	World Health Organization (WHO)	2021	Adults with chronic conditions (such as HBP, T2D, HIV, and cancer) should aim for at least 150–300 min of moderate-intensity aerobic exercise or at least 75–150 min of vigorous-intensity exercise per week, or an equivalent combination of moderate- and vigorous-intensity activities. To achieve greater health benefits, muscle strength training of moderate or higher intensity should be conducted on 2 or more days per week, targeting all major muscle groups. As part of their weekly exercise routine, older adults should participate in various forms of physical activity at least 3 days a week, emphasizing moderate or higher intensity balance and strength training to enhance functional ability and prevent falls. Additional health benefits can be obtained by engaging in more than 300 min of moderate-intensity aerobic exercise per week; or more than 150 min of vigorous-intensity aerobic exercise; or an equivalent combination of moderate- and vigorous-intensity activities. Sedentary time should be minimized; replacing sedentary behavior with PA/exercise of any intensity (including light activities) can enhance health benefits. To counterbalance the adverse health effects of prolonged sedentary behavior, all adults and older individuals should aim to engage in moderate-to-vigorous intensity PA/exercise beyond the guidelines' recommendations.
Exercise/physical activity in individuals with type 2 diabetes: A consensus statement from the American College of Sports Medicine ³⁵	ACSM	2022	To achieve substantial health benefits, individuals should complete at least 150–300 min of moderate-intensity aerobic exercise, or 75–150 min of vigorous-intensity aerobic exercise per week, or an equivalent combination of moderate and vigorous activities. It is preferable to spread the exercise sessions across different times throughout the week. Individuals whose physical condition (such as chronic diseases, advanced age, or frailty) precludes them from tolerating 150 min of moderate-intensity aerobic exercise weekly should engage in as much PA/exercise as their abilities and conditions allow. It is recommended to perform resistance training 2–3 days per week, but not on consecutive days. To enhance joint flexibility and reduce the risk of falls, flexibility and balance exercises are recommended for adults with T2D. To improve glucose levels and insulin sensitivity, individuals should interrupt the prolonged sitting with activity breaks.
Management of hyperglycemia in type 2 diabetes, 2022. A consensus report by the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD) ¹⁴⁷	ADA, EASD	2022	Adults with T2D should engage in regular physical exercise, exceeding 150 min of moderate to vigorous-intensity aerobic exercise per week. It is advised to reduce sedentary behavior and incorporate frequent active breaks to disrupt prolonged sitting. In addition to aerobic exercise, resistance, flexibility, and/or balance training should be incorporated 2–3 times per week. Balance training is strongly recommended for elderly individuals or those with limited mobility/functionality.
Facilitating positive health behaviors and well-being to improve health outcomes: Standards of care in diabetes-2025 ⁷	American Diabetes Association Professional Practice Committee	2024	It is recommended to perform 150 min or more of moderate to vigorous-intensity aerobic exercise weekly, spread over at least 3 days, ensuring no more than 2 consecutive days without exercise. Short, vigorous-intensity, or intermittent workouts (minimum of 75 min per week) may be more suitable for younger adults or those better conditioned for physical activity. It is recommended to engage in 2–3 sessions per week of resistance exercise on nonconsecutive days, as well as 2–3 times per week of flexibility training and balance training for older adults. All adults should reduce the amount of time spent sitting each day. To maximize glucose-related benefits, prolonged sitting should be interrupted every 30 min.

(continued on next page)

Table 6 (Continued)

Title	Issued by	Year of publication	Minimum exercise recommendations
Guideline for exercise therapy of type 2 diabetes mellitus in China (2024) ¹⁴⁸	National Center of Gerontology, Chinese Diabetes Society, and China Sport Science Society	2024	Exercise frequency should be maintained at no less than 3–5 days per week, and a frequency of 1–2 days per week can also yield health benefits, provided the exercise volume is equal. An energy expenditure of at least 1000 kcal per week through physical activity should be achieved. It is recommended to exercise for at least 10 min at a time, with an accumulation of 30–60 min per day and a total of at least 150 min of moderate-intensity aerobic exercise per week. If the intensity of the exercise increases, the duration of each session can be appropriately shortened. It is recommended to walk for no less than 6000 steps per day on at least 3 days per week, with a pace of no less than 60–90 steps per min (performed based on personal condition), ideally reaching a walking prescription of 100 steps/min. It is recommended to engage in regular resistance exercise 2–3 days per week. It is recommended to perform balance and flexibility exercises at least 2–3 days per week. All individuals with T2D are advised to partake in activities of any intensity every 30 min to interrupt prolonged sitting.
Guidelines for nutrition and exercise in hyperglycemia (2024 edition) ¹⁴⁹	National Health Commission of the People's Republic of China	2024	Reduce daily sedentary time, with continuous sitting time not exceeding 60 min Aerobic exercise: 3–7 days per week, with each session lasting or accumulating more than 30 min. Individuals with no prior exercise experience can start with 20 min and gradually increase to around 60 min. Resistance training: 2–3 sessions per week, with each session consisting of 2–4 sets of 10–15 repetitions, targeting the major muscle groups of the body. Training of the same muscle group should be spaced at least 1 day apart. Flexibility training: 2–3 stretches per week, with each stretch lasting 10–30 s, and each movement repeated 2–4 times, for a total stretch time of at least 60 s per movement.

Abbreviations: ACSM = American College of Sports Medicine; ADA = American Diabetes Association; EASD = the European Association for the Study of Diabetes; HBP = high blood pressure; HIV = human immunodeficiency virus; PA = physical activity; T2D = type 2 diabetes.

than 30 min. Subgroup analysis indicated that both high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) were similarly effective in managing postprandial glucose levels. Bellini et al.¹⁵⁹ (C) suggested that the initiation of moderate-intensity exercise shortly after meals (approximately 10–20 min before the anticipated glucose peak in healthy individuals or within 15–30 min post-meal for patients with T2D) for a duration of 30 min might be adequate to augment postprandial glycemic control. It has been demonstrated that even shorter durations of moderate-intensity exercise (e.g., 15–30 min) have the potential to serve as a feasible intervention to improve glycemic responses to meals in both healthy individuals and those with T2D. Premeal exercise, particularly in a fasting state, may enhance insulin sensitivity and fat oxidation, thereby contributing to glycemic stability¹⁶⁰ and might be preferable under certain circumstances.¹⁶¹ A cohort study involving 29,836 participants (2995 with T2D at baseline)¹⁶² (B) suggested that evening MVPA (6:00 p.m.–12:00 a.m.) was associated with a lower risk of mortality, CVD, and microvascular complications in patients with obesity compared with MVPA performed in the morning (6:00 a.m.–12:00 p.m.) or afternoon (12:00 p.m.–6:00 p.m.). However, the extant evidence remains inconclusive regarding whether exercising at specific times of day confers additional benefits¹⁶³ (C).

As RCT meta-analyses^{154,164} (A) have shown, a combination of aerobic and resistance exercises is more effective at improving HbA1c levels than aerobic exercise or resistance exercise alone. Hence, it is recommended that individuals with T2D adopt a combined aerobic and resistance exercise approach to achieve better glycemic control. However, a recent retrospective study from the USA¹⁶⁵ (C) indicated that adherence to the PA guidelines³⁶ for aerobic exercise (at least 150 min/week of MPA 75 min/week of VPA, or an equivalent amount of MVPA) was significantly associated with a reduced risk of diabetes-related mortality. Conversely, adherence to the PA guidelines for strength/resistance training (at least 2 days per week or more) was not associated with a reduction in diabetes-related mortality. This finding suggests a need for further investigation into the optimal exercise regimen for T2D. The study,¹⁶⁵ which included 13,350 participants aged 20–79 years from the 1999–2006 National Health and Nutrition Examination Survey (NHANES), showed that after adjusting for covariates, only Group 3 (meeting aerobic PA guidelines but not engaging in strength/resistance training) exhibited a significantly reduced risk of diabetes-related mortality (HR = 0.57, 95%CI: 0.37–0.88). Other PA patterns did not demonstrate a significant reduction in diabetes-related mortality, including: Group 1, no exercise at all; Group 2, insufficient aerobic exercise and no strength/resistance training; Group 4, no aerobic exercise but meeting strength/resistance

training guidelines; Group 5, insufficient aerobic exercise but meeting strength/resistance training guidelines; and Group 6, meeting both aerobic and strength/resistance training guidelines.

When providing daily guidance on exercise for individuals with T2D, in addition to estimating exercise intensity via the reference values for PA energy expenditure for healthy Chinese adults²⁵ (Table 3), the Borg rating of perceived exertion (RPE) scale (Supplementary Table 3) can help patients and their companions assess real-time exercise intensity. However, it is imperative to consider the scale's applicability within the population with T2D. A study involving 3582 patients with T2D¹⁶⁶ (B) reported that the RPE scale appropriately measured exercise intensity in approximately half of the participants with pre-obesity and T2D. However, over a third of participants using the RPE scale exhibited an elevated risk of exercising at intensities above the recommended level. Factors such as T2D-related autonomic neuropathy and pre-obesity/obesity may affect the correlation between RPE scores and percentage heart rate reserve (%HRR). Future research should concentrate on identifying the characteristics of individuals for whom the RPE scale accurately estimates exercise intensity and those for whom it does not. This will ensure more tailored and effective exercise recommendations for patients with T2D.

HIIT is a combined training program that alternates between short bursts of vigorous-intensity exercise (e.g., aerobic activities performed at 65%–90% of $\text{VO}_{2\text{peak}}$ or 75%–95% of maximum heart rate (HR_{max}) for 10 s to 4 min) and active or passive recovery intervals (e.g., recovery periods of 12 s to 5 min).^{7,167} In comparison with MICT, which necessitates sustained activity at 64%–75% HR_{max} for at least 10 min,¹⁶⁸ HIIT is considered a more time-efficient training modality¹⁶⁹ that has the potential to provide substantial physiological and metabolic benefits for patients with T2D.^{7,34,170} HIIT has been shown to rapidly improve skeletal muscle oxidative capacity, insulin sensitivity, and glycemic control in adults with T2D,¹⁷¹ as well as to enhance cardiorespiratory fitness.^{172,173} Moreover, owing to its brief episodes of VPA, HIIT imposes a reduced demand on cardiac output reserves and reduces the probability of experiencing respiratory distress or symptoms, hence making it a feasible option for patients with respiratory or cardiac limitations.²⁹ An RCT involving 82 poststroke patients (mean age = 64.9 years, average of 1.8 years poststroke)¹⁷⁴ (A) indicated that after 12 weeks of exercise intervention, the increase in $\text{VO}_{2\text{peak}}$ was significantly greater in the HIIT group compared to the MICT group. In the MICT group, participants followed a PA regimen commencing at 40%HRR with an RPE of 9–11/20 for 20 min, with a gradual increase of 10%HRR and 5 min every 4 weeks, up to 60%HRR with an RPE of 13–14/20 for 30 min. The $\text{VO}_{2\text{peak}}$ increased by 1.71 mL/kg $\times$ min (95%CI: 0.55–2.86). In contrast, the HIIT group followed a regimen that included 10 intervals of 1 min of VPA at 80%HRR with an RPE of 14–17/20, increasing by 10% every 4 weeks up to 100%HRR, interspersed with nine intervals of 1-min light-intensity intervals at 30%HRR for a total of 19 min. The enhancement in the

$\text{VO}_{2\text{peak}}$ was 3.52 mL/kg $\times$ min (95%CI: 2.47–4.57). The study concluded that short-term HIIT can serve as an effective alternative to MICT for improving cardiorespiratory fitness in patients with stroke. However, a meta-analysis summarizing 65 RCTs and non-RCTs¹⁷⁵ (A) suggested that HIIT does not demonstrate a clear advantage over MICT in terms of long-term adherence. The study underscored the necessity for RCTs designed to evaluate long-term adherence (a minimum of 12 months) and dropout rates of HIIT interventions.

3.4. Clinical question 4: What are the exercise strategies for elderly patients (aged 65 years and above) with T2D?

Recommendation 16: Although the general PA/exercise recommendations for adults also apply to older adults, it is critically important to have individualized exercise programs tailored to personal safety and health conditions (2E).

Recommendation 17: Older adults are encouraged to engage in regular daily PA according to their health status. They should aim to complete, or get as close as possible to 150–300 min of moderate-intensity aerobic exercise per week (equivalent to at least 450 MET-min/week), or 75–150 min of vigorous-intensity exercise per week (equivalent to at least 450 MET-min/week), or alternatively, an equivalent combination of moderate- and vigorous-intensity activities (assessed in MET-min/week) (1A). Individuals who are physically capable and healthy enough are encouraged to exceed these levels by aiming for more than 300 min of moderate-intensity aerobic exercise per week (equivalent to 900 MET-min/week or more), or more than 150 min of vigorous-intensity aerobic exercise per week (equivalent to 900 MET-min/week or more), or an equivalent combination of moderate- and vigorous-intensity activities (assessed in MET-min/week) (2C).

Recommendation 18: Where feasible, a combined intervention of aerobic and resistance training is recommended. In addition to aerobic exercise, older adults should engage in resistance training at least 2 days per week (1A).

Recommendation 19: Flexibility and balance training should be performed 2–3 times per week. Activities such as yoga or Tai Chi can be selected based on personal preference to enhance flexibility, muscle strength, and balance (1C).

Recommendations 16–19: Evidence and rationale

Although exercise offers numerous benefits, it has not been fully integrated into geriatric medical practice. Current recommendations for exercise in older adults vary, and this skill is not routinely included in the core training for geriatricians or other healthcare professionals. Moreover, due to the relatively limited research in this area, the impact of personalized exercise programs-tailored to individual health conditions-on older adults' physical function, activities of daily living, or other domains of intrinsic capacity, such as cognition, psychological well-being, or sensory impairments (e.g., vision or hearing), remains unclear.¹⁷⁶

With advancing age, older adults typically experience a decline in PA levels and potential deterioration in health status. Additionally, health conditions can vary significantly

even among individuals of the same age, making personalized PA/exercise interventions particularly important for this population. Increased sedentary time has been associated with a higher incidence of all-cause dementia in the elderly population¹⁷⁷(B). A meta-analysis by Cunningham et al.¹⁷⁸(B) indicated that exercise can reduce all-cause and cardiovascular mortality risks in individuals aged 60 years and older while also improving physical function, quality of life, and cognitive function. The MIDiab study⁵⁸ validated that, for older adults, any PA is preferable to prolonged sedentary behavior, and reducing sedentary time is critical for their overall health.

The optimal PA/exercise regimen for elderly individuals with T2D warrants further investigation. A cohort study conducted in the USA¹⁷⁹(B) included 14,399 elderly women (mean age = 71.8 years) and assessed the relationship between 7-day MVPA levels, step counts, and all-cause mortality and CVD risk using accelerometers. Over a median follow-up of 9 years, it was observed that each standard deviation increase in MVPA time was associated with a lower risk of all-cause mortality (HR = 0.82, 95%CI: 0.75–0.90), and a similar association was observed in the step count (HR = 0.74, 95%CI: 0.69–0.80). Longer MVPA time (2.22 additional months, 95%CI: 1.58–2.85) and higher step count (2.36 additional months, 95%CI: 1.73–2.99) were correlated with increased survival. Similar effects were observed in reducing the risk of CVD. A meta-analysis¹⁸⁰ (C) indicated that HIIT enhances body composition, physical function, and cardiorespiratory fitness in healthy older adults, benefiting muscle strength, increasing muscle mass, and promoting muscle hypertrophy. It is hypothesized that similar benefits may occur in older adults with T2D. An RCT by Hwang et al.¹⁸¹ (A) involving middle-aged and older adults (46–78 years) with T2D revealed that 8 weeks of exercise training improved maximal exercise capacity, particularly walking ability, in both the HIIT and MICT groups. These findings suggest that MICT and HIIT are both feasible training options for middle-aged and elderly adults with T2D. Another meta-analysis incorporating 14 RCTs¹⁸²(A) revealed that, compared with aerobic exercise alone, combined aerobic and resistance training significantly reduced IL-6 levels in middle-aged and elderly adults with T2D ($p < 0.00001$). Long-term exercise (>3 months) yielded a more significant improvement in TNF- α levels. A separate meta-analysis of 44 RCTs involving 4793 participants aged ≥ 50 years¹⁸³ (B) suggested that the cognitive benefits of exercise have no minimum threshold. The estimated minimum effective dose for achieving clinically meaningful cognitive improvements was 724 MET-min/week, whereas benefits plateaued beyond 1200 MET-min/week. Both combined aerobic and resistance exercise and resistance-only exercise exhibited an inverted “U-shaped” dose-response relationship with cognition. The optimal PA volume for cognitive enhancement was 601 MET-min/week for combined aerobic and resistance training or 376 MET-min/week for resistance-only exercise. Whether these findings apply specifically to older adults with T2D remains to be explored further.

Sarcopenia is closely associated with the aging process and is predominantly observed in the elderly. However, it is

important to note that chronic illnesses may induce sarcopenia in younger individuals. A retrospective analysis based on data from the NHANES III (1988–1994) and linked mortality files (up to 2019)¹⁸⁴ (C) revealed that sarcopenia is more prevalent among patients with metabolic dysfunction-associated steatotic liver disease (MASLD) (accounting for 11.7%) compared with participants without MASLD (3.0%) and is associated with higher mortality rates. Insulin resistance may serve as a primary pathological mechanism underlying both MASLD and sarcopenia. Sarcopenia demonstrated a significant negative correlation with higher levels of PA (OR = 0.74, 95%CI: 0.62–0.87) and adequate relative protein intake (OR = 0.48, 95%CI: 0.35–0.65). Conversely, no definitive associations were observed with absolute calorie, carbohydrate, protein, or fat consumption. Among patients diagnosed with sarcopenia, increasing the intensity and frequency of exercise is linked to improved outcomes, particularly among the elderly. Another study¹⁸⁵ demonstrated that short-term (2 days) moderate-intensity resistance exercise (50% of 1-repetition maximum (1-RM)) effectively reduced blood glucose levels and excursion in older patients with concomitant T2D and sarcopenia. For patients with T2D and sarcopenia, the implementation of exercise regimens has the potential to promote muscle mass accumulation through the elevation of hormone levels, such as testosterone and insulin-like growth factor-1 (IGF-1). It may also regulate mitochondrial function by inhibiting TNF- α and other inflammatory factors. Exercise further enhances anti-inflammatory and antiatrophic functions by upregulating PGC-1 α and downregulating Toll-like receptors. Autophagy contributes to reducing muscle synthesis and increasing protein breakdown in patients with chronic liver disease. Exercise training can counteract this process by stimulating phosphatidic acid to restore suppressed mammalian target of rapamycin complex 1 (mTORC1) signaling, thereby maintaining muscle mass through the activation of protein synthesis and inhibition of autophagy. Resistance training is particularly effective at stimulating skeletal muscle protein synthesis. However, further research is needed to validate the effects of different types of exercise in preventing sarcopenia and improving survival rates in affected individuals.¹⁸⁴ For further recommendations on optimizing body composition in the elderly, please refer to [Table 7](#).

Yoga-based interventions have been proposed as alternatives to traditional balance and flexibility exercise therapies.¹⁸⁶ Meta-analyses indicate that yoga can significantly reduce HbA1c levels as well as fasting and postprandial blood glucose¹⁸⁷ (B) while also showing notable benefits for lipid profiles and blood pressure-related metrics¹⁸⁸(B). Tai Chi, a moderate-intensity aerobic exercise with an energy expenditure of approximately 4.0 METs, is renowned for its ability to improve balance and postural control.¹⁸⁶ Meta-analyses suggest that Tai Chi can effectively enhance dynamic balance control in individuals with DPN, demonstrating effects comparable to other exercise interventions for postural control¹⁸⁹ (B). Among elderly patients (age ≥ 60 years) with sarcopenia or frailty, the practice of Tai Chi has been associated with improved performance in the 30-s chair stand test and timed

Table 7
Exercise recommendations for optimizing body composition in the elderly.¹⁷⁶

Exercise recommendations	Reduction in adipose tissue mass and visceral/ectopic fat deposition	Enhancement of muscle mass and function	Increase in bone mass and density while reduced fracture risk
Exercise forms	Aerobic or resistance training	Resistance training	Resistance training. For individuals with joint tolerance, vigorous-intensity exercises (≥ 6 METs) are advised (such as jumping with a weighted vest during exercises), but not suggested for individuals with spinal osteoporosis. Balance training.
Exercise frequency	Aerobic exercise: 3–7 days/week Resistance training: 3 days/week	3 days/week	Resistance training: 3 days/week. Balance training: 1–7 days/week.
Overall exercise volume	Aerobic exercise: at least 450 MET-min/week Resistance training: 6–8 muscle groups, 8–10 repetitions/set, with 2–3 sets	6–8 muscle groups, 8–10 repetitions/set, with 2–3 sets	6–8 muscle groups, 8–10 repetitions/set, with 2–3 sets. 50 vigorous-intensity jumps/set. 5–10 different static and dynamic balance positions, 2–3 repetitions.
Exercise intensity	Aerobic exercise: continuous moderate-intensity (3.0–5.9 METs) training or vigorous-intensity (≥ 6 METs) interval training Resistance training: 70%–80% 1-RM	70%–80% 1-RM	70%–80% 1-RM. Use a vest loaded with 5%–10% body weight during jumps; progressively increase the height of jumps or steps. Practice mastering the most challenging balance positions not yet achieved.

Abbreviations: 1-RM = 1-repetition maximum; MET = metabolic equivalent.

up-and-go test, as well as with reduced fall frequency and lower fear of falling. However, no statistically significant differences were observed in muscle mass, grip strength, or walking speed when compared with other exercise groups¹⁹⁰ (B). An RCT from China¹⁹¹ (A) demonstrated that 24 weeks of supervised Tai Chi training, performed 3 times a week for 60 min per session, improved overall cognitive function in older adults (age ≥ 60 years) with T2D and mild cognitive impairment (MCI). In comparison with a fitness walking group that engaged at the same frequency and duration, the Tai Chi group exhibited marginally elevated Montreal Cognitive Assessment (MoCA) scores at Week 36 (mean difference between groups = 0.84, 95%CI: 0.02–1.66, $p = 0.046$). Despite the absence of statistically significant differences between the groups at Week 24 in terms of mean MoCA scores, fasting glucose, HbA1c, HOMA-IR, or the ratio of advanced glycation end products to soluble receptor of AGE (AGE:sRAGE), the collective findings suggest that Tai Chi may provide a more enduring improvement in cognitive function than walking as a sole activity. Further high-quality research is required to confirm these effects in older adults with T2D.

3.5. Clinical Question 5: What are the exercise strategies for patients with T2D and obesity/pre-obesity?

Recommendation 20: For individuals with obesity who are pursuing a reduction in body fat, it is recommended that they engage in an exercise program of over 150 min per week of at least moderate-intensity aerobic exercise (equivalent to at least 450 MET-min/week), alongside medical nutrition treatment (MNT) (1A). A sustained exercise program, spanning a minimum of 6 months, is suggested to achieve clinically

meaningful reductions in fat mass, along with enhancements in abnormal fat distribution and deposition (2B). For individuals with obesity and T2D who are capable, it is recommended to aim for more than 250 min of aerobic exercise per week (or over 1500 kilocalories expenditure) (2A) and to maintain a high level of PA.

Recommendation 21: To achieve comprehensive health benefits, including weight loss and a reduction in fat mass, individuals with obesity/pre-obesity and T2D are advised to engage in a multimodal PA/exercise program (1E). This should encompass aerobic exercise, resistance training, mind-body exercises (e.g., yoga), and balance training (1E).

Recommendation 22: It is recommended that individuals with obesity/pre-obesity and T2D engage in resistance training 2–3 times per week to maintain the quality and function of muscles, bones, and joints (1B). For those capable of doing so, it is advised to develop an exercise program based on moderate-to-vigorous-intensity resistance training to preserve lean body mass (1A).

Recommendation 23: For individuals without contraindications, an HIIT program should be developed following a thorough CV risk assessment by healthcare professionals (1B).

Recommendation 24: To prevent weight regain after weight loss, individuals with obesity or pre-obesity and T2D are advised to perform 60–90 min of daily exercise (1C). In addition, increasing daily PA levels in conjunction with supervised exercise training is recommended to minimize the risk of weight regain (1B).

Recommendations 20–24: Evidence and rationale

Obesity is a chronic metabolic disease characterized by excessive accumulation of body fat to the extent that poses health risks. This condition can be attributed to an imbalance

between energy intake and expenditure, or alternatively, to metabolic changes that result in atypical fat accumulation, distribution, deposition, and dysfunction.¹⁹² BMI (= weight/height² (kg/m²))^{192–196} and waist circumference (WC)^{192,195,196} are commonly utilized metrics for assessing pre-obesity and obesity. As per the *Guidelines for food and nutrition in adults with obesity (2024 edition)*¹⁹² published by the General Office of the National Health Commission of the People's Republic of China, the BMI range designated as healthy for adults in China is $18.5 \text{ kg/m}^2 \leq \text{BMI} < 24.0 \text{ kg/m}^2$. A BMI between 24.0 kg/m^2 and 28.0 kg/m^2 is classified as pre-obesity, whereas a BMI $\geq 28.0 \text{ kg/m}^2$ indicates obesity and a BMI $< 18.5 \text{ kg/m}^2$ is considered underweight. Central pre-obesity is defined as $85 \text{ cm} \leq \text{WC} < 90 \text{ cm}$ for men and $80 \text{ cm} \leq \text{WC} < 85 \text{ cm}$ for women. Central obesity is identified by a WC $\geq 90 \text{ cm}$ for men and $\geq 85 \text{ cm}$ for women. However, when employing BMI as a diagnostic criterion for obesity and pre-obesity, it is generally accepted that the BMI thresholds for Asian populations are $\geq 27.5 \text{ kg/m}^2$ for obesity and $\geq 23 \text{ kg/m}^2$ for pre-obesity.^{197–199} Given that BMI does not adequately reflect fat distribution and WC can be influenced by height and other factors, an increasing number of authoritative academic organizations are recommending the waist-to-height ratio (WHtR) as a simple diagnostic indicator for obesity. The WHtR can be applied to individuals aged 5 years and older and is not affected by gender, age, or ethnicity. A WHtR > 0.5 is indicative of central obesity and is associated with increased health risks.^{193,200,201} A large cross-sectional real-world study involving 15.8 million individuals aged 18 years and older in China²⁰² indicated that, on the basis of the Chinese BMI classification criteria and the ADA diagnostic standards for diabetes and prediabetes (ADA Diabetes Diagnostic Criteria: (a) presence of both FBG and HbA1c values along with (b) a self-reported history of diabetes, or (c) self-reported use of antidiabetic medication, or (d) $\text{FBG} \geq 7 \text{ mmol/L}$, or (e) $\text{HbA1c} \geq 6.5\%$; ADA Prediabetes Diagnostic Criteria: (a) presence of both FBG and HbA1c values without (b) a self-reported history of diabetes or diabetes medication use, and (c) $5.6 \text{ mmol/L} \leq \text{FBG} < 7 \text{ mmol/L}$, or (d) $\text{HbA1c} < 6.5\%$), the prevalence of diabetes and prediabetes among the adult population with pre-obesity was 9.2% and 30.7%, respectively. Among adults with obesity, the prevalence rates of diabetes and prediabetes was 14.6% and 36.9%, respectively. The considerable number of affected individuals necessitates the dedicated attention of clinical practitioners.

Overall, endurance training predominantly focused on aerobic exercise and resistance training provides significant benefits to individuals with obesity by improving CV risk factors. Endurance training can enhance cardiorespiratory fitness and reduce visceral fat, while resistance training has been demonstrated to increase muscle strength and help preserve lean body mass during weight loss efforts.²⁰³ In order to achieve weight loss and reduce total fat, visceral fat, intrahepatic fat, and blood pressure, it is recommended to prioritize exercise programs centered on moderate-intensity aerobic exercise. Nevertheless, studies on individuals with pre-obesity or obesity indicated that the anticipated weight loss from

aerobic exercise alone averages no more than 2–3 kg¹⁹⁴ (A). Compared with dietary interventions alone, the engagement in any type of exercise training (aerobic, resistance, or a combination of both) or HIIT (conducted under supervision with a thorough CV risk assessment) has been shown to lead to weight loss (average weight reduction of 1.5 kg), fat reduction, and enhanced insulin sensitivity¹⁹⁴ (A). Moreover, the combination of aerobic exercise and HIIT has been shown to be more effective in diminishing visceral fat¹⁹⁴ (A). A meta-analysis by Zhao et al.²⁰⁴ (C) highlighted that, compared with other potential control interventions (including single-mode exercise interventions, general health consultations, or standard care), the combination of aerobic and resistance exercises (≥ 3 sessions per week, lasting ≥ 3 weeks) is more effective at reducing HbA1c, BMI, HOMA-IR, and DBP. Aerobic exercises include activities such as jogging, cycling, and brisk walking, while resistance exercises involve movements such as push-ups, abdominal crunches, chest presses, leg presses, squats, and knee extensions. Compared with dietary interventions alone, resistance training (rather than aerobic training) during a calorie-restricted diet is more effective at minimizing the loss of lean body mass among individuals with pre-obesity or obesity. Therefore, in order to maintain lean body mass during weight loss and enhance muscle strength, exercise programs based on moderate-to-vigorous-intensity resistance training are recommended¹⁹⁴ (B). A retrospective analysis of RCTs¹⁹⁴ (B) revealed that adults performing high volumes of PA or aerobic exercise ($\geq 250 \text{ min/week}$) were more likely to effectively maintain weight loss, although specific activity levels based on METs were not described. An RCT by Sandsdal et al.²⁰⁵ (A) revealed that weight loss achieved through dietary adjustments (approximately 12% reduction from baseline) significantly improved the severity of metabolic syndrome, although this effect was difficult to maintain. In a 1-year follow-up intervention, participants were randomized into 4 groups: a placebo group, an exercise-only group (a minimum of 150 min per week of moderate-intensity exercise, or 75 min per week of vigorous-intensity aerobic exercise, or an equivalent combination of moderate- and high-intensity activities), a group receiving glucagon-like peptide-1 receptor agonist treatment (receiving liraglutide 3.0 mg/day), and a combined exercise plus liraglutide group. The combination treatment approach demonstrated more significant reduction in the severity of metabolic syndrome, abdominal fat, and inflammatory markers when compared with either exercise or liraglutide treatment alone. These findings suggest that the combination of exercise and liraglutide therapy may be more effective at reducing CVD risk than liraglutide therapy alone, warranting further investigation in the future.

The consensus statement for adults with excess body weight and adiposity issued by the American College of Sports Medicine (ACSM) in 2024²⁰⁶ recommends that, in order to achieve health benefits beyond weight and fat reduction, individuals with excess body weight and fat accumulation should be encouraged to engage in a multimodal PA program rather than a single-mode PA. The following elements should be incorporated: (1) aerobic activities to maintain or improve CV fitness;

(2) resistance training to enhance muscle mass and maintain or improve muscle strength and function; (3) mind-body PA approaches (e.g., yoga) to help improve mobility and balance, enhance body awareness, and positively impact other areas that contribute to overall health; and (4) balance training to adjust changes in weight distribution, support safe movement, and help prevent falls.

Research has indicated that, despite the fact that HIIT may not surpass continuous MVPA in terms of weight loss or enhanced body composition, adults with excess body weight and adiposity may experience greater benefits from HIIT, particularly with regard to body composition improvement, when compared to adults with normal weight.²⁰⁷ Consequently, the 2024 ACSM consensus recommends HIIT as a PA option for individuals without contraindications, especially when it aligns with their preferences.²⁰⁶ Furthermore, HIIT and aerobic exercise have comparable effects on combating obesity, reducing fat, and improving insulin resistance. However, HIIT exhibits a greater advantage in enhancing cardiorespiratory fitness, often assessed by $\text{VO}_{2\text{max}}$ ¹⁹⁴ (B). Research involving individuals with obesity who participated in a 12-week program (4 sessions per week) of either HIIT (10×1 -min intervals at 90% HR_{max} with 1-min active recovery; $n=16$) or MICT (45 min at 70% HR_{max} ; $n=15$) demonstrated significant improvements in peripheral insulin sensitivity (measured by the hyperinsulinemic–euglycemic clamp) the day after exercise in both groups. These improvements occurred regardless of differences in the intensity and duration of the exercise programs, with no significant differences observed between the two groups²⁰⁸ (B). Compared with mere nutritional counseling, a 12-week HIIT program significantly improved cardiorespiratory fitness in sedentary adults with pre-obesity, whereas resistance training enhanced vascular health. These findings suggest that both HIIT and resistance training positively impact cardiometabolic risk factors²⁰⁹ (C). A real-world, 12-month study assessing the effectiveness of an unsupervised HIIT program for adults with pre-obesity/obesity²¹⁰ (C) demonstrated that HIIT was generally well-tolerated by participants. Despite the observed decline in adherence to regular unsupervised HIIT over the course of the year (from an initial participation rate of 60.8% to a final rate of 19.6%), those who sustained regular HIIT demonstrated more pronounced outcomes, including reductions in body weight and visceral fat.

The safety considerations for exercise training in individuals with obesity²¹¹ primarily involve addressing the increased mechanical load and biomechanical changes that can predispose these individuals to (degenerative and inflammatory) overuse symptoms in the bones, joints, and muscles. These symptoms can be alleviated or even prevented through progressive exercise adjustments, modifying the type of aerobic exercise, and incorporating low-impact exercise programs such as aquatic exercises, cycling, and rowing. To ensure safety, it is recommended to thoroughly assess the musculoskeletal system prior to initiating exercise training and to tailor the program accordingly. For adults with pre-obesity or obesity and T2D who require weight loss, moderate-

intensity aerobic exercises involving large muscle groups (e.g., walking, stepping, rowing, or cross-training) are recommended to maintain a high training volume and maximize overall caloric expenditure during exercise. In the pursuit of maximizing the reduction of body fat, resistance training should not be the primary focus. Instead, resistance training is most effectively employed as a supplementary element, following dietary calorie restriction and aerobic training.

3.6. Clinical Question 6: What are the exercise strategies for individuals with coexisting T2D and CVD, HBP, CKD, and/or MASLD?

Recommendation 25: Individuals with concomitant T2D and CVD or HBP should undergo cardiovascular function assessments before engaging in PA. It is imperative that exercise be performed only under stable health conditions and as guided by healthcare professionals (1E).

Recommendation 26: The PA recommendations for the general adult population are also applicable to individuals with recently stabilized CVD or HBP coexisting with T2D (1E). For individuals with HBP, isometric resistance training is recommended as an effective strategy for blood pressure management (1A).

Recommendation 27: For individuals with T2D who have recently experienced fluctuations in CVD symptoms, it is recommended that they initiate their exercise regimen with low-intensity exercise and gradually increase the intensity over time (1B). These individuals should aim to complete a minimum of 150 min of moderate-intensity exercise per week (equivalent to at least 450 MET-min per week) (1C). Resistance training should be considered secondary to the stabilization or recovery of cardiovascular function (1E).

Recommendation 28: For individuals with concomitant T2D and CVD or HBP who have experienced a recent cardiovascular event, gradually increasing exercise duration under the assessment and supervision of healthcare professionals is recommended (1E). The duration of exercise sessions should be based on individual tolerance, with sessions ranging from 20 min to 45 min, or even up to 60 min, while concurrently augmenting overall daily PA. It is recommended to exercise at least 5 days a week, with no more than 2 days between sessions (1C). A minimum commitment of 12 weeks to a structured exercise program is advised.

Recommendations 25–28: Evidence and rationale

A CV function assessment prior to exercise is essential, as outlined in earlier sections. The “Standardised exercise prescription for patients with chronic coronary syndrome and/or heart failure: A consensus statement from the EXPERT Working Group”²¹² recommends a graded training program for individuals who may experience significant physical deconditioning. Early PA as well as supervised and individualized exercise interventions should be administered within a supportive environment. Once the individual has achieved hemodynamic stability, early activities can be initiated. These include progressive therapeutic activities such as in-bed

exercises, sitting at the bedside, standing, transferring to a chair, and walking.

For individuals with concomitant T2D and stable chronic coronary syndrome (CCS), it is recommended to commence the exercise program during the initial phase (the 1st week, up to 2 weeks, or until a cardiopulmonary exercise test is conducted) with a continuous training duration of 10 min at low-to-moderate intensity, then gradually increase this duration to 20 min as tolerated. During the subsequent improvement phase (Weeks 2–12), the objective is to extend the duration of the exercise to 30–45 min. In the maintenance phase (8–10 weeks after clinical recovery), individuals are encouraged to complete 20–45 min of exercise per session. In the event that the intensity is well-tolerated, the duration may be further extended to 60 min or longer.

For individuals with concomitant T2D and HBP, 150–300 min per week of moderate-intensity aerobic exercise (equivalent to at least 450 MET-min per week) is recommended. A suitable range of activities includes brisk walking, jogging, cycling, swimming, stair climbing, dancing, and ball sports. A combination of varied forms of resistance training with flexibility exercises is also encouraged. Alternatively, individuals can perform 75–150 min per week of vigorous-intensity exercise (also equivalent to at least 450 MET-min per week) or a combination of moderate- and vigorous-intensity exercise.²⁰⁰ While reductions in SBP from exercise interventions may not match those achieved with antihypertensive medications, various types of exercise interventions appear to be as effective as many other medications, lowering SBP significantly compared to controls²¹³ (C). Compared with medication alone, the combination of exercise with medication has been shown to result in further enhanced reductions in SBP for adults with HBP²¹⁴ (A). Recently, pooled data highlighted a dose–response relationship between cardiorespiratory fitness and HBP risk. For each 1 MET increase in cardiorespiratory fitness (equivalent to 3.5 mL/min/kg VO₂), the likelihood of developing hypertension decreases by 8%²¹⁵ (A). Engaging in 30 min of aerobic exercise per week has been shown to lead to an average reduction in SBP by 1.78 mmHg, in DBP by 1.23 mmHg, in resting heart rate by 1.08 beats per minute, and in mean arterial pressure by 1.37 mmHg. The reductions in SBP and DBP are nonlinear and dose dependent, with the greatest blood pressure reduction occurring at 150 min of aerobic exercise per week²¹⁶ (C). Findings from the UK Biobank²¹⁷ (B) align with these results, revealing an inverse dose–response relationship between MVPA and both CVD incidence and mortality. Higher levels of MVPA are correlated with lower risk of CVD and all-cause mortality, with no evidence of harm from high levels of PA. Multiple RCT-based meta-analyses have confirmed that aerobic exercise and dynamic resistance training interventions of various designs can reduce both office and daytime ambulatory blood pressure, with greater reductions observed in patients already diagnosed with HBP (up to 8.3/5.2 mmHg reductions in office blood pressure)^{218–221} (A). A network meta-analysis²²² (A) further demonstrated that aerobic exercise (−4.49/−2.53 mmHg), dynamic resistance exercise (−4.55/−3.04 mmHg), combined

training (−6.04/−2.54 mmHg), HIIT (−4.08/−2.50 mmHg), and isometric training (−8.24/−4.00 mmHg) all significantly lowered resting SBP and DBP. Among these, isometric squat exercises and running were identified as the most effective modes for reducing SBP (90.4%) and DBP (91.3%), respectively. Isometric exercise training (IET) is particularly effective for lowering blood pressure^{218,223–226} (A) and has been incorporated as a non-pharmacological intervention in the guidelines for primary prevention of CVD by the American College of Cardiology (ACC) and the American Heart Association (AHA).²²⁷ Moderate-to-vigorous-intensity exercise, encompassing aerobic and dynamic resistance training, is recommended as a safe and effective treatment for managing HBP.^{228–231}

Resistance training refers to exercises that involve muscle contractions against external forces.²³² While resistance exercises can lead to inappropriate increases in blood pressure, this phenomenon can be mitigated by managing other factors contributing to blood pressure elevation during exercise.²¹² Although static (isometric) resistance training may elicit significant increases in blood pressure, light-to-moderate-intensity dynamic resistance training generally results in only moderate blood pressure elevations, which are comparable to those observed in moderate-intensity aerobic exercise. blood pressure responses during resistance training are contingent not only on the type of exercise (isometric or isotonic) but also on factors such as exercise intensity (relative to an individual's maximum strength), the amount of muscle mass involved, the number of repetitions, the speed/tempo, the duration of load application, the number of sets, and the rest intervals between sets. The Valsalva maneuver (forced exhalation against a closed glottis) during resistance training can lead to more pronounced blood pressure elevations. The underlying mechanism pertains to the fact that the Valsalva maneuver augments intrathoracic pressure, reducing venous return and potentially lowering cardiac output. Physiological responses include an increased heart rate to maintain cardiac output and peripheral vasoconstriction to stabilize blood pressure. In the absence of adequate maintenance of blood pressure, it may drop due to reduced cardiac output. Termination of the Valsalva maneuver results in a precipitous increase in venous return, causing a surge in cardiac output through the constricted arterial system. This sharp blood pressure fluctuation can impede myocardial oxygen delivery, potentially triggering dangerous arrhythmias and/or reducing coronary perfusion, which may culminate in myocardial ischemia. In order to minimize risks, it is recommended that individuals should avoid holding their breath during the exertion phase of weightlifting (contraction), instead exhaling during the concentric phase and inhaling during the relaxation phase. Resistance training should be performed in a rhythmic manner, at moderate speed, and through a full range of motion. It is imperative to refrain from continuous and excessive gripping. In the event that symptoms manifest, such as dizziness, palpitations, shortness of breath, and chest pain, training should be discontinued without delay.

A meta-analysis²³³ (B) demonstrated that adults who engaged in resistance training experienced a 15% lower risk of all-cause mortality and a 17% lower risk of CVD mortality

compared with those who did not perform resistance training. A correlation has been demonstrated between the performance of 30–60 min of resistance training per week and a substantial reduction in the risks of all-cause mortality and CVD. The study also revealed that, compared with adults who do not engage in PA, those who perform either aerobic exercise or resistance training alone, or a combination of aerobic and resistance training, experience reductions in all-cause mortality and CVD mortality by 18%–29% and 40%–46%, respectively. In light of these findings, the AHA²³² recommends that all adults, irrespective of CVD status, should engage in 30–60 min of resistance training per week. The recommended exercise guidelines include the utilization of moderate weights (40%–60% of the 1-RM), the execution of 8–10 distinct exercises targeting major muscle groups, the completion of 8–12 repetitions per set, and the engagement in exercise twice per week. Additional guidance is necessary for individuals engaging in resistance training, including the integration of standardized warm-up and stretching exercises to prepare and cool down the body, and an emphasis on proper technique by teaching and familiarizing individuals with correct movement execution.

Recommendation 29: For individuals with coexisting T2D and MASLD, engaging in a minimum of 150–240 min of moderate-intensity aerobic exercise per week (equivalent to 450–720 MET-min per week) to reduce hepatic fat accumulation is recommended (1B).

Recommendation 29: Evidence and rationale

MASLD is used to denote hepatic steatosis that occurs in the presence of metabolic dysfunction or specific characteristics of metabolic dysregulation, such as pre-obesity/obesity or T2D. MASLD, previously referred to as “nonalcoholic fatty liver disease (NAFLD)”, affects approximately one-quarter of the global adult population. It is associated with T2D, CVD, lifestyle-related cancers, and liver-related morbidity and mortality. The majority of studies have indicated that 150–240 min of moderate-intensity aerobic exercise per week can reduce hepatic steatosis by 2%–4%. However, even achieving a total of 135 min per week has been demonstrated to be effective. Although the long-term clinical implications of a 2%–4% absolute reduction in liver fat has yet to be fully substantiated, this effect is comparable to that of most pharmacological treatments²³⁴ (B) and is superior to an unrestricted Mediterranean diet^{235,236} (C). Emerging evidence suggests that HIIT may offer similar benefits for reducing hepatic steatosis. However, no clear intensity-dependent relationship has been identified. Research on resistance training alone for MASLD management has yielded inconsistent results^{237,238} (C). Consequently, while resistance training cannot replace aerobic training in the management of MASLD, a combination of both is recommended. Irrespective of weight loss, attaining the recommended levels of PA may improve central obesity, cardiorespiratory fitness, and cardiometabolic health. Further investigation is necessary to explore the benefits of HIIT, sprint interval training (SIT), and resistance training on MASLD management, including potential histological changes.²³⁹

Recommendation 30: In individuals with coexisting T2D and CKD, prolonged sedentary behavior should be interrupted, and overall sedentary time should be reduced by incorporating any form of PA^{240–242} (1B).

Recommendation 31: Individuals with concurrent T2D and CKD are encouraged to engage in bouts of MVPA lasting at least 10 min per session (2C). Aim for at least one training session per week initially, and progressively increase the total weekly MVPA time to exceed 150 min per week (equivalent to at least 450 MET-min per week of PA/exercise) (1B). A training program lasting at least 12 weeks is recommended and should be conducted under the supervision of healthcare professionals (2C).

Recommendations 30 and 31: Evidence and rationale

In the Dialysis Outcomes and Practice Patterns Study (DOPPS)²⁴³ (B), patients on hemodialysis who engaged in exercise at least once a week were identified as regular exercise participants. Compared with patients who self-reported never engaging in exercise, regular PA exhibited a robust correlation with improvements in health-related quality of life (HRQoL) and survival rates. Data from the Chronic Renal Insufficiency Cohort (CRIC) study²⁴⁴ revealed that individuals with CKD who adhered to the recommended PA guidelines (>150 min of MVPA per week, with a median MVPA level of 92.5 MET-h/week in this group) experienced substantially reduced risks of atherosclerotic events (such as myocardial infarction, stroke, or peripheral artery disease), new-onset heart failure, and mortality when compared with individuals who self-reported being inactive. A comparison of CKD patients in the lowest quartile of PA (median MVPA level of 6.0 MET-h/week) and those in the highest quartile (median MVPA level of 157.7 MET-h/week) revealed that individuals with higher PA levels exhibited significantly mitigated risks of CVD mortality (HR = 0.47, 95%CI: 0.35–0.64) and all-cause mortality (HR = 0.54, 95%CI: 0.46–0.63).

Exercise is regarded as a prospective therapeutic modality for addressing vascular dysfunction in patients with CKD. Endothelial dysfunction and atherosclerosis are critical contributors to the elevated CVD risk observed in individuals with CKD. Exercise has been demonstrated to improve a variety of physiological parameters, including blood flow, luminal shear stress, arterial pressure, and tangential wall stress. Collectively, these factors can contribute to alterations in arterial function, vessel diameter, and wall thickness. The physiological effects of exercise, such as increased nitric oxide (NO) bioavailability to enhance endothelial function and induce vascular adaptations through repeated hemodynamic stimuli from exercise training, hold significant clinical relevance. These benefits include a reduced atherosclerotic risk in conduit arteries, improved pressure regulation in resistance vessels, enhanced oxygen delivery and diffusion, and better microvascular health.²⁴⁵ A substantial body of studies on exercise training have demonstrated that PA effectively reduces CV risk, primarily because of the direct hemodynamic effects of PA on arterial walls.²⁴⁵ A meta-analysis of RCTs revealed that exercise training reduces arterial stiffness (measured by pulse wave velocity (PWV)) in individuals with CKD,

particularly in those undergoing hemodialysis. Moderate-to-vigorous-intensity exercise interventions (e.g., RPE > 12) have been shown to elicit pronounced improvements in PWV. Among the various types of exercise, aerobic training has shown greater advantages in improving PWV compared with walking, resistance training, or combined aerobic and resistance training²⁴⁶ (C). Moderate-intensity combined aerobic and resistance training appears to be the most effective intervention for improving 6MWT performance and managing blood pressure in hemodialysis patients²⁴⁷ (C). For optimal outcomes, training interventions should be sustained for at least 12 weeks²⁴⁸ (C).

Cohort studies conducted across various regions and ethnic groups^{242,249–254} (B) have consistently shown that insufficient MVPA and prolonged sedentary behavior are independently associated with a decline in the eGFR and the onset of CKD. The substitution of sedentary time with PA is advantageous for the preservation of renal function. Furthermore, the replacement of 30 min of sedentary time with MVPA may offer additional benefits for kidney transplant recipients²⁵⁵ (C). A recent analysis of 1746 participants in the Look AHEAD study (with baseline eGFRs < 60 mL/min/1.73 m²) revealed the following findings for individuals with concurrent T2D and pre-obesity/obesity who were followed for a median of 12 years²⁵⁶ (B): An additional 100 min per week of total MVPA was associated with a 9% decrease in CKD progression risk. An additional 100 min per week of MVPA in bouts lasting less than 10 min was associated with an 8% reduction in CKD progression risk. An additional 100 min per week of MVPA in bouts lasting 10 min or longer was associated with a 19% reduction in CKD progression risk. From the baseline to the 4th year, participants who increased their total MVPA time by at least 63.2 min per week exhibited a 33% lower risk of CKD progression compared to those with the most significant decrease in weekly MVPA time. These findings highlight the importance of encouraging individuals with T2D and CKD to engage in MVPA sessions lasting at least 10 min and to maximize their total weekly MVPA time whenever possible.

3.7. Clinical Question 7: What are the exercise strategies for individuals with T2D at high risk of diabetic foot?

Recommendation 32: For individuals with T2D who are at high risk of diabetic foot (IWGDF risk category 1 or 2), wearing properly fitted footwear and socks during weight-bearing activities is recommended. Regular monitoring of the skin for signs of (pre)ulcerative lesions is also advised (1E).

Recommendation 33: For individuals with T2D who are at high risk of diabetic foot (IWGDF risk category 1 or 2), an 8–12-week foot training program is recommended to reduce the risk factors for ulcers. This includes the reduction of peak plantar pressures, the enhancement of foot and ankle joint mobility, and the alleviation of neuropathy symptoms (2C).

Recommendation 34: For individuals with T2D who are at low to moderate risk of diabetic foot ulcers (IWGDF risk category 1 or 2), a moderate increase in weight-

bearing activities related to walking (e.g., an additional 1000 steps/day) may be safe (2E).

Recommendations 32–34: Evidence and rationale

The most extensively studied exercise intervention for individuals at high risk of diabetic foot is supervised walking training. This intervention has been shown to improve exercise tolerance and enhance functional performance in individuals with ischemic or neuro-ischemic foot conditions, without increasing the incidence of adverse events. It is regarded as a safe and effective treatment option.¹²⁹ Currently, there is an absence of direct evidence suggesting that foot-related exercises can prevent the development of diabetic foot ulcers (DFUs).^{131,133} However, when the objective is to improve modifiable risk factors for foot ulcers, various types of foot-related exercises can be beneficial. These include exercises aimed at improving plantar pressure distribution, alleviating neuropathic symptoms, addressing sensory deficits, and enhancing foot and ankle joint mobility and strength. Such training programs, typically spanning a duration of 8–12 weeks, encompass a range of exercises, including sensory protection and stress-enhancing exercises for foot and ankle muscles, as well as functional exercises such as balance and gait training. These programs should be conducted under the guidance or supervision of physical therapists or similarly trained professionals²⁵⁷ (C).

It has been revealed that weight-bearing exercises may result in an increase in cumulative plantar tissue pressure, thereby potentially elevating the risk of foot ulcers²⁵⁸ (E). However, 2 RCTs^{259,260} (C) have demonstrated that individuals at risk of foot ulcers who engaged in weight-bearing exercise programs did not experience an elevated incidence of ulceration. The IWGDF suggests that for individuals at low or moderate risk of ulcers (IWGDF risk category 1 or 2), a slight increase in daily weight-bearing activity may be safe.¹³³ A slight increase is defined as an additional 1000 steps per day. An RCT²⁶¹ (C) demonstrated that such an increase could also benefit glycemic control in individuals with diabetes. It is recommended to increase daily steps by no more than 10% per week until an overall increment of 1000 steps per day above baseline is achieved. For individuals at high risk of ulcers (IWGDF risk category 3), there is insufficient evidence to provide recommendations for safely increasing PA.¹³³ Further research is necessary to investigate the safety and benefits of other forms of PA or exercise, such as resistance training.

Nevertheless, there is lack of adequate high-quality evidence to draw definitive conclusions regarding the effects of exercise on patients with DFU or on the healing process.^{262–265} A small study²⁶⁶ (C) indicated that non-weight-bearing exercise in an outpatient care setting was safe and feasible for patients with DFU. Recent research from a New Zealand team²⁶⁷ (C) demonstrated that a supervised exercise program conducted during hospitalization and for 2-week post-discharge was feasible, acceptable, and safe among 20 hospitalized patients with DFU. The exercise interventions were tailored to the individual and aligned with the weight-bearing restrictions set by the clinical team. For example, participants permitted heel loading engaged in exercises that involved weight-bearing through the heels only, whereas those

allowed toe loading performed exercises that exclusively used the toes. In the event that 1 leg was strictly non-weight bearing, weight-bearing exercises were conducted on the unaffected leg, and non-weight-bearing exercises were prescribed for the affected limb. The selection of aerobic exercises was determined by patient preference and the off-loading requirements of wound-removable devices. The participants completed 5–20 min of exercise, ranging from upper-limb ergometry, single- or double-leg cycling on an upright bike, or recumbent cycling, with the duration tailored to the individual's exercise tolerance level. Strength training was executed in a circuit format utilizing body weight, resistance bands, free weights, and ankle weights. Each participant completed 2–3 sets of 8–15 repetitions per exercise. The training program was designed to target key muscle groups in the lower and upper extremities and was performed in standing, seated, or unilateral postures. Common exercises included bicep curls, shoulder presses, deltoid raises, seated or bent-over rows, leg presses, sit-to-stand, squats, bridges, heel raises, side-lying or standing hip abductions, and seated knee extensions. The participants were instructed to perform moderate-intensity aerobic and resistance exercises on the basis of the RPE scale. This study demonstrated that the implementation of early, active exercise programs is feasible and safe for hospitalized patients with DFU. However, larger-scale RCTs are needed to evaluate the overall effects of such interventions on foot health, the musculoskeletal system, and long-term outcomes in this population.

T2D combined with peripheral artery disease (PAD) is a risk factor for foot ulcers. In accordance with the exercise strategies for PAD⁹³(C), it is recommended that individuals with PAD participate in supervised or home-based walking training sessions 2–3 times per week, each lasting 30–60 min. A meta-analysis on the effects of supervised exercise for individuals with SLEPAD⁹⁰(A) indicated that light-to-moderate-intensity exercise is more effective at improving the MWD and PFWD compared to high-intensity exercise. Among various training modalities—HIIT, moderate-intensity training (MIT), and moderate-intensity interval training (MIIT)—MIIT demonstrated the greatest improvement in MWD (MIIT vs. HIIT vs. MIT: 235 m (95%CI: 188–281 m) vs. 149 m (95%CI: 88–210 m) vs. 159 m (95%CI: 106–212 m)). MIT was most effective in improving PFWD (MIT vs. HIIT vs. MIIT: 138 m (95%CI: 92–185 m) vs. 72 m (95%CI: 39–105 m) vs. 92 m (95%CI: 67–118 m)), whereas HIIT was more suitable for enhancing cardiorespiratory fitness (measured by VO_{2peak} : HIIT vs. MIT vs. MIIT: 2.9 mL O_2 /kg/min (95%CI: 2.2–3.6 mL O_2 /kg/min) vs. 1.2 mL O_2 /kg/min (95%CI: 0.5–1.9 mL O_2 /kg/min) vs. 1.9 mL O_2 /kg/min (95%CI: 0.8–3.1 mL O_2 /kg/min)). A 12-week, single-center, nonblinded RCT (the Angiof-HIIT study)²⁶⁸ is currently investigating the effects of supervised vigorous-intensity interval walking training compared with moderate-intensity walking training for individuals with PAD. Previous exercise strategies for PAD have not distinguished between foot ulcer risk types. Using the Delphi method, a research team in Spain developed exercise recommendations for individuals with diabetic foot

and those at risk²⁶⁹ (E). These recommendations address various factors, such as types of exercise, their frequency, methods for checking feet, sock types for individuals with PAD, neuropathy, or foot deformities, and considerations for patients with varying foot ulcer risk levels (IWGDF risk levels 0–3). Furthermore, they also provide guidance on precautions before, during, and after PA or exercise, offering valuable insights for the direction of future research in this field.

4. Conclusion

Physical inactivity, sedentary behavior, and their associations with the onset and progression of T2D underscore the significance of enhancing PA of any intensity. Interrupting sedentary time with PA of any intensity is recommended. All adults with T2D are encouraged to engage in a minimum of 150–300 min of moderate-intensity aerobic exercise per week, or at least 75–150 min of vigorous-intensity exercise per week, or an equivalent combination of moderate- and vigorous-intensity activities (totaling at least 450 MET-min per week). For individuals with T2D who are capable, engaging in moderate-to-high levels of exercise beyond these recommendations and incorporating a variety of exercise forms (aerobic, resistance, flexibility, and balance training) is encouraged. It is imperative to allocate particular attention to specific populations, including older adults, individuals with obesity or pre-obesity, and those who have or are at high risk of developing comorbidities such as CVD, HBP, CKD, MASLD, and diabetic foot. Further high-quality, evidence-based research is necessary to create optimal exercise strategies tailored to the unique needs of populations with diabetes.

Authors' contributions

NT contributed to the conception and design of the work; FZ, YZ, JL, and QL carried out literature searches and article reviews; FZ, JZ, ZT, WW, TH, ZS, LY, YP, and NT contributed to the acquisition, analysis, or interpretation of data for the work; FZ, JZ and NT drafted the manuscript; ZT, YZ, JL, QL, WW, TH, ZS, LY, and YP critically revised the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentations of the authors.

Declaration of competing interest

The authors declare that they have no competing interests.

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Supplementary materials

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