DOI:10.4274/tnd.2023.08684
Turk J Neurol 2023;29:241-248

Original Article / Özgün Araştırma

Interrelationship Among Fear of Falling, Gait Characteristics and Dynamic Balance in Stroke Survivors – A Case-control Study

İnme Geçiren Hastalarda Düşme Korkusu, Yürüyüş Özellikleri ve Dinamik Denge Arasındaki İlişki – Bir Olgu Kontrol Çalışması

Adebusola O. Borode[1], Taofeek O. Awotidebe[2], Adekola B. Ademoyegun[3], Adedayo O. Borode[1], Ibukun G. Falokun[2,4], Oluwatobi B. Omisore[2,4], Adepeju A. Kolade[4], Adekola J. Odunlade[2], Rufus A. Adedoyin[2]

[1]University of Medical Sciences, Faculty of Medical Rehabilitation, Department of Physiotherapy, Ondo, Nigeria
[2]Obafemi Awolowo University, College of Health Sciences, Department of Medical Rehabilitation, Ile-Ife, Nigeria
[3]Osun State University Teaching Hospital, Department of Physiotherapy, Osogbo, Nigeria
[4]Obafemi Awolowo University Teaching Hospitals Complex, Department of Medical Rehabilitation, Ile-Ife, Nigeria

Abstract

Objective: The influence of gait characteristics (GCs) and dynamic balance (DB) on fear of falling (FoF) among stroke survivors (SSs) remains unclear. This case-control study compared and correlated FoF, GC, and DB among SSs and apparently healthy controls (AHCs).

Materials and Methods: A total of 55 ambulant SSs and 110 age–sex-matched AHCs were recruited from two Nigerian hospitals. The FoF, GC (gait speed, cadence, stride length, and step length), and DB were assessed using the fall efficacy scale-international, accelerometer (BTS-G walk) and time-up and go test, respectively. Pearson's product-moment correlation coefficient and an independent t-test were applied. The alpha level was set at $P < 0.05$.

Results: The majority of SSs (87%) had a high risk of falling while AHCs (94.5%) had a low risk of falling. Additionally, 23.6% of SSs and 17.3% of AHCs had had a fall 12 months preceding the study. The SSs had significantly lower gait speeds (0.8 ± 0.3 m/s vs. 1.2 ± 0.3 m/s; t: -8.286; $P < 0.001$), cadence (80.5 ± 25.3 steps/min vs. 110.1 ± 11.3 steps/min; t: -10.399; $P < 0.001$), and DB (26.9 ± 18.1 s vs. 9.0 ± 2.4 s; t: 10.240; $P < 0.001$) than AHCs. The FoF was negatively correlated with cadence (r: -0.340; $P = 0.011$) and gait speed (r: -0.383; $P = 0.004$), and positively correlated with DB (r: 0.700; $P < 0.001$), while gait speed was negatively correlated with DB (r: -0.645; $P < 0.001$) among SSs. A similar pattern of correlations was observed among AHCs.

Conclusion: SSs demonstrated a high FoF, poor DB with an increased risk of falling, and altered GC compared with AHCs. In addition, significant relationships were found among FoF, DB, and GC among SSs and AHCs.

Keywords: Stroke, fall, walking, postural control, older adults

Öz

Amaç: İnme geçirmiş hastalarda (İGH) yürüyüş özelliklerinin (YÖ) ve dinamik dengenin (DD) düşme korkusu (DK) üzerindeki etkisi belirsizliğini korumaktadır. Bu olgu kontrol çalışması İGH ve sağlıklı kontroller (SK) arasında DK, YÖ ve DD'yi karşılaştırmış ve ilişkilendirmiştir.

Gereç ve Yöntem: Nijerya'daki iki hastaneden toplam 55 ayaktan İGH ve 110 yaş-cinsiyet uyumlu SK çalışmaya alındı. DK, YÖ (yürüyüş hızı, tempo, adım uzunluğu ve çift adım uzunluğu) ve DD, sırasıyla Uluslararası Düşme Etkinlik Ölçeği, akselometre (BTS-G walk) ve zamanlı kalk ve yürü testi kullanılarak değerlendirildi. Pearson momentler çarpımı korelasyon katsayısı ve bağımsız t-testi uygulandı. Alfa düzeyi $P < 0,05$ olarak belirlendi.

Bulgular: İGH'lerin çoğunluğunda (%87) yüksek düşme riski varken, SK'lerin (%94,5) düşük düşme riski vardı. Ayrıca çalışmadan 12 ay önce İGH'lerin %23,6'sı ve SK'lerin %17,3'ünde düşme yaşandı. İGH'lerde SK'lere kıyasla yürüyüş hızı (0,8 ± 0,3 m/s vs. 1,2 ± 0,3 m/s; t: -8,286; $P < 0,001$), kadans (80,5 ± 25,3 adım/dk vs. 110,1 ± 11,3 adım/dk); t: -10,399; $P < 0,001$) ve DD (26,9 ± 18,1 s vs. 9,0 ± 2,4 s; t: 10,240; $P < 0,001$) daha düşüktü. İGH'lerde DK, kadans (r: -0,340; $P = 0,011$) ve yürüyüş hızı (r: -0,383; $P = 0,004$) ile negatif, DD (r: 0,700; $P < 0,001$) ile pozitif korelasyon gösterirken, yürüyüş hızı DD ile negatif korelasyon gösterdi (r: -0,645; $P < 0,001$). SK'ler arasında da benzer korelasyon modeli gözlendi.

Sonuç: İGH SK'lere kıyasla yüksek DK, zayıf DD, artmış düşme riski ve bozulmuş YÖ gösterdi. Ayrıca İGH'ler ve SK'ler içerisinde DK, DD ve YÖ arasında önemli ilişkiler mevcuttu.

Anahtar Kelimeler: İnme, düşme, yürüme, postüral kontrol, yaşlı erişkinler

Address for Correspondence/Yazışma Adresi: Adekola B. Ademoyegun, Osun State University Teaching Hospital, Department of Physiotherapy, Osogbo, Nigeria
E-mail: aademoyegun@gmail.com ORCID: orcid.org/0000-0002-7711-7835
Received/Geliş Tarihi: 23.03.2023 **Accepted/Kabul Tarihi:** 31.08.2023

Introduction

Stroke is a major public health problem and a leading cause of death and disability among older adults worldwide, affecting about 80.1 million people globally (1,2). The highest incidence, prevalence, and case mortality were reported in Africa, with rates of 316/100,000, 14/1,000, and a one-month fatality up to 40%, respectively (3,4). The prevalence of stroke in Nigeria is 1.14 per 1.000 (5). Many stroke survivors (SSs) are left with residual hemiparesis, which impairs mobility and function in approximately two-thirds of the affected population (6). As a result, there is a high rate of physical inactivity following stroke, which has been found to propagate disability through deconditioning and learned non-use (6). Dysfunction in walking observed in stroke cases often results from weakened muscle strength, abnormal postural control, decreased mobility, and cognitive dysfunction, as well as other stroke-related characteristics (7,8). The most commonly stated priority of survivors is the recovery of functional independence, especially in walking, as it is an important determinant/factor for independent daily living (9,10). The most common reported complication among chronic survivors is a fall, and this occurs frequently during walking (11).

Fall is a major complication after acute stroke and has been deemed a major health concern that can occur throughout the life span of anSS (11,12). A high rate of falls occurs among stroke patients, making it the most frequent medical complication, constituting about 40% of all complications post-stroke (11). Compared with the general elderly population, patients with stroke are at higher risk and have a likelihood of falling repeatedly and consistently; this is typically attributed to residual disabilities present in SSs (13). With the increase in age of the population, the impact of falls also increases a loss of independent mobility for the survivor or even death (11,13). Of the cases of individuals with stroke who have had a fall, many develop a fear of falling (FoF). This is usually in response to a specific situation or perceived danger and is highly prevalent among women compared with men (14,15). Furthermore, FoF is associated with balance and gait deficits and frequently leads to a reduction in physical activity, uncertainty, deconditioning, and increased hospitalization with subsequent loss of independence among SSs (16). Balance and gait deficits are identified risk factors for falls and are the most important in terms of etiology (11). Several other factors have also been implicated in the development of FoF in SSs including depression, cognitive impairment, quadriceps strength/weakness, sensory deficits, spasticity, and hemi-neglect. Among SSs, there is a high chance of falling when walking, as many are not able to perform walk–talk functionality tasks (11). Balance deficits in patients with stroke are characterized by a reduction in postural stability when standing and reduced and delayed coordination to perturbations. There is greater postural sway, altered weight distribution, and smaller excursion in the direction of the weaker leg when moving around the base of support (17).

The deficits observed in hemiplegic gait include reduced propulsive force at push-off, decreased flexion of the hip and knee during the swing phase, and instability during the stance phase (18). The gait velocity, stride length, step length, cadence, and symmetry are key factors for analyzing gait. These parameters, called gait characteristics (GCs), connote walking patterns or sequences of limb motion that propel the body forward while maintaining stability (18,19).However, in patients with stroke, these characteristics are commonly altered and often compromised by overexertion and fatigue (20). This significantly affects the functional status of the SS, resulting in a low level of physical activity, exercise intolerance, and an inability to maintain a preferred walking pace (21). A reduction in gait speed and step length, as well as an increased time of double support and step width, was reported by Chamberlin et al. (22) in older adults with FoF, which is comparable to that observed in SSs (23). Obembe et al. (24) also observed that SSs typically have a reduced gait speed, which was noted as a potential predisposing factor for falls and poor balance confidence. Accordingly, gait ability and balance have to be improved to reduce the risk of falls in SSs. It is also imperative that attention be paid to how these factors precipitate FoF in SSs as this was found to negatively affect rehabilitation and recovery in SSs. To facilitate optimal recovery, it is essential to assess FoF and establish evidence regarding how GCs and dynamic balance (DB) influence FoF in SSs. Hence, this study aimed to assess, compare, and relate FoF, GC, and DB among SSs and apparently healthy controls (AHCs).

Material and Methods

Participants

Participants for this case-control study were SSs attending the physiotherapy clinics of two Nigerian tertiary hospitals and healthy controls who were age and sex-matched individuals recruited among hospital staff members and patients' relatives. The selected hospitals were Obafemi Awolowo University Teaching Hospitals Complex [(OAUTHC) Ife Hospital Unit, Ile-Ife and Wesley Guild Hospital, Ilesa], and Osun State University Teaching Hospital, Osogbo, Nigeria. This study included SSs who were at least 6 months post-stroke, receiving treatments at the selected hospitals, were 45 years and older, and were ambulant without the need for a walking aid post-stroke. Apparently healthy and physically fit controls were also included. However, SSs with vision and cognitive impairments, and who had difficulty comprehending verbal instructions, were excluded. The sample size for the study was calculated using the following formula: $N = 4\sigma^2(Z_{crit}+Z_{pwr})/D^2$, where N = the total sample size (for both groups being compared), σ= assumed the standard deviation of each group, Z_{crit}= the standard normal variate corresponding to the desired significance criterion (1.96 with α set at 0.05), Z_{pwr}=the standard normal variate corresponding to the desired statistical power (0.84 for 80% power), and D= minimum expected difference between the two means (25). The mean fall efficacy scale-international score for FoF in both SSs and older adults from established studies were 26.19 ± 7.5 and 30.44 ± 12.01, respectively (26,27).

$N= 4x7.5^2x\ (1.96+0.84)^2 \div (26.19\text{-}30.44)^2 = 4x7.5x7.5x7.84 \div (\text{-}4.25)^2 = 1764 \div 18.0625 = 97.67$

In this study, 10% attrition equals 97.67+9.767= 107 with an approximate value of 110.

Two controls were recruited for every stroke patient, making the total sample size for the study 165. Hence, a total sample size of 165 participants was recruited for the study.

Assessments

Fall history and physical characteristics including weight, height, body mass index, and waist and hip circumference were assessed. The FoF was assessed using the fall efficacy scale-international, a 16-item self-report questionnaire that provides information on the level of concern about falls for a range of daily activities (28,29). It was administered by hand using a paper-based format and was retrieved immediately after completion. The participant responses to items were collated and tallied. Scores between 16 and 27 indicated low concern and those over 27 showed high concern. The instrument has also been reported to have excellent validity and good internal consistency with Cronbach's alpha of 0.79 (28,29).

The timed up and go (TUG) test was used to examine the participants' DB. During the procedure, the participants were asked to rest for 5 minutes while seated on a standard chair. The test was demonstrated to the participants by the researcher and they were asked to perform the test as demonstrated by getting up from sitting and walking as fast as they could along a 3 m pathway before returning to sit down. The time taken by the participants to finish the procedure was noted and recorded in seconds (30). A normal healthy adult completed the task in 10 seconds or less, indicating independence in balance and mobility. A score of more than or equal to 14 seconds indicated a high fall risk (30).

The gait parameters assessed among participants included gait speed, cadence, and stride and step length. These parameters were measured using an accelerometer (BTS G-walk) (BTSG-walk, BTS SpA, Via della Croce Rossa, 11 Padova, Italy; SN: 0213-0378). The G-walk has a G-sensor with a bluetooth device that transfers the result of self-selected walks to a computer (HP model). An 8 m pathway was marked out for the walk by the participants. The sensor component of G-walk was then positioned at the 5th lumbar spine and wrapped around each participant at the waist level with a strap belt by the research assistant. Participants were then instructed to walk down the marked pathway at their preferred speed with the attached sensor. The laptop computer, which had the BTS G-Studio software program installed, ran the software and this was monitored by the researcher. The gait analysis started from the moment the participant began walking until they reached the end of the route. The gait parameters were generated by the G-walk device as the participant walked and sent the data to the laptop computer (31). The stride length, step length, cadence, and gait speed were recorded from the results of the gait analysis completed on the laptop. The BTS G-Walk accelerometer has excellent reliability (0.85–0.99) and validity (0.88–0.97) in gait assessments (32).

Procedure

Ethical approval was obtained from the Ethics and Research Committee of the OAUTHC, Ile-Ife, for this study (ERC/2020/02/03). Permission to recruit patients was sought and obtained from the physiotherapy departments of the selected hospitals. The purpose of the study was explained to the respective participants and written informed consent was obtained from them for inclusion in the research. A proforma was administered to them to obtain socio-demographic and clinical information and, following on, the fall efficacy scale was administered to them. Additionally, the AHCs were screened using the physical activity readiness questionnaire (PAR Q+) health checklist before administering the fall efficacy scale to them. The PAR Q+ was used to appraise the physical fitness of AHCs before participation in the study. The physical characteristics, fall history (frequency of fall over the past 12 months), and GCs of the participants were recorded.

Statistical Analysis

The data was summarized using descriptive statistics of frequency, percentages, and mean and standard deviation. Inferential statistics of Pearson's product-moment correlation were used to test the relationship between FoF, GCs, and DB among SSs and AHCs. An independent t-test was used to compare FoF, GCs, and DB between SSs and AHCs. The alpha level was set at $P < 0.05$. The International Business Machine Statistical Package for Social Sciences (IBM SPSS) version 20 (IBM Corp. Armonk, NY, USA) was used for statistical analysis.

Results

Table 1 shows the general characteristics of the SS and AHC participant groups. The mean age of the SSs and AHCswas 60.3 ± 9.5 and 60.8 ± 10.3 years, respectively. The majority of the SSs had right stroke laterality (52.7%). Table 2 shows that 23.6% of the SSs had experienced a fall 12 months preceding this study, with falls occurring once among 10.9%. Additionally, many of the falls happened indoors (12.7%) among SSs. For the control group, 17.3% had had a fall 12 months preceding this study, with falls occurring once in 13.6%. Many of the falls for the AHCs occurred outdoors (12.7%). Only a few of the SSs and AHCs sustained an injury during the fall (5.5% and 8.2%, respectively).

Figures 1 and 2 show the level of FoF and fall risk of the participants. About one-fifth of SSs had a high FoF (20%), while approximately 5.5% of AHCs had a high FoF. A high percentage of SSs had a high risk of falling (85.5%) while only a few were at such risk among the AHCs (5.5%). Tables 3 and 4 show the Pearson product-moment correlation coefficients for FoF, GCs, and DB among the participant groups. The results show a significant negative correlation between FoF and cadence results (r: -0.340, $P = 0.011$) and walking speeds (r: -0.383, $P = 0.004$) among SSs, while no significant correlation between FoF and both stride and step-length was observed. However, among the AHC group, there were significant negative correlations between the FoF and all GCs [stride length (r: -0.289, $P = 0.002$), cadence (r: -0.234, $P = 0.014$)] and walking speed (r: -0.300, $P = 0.001$), with step length being the exception. There were significant correlations between FoF and DB among both SSs (r: 0.700, $P = 0.001$) and AHCs (r: 0.271, $P = 0.004$) (see Table 3). Furthermore, the results showed that there were significant negative correlations between DB and cadence among both SSs and the AHCs (r: -0.536, $P = 0.001$ and r: –0.579, $P = 0.001$, respectively), as well as between DB and walking speed in both groups (r: –0.645, $P = 0.001$; r: –0.597, $P = 0.001$). Moreover, there was a significant correlation between DB and stride length among the AHCs; however, there was no such correlation among SSs (see Table 4). Table 5 shows the differences between the groups based on an independent t-test. The results reveal a significant difference in both cadence and walking speed between SSs and the AHC group (t: -10.399, $P = 0.001$ and t: –8.286, $P = 0.001$, respectively). There was also a significant difference in the DB between both groups (t: 10.240, $P = 0.001$).

Discussion

This study aimed to assess, compare, and relate FoF, GCs, and DB among SSs and age–sex-matched healthy individuals. The findings of this study showed that approximately one-fourth of SSs had experienced a fall in the 12 months preceding this study, while about one-fifth of AHCs had had a fall 12 months before the study. This is to be expected, as fallingis deemed a major complication of stroke and reportedly occurs at all recovery stages of having had a stroke. Accordingly, patients with stroke are more likely to fall compared with age-matched healthy controls due to specific factors, such as unilateral weakness, hemi-neglect, and impaired coordination (12,33). In line with the reports of previous studies (34,35), in this study, falls for SSs were observed to have occurred more indoors, while healthy controls tended to experience a fall when walking outdoors. This may be due to SSs' avoidance of social and physical activities, which predisposes them to having reduced physical capacity and, accordingly, experiencing a fall. That is, they are often inside the home and do not venture outdoors, indicating why they fall primarily indoors compared to the AHCs.

One-fifth of SSs in this study had a high FoF compared with the AHCs. Other studies observed similar reports of a high FoF among patients with stroke (35,36). It was noted that SSs were more likely to report a higher concern about falling than healthy controls. This could be due to the impaired balance and altered gait patterns exhibited by stroke patients, which pose limitations while walking. The development of FoF may not be fully explained, but patients with stroke may have psychologically internalized their physical limitations. This results in the adoption of behaviors that further increase their susceptibility to fall. FoF is related to balance and gait deficits, which are significant risk factors for a fall occurring. The sensory and motor impairments observed in stroke cases result in reduced gait quality. The important GCs that have been identified are gait velocity, cadence, stride length, and step

Table 1. The general characteristics of participants (n = 165)

Variable	Stroke survivors (n = 55) n (%)	Control group (n = 110) n (%)
Age (years)		
45-59	26 (47.3)	49 (44.6)
60-74	23 (41.8)	46 (41.8)
75-90	6 (10.9)	15 (13.6)
BMI (kg/m²) ($\overline{X}$ ± SD)	25.6 ± 5.3	24.7 ± 4.0
Gender		
Male	34 (61.8)	68 (61.8)
Female	21 (38.2)	42 (38.2)
Marital status		
Married	42 (76.4)	91 (82.7)
Divorced	-	2 (1.8)
Separated	1 (1.8)	6 (5.5)
Widowed	12 (21.8)	11 (10.0)
Ethnicity		
Yoruba	54 (98.2)	103 (93.6)
Others	1 (1.8)	7 (6.4)
Educational level		
No formal education	3 (5.5)	4 (3.6)
Primary	15 (27.3)	37 (33.6)
Secondary	13 (23.6)	31 (28.2)
Tertiary	24 (43.6)	38 (34.5)
Occupation		
Artisan/farmers	13 (23.6)	29 (26.4)
Business	3 (5.5)	4 (3.6)
Civil servants	13 (23.6)	54 (49.1)
Retiree	26 (47.1)	23 (20.9)
Stroke laterality		
Left	26 (47.3)	-
Right	29 (52.7)	
Stroke duration		
6 months-1 year	9 (16.4)	
2-4 years	14 (25.5)	-
5-7 years	13 (23.6)	
>8 years	19 (34.)	

BMI: Body mass index, $\overline{X}$ ± SD: Mean and standard deviation

Table 2. The fall history of stroke survivors and apparently healthy adults (n = 165)

Variable	Stroke survivors (n = 55) n (%)	Control group (n = 110) n (%)
Fall 12 months preceding the study		
Yes	13 (23.6)	19 (17.3)
No	42 (76.4)	91 (82.7)
Number of falls		
Once	6 (10.9)	15 (13.6)
Twice	4 (7.3)	3 (2.7)
≥3 times	3 (5.4)	1 (0.9)
Location of fall		
Indoor	7 (12.7)	5 (4.5)
Outdoor	3 (5.5)	14 (12.7)
Both	3 (5.5)	0 (0)
Injury sustained		
Yes	3 (5.5)	9 (8.2)
No	8 (14.5)	10 (9.1)
Type of injury		
Abrasion	1 (1.8)	1 (0.6)
Bruise (knee, elbow, arm)	1 (1.8)	5 (3.0)
Cut	1 (1.8)	0 (0)
Laceration	0 (0)	1 (0.6)
Tooth removal	0 (0)	1 (0.6)
Fracture (right arm)	0 (0)	1 (0.6)
None	52 (94.6)	101 (94.6)
Living situation		
With family/others	54 (98.2)	100 (90.9)
With friend	0 (0)	2 (1.8)
Living alone	1 (1.8)	8 (7.3)

Others: Housekeeper/other relatives

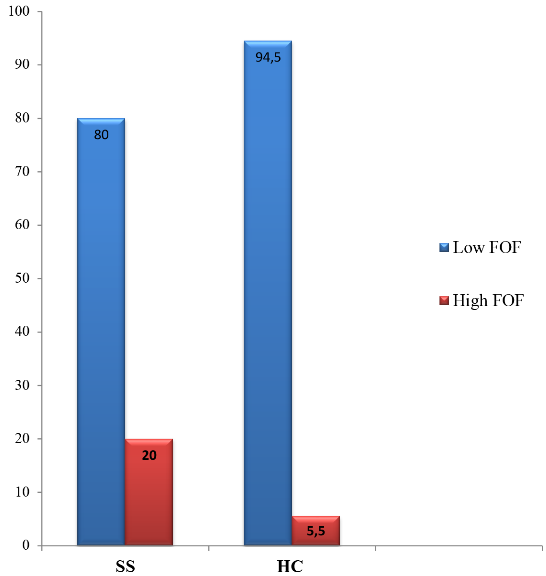

Figure 1. Level of fear of falling among participants
SS: Stroke survivor, HC: Healthy control, FoF: Fear of falling

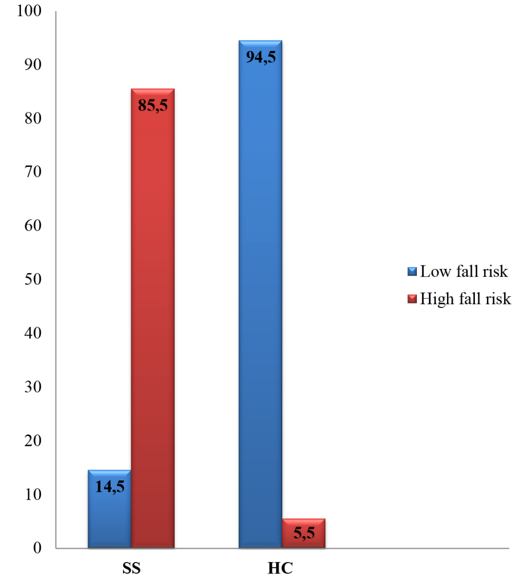

Figure 2. The level of fall risk among participants
SS: Stroke survivor, HC: Healthy control

Table 3. Correlations among fear of falling, gait characteristics, and dynamic balance among stroke survivors and healthy individuals (n = 165)

Variable	Fear of falling	
	Stroke survivors (n =55) r (*P* value)	Healthy control (n = 110) r (*P* value)
Gait characteristics		
Stride length (m)	-0.032 (0.818)	-0.289 (0.001)**
Step length (m)	-0.039 (0.776)	0.044 (0.648)
Cadence (steps/min)	-0.340 (0.011)**	-0.243 (0.014)*
Walking speed (m/s)	-0.383 (0.004)**	-0.300 (0.001)**
Dynamic balance (s)	0.700 (0.001)**	0.271 (0.004)**

*Correlation is significant at a 0.05 level, **Correlation is significant at the 0.01 level, m: Meters, m/s: Meter per second, step/min: Step per minute, s: Seconds, r: Correlation coefficient

Table 4. Correlation between gait characteristics and dynamic balance of stroke survivors and healthy individuals (n = 165)

Variable	Dynamic balance	
	Stroke survivors (n = 55) r (*P* value)	Healthy control (n = 110) r (*P* value)
Gait characteristics		
Stride length (m)	-0.127 (0.356)	-0.465 (0.001)**
Step length (m)	-0.083 (0.550)	-0.001 (0.996)
Cadence (steps/min)	-0.536 (0.001)**	-0.798 (0.001)**
Walking speed (m/s)	-0.645 (0.001)**	-0.597 (0.001)**

**Significant at the 0.01 level, m: Meters, m/s: Meter per second, step/min: Step per minute, s: Seconds, r: Correlation coefficient

Table 5. Comparison of gait characteristics and dynamic balance between stroke survivors and healthy individuals (n = 165)				
Variable	**Stroke survivors (n = 55) ($\overline{X}$± SD)**	**(n = 110) ($\overline{X}$± SD)**	**t-test**	***P* value**
Gait parameters				
Stride length (m)	1.4 ± 0.4	1.3 ± 0.2	1.021	0.309
Step length (m)	0.5± 0.1	0.5 ± 0.1	1.410	0.160
Cadence (steps/min)	80.5 ± 25.3	110.1 ± 11.3	-10.399	0.001**
Walking speed (m/s)	0.8 ± 0.3	1.2 ± 0.3	-8.286	0.001**
Dynamic balance (s)	26.9 ± 18.1	9.0 ± 2.4	10.240	0.001**

**Significant difference at $P < 0.01$, m: Meters, m/s: Meter per second, step/min: Step per minute, s: Seconds

length. Findings from this study showed that both the step and stride lengths of SSs are higher than those of AHCs; however, there was no significant difference when comparing the two groups. Wang et al. (37) revealed that higher step and stride lengths were observed in SSs with a lower walking speed. In contrast, both stride and step lengths among individuals with stroke were reduced compared to healthy controls (38). The results of this study could be attributed to compensatory mechanisms among SSs in a bid to walk and prevent falls.

In this study, the cadence and walking speed among participants with a stroke were significantly lower compared with the AHCs, which agrees with the results of studies by Obembe et al. (24) and Sheffler and Chae (39). The loss of selective motor control in stroke is believed to disrupt the normal coordination and sequence of walking, resulting in a significant reduction in gait parameters, particularly walking speed. Walking speed is a widely reported spatiotemporal parameter and is deemed the most important predictor of ambulation status in stroke (40,41). In addition, the assumed synergistic patterns and co-activation of muscles often observed among SSs may contribute to the lower gait speed and cadence. Specifically, the weakness of key muscles in the affected part of the body and the inherent need to support the body against gravity may be a major causative factor for a reduction in speed and cadence among SSs. These asymmetries and variations in gait parameters have also been found to be related to fall risk and balance among SSs. One of the major requirements for successful walking is DB control. The findings of this study show that the duration of completing the TUG test was higher among SSs than AHCs. This indicates a reduced DB and also shows that the risk of falling is higher among SSs compared with AHCs. This may be due to the asymmetric posture and compromised base of support in SSs, which may lead to subsequent falls (42). Furthermore, findings from this study show that AHCs had a significantly better DB than SSs. This is not surprising, as individuals with stroke may find it challenging to maintain a stable and upright posture when walking because of muscle weakness, spasticity, and impaired sensory function. They have also been observed to have greater postural sways than healthy age-matched individuals (17,43).

This study showed significant inverse relationships between FoF and each of cadence and walking speed among SSs. Similar results were also observed among the AHCs. This indicates that when participants' concerns about falling were higher, the walking speed became slower, and the number of successive steps taken while walking reduced. Bueno et al. (44) reported in their study similar findings of reduced walking speed and a high concern about falling. These gait changes may have been an attempt on the part of the patient to reduce the risk of falling. It has been observed in both older adults and SSs by several authors that when involved in dynamic activities such as walking, they adopt a cautious gait pattern which, in turn, reduces their walking speed (44,45,46). It can be inferred from this study that a reduction in cadence and walking speed may be observed among the elderly, with or without stroke, but that this tends to be more pronounced in patients with stroke. The findings of the current study show that FoF has a significant relationship with DB; this implies that DB has a major influence on FoF in SSs. Based on the present study, the observed poor DB precipitated FoF among SSs and implies a risk of falls among them. Balance compromise is a major consequence of stroke and is very common inall stroke phases. The authors observed that FoF produced anxiety when trying to complete a motor task, and during attempts to avoid loss of balance during threatening situations, SSs assumed a dynamic posture that eventually increased their risk of falling in the future (44).

The body is in a continuous state of imbalance with every step taken by an individual with age-related gait dysfunction (47). DB has been associated with gait, and the findings of this study showed that among SSs, both cadence and walking speed were significantly related to DB. The relationship with walking speed was found to be very strong. This was expected, as a previous study demonstrated walking speed to be a major predictive factor of ambulation (48). The results of this study also show that there is an inverse relationship between DB, cadence, and walking speed. Increasing the cadence and walking speed may be a compensatory means of stabilizing the body while walking. Therefore, an attempt to increase speed and the successive steps taken by SSs put them in a state of imbalance that increased their risk of falling. It should also be noted that the systems that serve to keep the body upright are already compromised or impaired in SSs. Similar findings seen among SSs were observed among healthy controls in the present study, which may be due to musculoskeletal conditions and other disease factors linked to age. Gait and balance control deficits have been identified as risk factors for falls precipitating FoF. A body of evidence shows that early identification of the FoF can lead to an effective intervention for fall prevention, thereby reducing other health consequences linked to FoF and eliminating a cyclical situation that is likely to ensue (49,50). As FoF is a consequence of experiencing a fall, interventions to prevent falls should also affect FoF positively.

Despite the significance of the findings of this study linked to stroke rehabilitation, the results of this research have potential limitations. The research was conducted as a case-control study and causal relationships could not be established. In addition, the use of relatively homogenous samples of ambulant SSs and fit healthy individuals may have limited the generalizability of the findings. Finally, we did not evaluate the infarction sites and volume concerning the magnitude of FoF, GCs, and DB in SSs. Thus, further longitudinal studies among patients with different stroke characteristics in multiple centers, and adjusting for all important covariates, are encouraged.

Conclusion

In conclusion, SSs demonstrate a high level of concern about falling, reduced cadence and walking speed, and poor DB with an increased risk for falling compared with healthy controls. Additionally, a significant association was observed among FoF, GCs, and DB in SSs and the AHCs. FoF should be taken as part of the baseline assessment of SSs at the early phase of stroke rehabilitation, and risk factors that precipitate FoF and increase the risk of falling after stroke should be identified early to ensure effective care.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Ethics and Research Committee of the OAUTHC, Ile-Ife, for this study (ERC/2020/02/03).

Informed Consent: Obtained.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: A.O.B., T.O.A., A.B.A., A.O.B., I.G.F., O.B.O., A.A.K., A.J.O., R.A.A., Concept: A.O.B., T.O.A., R.A.A., Design: A.O.B., T.O.A., A.B.A., Data Collection or Processing: A.O.B., T.O.A., A.B.A., A.O.B., I.G.F., O.B.O., A.A.K., Analysis or Interpretation: A.O.B., T.O.A., A.B.A., A.J.O., R.A.A., Literature Search: A.O.B., T.O.A., A.B.A., A.O.B., I.G.F., O.B.O., A.A.K., A.J.O., Writing: A.O.B., T.O.A., A.B.A., A.O.B., I.G.F., O.B.O., A.A.K., A.J.O., R.A.A.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Murray CJ, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012;380:2197-2223.
2. Billinger SA, Arena R, Bernhardt J, et al. Physical activity and exercise recommendations for stroke survivors: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2014;45:2532-2533.
3. Owolabi MO, Ugoya S, Platz T. Racial disparity in stroke risk factors: the Berlin-Ibadan experience; a retrospective study. Acta Neurol Scand 2009;119:81-87.
4. Sarfo FS, Ovbiagele B, Gebregziabher M, et al. Stroke among young West Africans. Evidence from the SIREN (Stroke Investigative Research and Educational Network) large multisite case-control study. Stroke 2018;49:1116-1122.
5. Wahab KW. The burden of stroke in Nigeria. Int J Stroke 2008;3:290-292.
6. Ryan AS, Dobrovolny CL, Silver KH, Smith GV, Macko RF. Cardiovascular fitness after stroke: role of muscle mass and gait deficit severity. J Stroke Cerebrovasc Dis 2000;9:185-191.
7. Bonan IV, Yelnik AP, Colle FM, et al. Reliance on visual information after stroke. Part II: effectiveness of a balance rehabilitation program with visual cue deprivation after stroke: a randomized controlled trial. Arch Phys Med Rehabil 2004;8:274-278.
8. Ademoyegun AB, Mbada CE, Ibitoye AG, et al. Influence of Clinical characteristics of stroke survivors on their walking capacity. Med Sportiva 2020;16:3211-3218.
9. Patterson KK, Parafianowicz I, Danells CJ, et al. Gait asymmetry in community- ambulating stroke survivors. Arch Phys Med Rehabil 2008;89:304-310.
10. Ada L, Dean CM, Lindley R, Lloyd G. Improving community ambulation after stroke: the AMBULATE Trial. BMC Neurol 2009;9:8.
11. Weerdesteyn V, de Niet M, van Duijnhoven HJ, Geurts AC. Falls in individuals with stroke. J Rehabil Res Dev 2008;45:1195-1213.
12. Batchelor FA, Mackintosh SF, Said CM, Hill KD. Falls after stroke. Int J Stroke 2012;7:482-490.
13. Liu TW, Ng GYF, Chung RCK, Ng SSM. Decreasing fear of falling in chronic stroke survivors through cognitive behavior therapy and task-oriented training. Stroke 2019;50:148-154.
14. Murphy SL, Williams CS, Gill TM. Characteristics associated with fear of falling and activity restriction in community-living older persons. J Am Geriatr Soc 2002;50:516-520.
15. Schinkel-Ivy A, Inness EL, Mansfield A. Relationships between fear of falling, balance confidence, and control of balance, gait, and reactive stepping in individuals with sub-acute stroke. Gait Posture 2016;43:154-159.
16. Kalron Aü, Achiron A. The relationship between fear of falling to spatiotemporal gait parameters measured by an instrumented treadmill in people with multiple sclerosis. Gait Posture 2014;39:739-744.
17. Tyson SF, Hanley M, Chillala J, Selley A, Tallis RC. Balance disability after stroke. Phys Ther 2006;86:30-38.
18. Manaf H, Justine M, Omar M, Md Isa KA, Salleh Z. Turning ability in stroke survivors: a review of literature. ISRN Rehabilition 2012.
19. Kirtley C. Clinical gait analysis: theory and practice. Edinburgh: Elsevier Churchill Livingstone, 2006.
20. Iosa M, Morone G, Fusco A, et al. Effects of walking endurance on gait stability in patients with stroke. Stroke Res Treat 2012;2012:810415.
21. West T, Bernhardt J. Physical activity in hospitalised stroke patients. Stroke Res Treat 2012;2012:813765.
22. Chamberlin ME, Fulwider BD, Sanders SL, Medeiros JM. Does fear of falling influence spatial and temporal gait parameters in elderly persons beyond changes associated with normal aging? J Gerontol A Biol Sci Med Sci 2005;60:1163-1167.
23. Kyrdalen IL, Thingstad P, Sandvik L, Ormstad H. Associations between gait speed and well-known fall risk factors among community-dwelling older adults. Physiother Res Int 2019;24:e1743.
24. Obembe AO, Olaogun MO, Adedoyin R. Gait and balance performance of stroke survivors in South-Western Nigeria--a cross-sectional study. Pan Afr Med J 2014;17(Suppl 1):6.
25. Eng J. Sample size estimation: how many individuals should be studied? Radiology 2003;227:309-313.
26. Liu JY. Fear of falling in robust community-dwelling older people: Results of a cross-sectional study. J Clin Nurs 2015;24:393-405.
27. Jamali S, Azad A, Taghizadeh G. Use of functional balance measurement tools to predict the fear of falling in faller and non-faller chronic stroke patients. Func Disabil J 2018;1:19-28.
28. Yardley L, Beyer N, Hauer K, et al. Development and initial validation of the falls efficacy scale-international (FES-I). Age Ageing 2005;34:614-619.
29. Delbaere K, Close JC, Mikolaizak AS, et al. The falls efficacy scale international (FES-I). A comprehensive longitudinal validation study. Age Ageing 2010;39:210-216.
30. Wall JC, Bell C, Campbell S, Davis J. The timed get-up-and-go test revisited: measurement of the component tasks. J Rehabil Res Dev 2000;37:109-113.
31. Pau M, Leban B, Collu G, Migliaccio GM. Effect of light and vigorous physical activity on balance and gait of older adults. Arch Gerontol Geriatr 2014;59:568-573.
32. De Ridder R, Lebleu J, Willems T, et al. Concurrent validity of a commercial wireless trunk triaxial accelerometer system for gait analysis. J Sport Rehabil 2019;28:jsr.

33. Akosile CO, Fabunmi AA, Umunnah JO, Okoye CDA. Relationships between fall indices and physical function of stroke survivors in Nigeria. Int J Ther Rehabil 2011;18:487-491.
34. Harris JE, Eng JJ, Marigold DS, Tokuno CD, Louis CL. Relationship of balance and mobility to fall incidence in people with chronic stroke. Phys Ther 2005;85:150-158.
35. Goh HT, Nadarajah M, Hamzah NB, Varadan P, Tan MP. Falls and fear of falling after stroke: a case-control study. PMR 2016;8:1173-1180.
36. Schmid AA, Acuff M, Doster K, et al. Poststroke fear of falling in the hospital setting. Top Stroke Rehabil 2009;16:357-366.
37. Wang Y, Mukaino M, Ohtsuka K, et al. Gait characteristics of post-stroke hemiparetic patients with different walking speeds. Int J Rehabil Res 2020;43:69-75.
38. Jonsdottir J, Ferrarin M. Gait disorders in persons after stroke. Handbook of Human Motion, 2016:1205-1216.
39. Sheffler LR, Chae J. Hemiplegic gait. Phys Med Rehabil Clin N Am 2015;26:611-623.
40. Lord SE, McPherson K, McNaughton HK, Rochester L, Weatherall M. Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? Arch Phys Med Rehabil 2004;85:234-239.
41. Schmid AA, Rittman M. Fear of falling: an emerging issue after stroke. Top Stroke Rehabil 2007;14:46-55.
42. Li J, Zhong D, Ye J, et al. Rehabilitation for balance impairment in patients after stroke: a protocol of a systematic review and network meta-analysis. BMJ Open 2019;9:e026844.
43. Cho K, Lee K, Lee B, Lee H, Lee W. Relationship between postural sway and dynamic balance in stroke patients. J Phys Ther Sci 2014;26:1989-1992.
44. Bueno GAS, Gervásio FM, Ribeiro DM, et al. Fear of falling contributing to cautious gait pattern in women exposed to a fictional disturbing factor: a non-randomized clinical trial. Front Neurol 2019;10:283.
45. Asai T, Misu S, Sawa R, Doi T, Yamada M. The association between fear of falling and smoothness of lower trunk oscillation in gait varies according to gait speed in community-dwelling older adults. J Neuroeng Rehabil 2017;14:5.
46. Moreira BS, Sampaio RF, Diz JB, et al. Factors associated with fear of falling in community-dwelling older adults with and without diabetes mellitus: findings from the frailty in Brazilian older people study (FIBRA-BR). Exp Gerontol 2017;89:103-111.
47. Lugade V, Wu A, Jewett B, Collis D, Chou LS. Gait asymmetry following an anterior and anterolateral approach to total hip arthroplasty. Clin Biomech (Bristol, Avon) 2010;25:675-680.
48. Bohannon RW. Population representative gait speed and its determinants. J Geriatr Phys Ther 2008;31:49-52.
49. Vearrier LA, Langan J, Shumway-Cook A, Woollacott M. An intensive massed practice approach to retraining balance post-stroke. Gait Posture 2005;22:154-163.
50. Cheng PT, Chen CL, Wang CM, Hong WH. Leg muscle activation patterns of sit-to-stand movement in stroke patients. Am J Phys Med Rehabil 2004;83:10-16.