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Research Article

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Evaluation of Walking Speed Metrics in Parkinson's Disease Using Consumer Smartwatch Telemetry: Distinguishing Overall Route Performance from Active-Movement Speed

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Abstract

Background: *Day-to-day variation and intermittent freezing of gait (FOG) complicate assessment of mobility in Parkinson's disease (PD). Commercial smartwatch systems provide walking speed estimates, but recorded distance may differ from a map-based route length, and total and moving times represent distinct aspects of performance.*

Objective: *To compare three practical speed indices—recorded distance/total time (RD/TT), map distance/total time (MD/TT), and map distance/moving time (MD/MT)—using repeated real-world walking tests.*

Methods: *Thirteen routine outdoor walking tests from one individual with PD were analyzed (Harbin, China; August–September 2026). Route distances were determined in Google Maps, and activity summaries were obtained with Apple Watch Ultra 2, WorkOutDoors, and HealthFit. Tests with conspicuous recording anomalies were treated in a separate measurement-error investigation and not included. Speed indices were recalculated from source distance and time fields; results were summarized descriptively and examined in relation to the operational FOG ratio (TT−MT)/TT.*

Results: *RD/TT averaged 30.05 ± 8.37 m/min, MD/TT 22.13 ± 7.11 m/min, and MD/MT 51.36 ± 7.51 m/min (mean ± SD, n=13). The operational FOG ratio was strongly inversely correlated with MD/TT (r=−0.890), but not with MD/MT (r=0.088). The former association is partly algebraic because MD/TT = (MD/MT) × (MT/TT).*

Conclusions: *Map-based route speed and detected-movement speed describe complementary operational aspects of gait performance in repeated real-world PD testing. The approach is simple and accessible; interpretation depends on accurate route distance and time fields, and the clinical validity of algorithm-defined moving time remains to be established.*

Keywords: Parkinson's Disease, Walking Speed, Freezing Of Gait, Smartwatch, Digital Mobility, Real-World Monitoring, Map Distance, Within-Person Variability

1. Introduction

Walking impairment in Parkinson's disease (PD) fluctuates within and between days. Short clinical assessments can be informative but may not represent prolonged, everyday mobility. Quantitative repeat measurements in familiar environments provide a complementary view of disease course, medication effects, gait instability, and freezing. Many instrumented gait assessments require specialized equipment and controlled conditions, limiting the frequency with which individuals can record their own walking ability. Our previous studies used readily available smartphones, smartwatches, and applications for longitudinal monitoring of walking function, identification of medication-associated

deterioration, evaluation of walking asymmetry, scrutiny of data aggregation, and quantification or classification of freezing-related gait changes [1–6]. Together these studies motivated a practical goal: to allow patients to assess walking quantitatively in real-world settings at different times and over routes of varying lengths, without requiring laboratory-based gait equipment.

In structured outdoor tests, however, the software-reported recorded distance (RD) can diverge considerably from the independently identified route length on Google Maps (MD). Our companion investigation describes such distance discrepancies together with inconsistencies in reported activity times and re-imported records [7]. These observations raise a separate clinical question: which simple speed index best represents the aspect of walking performance of interest? The present study compares three operational indices [8,9]. RD/TT approximates the conventional summary based on device-reported distance, MD/TT represents total route completion performance, including interruption of locomotion during an unpaused recording, and MD/MT represents distance divided by the application-defined moving time, potentially indicating performance during movement. We investigated their distributions and relation to the operational FOG ratio using repeated measurements in a single person with PD. This article addresses the interpretation of speed indices, not the technical causes of measurement error.

2. Materials and Methods

2.1. Study Design and Field Setting

Between 17 August and 21 September 2026, one individual with PD completed 13 routine outdoor walking tests in an elongated park in Harbin, China. A dedicated pedestrian/jogging route within a park extending over 5 km was used, it had no traffic signals and relatively few pedestrians. The starting point was common, while endpoints were identified using distinctive landmarks (including flower beds, toilets, or path junctions), allowing test distances to vary. The walking route was mapped using Google Maps. Deliberate rest breaks were manually paused and the recording resumed afterwards. Symptoms and motor performance were expected to vary from day to day. The original field series also included nine PD sessions with conspicuous recording irregularities and two healthy-control sessions. These observations were analyzed in the separate measurement-error paper rather than combined with the present speed-index analysis. The selection of 13 routine tests does not mean that their RD agreed with MD, all 13 retain positive distance discrepancies. The grouping was based on the source study's routine-test and flagged-case classifications.

2.2. Equipment and Measurement Variables

An Apple Watch Ultra 2 worn on the left wrist recorded outdoor activity with WorkOutDoors, HealthFit was used to review activity time and other summary fields. Source entries were transcribed to Excel. The variables used here were recorded distance (RD, m), route distance measured using Google Maps (MD, m), total time (TT, min), and software-defined moving time (MT, min). TT and MT are interpreted according to the exported activity fields, with manually paused deliberate breaks not intended as part of active test time. Their exact processing algorithms are not publicly established here.

2.3. Derived Walking-Speed Metrics

The three speeds were RD/TT, MD/TT, and MD/MT (all in m/min). They were calculated per session, not as a ratio of group-average distance to group-average time. The signed measurement discrepancy was MER = 100 × (RD−MD)/MD. As an operational index used in our previous studies, the FOG ratio was defined as (TT−MT)/TT. This provides a reproducible, software-derived index of interruptions in detected movement, referred to in earlier publications as FOG ratio, it should not be read as a separately timed clinical diagnosis of each freezing episode. Importantly, the speed indices and FOG ratio share time variables: MD/TT = (MD/MT) × (1−FOG ratio), provided TT and MT refer to the same activity and are positive. Associations among these quantities therefore cannot be interpreted as fully independent physiological validation.

2.4. Statistical Analysis

Each of the 13 sessions was the unit of observation, with one PD participant, measurements were not treated as independent patients. Mean, sample SD, median, minimum, maximum, and coefficient of variation (CV = SD/mean × 100%) were computed for each speed index. Pearson correlations with the operational FOG ratio were explored to describe within-person associations, not to establish causality. Because the indices are mathematically related, inferential tests comparing them were not used to claim superiority.

3. Results

3.1. Comparative Distributions of Three Walking Speed Indices (Table 1)

Across the 13 tests, RD/TT had a mean of 30.05 m/min (SD 8.37), compared with 22.13 m/min (SD 7.11) for MD/TT and 51.36 m/min (SD 7.51) for MD/MT (Table 1, Figure 1). RD/TT exceeded MD/TT in every test, consistent with the positive distance discrepancy recorded in the same 13 activities. The median RD/TT was 27.50 m/min, median MD/TT 20.65 m/min, and median MD/MT 52.79 m/min. The mean MER was +38.45% (SD 19.92%). The dispersion also differed: the CV was 27.9% for RD/TT, 32.1% for MD/TT, and 14.6% for MD/MT. These values describe within-person between-test variation and do not establish that MD/MT is inherently more reliable: MT is a software-defined quantity, and the three ratios differ mathematically. Speed indices were computed separately for each activity before summary. FOG ratio is an operational app-based metric, MER uses mapped distance as its practical reference. Three calculated speed indices in 13 outdoor PD walking tests (Test 1–13) are shown in Figure 1.

Variable	Mean ± SD	Median	Min–max	CV (%)
RD/TT (m/min)	30.05 ± 8.37	27.50	14.90–42.24	27.9
MD/TT (m/min)	22.13 ± 7.11	20.65	11.34–35.29	32.1
MD/MT (m/min)	51.36 ± 7.51	52.79	38.47–61.76	14.6
FOG ratio (TT−MT)/TT	0.568 ± 0.126	0.577	0.377–0.791	22.1
MER (%)	+38.45 ± 19.92	+36.67	+14.29–+81.08	51.8

Table 1: Descriptive Statistics of Speed Indices and Operational Movement-Interruption Ratio (13 PD tests).

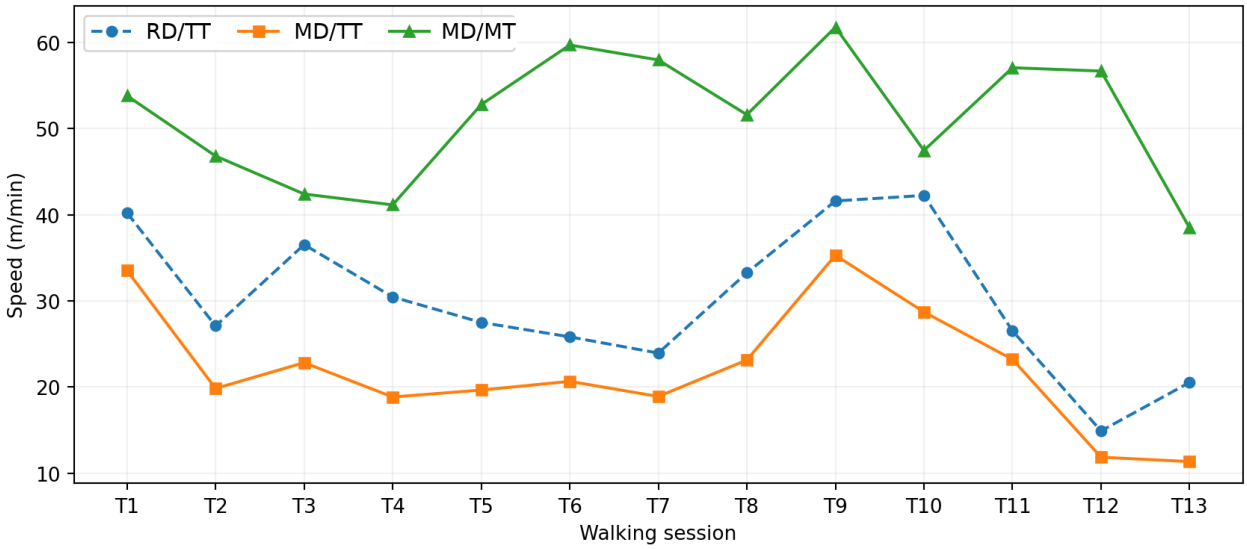


Figure 1: Three calculated speed indices in 13 outdoor PD walking tests (Test 1–13). RD/TT uses the software-recorded distance and total time; MD/TT uses the Google Maps route distance and total time; MD/MT uses the mapped distance and application-defined moving time. The lines connect test order, not continuous recordings. Rest breaks were manually paused.

3.2. Relationship with the Operational FOG Ratio (Figure 2, Table 2)

The operational FOG ratio varied from 0.377 to 0.791 (mean 0.568). Its Pearson correlation with MD/TT was r = −0.890 (n=13, exploratory two-sided p = 0.000046), whereas the correlation with MD/MT was r = 0.088 (p = 0.775). Its correlation with RD/TT was r = −0.980, but RD/TT shares the same TT denominator and is affected by distance discrepancies. The strong inverse MD/TT association partly follows algebraically from MD/TT = MD/MT × (1−FOG ratio), and must not be presented as independent evidence that FOG causes slower walking.

Test	RD/TT	MD/TT	MD/MT	FOG ratio	MER (%)
1	40.22	33.52	53.81	0.377	+20.0
2	27.09	19.82	46.81	0.577	+36.7
3	36.53	22.83	42.40	0.462	+60.0
4	30.46	18.84	41.14	0.542	+61.7
5	27.50	19.64	52.79	0.628	+40.0
6	25.82	20.65	59.70	0.654	+25.0
7	23.94	18.90	57.97	0.674	+26.7
8	33.25	23.13	51.61	0.552	+43.8
9	41.60	35.29	61.76	0.429	+17.9
10	42.24	28.71	47.46	0.395	+47.1
11	26.52	23.20	57.07	0.593	+14.3
12	14.90	11.85	56.68	0.791	+25.7
13	20.53	11.34	38.47	0.705	+81.1

Table 2: Test-by-test values used for the Primary Descriptive Comparison (m/min except FOG and MER).

4. Discussion

4.1. Different Operational Meanings of Speed

Our results highlight the value of explicitly identifying the numerator and denominator of reported "walking speed." When recorded distance is inflated relative to the mapped route, RD/TT overstates route completion speed under the study's distance reference. MD/TT instead combines the time needed to cover a practical real-world route with the episodes of interrupted progression that characterize PD. MD/MT removes periods identified by the application as nonmoving and, in these 13 tests, remained

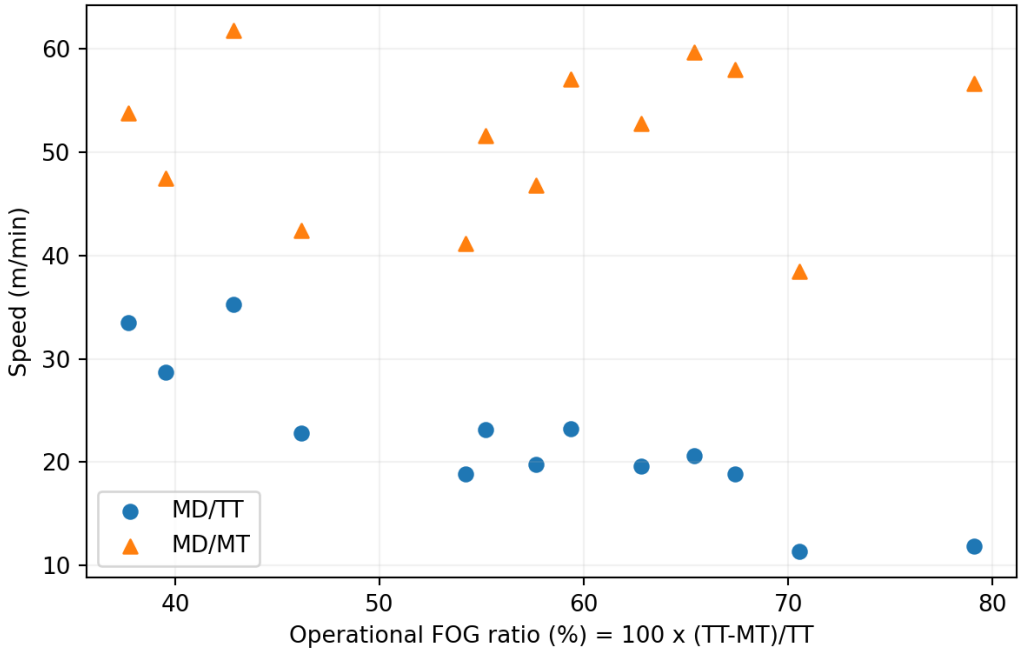


Figure 2: Relationship between operational FOG ratio and mapped route speeds. Circles denote MD/TT and triangles MD/MT. The operational FOG ratio, calculated as 100 × (TT−MT)/TT, is mathematically connected to both speeds through the time fields; the plotted relationships therefore describe the calculation and variation across tests rather than independent diagnostic validation.

Appreciably higher. Thus, the two map-based indices are complementary rather than competing attempts to measure a single biological quantity. MD/MT may be clinically helpful because a patient with low overall route performance can still show a meaningful level of movement-period capacity. However, a ratio based on algorithm-defined MT is only as interpretable as that time field. It should not be called the maximal, intrinsic, or validated walking speed of the patient. Simultaneously, MD/TT must not be considered an error-free ground-truth measurement: route identification, recorded TT, and treatment of paused breaks all matter.

4.2. Day-to-Day Variation is Information, not Automatically Error

A primary motivation for repeated consumer-device testing is the pronounced day-to-day fluctuation of PD gait. An unusually slow test may be clinically important, not merely an outlier. The variation in MD/TT in this dataset is compatible with fluctuating route completion performance, its cause cannot be resolved from summary data alone. The lower CV in MD/MT is compatible with more stable performance during detected movement, but might also reflect how the application classifies movement. Repeated personal monitoring may be more useful than relying solely on a brief visit to a clinic, while conventional assessments remain valuable for diagnosis and validation.

4.3. Simplicity and Continuity with Earlier Work

The central purpose of this research program is to enable repeated quantitative monitoring by patients using widely available consumer devices and applications, without the burden of specialist gait laboratories or fixed short test distances. The use of a recognizable route and Google Maps provides a practical distance reference for such repeated tests. Our earlier studies addressed longitudinal changes, medication-associated effects, gait asymmetry, data-processing pitfalls, and freezing-related phenomena [1–6]. The present report extends that work by making explicit which aspect of performance each speed index represents. It is not intended to define a complex new calibration procedure.

4.4. Measurement Issues and Limitations

A companion report identified both route-distance discrepancies and time-field inconsistencies in other walks from the same field series [7]. Accordingly, only the 13 routine Test records were used here, but their RD values remain substantially higher than MD. This matters when describing the cohort: "routine record" must not be equated with "GPS error-free" . The study involves a single PD participant and 13 activity records, with no independent, externally timed observation of actual movement and freezing, the approach

and findings are not yet generalizable across PD populations or devices. Google Maps provided the practical distance reference, not a surveyed absolute distance. The model cannot isolate biological changes from measurement variability using these data alone. Most importantly, TT and MT are processed data fields, and the operational FOG ratio is algebraically coupled to the map-based speeds. Claims about independence or predictive accuracy require additional evidence beyond correlations of derived ratios. These limitations do not undermine the practical motivation for the method, but determine the strength of conclusions that can be drawn.

5. Conclusion

In repeated outdoor walks by one person with PD, MD/TT provided a practical index of overall route completion performance, whereas MD/MT described speed during periods identified by the application as moving. Both measures are obtainable from ordinary consumer-device records and map-based route distances. They capture different operational aspects of walking and may be useful for repeated, real-world, within-person tracking. Their clinical value should be tested further, with attention to time-field consistency and preservation of true day-to-day motor fluctuations.

Declarations

Author Contributions: K.Y. conceived and supervised the study and interpreted the data, Z.L. contributed to data organization and analysis. Both authors are responsible for reviewing and approving the final manuscript.

Funding: No external funding was received. Competing interests: The authors declare no competing interests.

Ethics and Consent: Self-collected gait data from a person with PD were analyzed with consent.

Data Availability: Data are available from the corresponding author upon reasonable request.

Declaration of generative AI: ChatGPT was used to assist with statistical organization, drafting, and language editing. The authors checked the calculations against the source workbook and take full responsibility for the contents.

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