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Shreya G. Mendon, Suroshree Mitra, Apurv P. Shimpi
Department of Community Physiotherapy, Sancheti Institute for Orthopaedics and Rehabilitation College of Physiotherapy, Pune, Maharashtra, India

Effect of Single, Accumulated, and Conventional Walking on Glucose Level, Aerobic Capacity, Fatigue, and Quality of Life in Type 2 Diabetes: A Randomized Trial

ABSTRACT

Objective: This study evaluated the effectiveness of different walking protocols on various physiological and psychological factors in type 2 diabetes (T2D).

Materials and methods: In this randomized study, 45 individuals with T2D, aged 55–65 years, with diabetes duration between 1 and 10 years were recruited. They were randomly assigned to 1 of 3 groups: single walking (SW), accumulated walking (AW), or conventional walking (CW). The primary outcome measure was fasting blood glucose (FBG) while secondary outcomes assessed were 6-minute walk distance (6MWD), fatigue, and quality of life (QoL). Intervention was given for 6 weeks. Intra-group changes were analyzed using the Wilcoxon signed rank test, while inter-group differences were evaluated with the Kruskal-Wallis test.

Results: 42 participants completed the study. The baseline data showed non-significant difference across the groups for age and duration of diabetes. FBG showed a minor reduction in the SW (12%) and AW (15.5%) groups, while it increased in the CW group (2.5%). The 6MWD improved significantly in the SW (21.3%, p = 0.003) and AW (21%, p = 0.008) groups, but decreased in the CW (9.5%) group. Fatigue decreased in the SW (4.5%, p = 0.027) and AW (4.8%, p = 0.003) groups, while it slightly increased in the CW (0.5%) group. QoL improved in the SW (2.3%, p = 0.016) and AW (4.3%, p = 0.008) groups but decreased in the CW (1.78%) group. Post-hoc analysis showed significant differences in 6MWD (p = 0.010) and QoL (p = 0.008) between the AW and CW groups.

Conclusions: SW and AW showed similar effects on glucose levels, aerobic capacity, fatigue, and QoL. However, AW is more effective than CW in enhancing aerobic capacity and QoL.

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Keywords: type 2 diabetes, fasting blood glucose, aerobic capacity, walking

Address for correspondence:
Shreya G. Mendon
11/12, Thube Park, Sancheti Institute for Orthopaedics and Rehabilitation College of Physiotherapy, Department of Community Physiotherapy, Shivajinagar, Pune 411005, Maharashtra, India
E-mail: shreyamendon30@gmail.com
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Introduction

Type 2 diabetes (T2D) is a chronic metabolic disorder characterized by hyperglycemia due to insulin resistance. It is linked with insulin secretory deficits due to genetics, inflammation, and metabolic stress. It makes up 90% of all diabetes cases and is a worldwide epidemic. Approximately 77 million individuals in India had diabetes in 2019, and by 2045 it is projected to reach over 134 million. As it is a long-term disorder, it can lead to adverse complications, which are associated with increased expenditure on the family, community, and healthcare system [1–3].

Exercise is an essential part of T2D management because it helps optimize glycemic levels, improve insulin sensitivity, and positively impacts cardiovascular health. Unfortunately, most of these individuals are physically inactive and have reduced aerobic capacity. Inadequate glycemic control (GC) can cause uncontrolled diabetes and its associated consequences, which can significantly lower quality of life (QoL), shorten life expectancy, and raise healthcare costs [4, 5].

Fatigue has been reported as a frequent symptom in those with T2D, resulting in poor self-reported health. It may reduce an individual's capacity to perform daily activities necessary for optimal GC (e.g., glucose monitoring, preparing a healthy meal, and regular physical activity). Despite this, it is often unnoticed during healthcare visits because acute issues take priority. T2D is a psychologically demanding chronic condition because it affects many aspects of QoL. Episodes of hypoglycemia, changes in lifestyle, and concerns of long--term effects may all affect QoL [6–9].

Walking is an easy, convenient, and cost-effective means to adopt a physically active lifestyle. It is the most preferred form of leisure-time exercise, and because it involves the use of large skeletal muscles, it contributes to peripheral glucose uptake and improves glucose homeostasis [10, 11]. T2D is associated with obesity, fatigue, and certain health conditions such as hip and knee osteoarthritis, which limit engagement in extended, continuous bouts of exercise. Hardman noted in a systematic review on the benefits of exercise fractionation that multiple short sessions of exercise are just as effective as longer continuous sessions. The former may be both practical and effective. However, the advantages of such modifications remain unclear [12, 13]. So, this study aims to assess the effects of different walking exercises on glucose level, aerobic capacity, fatigue, and QoL in persons with T2D.

Materials and methods

Subjects

Individuals with T2D, aged 55 to 65 years, were recruited from settings such as residential societies and physiotherapy outpatient departments. This was done with the help of in-person outreach, informational flyers, and referrals from healthcare providers. Participants with duration of diabetes between 1 and 10 years, with fair glycemic control (HbA1c < 7%, or fasting blood glucose (FBG) level 70–130 mm/dL, or postprandial blood glucose level <180 mm/dL) and on an oral hypoglycemics regimen were included. Exclusion criteria included one or more positive marks on the Physical Activity Readiness Questionnaire (PAR-Q), history of stroke, cancer, acute illness, lower limb pain, complications (a general sensory, motor, and vascular examination was done to rule out complications), or those participating in regular exercise (minimum 20 minutes on 3 or more days per week). Participants were randomly assigned to one of three groups: single walking, accumulated walking, or conventional walking.

Study design

This was a randomized, single-blinded, parallel-group, active-controlled study. Group allocation was done using sealed, opaque envelopes and computer-generated randomization (www.random.org), as illustrated in Figure 1. Participants remained unaware of their assigned groups. Group allocation was blinded to the participants.

Data collection

The outcome measures were assessed at baseline and after 6 weeks of intervention.

Primary outcome measure for glucose level was FBG level, which was measured using a glucometer (Accu Chek Instant S, Roche Diabetes Care GmbH, Mannheim, Germany) after 8 hours of overnight fasting. It has acceptable accuracy [14].

Secondary outcomes included aerobic capacity, fatigue, and QoL. Six-minute walk test (6MWT) was performed using the American Thoracic Society guidelines, and the six-minute walk distance (6MWD) in meters was calculated to measure the aerobic capacity [15].

Multidimensional Fatigue Inventory 20 (MFI-20) was used to evaluate fatigue. It is a 20-item, self-reported questionnaire that assesses 5 dimensions of fatigue including general fatigue, physical fatigue, mental fatigue, reduced motivation, and reduced activity. It uses a 5-point Likert scale with scores ranging from 20 to 100. Higher scores indicate a higher burden of fatigue. It has a reliability of 0.84 with acceptable validity [16].

The appraisal of diabetes scale (ADS) was used to assess QOL. This is a 7-item, self-reported questionnaire that evaluates an individual's appraisal of their diabetes. It uses a 5-point Likert scale with scores ranging from 0 to 35. The lower the score, the better the QoL. It has a reliability of 0.73 [17].

Intervention

Single walking (SW) exercise group

Participants started the exercise with a 3-minute warm-up, walking at a leisurely pace. This was followed by 30 minutes of brisk walking at a moderate intensity,

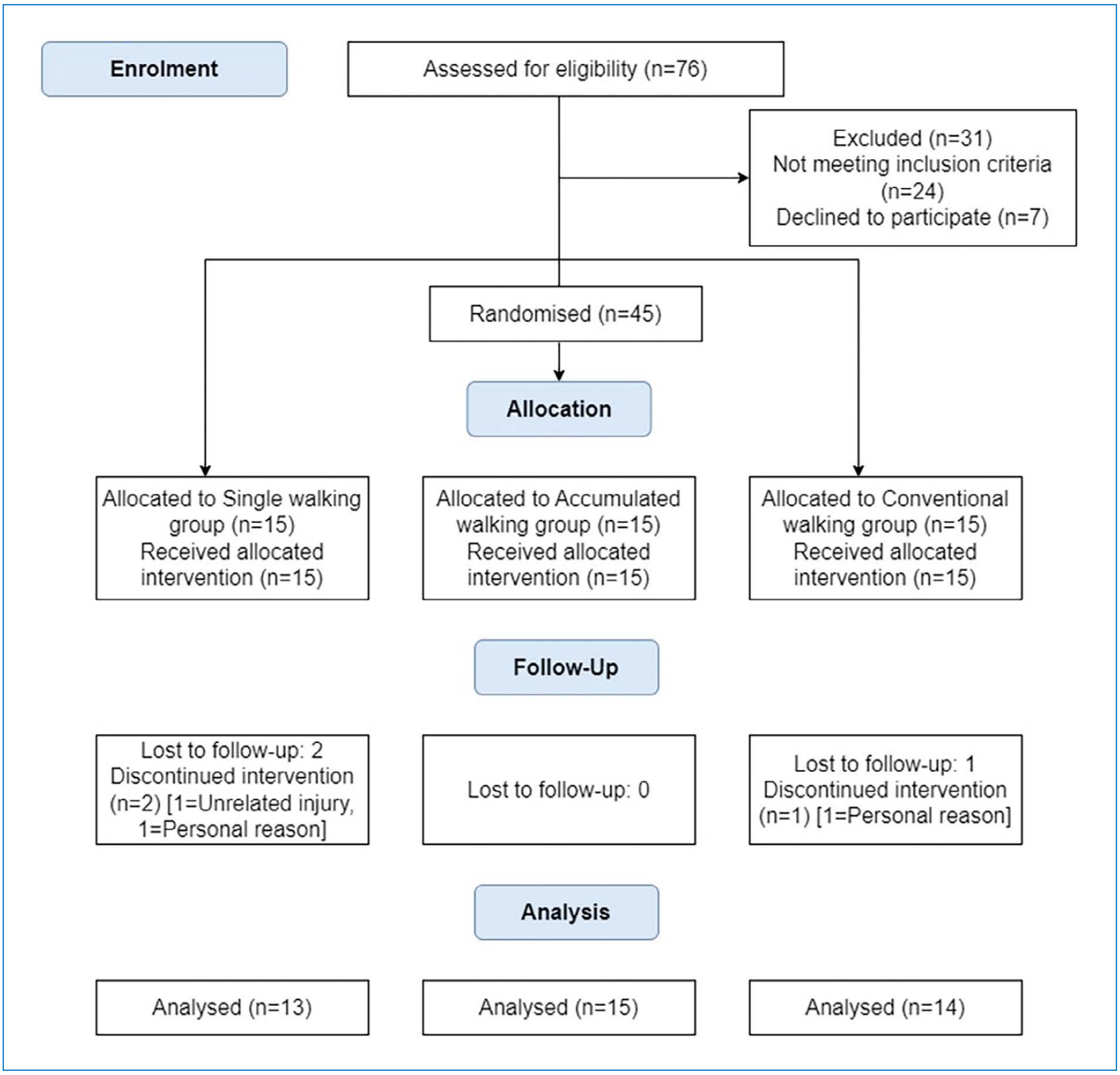

Figure 1. CONSORT Flow Diagram

i.e., rate of perceived exertion (RPE) of 5 to 6 [13]. They were advised to walk at a pace at which breathing was slightly hard but still allowed for conversation without gasping (talk test) [18]. After this, participants performed a cool-down with another 3 minutes of leisurely walking. This routine was performed on 3 alternate days per week for 6 weeks. One session each week was supervised, while the remaining sessions were done at home. Participants were asked to log their activities on an exercise chart with weekly follow-ups via phone calls or text messages.

Accumulated walking (AW) exercise group

Participants started the exercise with a one-minute warm-up, walking at a leisurely pace. This was followed by 10 minutes of brisk walking at a moderate intensity, i.e., RPE of 5 to 6 [13]. They were advised to walk at a pace at which breathing was slightly hard but still allowed for conversation without gasping (talk test) [18]. After this, participants performed a cool-down with another minute of leisurely walking. This routine was performed thrice a day (with an interval of 4 to 5 hours between each exercise bout) on 3 alternate days per week for 6 weeks. One session each week was supervised, while the remaining sessions were done at home. Participants were asked to log their activities on an exercise chart with weekly follow-ups via phone calls or text messages.

Conventional walking (CW) exercise group

Participants in the control group were instructed to walk for 30 minutes per day on 3 alternate days each

Table 1. Demographic Data of All Participants

	SW group	AW Group	CW Group	F	p-value
Gender:					
Male	6 (40%)	10 (66.6%)	7 (46.6%)	—	—
Female [N (%)]	9 (60%)	5 (33.3%)	8 (53.3%)		
Age [years] (Mean ± SD)	60.3 ± 2.6	59.6 ± 3.5	58.5 ± 4.3	0.965	0.389
Duration of diabetes [years] (Mean ± SD)	5.5 ± 2.7	5.1 ± 3.3	6.5 ± 2.2	1.170	0.320

Values are N (%) or mean ± SD; F and p-values were derived from one-way ANOVA

AW — accumulated walking; CW — conventional walking; SD — standard deviation; SW — single walking

Table 2. Intra-Group Analysis

Group	Outcome measure	Baseline	Post 6 weeks	p-value
Single	MFI-20 score	50.8 ± 16.9	46.3 ± 17.0	0.027
	ADS score	24.3 ± 6.7	22 ± 5.4	0.016
	FBG [mm/dL]	97.9 ± 18.1	85.9 ± 14.4	0.004
	6MWD [m]	396.7 ± 49.0	418.0 ± 43.0	0.033
Accumulated	MFI-20 score	41.7 ± 15.5	36.8 ± 14.6	0.003
	ADS score	25.2 ± 7.9	20.9 ± 6.6	0.008
	FBG [mm/dL]	107.6 ± 14.1	91.9 ± 15.3	0.001
	6MWD [m]	384.1 ± 33.1	405.1 ± 35.9	0.008
Conventional	MFI-20 score	40.6 ± 13.0	41.1 ± 13.5	0.801
	ADS score	20.3 ± 6.8	22.1 ± 8.5	0.094
	FBG [mm/dL]	109.0 ± 17.7	106.5 ± 18.8	0.594
	6MWD [m]	382.2 ± 56.2	372.6 ± 66.5	0.198

Values are mean ± SD; p-value was set at 0.05

6MWD — six-minute-walk-distance; ADS — appraisal of diabetes scale; FBG — fasting blood glucose; MFI-20 — Multidimensional Fatigue Inventory-20; SD — standard deviation

week for 6 weeks [13]. All sessions were home-based, and participants were asked to log their activities on an exercise chart. Weekly follow-ups were conducted via phone calls or text messages to ensure a compliance rate of at least 70%.

Participants who were considered dropouts were the ones who chose to withdraw due to personal reasons and sustained an injury that necessitated discontinuation of exercise until recovery.

Statistical analysis

The results are presented as numbers, percentages, and mean ± standard deviation (SD). Sample size was calculated using the formula $[2 \times SD^2 \times (1.96 + 0.84)]/d^2$. SD and d (mean difference) values were based on previous studies [19]. The sample size was found to be 45, i.e., 15 for each group. Intra-group analysis was done using the Wilcoxon Signed Rank test, and intergroup analysis was done using the Kruskal-Wallis test. Post hoc analysis was done for group-wise comparison. The statistical significance was set at $p \leq 0.05$ and the confidence interval at 95%. Data analysis was done using Statistical Package for the Social Sciences (SPSS) version 26.

Results

Of 45 participants, 42 (93.33%) were followed up in the study. Loss to follow-up was 6.67%. Figure 1 shows the number of participants at each stage according to the CONSORT diagram. Table 1 shows the baseline demographic characteristics of all participants with T2D comparable across the study groups.

Glucose level

FBG significantly reduced in the SW (12%) and AW (15.5%) groups while the decrease in the CW group (2.5%) was non-significant. Inter-group analysis was non-significant (Tab. 2 and 3).

Aerobic capacity

Significant improvements in 6MWD were seen in the SW (21.3%) and AW (21.05%) groups while it de-

Table 3. Inter-Group and Post Hoc Analysis

Outcome measure	Group	Mean ± SD	p-value	Pair wise groups	p-value
MFI-20 score	Single	4.5 ± 5.9	0.039	Single — Accumulated	1.000
	Accumulated	4.8 ± 5.3		Single — Conventional	0.065
	Conventional	−0.5 ± 6.2		Accumulated — Conventional	0.109
ADS score	Single	2.3 ± 3.7	0.008	Accumulated — Single	1.000
	Accumulated	4.3 ± 5.9		Accumulated — Conventional	0.008
	Conventional	−1.7 ± 3.3		Single — Conventional	0.107
FBG [mm/dL]	Single	12 ± 10.7	0.389	—	—
	Accumulated	15.6 ± 13.5			
	Conventional	−2.5 ± 25.9			
6MWD [m]	Single	21.3 ± 27.7	0.008	Conventional — Single	0.054
	Accumulated	21.0 ± 26.6		Conventional — Accumulated	0.010
	Conventional	−9.5 ± 23.2		Single — Accumulated	1.000

Values are mean ± SD; p-value was set at 0.05

6MWD — 6-minute-walk-distance; ADS — appraisal of diabetes scale; FBG — fasting blood glucose; MFI-20 — Multidimensional Fatigue Inventory-20; SD — standard deviation

creased in the CW group (9.57%). Inter-group analysis was significant ($p = 0.008$). Post hoc analysis showed that the change in aerobic capacity between the AW and CW groups was significant ($p = 0.010$) (Tab. 2 and 3).

Fatigue

This lowered significantly in the SW (4.53%) and AW (4.86%) groups while the CW group (0.5%) showed a non-significant increment. Inter-group analysis was significant ($p = 0.039$); however, post-hoc analysis was insignificant (Tab. 2 and 3).

Quality of Life

QoL improved significantly in the SW (2.38%) and AW (4.33%) groups while it decreased in the CW (1.78%) group. Inter-group analysis was significant ($p=0.001$). Post hoc analysis was significant between the AW and CW groups ($p = 0.008$) (Tab. 2 and 3).

Discussion

We observed a significant decrease in glucose levels in both intervention groups (SW and AW) as compared to the control group (CW) along with a greater reduction in the AW group. Similar results were demonstrated in the study done by Eriksen et al. [20] in 2007, in which improvements in FBG in adults with T2D after engagement in multiple-bout, moderate-intensity aerobic exercise for 5 weeks were seen. This finding is consistent with 2 previous studies which showed reduced postprandial glycemia with post-meal walking bouts compared with one-time daily exercise in T2D [21, 22]. This could be due to higher energy expenditure during multiple bouts of exercise than during a single bout of exercise, because of an acute rise in exercise-induced metabolic rate caused by excess post-exercise oxygen consumption, which improves glucose homeostasis [23].

As demonstrated by Eriksen et al. [20] in 2007, cardiorespiratory fitness had similar increases with both single and multiple sessions of exercise training done for 5 weeks. Similar findings have been reported in a previous review that compared the effectiveness of accumulating exercise in multiple bouts of at least 10 minutes throughout a day with exercise completed in a single bout in inactive healthy individuals [24]. Aerobic exercise involves repetitive contractile activity of muscles, which is known to stimulate an increase in mitochondrial size, number, and mitochondrial enzymes, thus improving the aerobic capacity, which could explain the results of this study [25].

In comparison to the control group, participants in both intervention groups saw equal and favorable changes in fatigue. According to a study by Abd El Kader et al. [19] in 2015, aerobic exercise performed for 12 weeks improved fatigue symptoms in obese people with T2D. Short and long bouts of low-impact aerobic exercise have a similar influence on fatigue in sedentary women with fibromyalgia, according to the results of another study by Schachter et al. in 2003 [12]. Fatigue in T2D can occur due to endocrine-related causes such as poor glucose control or inflammatory markers, as well as lifestyle factors like inactivity. Due to inactivity, these individuals are frequently overweight or obese, which raises the level of pro-inflammatory cytokines and causes fatigue. This inflammatory marker production is inhibited by aerobic exercise [19, 26–28]. Furthermore, research by Park et al. [29] in 2015 asserted that only in patients with elevated HbA1c levels does fatigue have a direct correlation to glucose control. Fatigue is mostly influenced by the presence of diabetic symptoms and distress with adequate glycemic control.

Individuals with T2D have a lower QoL than those without the disease due to a variety of causes such as the accompanying complications and psychological issues including anxiety and depression, which influence psychosocial life and functioning and thus lower QoL. Comorbidities and different treatment regimen demands also have an impact on QoL. It declines with increasing age, disease duration, poor metabolic management, combination treatment with oral hypoglycemics and insulin, sedentary lifestyle, in women, and the presence of comorbidities [30]. Incentives such as regular phone follow-ups, supervised training sessions, self-monitoring of exercises, and group sessions boost participant motivation and adherence, promote a positive mindset, and encourage increased physical activity, hence enhancing QoL. Aerobic exercise improves QOL by increasing physical activity and altering body composition while maintaining glycemic control, blood pressure, and insulin resistance [31]. Previous research by Esha et al. [32] in 2019, Guglani et al. [9] in 2014, Praet et al. [33] in 2008, and Aylin et al. [34] in 2009 that found that walking-based training increased QOL in T2D, confirming the findings of this study.

As a result of having more individuals with hypertension (Group SW = 4, Group AW = 2) and female participants (Group SW = 9, Group AW = 5) than Group AW, Group SW experienced lower increases in QoL (Tab. 1).

Even though the current study's results show a positive effect of exercise on fasting blood glucose level, Morton et al. [35] in 2010 claimed that a 7-week walking exercise program improved cardiorespiratory fitness but had no effect on blood glucose levels. The perceived intensity of the exercise protocol in the study was light whereas in this study it was of moderate intensity.

Most individuals with T2D do not achieve the recommended amount of physical activity per day. In catering to the needs of this large number of individuals, a better understanding of the kind of exercise program that they can effectively benefit from is necessary. Although there are pharmacological regimens to manage diabetes and its symptoms, those alone cannot effectively address the various aspects of the condition. In the current study, an accumulated walking exercise protocol was proven to be more practical and effective in optimizing aerobic fitness and QoL.

The strengths of this study include emphasis on efficacy and the use of a cost-effective exercise regimen. Low discontinuation rates indicate that the exercise program was well tolerated. The study also had some limitations. There was no long-term follow-up to understand the durability of the treatment effect. Due to certain constraints, only urban populations with access to personal electronic gadgets were included. Also, factors like stress, daily activity levels, sleep quality, obesity, and dietary intake were not considered during the treatment process to see if they influenced the outcomes.

Conclusions

There is no difference between single and accumulated walking exercises on glucose level, aerobic capacity, fatigue, and QoL in those with T2D. However, as compared to the control group, accumulated walking is preferable in improving aerobic capacity and QoL.

Future studies on long-term follow-up can be done to determine the effectiveness of the walking intervention. The effect of exercises along with other factors can also be evaluated to understand the role of both.

Article information

Data availability statement

The original contributions presented in this study are detailed within the article, and any additional inquiries can be directed to the corresponding author.

Ethics statement

This study was approved by Institutional Ethics Committee (under the number IEC — SIOR/Agenda 070 on 08/07/2022) and was registered with the Clinical Trials Registry – India (https://ctri.nic.in/Clinicaltrials/login.php) with identifier CTRI/2022/08/044936. Written informed consent was obtained from all the participants prior to commencement of the study, and the data were used solely for research and educational purposes. The study was conducted in accordance with the guidelines of the Helsinki Declaration 2013 prior to its start.

Author contributions

SGM: conceived and designed the study, acquired the data, performed the statistical analysis, and prepared the first draft of the manuscript. SM: contributed to the concepts, design, and manuscript editing and review. APS: contributed to the concepts and design, interpretation of data, and reviewed the manuscript. All contributors reviewed, edited, and approved the final submission of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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