Original Article

Reliability of Sennogait Technology in Running Gait Analysis of Recreational Runners

Faye A. Dela Cruz, Halle Jo C. Ebia, Gabrielle Marie L. Santos*, Abigail M. De Lios, Er D. Petil Jr.

Manila Central University
EDSA, Caloocan City 1400

*Corresponding Author:
gaby630santos@gmail.com

Abstract

This study aims to test the reliability of SennoGait Technology in running gait analysis of recreational runners who are prone to running-related injuries (RRIs) due to repetitive stress and overload. This makes early detection of running gait abnormalities crucial, which is typically done through running gait analysis tools. The usual methods, including observational, two-dimensional, and three-dimensional, have limitations and an emerging wearable gait analysis tool, SennoGait Technology, may offer a potential solution. Thirty recreational runners (18–45 years old, 160–170 cm in height, running weekly for at least 12 months and accumulating 15–20 km) participated. Each runner performed activities on a treadmill: a two-minute warm-up jog, three one-minute running trials at 2.27 m/s (with one-minute rest periods), and a two-minute cool-down walk. Data were recorded using the SennoGait application. The Intraclass Correlation Coefficient (ICC) was used to assess intra-rater reliability. Results showed that six parameters showed good reliability in both feet, two temporal (foot flat, pushing) and four spatial (heel-strike, strike inversion angle, toe-off angle, strike pitch velocity). Two temporal parameters (loading, swing) showed moderate-to-good reliability, and one spatial parameter (maximum eversion velocity) had good-to-excellent reliability. Additionally, two spatial parameters (eversion extent, toe-out angle) exhibited excellent reliability in both feet. Overall, most parameters demonstrated good reliability, indicating that SennoGait Technology has good intra-rater reliability. These findings suggest that SennoGait Technology is a reliable tool for assessing the running gait patterns of recreational runners and can be an alternative tool for running gait analysis in both clinical and research settings.

Keywords: physical therapy, running gait analysis, intra-rater reliability, SennoGait technology, recreational runners

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Introduction

Running is one of the most popular sports in the world. It is inexpensive and requires minimal equipment, making it accessible to a lot of people. More importantly, running provides enormous health benefits, such as contributing to the prevention of chronic diseases by lowering risks, such as cardiovascular disease and different types of cancer. Despite this, there are many running-related injuries (RRIs) that these runners become susceptible to due to repetitive stress and overload with the increased ground reaction on affected joints and muscles in the lower extremity. All types of runners are prone to this, including recreational runners. People who engage in running for the sake of enjoyment and relaxation are defined as "recreational runners". Unlike competitive runners, they run for leisure; therefore, they usually engage in shorter distances without much physical preparation and lack the same amount of expertise and skill. This is why they are prone to sustaining musculoskeletal injuries in the lower extremity. The overall injury incidence rate and prevalence of runners are accounted for in the knee, ankle, and lower leg, with frequent cases of Achilles tendinopathy, medial tibial stress syndrome, patellofemoral pain syndrome, plantar fasciitis, and ankle sprain. This highlights the importance of early detection in them, given that they are less experienced and more likely to have abnormal misalignments in their running gait. Thus, giving the idea that a comprehensive evaluation and assessment tool is needed. Wearable technology is an emerging type of running gait analysis method due to its portability. It provides detailed data, including spatiotemporal parameters. In recent years, there has been a type of it that is gaining popularity, which is SennoGait Technology. Although people already utilize this, there is still no evidence in the literature about its reliability in running gait analysis.

Running gait analysis is an assessment of one's running gait patterns and style. With this, clinicians can see the way in which joints and muscles are involved, how they absorb weight, and also detect any abnormalities in the person's cycle (Kakouris et al., 2021). According to Agresta (2020), running gait analysis is vital to address the high risk of injuries to runners. Traditionally, observational gait analysis has been the standard way in which this assessment has been done. Here, the clinicians utilize their naked eye and knowledge of running gait parameters (Taly & Gupta, 2019). However, running gait has an increased cadence, making it hard to spot these abnormalities and misalignments. With this, there was the development of two-dimensional (2D) video analysis, which utilizes motion capture technology to acquire measurements, angles, and distance with proper camera positioning and quality (Fatone & Stine, 2015). Although this does not provide plantar pressure, forces, or capture kinetic data, it is limited in data collection. Three-dimensional (3D) gait analysis was then developed, offering camera arrays, track markers, and force plates to capture kinetic data and plantar pressure. This allows for a more comprehensive collection of data. However, due to its high cost and inability to be portable, it has become the least available in a clinical setting worldwide, making it not very accessible for clinicians and users (Hulleck et al., 2022). Furthermore, Fidel et al. (2021) state that studies on gait analysis utilizing 3D gait analysis have been primarily undertaken in Western countries, with no reference data among Filipinos, exhibiting the deficiency in this method in the Philippines. Mason et al. (2022) claim that wearable technology offers qualities that address the shortcomings of current assessment tools. This kind of technology utilizes accelerometers, gyroscopes, and magnetometers, as well as pressure-sensitive insoles that allow the quantification of a combination of spatiotemporal, kinetic, and kinematic variables. The primary benefit of wearable technology is its portability, allowing it to measure various aspects of running gait in any environment. A new type of this technology is gaining popularity, which is the SennoGait Technology.

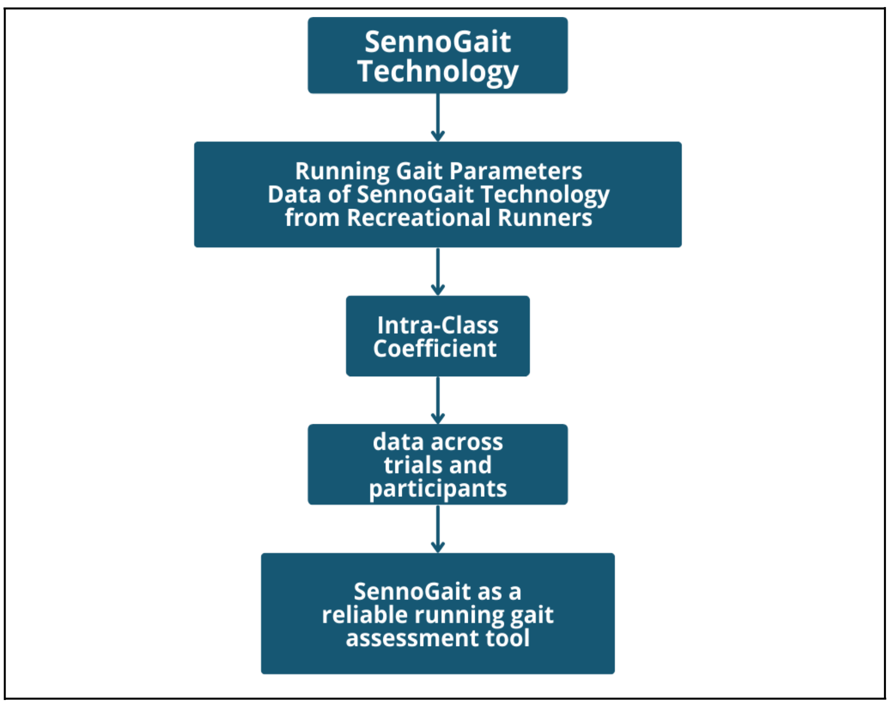
SennoGait Technology was introduced by a company from Shenzhen, China called SennoTech in August 2016 (SennoTech, 2018). This product is a portable gait analysis system that comes with insoles, sensors, and an application that allows it to be an accessible, convenient, and efficient method to gather data. SennoGait Technology provides information about the user's gait parameters. Additionally, it provides feedback reports and interprets data using AI-generated images of the user's gait and foot plantar pressure. These features enable clinicians to conduct simpler and more comprehensive assessments for diagnostic and treatment purposes. Alindogan et al. (2022) explored the reliability and validity of SennoGait Technology in assessing the walking gait analysis of healthy individuals, where they gained positive results. However, in the context of running gait analysis, there is still no existing literature, making its utilization questionable.

With this, the researchers aim to test the reliability of SennoGait Technology on running gait analysis of runners, specifically recreational runners. This can answer the gap between the technology and address the question of whether it can serve as a reliable tool that can be considered as an alternative tool for running gait analysis in various settings, such as in clinics and research.

Conceptual Framework

Figure 1

Conceptual Framework



SennoGait Technology was utilized on 30 participants to gather their running gait parameters. This was done over three trials of running on a treadmill for one minute, with one minute of rest intervals between each. The data from the three trials of each participant were gathered and input into a statistical tool for analysis. Intraclass Correlation Coefficient (ICC) was utilized which evaluates intra-rater reliability of SennoGait Technology by correlating the data of three trials across all participants to test the consistency of SennoGait Technology. With this, the researchers were able to determine whether SennoGait Technology is a reliable tool for running gait analysis

Methodology

Research Design

The study used a cross-sectional quantitative research design. The quantitative method deals with quantifying and analyzing variables to get results. This involves gathering numerical data, which is scrutinized by statistical tools. With this, certain questions can be answered, which can support or refute alternative knowledge claims (Apuke, 2017). In this study, the researchers examined the parameters of running gait with SennoGait Technology, where its intra-rater reliability was measured with the use of Intraclass Correlation (ICC). In such a manner, the hypothesis of the study was determined. Additionally, a cross-sectional type was implemented, which is defined as an observational study that analyzes data from a population at a single point in time. Moreover, in this type of research, the subjects were chosen from the available population that is relevant to the study's question (Wang & Cheng, 2020). 30 recreational runners that met the inclusion requirements, while not having any characteristics that fell in the exclusion criteria, were gathered and included in the research. These participants underwent three trials of a one-minute running session on a treadmill with a one-minute resting period. From this, the important data was collected, and the research question was addressed.

Participants

The target participants were recreational runners who run two to five times a week, covering a total distance of 15 to 20 kilometers with 12 months of experience (Fredette et al., 2021; Desai et al., 2021; Encarnación-Martínez et al., 2021). The age of participants was around 18 to 45 years old with a height of 160 to 170 centimeters (Encarnación-Martínez et al., 2021; Fidel et al., 2021). The total number of participants is 30. A larger number of participants improves the reliability, accuracy, and generalization of research findings, allowing greater credibility to the study's conclusions.

Sampling Technique

To select participants, the researchers made use of purposive sampling, which is a collection of non-probability sampling methods where groups are chosen based on the qualities that the researchers require in their sample (Bisht, 2024).

Instrument

In this study, researchers utilized Sennogait Technology, which is a wearable insole device designed for human gait analysis that uses sensor arrays and an inertial measurement unit (IMU) to measure plantar pressure. This is to check the running gait parameters of the participants. Additionally, with the use of a treadmill with a readable speed tracker, the participants ran at 2.27 m/s (Encarnación-Martínez et al., 2021).

Intervention

The researchers made use of the wearable insole technology and a treadmill for the procedure. The participants took part in certain sequences of activities. They did a two-minute jog as a warmup followed by a one-minute rest. After this, the three trials started, which consisted of a one-minute running session with one-minute resting intervals in between. It ended with a two-minute walk as a cool down (Gilmore, 2019; Urvi et al., 2021).

Data Collection Procedure

The researchers sought thirty recreational runners from Manila Central University (MCU) students and non-MCU students from Quezon City, aged 18 to 45 years old, with a height of 160 to 170 centimeters. All of them must run two to five times and accumulate a total distance of 15 to 20 kilometers a week. Moreover, they had been doing it for 12 months. All individuals who have experienced an injury or surgery in the past six months, with cardiovascular disease, and competitive runners were excluded. To find participants, the researchers utilized a social media poster that was posted on their Facebook accounts. It was then spread through running groups and Facebook Messenger. Each possible participant was provided with an informed consent that consisted of the research purpose, the research procedure, the potential risks, the potential benefits, and the type of individual the study focuses on. Thus, inclusion and exclusion criteria are involved, making sure the participants are aware of the requirements and properly screened. The participants were asked to fill in the informed consent form, indicating they were willing to participate in the study. Researchers scheduled and gathered ten participants in a day in the testing area, which is the Manila Central University Filemon D. Tanchoco Building, Room 104, also known as the College of Physical Therapy Gym. The total number of days that the implementation was conducted is three days. Before the day of the procedure, researchers advised the participants to wear any comfortable running shoes. On the day of the procedure, participants were asked to sign a form containing information about demographic profiles such as age, sex, and height, which would give additional data to properly check if the participants fit the study. Moreover, they chose the appropriate size of insole for them and wore it. After that, the proper procedure took place on a treadmill. Participants were asked to perform certain sequences of activities, starting with a two-minute warm-up. It is followed by three trials of a one-minute running session that is set to 2.27 m/s, and this is where the recording of data is conducted. Each trial had an interval of one-minute rest. The procedure ended with a two-minute walk for their cool down. All data is then stored in the SennoGait Technology application.

Data Analysis Procedure

The statistical tool that was utilized in data interpretation for the reliability of SennoGait Technology is:

Intraclass Correlation Coefficient (ICC)

The intraclass correlation coefficient, or ICC, is a concept that was originally presented by Ronald Fisher in 1954 as a modification of the Pearson correlation coefficient (Correa-Rojas, 2021). It is a statistical measure used to assess the reliability of measurements by quantifying the consistency or agreement between repeated observations. This is a widely used reliability index for internal consistency in medical literature that is useful in cross-study reliability that reflects the degree of correlation and agreement between measurements (Xue et al. 2021; Koo & Li, 2016). Moreover, the researchers of this study selected this reliability index due to its sensitivity to robust changes in raters, making it less prone to measurement errors and minimizing bias (Bobak et al., 2018). ICC models are classified into three main types: (1) one-way random-effects model, (2) two-way random-effects model, and (3) two-way mixed-effects model. Each model can be further categorized based on whether single measures or average measures are analyzed, as well as whether absolute agreement or consistency is evaluated.

In this study, the researchers sought to evaluate whether SennoGait Technology provides consistent assessments of running gait parameters across multiple trials of each participant. With the data that SennoGait Technology provides, the researchers find the significance of a one-way random effects model with consistency ICC for single measures to be the most suitable approach, with its ability to measure the consistency among the multiple trials and respondents. This model is effective since each subject is being measured by a single rater, which is the SennoGait Technology, in assessing their temporal and spatial parameters. The consistency of ICC was selected instead of absolute agreement since the primary focus was to determine the relative stability of the measurements across repeated trials. The single-measure ICC was preferred because individual measurements from the device were analyzed rather than averaged scores from multiple raters.

Choosing the correct ICC model is essential to ensure proper interpretation of reliability results. If multiple measurement systems were involved, a two-way random-effects model would have been ideal. Alternatively, if multiple raters and multiple subjects were used, then a two-way mixed-effects model would have been most appropriate.

The interpretation of ICC values follows the widely accepted thresholds proposed by Koo and Li (2016), which categorize reliability into poor, moderate, good, and excellent based on the magnitude of ICC estimates. The ICC range includes the following: if it is less than 0.50, it is interpreted as poor, if it ranges from 0.50 to 0.75, then it is interpreted as moderate, 0.75 to 0.90 is rated as good while if it is greater than 0.90 then it is excellent.

Results and Discussion

Intra-rater Reliability of SennoGait Technology in Measuring Temporal Parameters

Table 1

Summary of the Intraclass Correlation Coefficients for the Intra-rater Reliability of SennoGait Technology in Measuring Temporal Gait Parameters for Recreational Runners

Temporal Parameters	Left Foot		Right Foot	
	ICC	95% CI	ICC	95% CI
Loading	0.758	(0.61, 0.866)	0.701	(0.532, 0.831)
Foot Flat	0.757	(0.609, 0.866)	0.803	(0.675, 0.892)
Pushing	0.822	(0.705, 0.904)	0.786	(0.651, 0.883)
Swing	0.757	(0.609, 0.865)	0.674	(0.496, 0.814)

The results presented in Table 1 provide an assessment of the intra-rater reliability of the SennoGait Technology in measuring the temporal gait parameters of recreational runners. Intraclass Correlation Coefficients (ICCs) were computed separately for the left and right foot, with corresponding 95% confidence intervals (CIs) to evaluate the consistency of the measurements.

For the left foot, the ICC values indicate good reliability across all temporal gait parameters. Specifically, the highest ICC value was observed for the pushing phase (ICC = 0.822, 95% CI: 0.705 – 0.904), suggesting strong consistency in measuring this parameter. The loading (ICC = 0.758, 95% CI: 0.610 – 0.866), foot flat (ICC = 0.757, 95% CI: 0.609 – 0.866), and swing (ICC = 0.757, 95% CI: 0.609 – 0.865) phases all demonstrated good reliability as well. These findings suggest that SennoGait Technology provides stable and repeatable measurements for the left foot across different trials.

Conversely, the ICC values for the right foot were slightly lower, with results ranging from moderate to good reliability. The highest ICC value was recorded for the foot flat phase (ICC = 0.803, 95% CI: 0.675 – 0.892), indicating good reliability in measuring this parameter. The pushing phase also exhibited good reliability (ICC = 0.786, 95% CI: 0.651 – 0.883). However, the reliability for the loading (ICC = 0.701, 95% CI: 0.532 – 0.831) and swing (ICC = 0.674, 95% CI: 0.496 – 0.814) phases fell within the moderate range.

Overall, the findings indicate that SennoGait Technology demonstrates good intra-rater reliability for measuring the temporal gait parameters of recreational runners, particularly for the left foot.

The document review started with a letter requesting permission from the Board of Director Chairman to gather the data needed for the study, particularly to obtain copies of the documents/reports. The documents reviewed are the following: (1) the Cooperative's Board Resolutions, (2) By-laws for the past three years of operations, (3) Financial annual reports/records, (4) Annual accomplishment reports, (5) Policy and Procedural Guidelines of QMC, and (6) Memorandum Circulars. Also included in the review is the cooperative's legal mandate, namely the Republic Act No. 9520, otherwise known as the Philippine Cooperative Code of 2008.

Intra-rater Reliability of SennoGait Technology in Measuring Spatial Parameters

Table 2

Summary of the Intraclass Correlation Coefficients for the Intra-rater Reliability of SennoGait Technology in Measuring Spatial Gait Parameters for Recreational Runners

Spatial Parameters	Left Foot		Right Foot	
	ICC	95% CI	ICC	95% CI
Heel-strike Angle	0.798	(0.668, 0.889)	0.856	(0.756, 0.923)
Strike Inversion Angle	0.801	(0.672, 0.891)	0.764	(0.619, 0.869)
Toe-off Angle	0.879	(0.794, 0.936)	0.754	(0.604, 0.863)
Eversion Extent	0.966	(0.938, 0.982)	0.964	(0.936, 0.982)
Strike Pitch Velocity	0.804	(0.677, 0.893)	0.866	(0.804, 0.939)
Maximum Eversion Velocity	0.825	(0.709, 0.905)	0.903	(0.831, 0.949)
Toe-out Angle	0.91	(0.843, 0.953)	0.91	(0.844, 0.953)

Table 2 presents the intraclass correlation coefficients (ICCs) for the intra-rater reliability of SennoGait Technology in measuring spatial gait parameters of recreational runners. The ICC values, along with their 95% confidence intervals (CIs), were computed separately for the left and right foot to determine the consistency of the measurements across different trials.

For the left foot, the ICC values suggest good to excellent reliability across all spatial gait parameters. The highest ICC was recorded for eversion extent (ICC = 0.966, 95% CI: 0.938 – 0.982), indicating excellent reliability with minimal variability across repeated measures. Comparably, toe-out angle (ICC = 0.910, 95% CI: 0.843 – 0.953) also demonstrated excellent consistency, suggesting that SennoGait Technology provides stable measurements for this parameter. Other parameters, including heel-strike angle (ICC = 0.798, 95% CI: 0.668 – 0.889), strike inversion angle (ICC = 0.801, 95% CI: 0.672 – 0.891), toe-off angle (ICC = 0.879, 95% CI: 0.794 – 0.936), strike pitch velocity (ICC = 0.804, 95% CI: 0.677 – 0.893), and maximum eversion velocity (ICC = 0.825, 95% CI: 0.709 – 0.905), all exhibited good reliability, indicating that the measurements for these spatial parameters are consistently repeatable for the left foot.

Similarly, the ICC values for the right foot indicate good to excellent reliability for all spatial parameters. The eversion extent (ICC = 0.964, 95% CI: 0.936 – 0.982) and toe-out angle (ICC = 0.910, 95% CI: 0.844 – 0.953) once again demonstrated excellent reliability, reinforcing the precision of SennoGait Technology in assessing these parameters. Additionally, maximum eversion velocity (ICC = 0.903, 95% CI: 0.831 – 0.949), exhibited high ICC values, reflecting excellent reliability as well. On the other hand, strike pitch velocity (ICC = 0.866, 95% CI: 0.804 – 0.939), heel-strike angle (ICC = 0.856, 95% CI: 0.756 – 0.923), strike inversion angle (ICC = 0.764, 95% CI: 0.619 – 0.869), and toe-off angle (ICC = 0.754, 95% CI: 0.604 – 0.863) demonstrated good reliability.

Overall, the results indicate that SennoGait Technology provides good reliable measurements for spatial gait parameters, particularly for eversion extent, toe-out angle, and maximum eversion velocity.

Based on the findings, SennoGait Technology showed moderate to good reliability in the analysis of temporal parameters. These parameters are time-related aspects in running gait analysis, which are prone to change as they depend on a certain individual's consistent rhythm and timing. As the individual adjusts their running pace to adapt or compensate, changes in their tempo occur, which may cause variations in the data (Walha et al., 2021). Another factor that could affect the temporal parameters is the treadmill utilized in the study, as it is noted to be relatively small and narrow. This may have restricted participants from naturally running their normal stride length and stride width, which may, in turn, affect their cadence and show overall inefficiencies (Mason et al., 2022). Furthermore, it was noted that the left foot showed good temporal parameters overall, while the right foot showed two moderate parameters. This difference may be noted from limb or foot dominance because every individual may have a more dominant limb or foot, which could explain some of the variation since it affects braking/propulsion and mediolateral ground force components (Polk, J., 2017).

The findings of spatial parameters, on the other hand, range from good to excellent. This parameter emphasizes foot positioning and foot angle, which are factors that are not easily altered (Walha et al., 2021). However, not all measurements achieved excellent results due to several influencing factors. One reason is the need for regular calibration maintenance, which ensures accuracy. In between trials, researchers did not adjust the sensors and only removed them at the end of the trials. Additionally, as SennoGait technology operates via Bluetooth, errors in signal filtering can occur, particularly when the application requires resetting, which can affect the precision of the measurements (Ribeiro & Santos, 2017). Despite having a variance and range of results of moderate to excellent reliability, the fact that the majority of spatiotemporal parameters resulted in a good intraclass correlation coefficient (ICC) value, it can be pointed out that SennoGait Technology has a good intra-rater reliability status (Marom et al., 2024).

Conclusion

The present study conducted an examination of the intra-rater reliability of SennoGait Technology in the running gait analysis of recreational runners. The two vital components of running gait analysis, temporal parameters (loading, foot flat, pushing, and swing) and spatial parameters (heel-strike angle, strike inversion angle, toe-off angle, eversion extent, strike pitch velocity, maximum eversion velocity, and toe-out angle), were assessed. Six parameters, consisting of two temporal parameters (foot flat and pushing) and four spatial parameters (heel-strike angle, strike inversion angle, toe-off angle, and strike pitch velocity), demonstrated good reliability in both feet. Three parameters showed differences between the left and right foot, including two temporal parameters, loading and swing, which had good reliability in the left foot but moderate reliability in the right, and one spatial parameter, maximum eversion velocity, which had good reliability in the left foot but excellent reliability in the right. Additionally, two spatial parameters, eversion extent and toe-out angle, consistently demonstrated excellent reliability in both feet. Given that almost all spatiotemporal parameters showed good intra-rater reliability, the researchers concluded SennoGait Technology is a reliable tool for analyzing running gait patterns in recreational runners. Therefore, SennoGait Technology can serve as an alternative tool for running gait analysis in clinical and research settings, aiding in the early detection of gait abnormalities and misalignments, preventing running-related injuries, and supporting proper interventions.

Recommendations

This study is the first to explore the use of SennoGait Technology for running gait analysis, serving as a pilot study in this area, and further research is needed to fully establish its role. Future studies should assess other types of reliability, such as inter-rater and test-retest reliability, and investigate the device's validity against gold-standard methods like three-dimensional (3D) gait analysis to confirm its accuracy. Furthermore, testing it under different conditions, such as an inclined or declined treadmill should be considered. This would provide a better understanding of how technology performs in various circumstances, which could significantly alter running gait mechanics. Additionally, consider using a longitudinal approach by extending the gap of time between trials since this study utilized a cross sectional approach where all trials were taken in one day with only a minute interval. Also including a larger pool of participants with more diversity such as different types of runners such as competitive runners to improve its generalizability among populations. Improvements to temporal parameters must be included as well through conducting trials in overground environments, which allow natural variations in stride and terrain, while spatial parameters could benefit from regular recalibration between trials to ensure consistent measurements. Additionally, the manufacturer could enhance the technology by integrating sensors into insoles, improving Bluetooth stability, refining hardware and software, offering more size and width options, and using durable materials for long-term consistent performance. Implementing these recommendations would reinforce the credibility and validity of SennoGait Technology, supporting its use in both clinical and research settings.

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