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RESEARCH ARTICLE



Concurrent validity and TEST-RETEST reliability of the incremental shuttle walk TEST in patients with type 2 diabetes mellitus

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is a chronic metabolic-endocrine disorder characterized by insulin resistance and relative insulin deficiency. Functional capacity is considered a key determinant of the ability to perform activities of daily living and maintain quality of life, and it is frequently impaired in individuals with T2DM. The Incremental Shuttle Walk Test (ISWT) is a low-cost, externally paced field test used to assess maximal exercise capacity; however, evidence regarding its validity and reliability in individuals with T2DM remains limited.

Objective: Investigate the concurrent validity of the ISWT against the Six-Minute Walk Test (6MWT) and determine its test-retest reliability in individuals with T2DM.

Methods: Twenty-six individuals with T2DM (16 females, 10 males; mean age 56.0 ± 12.02 years) were included. Concurrent validity of the ISWT was assessed by comparison with the 6MWT. Test-retest reliability was evaluated by repeating the measurements after 7 days, provided that participants' clinical condition remained stable. Statistical analyses were performed using SPSS Statistics version 31.

Results: The ISWT demonstrated acceptable-to-good test-retest reliability, with an intraclass correlation coefficient $ICC_{3,1}$ of 0.778 (95% confidence interval: 0.568–0.893; $p < .001$). No significant difference was found between the first and second measurements (336.54 ± 102.53 m vs. 323.85 ± 84.95 m; $t(25) = 1.032$; $p = .312$), indicating that no statistically significant systematic change was observed between the test and retest assessments. The standard error of measurement (SEM) was 48.3 m, and the minimal detectable change at the 95% confidence level (MDC_{95}) was 134.0 m.

Conclusion: The ISWT demonstrated acceptable concurrent validity with the 6MWT and good test-retest reliability in individuals with T2DM. Therefore, it may be a useful tool for assessing functional exercise capacity and objectively evaluating functional status in clinical practice. However, SEM and MDC values should be carefully considered when interpreting individual changes in this population.

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Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by hyperglycemia resulting from partial or complete deficiency of the insulin hormone or insulin resistance (Bennett and Knowler, 2005). Diabetes negatively affects overall health by causing structural and functional dysfunction in various tissues and organs throughout the body, along with lifelong chronic hyperglycemia (American Diabetes Association, 2013).

Functional capacity plays a key role in determining independence and quality of life during activities of daily living and is adversely affected in individuals with Type 2 Diabetes Mellitus (T2DM). Decreased functional capacity has been reported in patients with T2DM, with evidence showing significantly lower functional exercise capacity and walking distance compared with healthy individuals (Awotidebe et al, 2017; Kuziemska, Słomiński, and Jassem, 2019; Leenders et al, 2013; Singh et al, 2014). Therefore, the objective

assessment and regular monitoring of functional capacity are important components of clinical evaluation and rehabilitation planning in patients with T2DM.

In the objective assessment of functional capacity, the Cardio-Pulmonary Exercise Test (CPET) measures maximum oxygen consumption and is considered the gold standard (American Thoracic Society and American College of Chest Physicians, 2003). However, since CPET requires specialized personnel and expensive equipment, there is a need for more accessible alternative tests in clinical practice. Field tests are widely used to assess individuals' functional exercise capacity, determine the prognosis of diseases, identify the results of clinical studies, and monitor the response to treatment of various chronic respiratory diseases. Among the most commonly used field tests in the clinic are the Six-Minute Walk Test (6MWT) and the Incremental Shuttle Walk Test (ISWT) (Singh et al, 2014). These tests are known to be used in relevant populations after determining their disease-specific validity and reliability.

It has been determined that the 6MWT is a valid and reliable measurement method for patients with T2DM (Alfonso-Rosa et al, 2014). Furthermore, recent evidence has demonstrated that a tele-assessed 6MWT is also a valid and reliable method for evaluating functional capacity in individuals with T2DM, highlighting the versatility and clinical applicability of the 6MWT across different assessment settings (Pepera et al, 2023). Although the 6MWT is widely accepted as a valid measure of functional exercise capacity, its submaximal nature may limit its ability to reflect maximal exercise capacity. In this context, the ISWT has emerged as a standardized, externally paced field test for the assessment of exercise capacity.

The ISWT is a widely used maximal field test designed to assess functional capacity and exercise tolerance, as it is low-cost and easily used in clinical practice. It was first introduced in 1992 to evaluate exercise capacity in individuals with chronic obstructive pulmonary disease (Singh et al, 1992). It has been suggested that the ISWT exhibits a stronger association with VO_2 peak compared to the 6MWT, indicating its potential to more closely reflect maximal exercise capacity (Chae et al, 2022).

The ISWT has been applied across a wide range of chronic disease populations, including cardiovascular and pulmonary diseases. Previous studies have demonstrated its favorable measurement properties and clinical applicability in these populations, supporting its use for the assessment of maximal functional exercise capacity. Furthermore, the ISWT has been reported to be a valid, reliable, and responsive tool for monitoring

rehabilitation outcomes (Campo et al, 2006; Pepera and Sandercock, 2022; Pepera, McAllister, and Sandercock, 2010; Singh, Moiz, Ali, and Talwar, 2018).

Evidence regarding the measurement properties of the ISWT in individuals with T2DM remains limited. To our knowledge, no previous study has specifically investigated the concurrent validity and test-retest reliability of the ISWT in individuals with T2DM. Therefore, the aim of the present study was to determine the concurrent validity and reliability of the ISWT in individuals with T2DM.

Material and methods

This study was approved by the Local Ethics Committee (Approval No: 2024/272) and registered on ClinicalTrials.gov (NCT06519318). The study was conducted between June 2024 and September 2025 at the Department of Physiotherapy and Rehabilitation, in accordance with the principles of the Declaration of Helsinki. All participants were informed about the purpose and procedures of the study prior to participation, and written informed consent was obtained.

Participants

Individuals aged 18–65 years with a diagnosis of T2DM who were clinically stable, HbA1c values between 6.5% and 11%, no cognitive impairment, and the ability to walk independently were included in the study. The inclusion criteria were determined by the research team based on the relevant literature and the clinical characteristics of the target population. All assessments were performed under standardized testing conditions. Exclusion criteria were uncontrolled diabetes mellitus, uncontrolled hypertension, unstable cardiovascular or pulmonary conditions, chronic diabetic complications that could affect walking performance, vertigo or vestibular disorders, severe neurological or respiratory diseases, major musculoskeletal disorders, and pregnancy.

Sample size calculation was performed using G*Power 3.1 software (version 3.1.9.7; Heinrich-Heine Universität Düsseldorf, Düsseldorf, Germany), based on an expected moderate correlation ($r = 0.50$) between ISWT and 6MWT walking distances, with a power of 80% and an alpha level of 0.05. Accordingly, the minimum required sample size was calculated as 26 participants (Cohen, 1988). The sample size calculation was based on the expected correlation between the ISWT and the 6MWT, as the a priori sample size estimation was performed for the validity analysis. Therefore, an $\text{ICC}_{3,1}$ based sample size calculation was not undertaken.

Study design and procedure

This study was designed as a prospective methodological study evaluating the validity and test-retest reliability of the ISWT in individuals with T2DM. At the initial assessment, the researchers collected participants' socio-demographic and clinical data, including gender, age, height, weight, body mass index, education and occupational status, smoking and alcohol use, duration of diabetes diagnosis, diabetes-related treatments, fasting plasma glucose and HbA1c levels from the most recent blood tests, and information on additional comorbidities.

For validity analysis, the 6MWT was performed. Walking distance results obtained from the ISWT were compared with those from the 6MWT. Tests were administered sequentially on the same day by the same researcher. To minimize fatigue-related effects, a standardized 30-minute rest period was provided between the two tests, and one practice trial was conducted for each test. The use of a single practice trial was considered sufficient to familiarize participants with the testing procedure while minimizing potential learning effects and maintaining the feasibility of the assessment protocol, consistent with previously reported ISWT testing procedures (Holland et al, 2014; Singh et al. 1992).

To assess test-retest reliability, ISWT measurements were used. Provided that no significant change occurred in the participants' clinical condition, the second assessment was conducted 7 days after the initial assessment.

The ISWT is a standardized field test used to assess exercise capacity in individuals with chronic diseases based on maximal exercise performance limited by symptoms. During the test, participants were instructed to walk back and forth between two cones placed 9 meters apart. The test consists of a maximum of 12 levels, each lasting one minute. The initial walking speed was set at 0.5 m/s and increased by 0.17 m/s every minute, resulting in a maximum test duration of 12 minutes. Participants received standardized verbal instructions to maintain the required walking pace (Singh et al. 1992).

Heart rate, blood pressure, oxygen saturation (measured by pulse oximetry), perceived fatigue (Modified Borg Fatigue Scale, 0–10), and dyspnea (Modified Borg Dyspnea Scale, 0–10) were recorded before and immediately after the test.

The test was stopped if the participant was unable to continue because of excessive dyspnea or fatigue, or if they failed to reach the signal sound on two consecutive occasions. At the end of the test, the distance walked, the number of shuttles, and the peak VO_2 calculated using

the ISWT formula were recorded (Probst et al. 2012; Singh et al. 1992).

The validity of the 6MWT in individuals with T2DM has been demonstrated (Lee, 2018). The 6MWT was performed in accordance with the guidelines of the American Thoracic Society (ATS) (ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories, 2002).

Participants were instructed to walk as far as possible at a self-selected brisk pace for 6 minutes along a 30-meter straight corridor. Heart rate, blood pressure, oxygen saturation, perceived fatigue (Modified Borg Fatigue Scale, 0–10), and dyspnea (Modified Borg Dyspnea Scale, 0–10) were assessed before and after the test. Participants were informed that they could stop and rest if they experienced severe fatigue, dizziness, or nausea. Standardized encouragement was provided during the test. The total walking distance was recorded in meters (Holland et al. 2014). Predicted 6MWT distances were calculated using the reference equation proposed by Enright, (2003).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 31.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were calculated for continuous and categorical variables, and the level of statistical significance was set at $p < .05$ for all analyses. Test-retest reliability of the ISWT was assessed using the intraclass correlation coefficient $\text{ICC}_{3,1}$ based on a two-way mixed-effects model, single measurement, absolute agreement.

Reliability was interpreted according to established guidelines, where $\text{ICC}_{3,1}$ values < 0.50 indicate poor reliability, 0.50–0.75 moderate reliability, 0.75–0.90 good reliability, and > 0.90 excellent reliability (Koo and Li, 2016). The standard error of measurement (SEM) was calculated using the formula $\text{SEM} = \text{SD} \times \sqrt{1 - \text{ICC}}$. The minimum detectable change at the 95% confidence level (MDC_{95}) was calculated as $\text{MDC}_{95} = [\text{SEM} \times 1.96 \times \sqrt{2}]$ (de Vet, Terwee, Knol, and Bouter, 2006). Concurrent validity of the ISWT was examined by analyzing the correlation between ISWT and 6MWT walking distances. Pearson's correlation coefficient was used for normally distributed variables. Pearson correlation coefficients were interpreted as very strong (0.90–1.00), strong (0.70–0.89), moderate (0.50–0.69), weak (0.30–0.49), and negligible (0.00–0.29) (Mukaka, 2012). Agreement between the ISWT and 6MWT was further explored using Bland-Altman analysis to identify systematic bias and determine the limits of agreement (Figure 1).

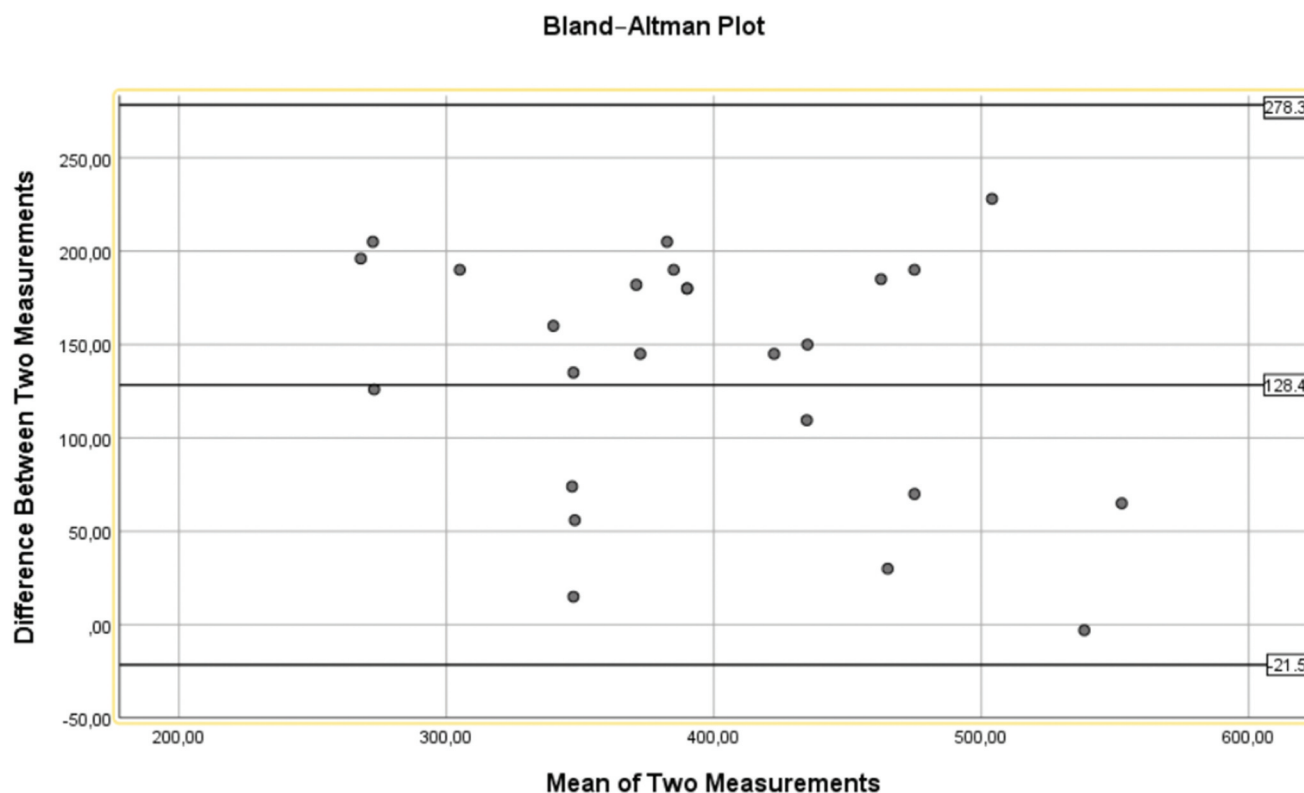


Figure 1. Bland-Altman plot for incremental shuttle walk test and six minute walking test. The mean bias was 128.4 m, with 95% limits of agreement ranging from -21.5 m to 278.3 m. The solid line represents the mean bias, and the dashed lines represent the 95% limits of agreement.

Agreement between the first and second ISWT measurements was further evaluated using Bland-Altman analysis to identify systematic bias and determine the limits of agreement.

Results

A total of 26 individuals with T2DM were included in the study. The mean age of the participants was 56.0 ± 12.02 years. No adverse events were reported by any participant during the test procedures. Other demographic and clinical characteristics are presented in Table 1. None of the participants had documented chronic diabetes-related complications. At the initial assessment, the mean ISWT walking distance was 336.54 ± 102.53 m. At the retest assessment, the mean ISWT walking distance was 323.84 ± 84.95 m. The mean distance achieved in the 6MWT was 464.94 ± 74.69 m. (Table 2).

The ISWT demonstrated acceptable-to-good test-retest reliability, with an $ICC_{3,1}$ of 0.778 (95% confidence interval: 0.568–0.893, $p < .001$). Internal consistency between the two ISWT measurements was high (Cronbach's $\alpha = 0.875$). No significant difference was observed between the first and second ISWT distances

(336.54 ± 102.53 m vs. 323.85 ± 84.95 m; $t(25) = 1.032$, $p = .312$), indicating that no statistically significant systematic change was observed between the test and retest assessments. The standard error of measurement (SEM) was 48.3 m, and the minimal detectable change at the 95% confidence level (MDC) was 134.0 m.

Bland-Altman analysis demonstrated a mean bias of 128.4 m between the ISWT and the 6MWT, with 95% limits of agreement ranging from -21.5 m to 278.3 m (Figure 1). Most observations fell within the limits of agreement, indicating acceptable agreement between the two field tests across the observed range of walking distances. Bland-Altman analysis of the test-retest measurements demonstrated a mean bias of -12.7 m, with 95% limits of agreement ranging from -135.6 m to 110.2 m (Figure 2). Most observations fell within the limits of agreement, indicating acceptable agreement between the two ISWT measurements. A significant positive moderate correlation was observed between ISWT and 6MWT distances ($r = 0.669$, $p < .001$), as shown in Table 3.

Discussion

The present study investigated the concurrent validity and test-retest reliability of the ISWT in individuals with

Table 1. Sociodemographic and clinical characteristics of the participants.

	Mean $\pm$ SD (n = 26)	
Age (years)	56 $\pm$ 12.01	
Height	164.46 $\pm$ 12.61	
Weight	79.46 $\pm$ 16.05	
Duration of diabetes (year)	9.92 $\pm$ 7.98	
HbA1c (%)	7.45 $\pm$ 1.64	
Fasting glucose (mg/dL)	148.08 $\pm$ 64.80	
Triglycerides (mg/dL)	277.11 $\pm$ 261.98	
HDL cholesterol (mg/dL)	46.61 $\pm$ 8.41	
LDL cholesterol (mg/dL)	152.59 $\pm$ 75.97	
Gender	n	%
Female	16	61.5
Male	10	38.5
Smoking Status		
Current	11	42.3
Never	8	30.8
Former	7	26.9
Alcohol Consumption		
Current	2	7.7
Never	24	92.3
Type Of Treatment		
Diet and exercise	0	0
Oral medication only	24	92.3
Insulin only	0	0
Insulin + oral medication	2	7.7

*Data are presented as mean $\pm$ standard deviation (SD) for continuous variables and as frequency (n) and percentage (%) for categorical variables.

*mg/dL = milligrams per deciliter; HbA1c: glycated hemoglobin; HDL: high-density lipoprotein; LDL: low-density lipoprotein.

Table 2. Descriptive statistics of walking test performance.

Outcome measure	n	Mean $\pm$ SD (m)
ISWT (test)	26	336.54 $\pm$ 102.53
ISWT (retest)	26	323.85 $\pm$ 84.95
6MWT	26	464.94 $\pm$ 74.69

*Data are presented as mean $\pm$ standard deviation (SD). Distances are reported in meters (m). ISWT: Incremental Shuttle Walk Test; 6MWT: Six-Minute Walk Test.

*Test refers to the initial assessment and retest refers to the repeated assessment performed 7 days later for evaluation of test-retest reliability.

T2DM. The ISWT demonstrated moderate validity and acceptable-to-good test-retest reliability in individuals with T2DM. The moderate correlation between the ISWT and the 6MWT supports the concurrent validity of the ISWT in this population. Furthermore, the ICC_{3,1} values observed in this study indicated that the ISWT demonstrates good relative reliability across repeated measurements. Based on the findings of the repeated ISWT measurements conducted for reliability assessment, no statistically significant systematic change was observed between the test and retest assessments.

According to findings from studies comparing ISWT with 6MWT in different patient populations, the ISWT

has been reported to better reflect maximal oxygen consumption (VO₂max) due to its progressively increasing workload and externally accelerated structure. The relationship observed between the ISWT and 6MWT in the present study suggests that, although the two tests are related, they may reflect different dimensions of exercise performance. This study observed a moderate correlation between ISWT and 6MWT.

A pilot study by Nair, Shetty, and Prathik (2025) in middle-aged individuals with T2DM reported that ISWT was more suitable than 6MWT for assessing VO₂max; however, the walking distance covered during ISWT was significantly shorter than during 6MWT (ISWT: 123.13 m; 6MWT: 338.33 m). The authors attributed the shorter distance covered during ISWT to the externally paced and gradually increasing nature of the test protocol. They also suggested that the ISWT may be more suitable for assessing maximal exercise capacity, whereas the 6MWT may be more appropriate for assessing submaximal endurance (Nair, Shetty, and Prathik, 2025). In the present study, participants also walked longer distances in 6MWT compared to ISWT (ISWT1: 336.54 $\pm$ 102.53 m, ISWT2: 323.84 $\pm$ 84.95 m, 6MWT: 464.94 $\pm$ 74.69 m). The externally regulated structure of ISWT is associated with a gradually increasing exercise load, which parallels an increase in heart rate and perceived exertion level (fatigue). Therefore, the distance covered during ISWT is generally lower than in 6MWT, which is performed at its own pace (Nair, Shetty, and Prathik, 2025; Singh et al. 2014). However, although a similar pattern was observed in this study, the difference in walking distance between ISWT and 6MWT is not as significant as reported by Nair, Shetty, and Prathik (2025). This difference may be attributed to methodological variations between the studies. In the pilot study conducted by Nair, Shetty, and Prathik (2025) the aim was to compare the results of the 6MWT and the ISWT in middle-aged patients with T2DM. In that study, individual differences such as age, gender, and duration of T2DM were taken into account, and the investigation of relationships among these variables may have contributed to the differences observed between their findings and our results.

Studies conducted in various clinical populations suggest that the ISWT may more accurately reflect maximal aerobic capacity (Lim, Jee, and Lee, 2022). Additionally, several studies have reported that the ISWT better reflects VO₂max and exercise tolerance compared to 6MWT in other clinical populations, such as chronic heart failure and pulmonary hypertension (Irisawa et al. 2014; Pulz et al. 2008). In the present study, the validity of the ISWT was not assessed using CPET; therefore, no definitive

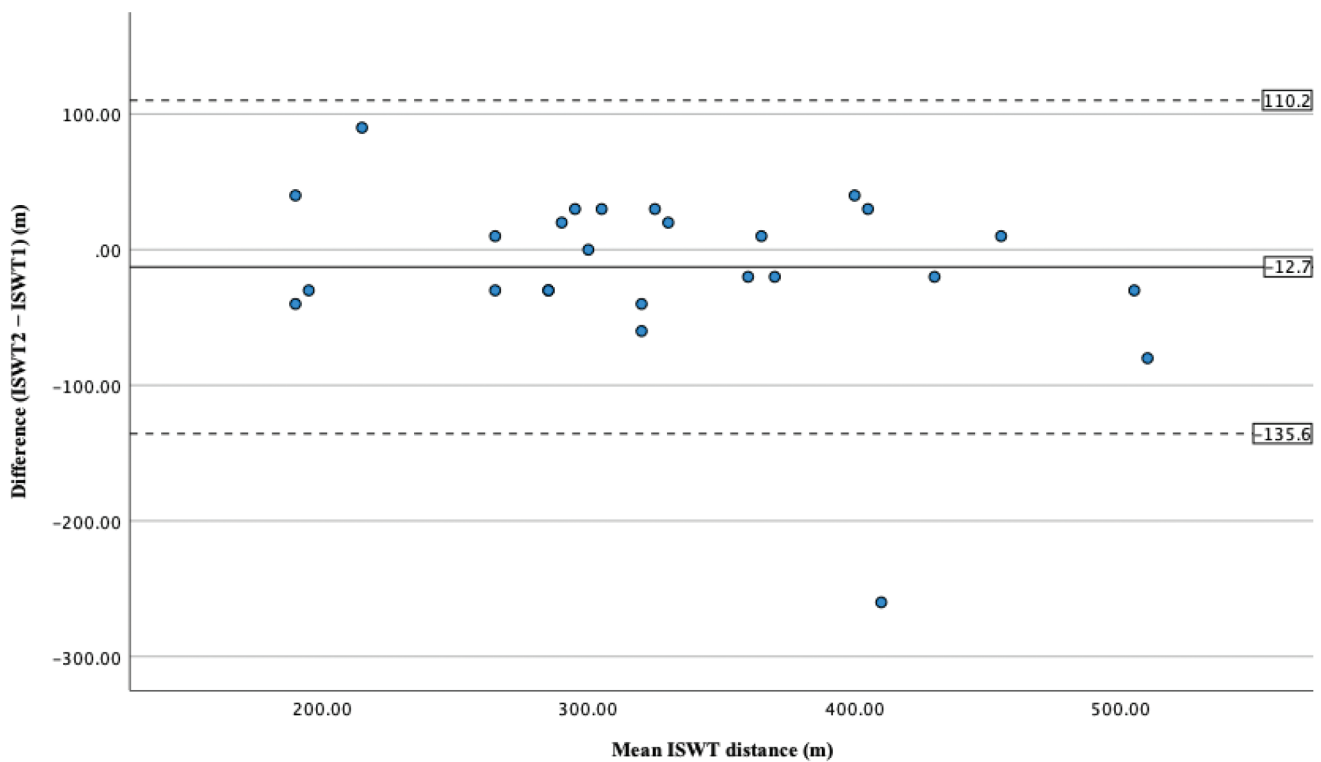


Figure 2. Bland-Altman plot showing the agreement between the first and second incremental shuttle walk test measurements. The mean bias was -12.7 m, with 95% limits of agreement ranging from -135.6 m to 110.2 m. The solid line represents the mean bias, and the dashed lines represent the 95% limits of agreement.

Table 3. Test-retest reliability and concurrent validity results of the incremental shuttle walk test.

Parameter	Value
ICC _{3,1}	0.778 (0.568–0.893)
Cronbach's α	0.875
Paired t-test (ISWT test vs. retest)	$t(25)=1.032, p=.312$
SEM (m)	48.3
MDC ₉₅ (m)	134.0
Correlation ISWT-6MWT (r)	0.669, $p<.001$

* ICC_{3,1}: Intraclass Correlation Coefficient based on a two-way mixed-effects model with absolute agreement (single measures); Cronbach's α : Cronbach's alpha coefficient; SEM: standard error of measurement; MDC₉₅: minimal detectable change at the 95% confidence level; m: meters; ISWT: Incremental Shuttle Walk Test; 6MWT: Six-Minute Walk Test; r: Pearson correlation coefficient.

*Reliability was evaluated using repeated ISWT measurements performed 7 days apart. Concurrent validity was assessed by examining the correlation between ISWT and 6MWT walking distances.

conclusions regarding VO_2max can be drawn. Accordingly, the moderate correlation observed between the 6MWT and ISWT may be considered an expected finding and is consistent with prior research.

The validity of the 6MWT has been well established in individuals with T2DM (Lee, 2018). In the present study, a moderate positive correlation was found between the two tests. This finding supports the concurrent validity of the ISWT for assessing functional capacity in individuals with T2DM. The

ISWT may serve as a clinically useful alternative for evaluating functional exercise capacity, particularly in clinical settings where a more standardized and externally paced assessment is preferred. Furthermore, the ISWT may facilitate individualized exercise prescription in individuals with T2DM while its standardized incremental protocol enables a more standardized and reproducible assessment of maximal exercise capacity, thereby contributing to more consistent monitoring of rehabilitation outcomes over time.

In this study, the SEM value of the ISWT was found to be 48.3 m, and the MDC at the 95% confidence level was 134.0 m. Although the MDC value appears relatively high, this finding likely reflects the heterogeneity in functional exercise capacity among individuals with T2DM and the moderate-to-good level of test-retest reliability observed in the present study.

The SEM value reflects the repeatability and precision of the ISWT. In the present study, the SEM value obtained for the ISWT was 48.3 m. Hanson, Taylor, and McBurney (2016) reported an SEM of 17 m in patients referred to cardiac rehabilitation and indicated that a change of approximately 54.0 m was required at the individual level to exceed measurement error. These findings suggest that the measurement precision of the ISWT may vary across different clinical populations depending on population-specific characteristics.

Compared with other chronic disease populations, the test-retest reliability observed in the present study is generally consistent with previous findings; however, measurement error may vary across populations. In cardiovascular populations, the ISWT has demonstrated high test-retest reliability in patients referred to cardiac rehabilitation and good long-term reliability in clinically stable patients with cardiovascular disease (Hanson, Taylor, and McBurney, 2016; Pepera, McAllister, and Sandercock, 2010). In chronic respiratory diseases, the ISWT has also been reported to demonstrate good-to-excellent reliability (Singh et al. 2014; Singh, Moiz, Ali, and Talwar, 2018). In the present study, the ICC_{3,1} of 0.778 was consistent with previous findings, although the SEM of 48.3 m was higher than that reported by Hanson, Taylor, and McBurney (2016). These differences may be related to variations in disease characteristics, functional capacity, sample size, and testing protocols.

The MDC value is an important parameter for clinical follow-up. In this study, the relatively high MDC value may be attributed to the heterogeneous functional capacity of the study population (with some individuals walking considerably shorter and others considerably longer distances). We consider that this situation may have contributed to an increase in measurement error. Possible reasons for higher SEM and MDC values in T2DM may include the relatively small sample size. Furthermore, the observed ICC_{3,1} indicated acceptable-to-good test-retest reliability, the relatively wide 95% confidence interval suggests limited precision of the reliability estimate, likely due to the relatively small sample size. Therefore, the reliability findings should be interpreted with caution, and future studies including larger samples are warranted to obtain more precise estimates.

From a clinical perspective, T2DM is primarily a metabolic disease, and in some individuals, respiratory and/or cardiac function may be normal or only mildly affected. Therefore, while the ISWT can be considered a reliable outcome measure in this population, relatively large changes in ISWT distance may be required to confidently detect true individual-level changes in clinical practice. In addition, because concurrent validity was evaluated against the 6MWT rather than the gold-standard CPET, the findings should be interpreted as reflecting concurrent validity with an established field walking test.

Limitations

This study has several limitations. First, the small sample size ($n = 26$) may limit the generalizability of the findings to patients with T2DM. Second, concurrent validity was assessed solely using the 6MWT, and the CPET, which is the recommended gold standard for assessing maximal aerobic capacity, was not performed in this study, therefore limiting the interpretation of aerobic capacity. Third, the study included clinically stable and independently ambulatory individuals without diabetes-related complications affecting walking; therefore, the findings may not represent the broader T2DM population.

Conclusion

Given that reduced exercise capacity is a common consequence of T2DM and is associated with impaired functional status and quality of life, the availability of a practical, low-cost, and standardized field test is clinically important. Therefore, accurate and standardized assessment of functional exercise capacity is essential for clinical evaluation and monitoring in this population.

The ISWT demonstrated acceptable concurrent validity with the 6MWT and acceptable-to-good test-retest reliability in individuals with T2DM. These findings suggest that the ISWT may be a useful tool for assessing functional exercise capacity and objectively evaluating functional status in clinical practice. Moreover, since the ISWT allows for the estimation of VO₂max, it may provide complementary information for exercise assessment. However, considering the obtained SEM and MDC values, it can be suggested that changes in ISWT distance in individuals with T2DM should be interpreted with caution in order to determine individual-level changes.

Author contributions

CRedit: **Melis Usul:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation,

Visualization, Writing – original draft, Writing – review & editing; **Gülenay Yıldırım**: Conceptualization, Data curation, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing; **İlayda Kayapınar**: Conceptualization, Formal analysis, Methodology, Validation, Writing – original draft; **Semiramis Ozyilmaz**: Conceptualization, Methodology, Resources, Supervision; **Muhammed Tunc**: Resources.

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References

- Alfonso-Rosa RM, Del Pozo-Cruz B, Del Pozo-Cruz J, Sañudo B, Rogers ME 2014 Test-retest reliability and minimal detectable change scores for fitness assessment in older adults with type 2 diabetes. *Rehabilitation Nursing* 39: 260–268
- American Diabetes Association 2013 Diagnosis and classification of diabetes mellitus. *Diabetes Care* 36(Suppl 1): S67–S74.
- American Thoracic Society, American College of Chest Physicians. 2003 ATS/ACCP statement on cardiopulmonary exercise testing. *American Journal of Respiratory and Critical Care Medicine* 167: 211–277.
- ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. 2002 ATS statement: Guidelines for the six-minute walk test. *American Journal of Respiratory and Critical Care Medicine* 166: 111–117.
- Awotidebe TO, Adedoyin RA, Oke KI, Ativie RN, Opiyo R, Ikujeysi EO, Ikem RT, Afolabi MA 2017 Relationship between functional capacity and health-related quality of life of patients with type-2 diabetes. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews* 11: 1–5
- Bennett PH, Knowler WC 2005 Definition, diagnosis and classification of diabetes mellitus and glucose homeostasis. In: Kahn CR, Weir GC, King GL, Jacobson AM, Moses AC Smith RJ (Eds) *Joslin's Diabetes Mellitus* 14th ed. Philadelphia, PA: Lippincott Williams & Wilkins pp. 331–339
- Campo LA, Chilingaryan G, Berg K, Paradis B, Mazer B 2006 Validity and reliability of the modified shuttle walk test in patients with chronic obstructive pulmonary disease. *Archives of Physical Medicine & Rehabilitation* 87: 918–922.
- Chae G, Ko EJ, Lee SW, Kim HJ, Kwak SG, Park D, Ra SW 2022 Stronger correlation of peak oxygen uptake with distance of incremental shuttle walk test than 6-min walk test in patients with COPD: A systematic review and meta-analysis. *BMC Pulmonary Medicine* 22: 102.
- Cohen J 1988 *Statistical power analysis for the behavioral Sciences*. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates
- de Vet HCW, Terwee CB, Knol DL, Bouter LM 2006 When to use agreement versus reliability measures. *Journal of Clinical Epidemiology* 59: 1033–1039.
- Enright PL 2003 The six-minute walk test. *Respiratory Care* 48: 783–785.
- Hanson LC, Taylor NF, McBurney H 2016 The 10m incremental shuttle walk test is a highly reliable field exercise test for patients referred to cardiac rehabilitation: A retest reliability study. *Physiotherapy* 102: 243–248.
- Holland AE, Spruit MA, Troosters T, Puhan MA, Pepin V, Saey D, McCormack MC, Carlin BW, Sciurba FC, Pitta F, et al. 2014 An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. *The European Respiratory Journal* 44: 1428–1446.
- Irisawa H, Takeuchi K, Inui N, Miyakawa S, Morishima Y, Mizushima T, Watanabe H 2014 Incremental shuttle walk test as a valuable assessment of exercise performance in patients with pulmonary arterial hypertension. *Circulation Journal* 78: 215–221.
- Koo TK, Li MY 2016 A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine* 15: 155–163.
- Kuziemski K, Słomiński W, Jassem E 2019 Impact of diabetes mellitus on functional exercise capacity and pulmonary functions in patients with diabetes and healthy persons. *BMC Endocrine Disorders* 19: 2.
- Lee MC 2018 Validity of the 6-minute walk test and step test for evaluation of cardio respiratory fitness in patients with type 2 diabetes mellitus. *Journal of Exercise Nutrition & Biochemistry* 22: 49–55.
- Leenders M, Verdijk LB, van der Hoeven L, Adam JJ, van Kranenburg J, Nilwik R, van Loon LJC 2013 Patients with type 2 diabetes show a greater decline in muscle mass, muscle strength and functional capacity with aging. *Journal of the American Medical Directors Association* 14: 585–592
- Lim HJ, Jee SJ, Lee MM 2022 Comparison of incremental shuttle walking test, 6-minute walking test, and cardiopulmonary exercise stress test in patients with myocardial infarction. *Medical Science Monitor* 28: e938140.
- Mukaka MM 2012 Statistics corner: A guide to appropriate use of correlation coefficient in medical research. *Malawi Medical Journal* 24: 69–71
- Nair VK, Shetty BA, Prathik P 2025 Comparison between 6 min walk test and incremental shuttle walk test in middle age people with type 2 diabetes: A pilot study. *International Journal of Health Sciences and Research* 15: 72–77.
- Pepera G, Karanasiou E, Blioumpa C, Antoniou V, Kalatzis K, Lanaras L, Batalik L 2023 Tele-assessment of functional capacity through the six-minute walk test in patients with diabetes mellitus type 2: Validity and reliability of repeated measurements. *Sensors* 23: 1354.

- Pepera G, McAllister J, Sandercock G [2010](#) Long-term reliability of the incremental shuttle walking test in clinically stable cardiovascular disease patients. *Physiotherapy* 96: 222–227.
- Pepera G, Sandercock GRH [2022](#) Incremental shuttle walking test to assess functional capacity in cardiac rehabilitation: A narrative review. *International Journal of Therapy and Rehabilitation* 29: 1–10.
- Probst VS, Hernandez NA, Teixeira DC, Felcar JM, Mesquita RB, Gonçalves CG, Hayashi D, Singh S, Pitta F [2012](#) Reference values for the incremental shuttle walking test. *Respiratory Medicine* 106: 243–248.
- Pulz C, Diniz RV, Alves ANF, Tebexreni AS, Carvalho AC, de Paola Aav NAV, Almeida DR [2008](#) Incremental shuttle and six-minute walking tests in the assessment of functional capacity in chronic heart failure. *Canadian Journal of Cardiology* 24: 131–135.
- Singh S, Moiz JA, Ali MS, Talwar D [2018](#) Reliability, validity, and responsiveness of the incremental shuttle walk test in patients with interstitial lung disease. *Journal of Cardiopulmonary Rehabilitation and Prevention* 38: 425–429.
- Singh SJ, Morgan MDL, Scott S, Walters D, Hardman AE [1992](#) Development of a shuttle walking test of disability in patients with chronic airways obstruction. *Thorax* 47: 1019–1024.
- Singh SJ, Puhan MA, Andrianopoulos V, Hernandez NA, Mitchell KE, Hill CJ, Lee AL, Camillo CA, Troosters T, Spruit MA, et al. [2014](#) An official systematic review of the European Respiratory Society/American Thoracic Society: measurement properties of field walking tests in chronic respiratory disease. *The European Respiratory Journal* 44: 1447–1478.