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Maciej Dubaj[1], Karol Bigosiński[1], Marcin Caliński[1], Mateusz Raniewicz[1], Dominik Porada[2]

[1]Section of Diabetology, Student Scientific Association at the Chair and Department of Endocrinology, Diabetology and Metabolic Diseases, Medical University of Lublin, Poland

[2]Chair and Department of Endocrinology, Diabetology and Metabolic Diseases, Medical University of Lublin, Poland

Small Steps, Big Changes: The Impact of Daily Step Counts on Diabetes Prevention and Management — A Systematic Review

ABSTRACT

Objective: Physical activity is one of the primary components of non-pharmacological therapy for impaired glucose metabolism. The following study aimed to investigate the impact of daily step counts on the prevention and management of type 2 diabetes (T2D).

Materials and methods: A systematic review of 15 publications available from scientific databases (PubMed, Medline, Google Scholar, WOS) spanning the period 2014–2024 was conducted.

Results: Daily physical activity, which can be measured indirectly by the daily step count, has been shown to reduce overall morbidity and mortality from T2D. Optimal effects on glucose metabolism are seen with a daily step count ranging from 4500 to 9000 per day. Going beyond this range is not associated with a direct health benefit for T2D prevention and management.

Conclusions: Advising patients with glucose metabolism disorders, such as T2D, to take at least 10,000 steps per day is not recommended due to the lack of metabolic benefits and potential discouragement of setting too high of a goal. Recommending at least 4500 steps per day appears to be more appropriate. (Clin Diabetol 2025; 14, 1: 56–64)

Keywords: steps per day, diabetes, physical activity, treatment; monitoring, prevention

Address for correspondence:
Maciej Dubaj, MD
Section of Diabetology, Student Scientific Association at the Chair and Department of Endocrinology, Diabetology, and Metabolic Diseases, Medical University of Lublin; Jaczewskiego Str. 8, 20-954 Lublin, Poland
E-mail: maciej.dubaj99@gmail.com
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Introduction

Diabetes mellitus is one of the most prevalent chronic diseases worldwide, with an increasing incidence. The IDF (International Diabetes Federation) estimates that there are currently 537 million people aged 20–79 years with diabetes globally, regardless of etiology. This number is projected to reach 643 million in 2030, and by 2045 it could be as high as 783 million. It also poses an extremely difficult challenge for modern medicine, not only because of its prevalence in the population but also because of the number of deaths caused by it and the huge economic costs associated with the disease. In 2021, diabetes accounted for approximately 6.7 million deaths annually, and its financial burden is estimated at $966 trillion [1].

Pharmacological treatment of this disease is based on insulin therapy as well as non-insulin drugs. It has been suggested that a daily walking habit combined with the use of an oral hypoglycemic drug helps achieve better control of type 2 diabetes (T2D) [2]. Non-pharmacologic management of all patients with diabetes includes ongoing education and adequate personalized nutritional management, regular physical activity, avoidance of stimulants (e.g., smoking cessation), psychological support, proper sleep hygiene, and maintenance of normal weight or reduction of excessive weight [3].

Physical activity, which is associated with a better quality of life, can reduce morbidity and mortality from many chronic diseases, including diabetes [4]. The steps count taken per day is a simple measure of physical activity. Monitoring daily steps is now easier than ever because applications, smartwatches, wristbands, etc. are becoming increasingly available and popular [5]. For all patient groups, doing a certain amount of physical activity is better than none [4].

The main aim of this paper was to explore the relationship between taking a certain number of steps daily and the prevention and effectiveness of diabetes treatment.

Materials and methods

A systematic review of publications in the PubMed, Medline, Web of Science, and Google Scholar databases was conducted using the keywords "diabetes" and "daily step count". Initially, 450 articles were obtained. Then the time criterion was set to the period 2014–2024. One article from 2012 [6] was included due to its high value of content. As a result of eliminating duplicate articles and setting the time criterion, 134 papers were obtained. Then only full-text papers were included — 98 of them were received. Then, the authors analyzed the titles and abstracts of all papers and selected 17 articles for inclusion in the final analysis.

The impact of physical activity on the course of glucose metabolism disorders from a molecular perspective

During any physical activity, there is an increased uptake of glucose into active skeletal muscle cells through insulin-independent pathways [7]. Regular physical activity improves systemic and hepatic insulin sensitivity, counteracting the progression of insulin resistance in T2D. Physical activity has also been shown to improve the secretory functioning of pancreatic β-cells and impact the functioning of the intestinal microflora [7, 8]. The process of glucose uptake from the extracellular fluid into the skeletal muscle cell is mediated by 2 families of proteins found in the cell membrane: solute carriers family 2 (SLC2), which includes 14 glucose transporters (GLUT1-14), and solute carriers family 5 (SLC5), which includes 6 sodium-dependent glucose cotransporters (SGLT1-6). The GLUT4 isoform is most abundant in skeletal muscle cells, where it moves from intracellular vesicles to the cell surface when exposed to physical activity, playing a significant role in glucose transport into muscle. It is worth noting here that in diabetes, there is an impairment of insulin-stimulated GLUT4 translocation to the cell surface, while exercise-induced translocation remains intact [9]. In the cell, glucose becomes phosphorylated by hexokinase, forming glucose-6-phosphate. According to some studies, aerobic training increases hexokinase activity [9]. Glucose is stored in the cell as glycogen. It is known that aerobic activity increases the level and rate of expression of glycogen in the cell (walking up stairs can intensify glycogen synthesis in the muscles by up to 2 times). The process of glycolysis in the cell takes place after fructose-6-phosphate is converted to fructose-1,6-bisphosphate by the enzyme phosphofructokinase (PFK). Studies have shown a more than twofold increase in PFK activity in association with aerobic training. Therefore, it can be concluded that regular physical activity induces a beneficial effect on systemic glucose homeostasis in every aspect occurring at the molecular level [9].

Muscle cells receive fatty acids through chylomicrons, the number of which remain unchanged, even with chronic training. Instead, total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) levels decrease, while high-density lipoprotein cholesterol (HDL-C) concentrations increase. It is worth noting that lipids could be the substrate in short-interval light- to moderate-intensity exercise [10]. Triacylglycerol lipase of fatty acids is characterized by increased activity during training compared to resting [11]. All these processes prove that physical exercise in any form has health-promoting effects in the context of molecular mechanisms. A summary of the molecular mechanisms of the effects of physical activity on carbohydrate and lipid metabolism is shown in Figure 1.

Daily step count and its health effects

When giving recommendations to patients on the appropriate amount of physical activity, doctors often face the problem of defining the appropriate length or intensity. In 2004, Tudor-Locke and Bassett proposed a classification of physical activity according to the daily step count [12].

Daily step count vs. overall mortality

It is widely believed that a daily step count appropriate for good health is 10,000, but there is only limited scientific evidence to support this thesis. Moreover,

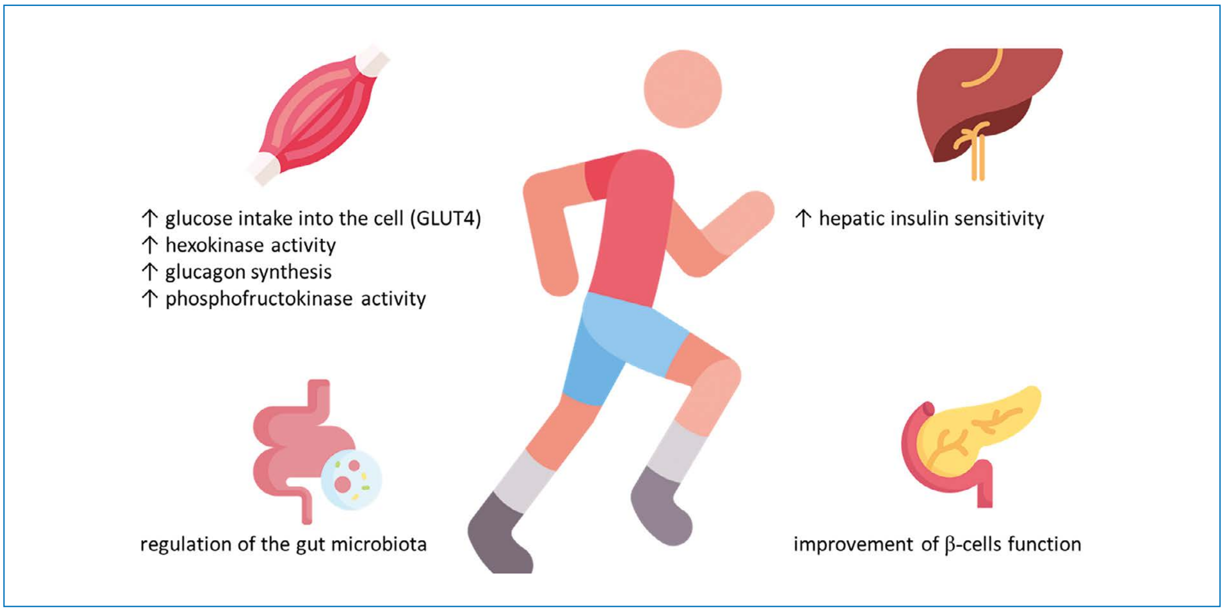

Figure 1. Molecular Mechanism of the Effect of Physical Activity on Carbohydrate and Lipid Metabolism [7–11]

recommending this scale of activity to a patient may discourage people from following it, intensifying a sedentary lifestyle. Saint-Maurice, in a study in a group of 4840 people, observed that a higher daily number of steps was associated with a reduction in overall mortality. According to them, walking 8000 steps per day significantly reduced all-cause mortality compared to 4000 steps per day (HR = 0.49; 95% CI = 0.44–0.55), similarly for 12,000 steps per day (HR = 0.35; 95% CI = 0.28–0.45). Interestingly, mortality was not affected by walking intensity [13]. Similar conclusions were made by Paluch et al. in their meta-analysis of 15 studies (n = 47,471). They divided the subjects into 4 groups, depending on the median daily number of steps, respectively: 3553, 5801, 7842, and 10,901. The HR for mortality compared to group one was, respectively: HR = 0.60; 95% CI = 0.51–0.71 for group two; HR = 0.55; 95% CI = 0.49–0.62 for group three; and HR = 0.47; 95% CI = 0.39–0.57 for group four [14]. This means that taking up physical activity reduces mortality from any cause; however, there is no definitive ratio between these phenomena. In a meta-analysis, Stens et al. (n = 111,309) found that taking 2517 steps per day reduces the risk of death from any cause (HR = 0.92; 95% CI = 0.84–0.999). This relationship was observed up to 8763 steps (HR = 0.40; 95% CI = 0.38–0.43). Above this value, a significant decrease in mortality was no longer observed, so 8800 steps per day was defined as the health optimum [15]. Moreover, Sheng et al. (n = 132,674) indicated that a 1000-step increment is associated with an 11% reduction in mortality (RR = 0.87; 95% CI = 0.84–0.91). In another subgroup of this study (n = 130,209), the authors observed that taking 6893 steps per day versus 4228 steps was associated with a 21.6% lower risk of death from any cause, and taking 9188 steps per day was associated with a 36.65% lower risk (RR = 0.31, 95% CI = 0.23–0.42) [16]. A Polish meta-analysis by Banach et al. (n = 226,889) found that increasing the number of steps by 1000 per day was associated with a reduced risk of death from any cause by 15% (HR = 0.85; 95% CI = 0.81–0.91). In addition, daily step numbers of 5537, 7370, and 11,529, were associated with 48, 55, and 67% lower mortality rates, respectively, compared with 3867 steps [17]. Jayedi et al. in their meta-analysis indicated that each additional 1000 steps were associated with lower mortality (HR = 0.88; 95% CI = 0.83–0.93), as was a total of 10,000 steps (HR = 0.44; 95% CI = 0.31–0.63) [18]. A similar number of steps was indicated by Del Pozo Cruz et al. (n = 78,500). According to them, it was associated with lower overall mortality [mean rate of change (MRC) = = –0.08; 95% CI = –0.11, –0.06] [19]. Ahmadi et al. (n = 72,174) defined the minimum daily step count as 4000–4500, and the best in reducing the risk of mortality from any cause as 9000–10,500 (HR = 0.61; 95% CI = 0.53–0.71 for high sedentary time and HR = 0.69; 95% CI = 0.52–0.92 for low sedentary time) [20]. The results of the above studies suggest that there is no single and universal answer to the question of the optimal daily number of steps. Based on these studies, even at just 4000 steps per day, there may be health benefits, and increasing this number by 1000 steps is associated with a significantly lower risk of death from any cause. The mortality benefit is proportional to the increase in steps up to 8000–9000 per day.

Interestingly, measuring the number of steps using a wrist pedometer can be characterized by an overestimation of the number of steps, falsifying the results. On the other hand, using a much more precise accelerometer requires a minimum speed of 67 m/min for the measurement to be reliable [16]. In addition, it is indicated that an accelerometer placed near the waist performs better than one on the wrist [21]. This shows that the accuracy of measurements is also affected by the selection of the right device.

Daily steps and progression and treatment outcomes of diabetes

Impact on anthropometric measurements

Majoo et al. conducted a study in a group of 190 people with an average duration of diabetes of 10 years. The average number of steps in this group was 5338, which was characterized as low physical activity. Increasing the number of steps by a standard deviation value (SD = 2609) was associated with a significant reduction in BMI by 1.6 kg/m^2 (95% CI = –2.4, –0.8), waist circumference by 4.6 cm (95% CI = –6.4, –2.8), and waist–hip ratio (WHR) by 0.01 (95% CI = –0.02, –0.00). In addition, increasing the number of steps by the SD value resulted in a decrease in HbA1c by 0.21% (95% CI = –0.41, –0.02), but when adjusted for BMI, WC, or WHR the change was not significant [6]. Herzig et al. (n = 78) noted that taking at least 6520 steps per day or walking for 90 minutes at a speed of 2–3 km/h resulted in a statistically significant reduction in low-density lipoprotein (LDL) levels by 0.7 mmol/L (95% CI = 0.1–1.2) and visceral fat area by 16 cm^2 (95% CI = 7–25) in a 3-month follow-up. In contrast, they found no significant relationship between the daily number of steps and glucose and insulin levels at fasting and 2 h after main meals, or the HOMA-IR index [22]. Improving these indices as components of the metabolic syndrome would enable better control of diabetes. On the other hand, Nakanishi et al. (n = 236), in a 12-month follow-up, noted that patients taking at least 7500 steps per day were significantly more likely to reduce BMI (HR = 4.54; 95% CI = 1.48–13.920) and visceral fat volume (HR = 6.96; 95% CI = 1.98–24.45), independently of sedentary time and waist circumference at high ST segment on electrocardiography (ECG) (HR = 5.27; 95% CI = 1.69–16.47) [23]. Thus, they indicated that physical activity is an important component of diabetes treatment. Ferrari et al. in a study in Latin American countries (n = 2524) observed a weak negative correlation between daily step count and BMI ($r = -0.17$; $p < 0.05$) and waist circumference ($r = -0.16$; $p < 0.05$) [24]. The above data suggest that taking an adequate number of steps (6500–8000) is associated with beneficial effects on metabolic and anthropometric parameters, particularly BMI and adipose tissue volume.

Impact on the risk of developing type 2 diabetes and carbohydrate metabolism

Kraus et al. (n = 7118) divided their study group into 4 cohorts according to average number of steps: 1831, 4652, 7096, and 11,240. The authors observed that increasing the daily number of steps by 2000 to 10,000 steps resulted in a 5.5% significantly lower risk of developing diabetes (HR = 0.95; 95% CI = = 0.92–0.97). The aforementioned number of steps corresponds to about 20 minutes of walking at a moderate pace [25]. Cuthbertson et al. in a study in a group of 6634 U.S. residents of Hispanic origin observed that each 1000-step increase was associated with a 2% decrease in the risk of developing diabetes (HR = = 0.98; 95% CI = 0.95–1.0). Moreover, in adults with pre-diabetes, taking 10,000 steps resulted in a 26% lower risk of developing diabetes compared to 3400 steps (HR = 0.74; 95% CI = 0.58–0.95) [26]. The lower risk of diabetes in this case was mainly related to the reduction of obesity as one of the main factors in the development of this disease, as well as improvements in muscle glucose transport and metabolism [26, 27]. Ballin et al. in a study in a group of 3055 seniors in their 70s observed that a reduction in diabetes risk is most strongly associated with 4500 steps per day, decreasing slightly at 6000 steps, and stabilizing at 8000 steps a day. Those with ≥ 4500 steps per day had a 59% lower risk of developing diabetes than those with a lower step count (HR = 0.41; 95% CI = 0.25–0.66). The authors identified physical activity as a factor that reduces insulin resistance by affecting muscle glucose metabolism and reducing the visceral adipose tissue [28]. Other conclusions were reached by Perry et al. (n = 5677). They noted that any increase in daily steps is reflected in a reduction in diabetes risk. With an increase from 6000 to 10,700, the risk decreased by 44% (95% CI = =15–63%). At an activity of 4301 (10th percentile) the predicted cumulative incidence of the disease was 2.3% (95% CI = 1.4–3.3%), and at 13,245 steps (90th percentile) it was already 0.8% (95% CI = 0.3–1.3%) over 5 years. This represents as much as a 3-fold decrease. Moreover, the result was not influenced by BMI, length of time spent sedentary, or age and gender [29]. Master et al. (n = 6042) observed a decrease in the risk of diabetes with an increase in the number of steps up to about 9000, while after that it remained constant. Moreover, increasing the number of steps resulted in a 36-50% decrease in BMI [30].

Siddiqui et al. (n = 95) observed that an increase in the average daily number of steps from 4610 to 7245 in the study group resulted in a statistically significant decrease in HbA1c of 1.04% over 3 months. In the control group, taking an average of up to 3431 steps per day, an increase in HbA1c of 0.86% was observed. In contrast, there was no significant change in BMI values in either group. The authors concluded that taking at least 7000 steps per day has a positive effect on glycemic levels in the diabetic patient population [31]. Wang et al. (n = 9509) observed that taking at least 5000 steps per day reduces average weekly glucose levels by about 13 mg/d (95% CI = –22.6; –3.14). An extra day of taking > 8000 steps reduces average weekly glucose levels by 0.47 mg/d (95% CI = –0.77; –0.16) [32]. Similar conclusions were made by Dhali et al. in their review. They noted that increased physical activity resulted in a decrease in fasting glucose levels by 12.37 mg/d, (95% CI = –20.06, –4.68) and HbA1c by 0.35% (95% CI = –0.70, –0.01) [33]. Kerr et al. in a study of 121 Hispanic patients noted that increased step count was associated with decreased HbA1c levels in those < 50 years of age ($r = -0.47$; $p < 0.005$) and in those who were overweight ($r = -0.429$; $p = 0.005$) [34]. Fayehun et al. in a Nigerian study in a group of 121 diabetic patients noted that a difference of 2913 steps between the study and control groups was associated with a 0.74% lower HbA1c level (95% CI = –1.32%, –0.02%), which indicated a significant improvement in control of carbohydrate balance [35]. The results from the above studies show a significant relationship between daily step count (preferably in the range of 4500–8000) and parameters of carbohydrate metabolism in patients with T2D.

Impact on systemic complications of type 2 diabetes

Researchers agree that physical activity, especially walking, is fundamental to diabetes treatment [36, 37]. It is also one of the effective methods of preventing systemic complications of T2D [36–38].

Macroangiopathy

Yu et al. (n = 1415) analyzed the effect of the step count on the course of diabetes and its associated complications. An increased daily number of steps was associated with reduced subclinical myocardial injury (lower troponin T [$\beta = -0.207$; $r = 0.14$; $p < 0.001$]) [39]. Zucatti et al. (n = 151) observed that taking > 4873 steps per day was correlated with lower systolic blood pressure (SBP) values ($\beta = 6.40$; 95% CI = = 0.31–12.46; $p = 0.040$), 24-hour SBP ($\beta = 5.32$; 95% CI = 0.89–9.74; $p = 0.019$), daytime SBP ($\beta = 6.29$; 95% CI = 1.90–10.69; $p = 0.005$), and mean daily BP ($\beta = 3.24$; 95% CI = 0.20–6.28; $p = 0.037$) [40]. Moreover, Yates et al. in a randomized trial (n = 9306) observed that an increase in daily step count by 2000 was associated with a decrease in the risk of a cardiovascular event by 10% (HR = 0.90, 95% CI = 0.84–0.96), and by 8% (HR = 0.92; 95% CI = 0.86–0.99) after one year [41]. Dasgupta et al. (n = 230) noted that an increase of 1000 steps/day was significantly associated with a decrease in carotid-femoral pulse wave velocity (cfPWV) of 0.13 m/s (95% CI = –0.2, –0.02). CfPWV is the gold standard for measuring vessel wall stiffness and overall vascular health [42].

Microangiopathy

Yu et al. (n = 1415) showed that higher daily step count was associated with significantly better renal function and reduced microalbuminuria (lower urine albumin/creatinine ratio [$\beta = -0.0268$; $r = 0.087$; $p < 0.001$], and higher glomerular filtration rate [$\beta = 0.709$; $r = 0.16$; $p < 0.001$]) [40]. These data are confirmed by a meta-analysis by Cai et al. The authors, while not indicating the exact number of steps, note the positive effect of physical activity on renal function in patients with diabetes. They observed increases in the glomerular filtration rate [standardized mean difference (SMD) = 0.01, 95% CI = 0.02–0.17] and decreases in the urinary albumin creatinine ratio (SMD = −0.53, 95% CI = −0.72, −0.34), rate of microalbuminuria (OR = 0.61, 95% CI = 0.46–0.81), rate of acute kidney injury (OR = 0.02, 95% CI = 0.01–0.04), and rate of renal failure (OR = 0.71, 95% CI = 0.52–0.97) [43]. Unfortunately, patients with diabetic chronic kidney disease take significantly fewer steps per day than patients without diabetes (3580 vs. 5628, $p = 0.008$) [44]. Many studies have also reported on the effectiveness of aerobic exercise and physical activity in preventing and inhibiting the progression of microvascular complications of T2D: diabetic foot, diabetic neuropathy, or diabetic retinopathy [45–52]. However, these studies do not indicate the exact cutoff points for the daily number of steps. The results of the presented studies lead to the conclusion that aerobic activity, including walking and Nordic walking, are essential elements in the prevention and treatment of diabetes in the context of its complications.

The above data from the literature review are presented in Table 1. The effect of the optimal number of steps on the development and control of diabetes is shown in Figure 2.

Table 1. The Effect of Daily Step Counts on the Development and Control of Diabetes

Research	Country	Study group	Device used to measure steps	Mean number of steps (SD)	Significant increase in the number of steps	Effect of increasing the number of steps
Manjoo et al. 2012 [6]	Canada	n = 190	Pedometer	5338 (2609)	2609	↓ WHR, ↓ BMI, ↓ waist circumference, ↓ HbA1c
Herzig et al. 2014 [22]	Finland	n = 78	Accelerometer	5870 (3277)	> 6520	↓ LDL, ↓ visceral fat
Nakanishi et al. 2021 [23]	Japan	n = 236	Pedometer	6666 (2981)	7500	↓ BMI, ↓ visceral fat, ↓ waist circumference
Ferrari et al. 2021 [24]	Chile, Argentina, Brazil, Columbia, Costa Rica, Venezuela, Peru, Ecuador	n = 2524	Accelerometer	10,699 (5148)	1000	↓ BMI, ↓ waist circumference
Kraus et al. 2018 [25]	USA	n = 7118	Pedometer	1831 (1151) 4652 (659) 7096 (800) 11,240 (2344)	2000, up to 10,000	↓ the risk of developing diabetes
Cuthbertson et al. 2022 [26]	USA	n = 6634	Accelerometer	8164	1000	↓ the risk of developing diabetes
Ballin et al. 2020 [28]	Sweden	n = 3055	Accelerometer	7193 (3072)	> 4500	↓ the risk of developing diabetes
Perry et al. 2023 [29]	USA	n = 5677	Accelerometer	7924	All	↓ the risk of developing diabetes
Master et al. 2022 [30]	USA	n = 6042	Accelerometer	7731	1000	↓ the risk of developing diabetes, ↓ BMI
Siddiqui et al. 2018 [31]	South Africa	n = 95	Pedometer	4610 (1702) 7245 (1419)	2635 > 7000	↓ HbA1c
Wang et al. 2022 [32]	USA	n = 9509	Pedometer	4833 (3266)	≥ 5000	↓ glucose
Kerr et al. 2024 [34]	USA	n = 121	accelerometer	7751.9 (3255.9)	1000	↓ HbA1c
Fayehun et al. 2018 [35]	Nigeria	n = 46	Pedometer	6507 (1716)	2913	↓ HbA1c
Yu et al. 2023 [39]	China	n = 1415	Pedometer	6370 (4431)	1000	↓ TnT, ↓ UACR
Zucatti et al. 2017 [40]	Brazil	n = 151	Pedometer	6391 (3357)	> 4873	↓ office SBP, ↓ 24 h SBP, ↓ daytime SBP, ↓ mean BP
Yates et al. 2014 [41]	The USA	n = 9306	Pedometer	—	> 2000	↓ risk of cardiovascular event
Dasgupta et al. 2017 [42]	Canada	n = 230	Pedometer, accelerometer	5010 (2800)	> 1000	↓ cfPWV

BMI — body mass index; BP — blood pressure; cfPWV — carotid-femoral pulse wave velocity; HbA1c — glycated hemoglobin; LDL — low-density lipoprotein; n — number; SBP — systolic blood pressure; SD — standard deviation; TnT — troponin T; UACR — urine albumin–creatinine ratio; USA — United States of America; WHR — waist–hip ratio

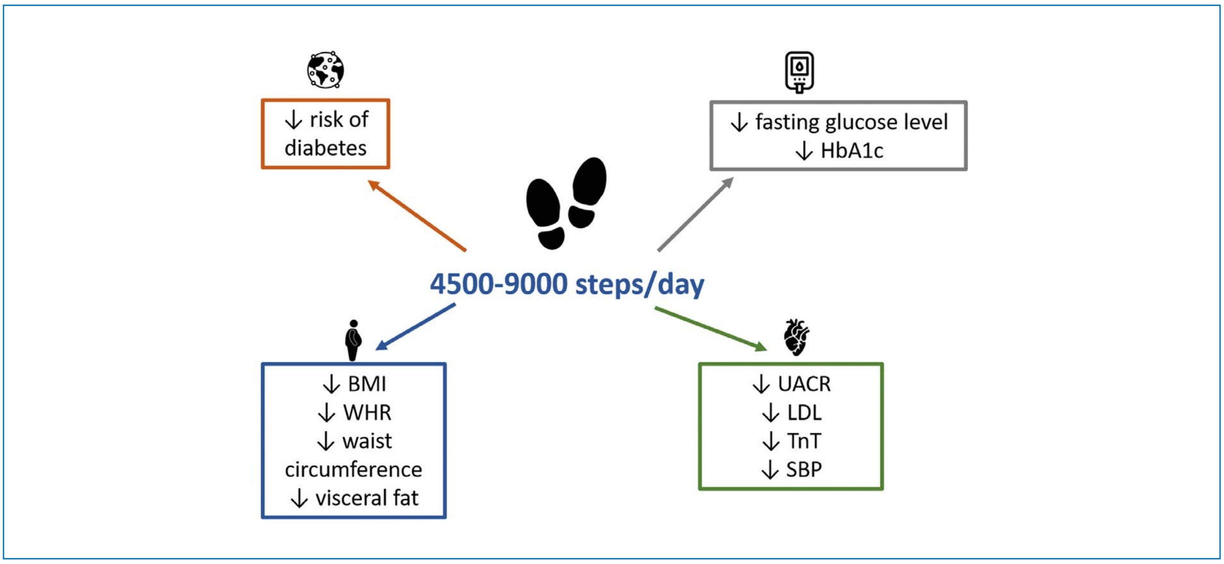

Figure 2. Impact of the Recommended Daily Number of Steps on the Development and Course of Diabetes and their Factors [6, 23–43]

BMI — body mass index; HbA1c — glycated hemoglobin; LDL — low-density lipoprotein; SBP — systolic blood pressure; TnT — troponin T; UACR — urine albumin-creatinine ratio; WHR — waist–hip ratio

Conclusions

The daily number of steps affects both mortality from any cause and the risk of developing and controlling the course of T2D. Any physical activity has positive health effects, but the most beneficial effects for are observed in the range of 4500–9000 steps per day. Advising patients to take 10,000 or more steps per day may negatively affect their motivation to engage in activity, while not significantly improving the risk or course of T2D.

Article information

Author contribution

Conceptualization: MD, DP; methodology: MD, KB, MC, MR, DP; software: MD; data collection: MD, KB, MC, MR, writing — original draft preparation: MD, KB, MC, MR; writing — review and editing: MD, KB, MC, MR, DP; supervision: MD, DP. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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