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# Quantitative Gait Dynamics Characterization in Aging and Parkinson's Disease using Stride Interval Analysis

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**ABSTRACT**: This work is to quantitatively analyze gait dynamics in aging individuals and those with Parkinson's disease (PD) by using stride interval analysis. Gait deterioration, particularly in neurodegenerative conditions like PD, severely impacts quality of life and increases morbidity. The research employs a non-invasive gait analysis approach to evaluate motor control and identify subtle precursors to clinical diagnosis. By examining stride intervals, which indicate the timing between footfalls, the study aims to capture the irregularities in pathological gait patterns. Signal processing techniques and statistical modeling are utilized to extract and compare features from stride interval data across three groups: healthy young adults, healthy elderly individuals, and elderly individuals with Parkinson's disease. The goal is to establish quantitative metrics that differentiate between healthy aging, early-stage PD, and advanced disease states. The analysis uncovers significant differences in gait characteristics through assessments of mean stride interval, variability indices, and other statistical descriptors.

KEYWORDS: Gait analysis, Stride variability, Aging, Parkinson's Disease, ANOVA, Heatmap

#### I. INTRODUCTION

Gait, an intricate motor function, when analyzed, it provides the precise quantification of functional integration during human locomotion, which employing a variety of analytical strategies Gait is often compromised by the effects of aging and neurodegenerative conditions such as Parkinson's Disease (PD), leading to diminished quality of life and heightened fall risk [1], [2]. The rhythmic and cyclical nature of gait, involving coordinated movements of the lower limbs, offers a rich data source for understanding an individual's physiological and physical state, extending to characteristics like weight, gender, health status, and age [3]. Specifically, PD the second most prevalent neurodegenerative disorder after Alzheimer's, affects a substantial portion of the aging population, approximately 2-3% of individuals over the age of 65 [4]. The risk factor is high in individuals with PD, with reported fall rates ranging from 35% to 68% over a 12-month period, predominantly occurring during ambulation, raising significant concerns due to the severe medical and socioeconomic ramifications linked to falls, which can have lasting impacts on an individual's well-being [5]. Effective coordination among neural components, encompassing the basal ganglia brainstem system, regulated muscle tone, and sensory information processing, is crucial for normal gait, but these functions decline with age, increasing the likelihood of falls [6] that cause injury and mortality among older individuals [7].

Traditional clinical assessments of gait often rely on observational methods and subjective rating scales, which may lack the sensitivity and precision required to detect subtle gait abnormalities, and these assessments may suffer from limitations such as high interrater variability and susceptibility to practice effects [8]. Moreover, the multifactorial nature of falls in PD underlines the importance of comprehensive assessment strategies that consider motor and non-motor symptoms, as well as environmental factors. Advanced gait analysis techniques, particularly those employing wearable sensors and computational algorithms, offer the potential to overcome these limitations by providing objective, quantitative measures of gait parameters such as stride length, gait speed, and variability, which can be used to identify individuals at high risk of falling and to monitor the effects of interventions [9]. Studies indicate that





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individuals with PD are more susceptible to falls compared to healthy individuals of the same age or those with other neurological conditions, increasing the likelihood of recurrent falls by approximately ninefold [10].

Falls in PD are frequently linked to multiple coexisting risk factors, including a history of falls, postural instability, freezing of gait, leg muscle weakness, and cognitive impairment, emphasizing the importance of identifying these contributing factors to inform targeted intervention strategies [11], [12]. Instrumented gait analysis offers accurate and precise quantitative measurements, in contrast to the questioned validity, reliability, specificity, and responsiveness of qualitative methods, which may be inadequate for analysing the multifaceted aspects of gait variability and complexity [13]. Ultimately, the integration of quantitative gait analysis into clinical practice has the potential to transform the management of individuals with PD and other conditions associated with gait impairments, leading to more personalised and effective strategies for fall prevention and rehabilitation.

#### **II. LITERATURE REVIEW**

The application of stride interval analysis to characterise gait dynamics in aging and PD is supported by a robust literature show the utility of this approach for detecting subtle gait abnormalities and predicting fall risk.

Studies have shown that stride interval variability, a measure of the consistency of stride time, is increased in older adults and individuals with PD compared to healthy young adults, reflecting impaired motor control and adaptability [14]. The utilization of wearable sensors in gait analysis has gained momentum, offering a non-invasive means to gather extensive data on gait parameters in diverse settings. Wearable sensor technology holds promise for enhancing clinical assessment accuracy through continuous gait monitoring in real-world scenarios [15]. These devices facilitate the gathering of ecologically valid gait data, capturing gait patterns during daily activities, providing insights beyond the constraints of controlled laboratory settings. The ability to assess gait in real-world environments is particularly relevant for individuals with PD, whose gait impairments may vary depending on environmental context and task demands [16]. Machine learning algorithms have also been applied to gait data to develop predictive models for fall risk in older adults and individuals with PD. Gait impairments can be detected and quantified using a gait modelling method based on ground reaction force signals, and combining data from multiple sensors can improve the accuracy of gait space-time measurements [17]. The progression of fifth-generation wireless networks has enabled seamless data exchange, contributing to smart healthcare applications for human motion detection [18]. A similar statistical analysis was performed on different biomedical signals, including fPCG, EHG and EEG, to predict normal and emergency situations by obtaining these signals through non-invasive methods [20-22]. The wearable device is demonstrated to provide with the successful acquisition of physiological responses from users when measuring stress and exercise responses with a large differences between conditions (p < 0.0001) and sex (p < 0.0001) [23]. Further, comparisons of air and sponge conditions in PCA and clustering have demonstrated the greater priority of pressure distribution and comfort of air samples, suggesting that sophisticated analysis is useful in the studies on posture and sleep [24].

#### **III. METHODOLOGY**

This study involves the collection and analysis of stride interval data from young old and PD patients. Data were obtained from the Gait in Aging and Disease Database available on PhysioNet [25]. It includes stride interval time-series from: (i) 5 young healthy adults (age 21-29 years); (ii) 5 older healthy adults (age 71-77 years); (iii) 5 PD patients (age 60-77), each subject's stride interval (time between same-foot heel strikes) was recorded for 6–15 minutes using foot-embedded force sensors.

After data collection, form each subject's stride interval series, we extracted statistical features like mean, median, standard deviation (SD), range, interquartile range (IQR), median absolute deviation (MAD), coefficient of variation (CV), skewness and kurtosis. Then, we performed statistical group comparisons among all cohorts. Then statistical and visualization analysis is performed through ANOVA, boxplots PCA plots and heatmaps and finally grouped bar charts were produced to observe the groupwise trends.





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**IV. RESULTS AND DISCUSSION** 

Table 1 shows the statistical analysis of the extracted features revealed significant differences in gait dynamics among the study groups, including stride time variability, which was found to be significantly higher in older adults and individuals with PD compared to young adults.

Table 1: Statistical feature among young, old and PD patients

Feature	Young (±SD)	Old (±SD)	Parkinson (±SD)
Mean SI (s)	$1.1043 \pm 0.0669$	$1.0276 \pm 0.0900$	$1.1555 \pm 0.1588$
Std SI	$0.0236 \pm 0.0040$	$0.0266 \pm 0.0144$	$0.0784 \pm 0.0387$
CV	$0.0213 \pm 0.0028$	$0.0255 \pm 0.0118$	$0.0666 \pm 0.0264$
Range	$0.1550 \pm 0.0285$	$0.3774 \pm 0.4118$	$0.7827 \pm 0.3620$

Figure 1 and 2 shows the feature importance using ANOVA f scores and found that rangeSI, cvSI, stdSI, and kurtSI are the most useful features to distinguish pathological gait.



Figure 1: Feature importance using ANOVA F scores

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![](_page_4_Picture_2.jpeg)

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![](_page_4_Figure_4.jpeg)

![](_page_4_Figure_5.jpeg)

Correlation heatmap to identify redundant features form gait features is shown in figure 3. Heatmap clearly shows that there is strong correlation between stdSI, CVSI range SI and iqrSI ( $\rho \approx 0.77-0.98$ ). Mean and median are strongly correlated so can be reduced. But kurtosis is negatively correlated with rangeSI which can be useful. Skew show week correlation with most of the other features.

Figure 4 shows grouped bar chart that conclude that there is low variability in young age group and moderately high in old age group but very high variability in PD patients. These findings align with previous research indicating that gait variability is a sensitive marker of age-related and disease-related changes in motor control [19].

Spearman Correlation Between Gait Features												. 4	
meanSI	1.00	0.51	0.42	0.26	0.57	1.00	0.65	0.12	0.70	-0.17	0.00		1
stdSI	0.51	1.00	0.98	0.77	0.97	0.51	0.95		0.83	0.35	0.46		0.8
cvSI	0.42	0.98	1.00	0.77	0.94	0.42	0.93	-0.55	0.81	0.39	0.47		0.6
rangeSI	0.26	0.77	0.77	1.00	0.72	0.26	0.71	-0.75	0.72	0.29	0.87		0.4
iqrSI	0.57	0.97	0.94	0.72	1.00	0.57	0.98	-0.41	0.80	0.33	0.39		0.2
medianSI	1.00	0.51	0.42	0.26	0.57	1.00	0.65	0.12	0.70	-0.17	0.00		
madSI	0.65	0.95	0.93	0.71	0.98	0.65	1.00	-0.36	0.85	0.29	0.37		0
minSI	0.12	-0.52	-0.55	-0.75	-0.41	0.12	-0.36	1.00	-0.33	-0.01	-0.82	-	-0.2
maxSI	0.70	0.83	0.81	0.72	0.80	0.70	0.85	-0.33	1.00	0.36	0.47	-	-0.4
skewSl	-0.17	0.35	0.39	0.29	0.33	-0.17	0.29	-0.01	0.36	1.00	0.18		-0.6
kurtSI	0.00	0.46	0.47	0.87	0.39	0.00	0.37	-0.82	0.47	0.18	1.00		ا
	meanSI	stdSI	cvSI	rangeSI	iqrSl	medianSI	madSI	minSI	maxSI	skewSl	kurtSI		-0.8

Figure 3: Correlation heatmap of statistical features

![](_page_5_Picture_0.jpeg)

![](_page_5_Picture_2.jpeg)

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Figure 4: Grouped bar chart of statistical features among young, old and PD patients

#### V. CONCLUSION

This study provides quantitative evidence for the distinct gait dynamics associated with ageing and PD, highlighting the utility of stride interval analysis for characterizing gait impairments and differentiating between these populations. Non-linear features such as kurtosis and CV provide powerful discriminators of pathological gait. The quantitative data presented in this study provide valuable insights into the pathophysiology of gait disorders and support the development of targeted interventions to improve mobility and reduce fall risk in older adults and individuals with PD. Future research should focus on validating these findings in larger and more diverse populations, as well as exploring the potential of stride interval analysis to predict disease progression and treatment response in PD.

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![](_page_6_Picture_0.jpeg)

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