

IMUs-Stratified Gait Phases in Stroke Patients: Analyzing Functional Ambulation Categories

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Objective

❖ The purpose of this study is to quantitatively analyze differences in gait cycle characteristics according to the Functional Ambulation Category (FAC) in stroke patients using Inertial Measurement Units (IMUs). As previous research lacks analysis of gait characteristics by FAC level using IMUs, this study aims to identify quantitative differences in gait cycles according to functional ambulation levels.

Methods

❖ This study was conducted on 83 stroke patients who visited the hospital. Subjects were classified into six groups according to the Functional Ambulation Category (FAC) scale, from FAC 0 to FAC 5 (FAC 0: 14 patients, FAC 1: 10 patients, FAC 2: 10 patients, FAC 3: 20 patients, FAC 4: 15 patients, FAC 5: 14 patients). IMUs were attached to both thighs, both shanks, and both dorsum of the feet to measure the stance phase and swing phase duration of the affected side. One-way ANOVA was performed to verify differences in gait cycle characteristics according to FAC levels, and Tukey's post-hoc test was conducted to identify differences between groups. The statistical significance level (α) was set at 0.05

Figure 1. This image shows a gait experiment being conducted with attached 7 types of IMU



Table 1. Physiological results from clinical evaluations

FAC	0	1	2	3	4	5	p value
Age	59(6.5)	59(9.9)	59(9.9)	53(17.1)	58(13.5)	51(14.2)	>.05
BMI	23(1.3)	24(1.7)	21(1.6)	23(2.2)	23(2.0)	27(3.5)	<.05 2<5
BBS	2(0.9)	18(9.0)	18(5.3)	27(14)	46(9.7)	49(6.0)	<.05 0<1,2,3<4,5

BMI;Body Mass Index (Kg/m²), BBS; Berg Balance Scale

Results

❖ The Analysis of the relationship between FAC levels and the duration of affected stance and swing phases during gait revealed statistically significant differences in both variables (affected stance phase: $F=18.038$, $p<0.001$, affected swing phase: $F=8.674$, $p<0.001$). As FAC levels increased, the mean value of the affected stance phase showed a significantly decreasing pattern (FAC 0: 2.73 ± 0.95 seconds, FAC 5: 0.84 ± 0.16 seconds, $p<0.001$), and the mean value of the affected swing phase also demonstrated a similar decreasing pattern (FAC 0: 1.29 ± 0.60 seconds, FAC 5: 0.54 ± 0.10 seconds, $p<0.001$). Post-hoc test results showed that for the affected stance phase, FAC 0 exhibited significant differences from all other FAC levels (FAC 1: $p=0.009$, FAC 2-5: $p<0.001$), and FAC 5 showed significant differences from all groups except FAC 4 (FAC 0, 1: $p<0.001$, FAC 2: $p=0.009$, FAC 3: $p=0.005$). In contrast, the difference between FAC 0 and FAC 1 was not significant for the affected swing phase ($p=0.174$), and there were relatively fewer differences between groups compared to other gait cycle parameter

Table 2. Gait Phase Parameters by FAC level

FAC level	Affected side		
	Stance phase (s)	Swing phase (s)	Stance/Swing ratio
0 (n=14)	2.73 (0.95)	1.29 (0.60)	2.12
1 (n=10)	1.90 (0.52)	0.96 (0.38)	1.98
2 (n=10)	1.67 (0.82)	0.87 (0.21)	1.92
3 (n=20)	1.54 (0.41)	0.81 (0.27)	1.89
4 (n=15)	1.23 (0.26)	0.66 (0.18)	1.86
5 (n=14)	0.84 (0.16)	0.54 (0.10)	1.56

Table 3. FAC level-based Tukey post-hoc test results- comparison between stance and swing phase

FAC level	0	1	2	3	4	5
0		P=.009 x	P<.001 P=.04	P<.001 P<.001	P<.001 P<.001	P<.001 P<.001
1	P=.009 x		x x	x x	P=.049 x	P<.001 P=.04
2	P<.001 P=.04	x x		x x	x x	P=.009 x
3	P<.001 P<.001	x x	x x		x x	P=.005 x
4	P<.001 P<.001	P=.049 x	x x	x x		x x
5	P<.001 P<.001	P<.001 P=.04	P=.009 x	P=.005 x	x x	

■; shows the stance phase, ■; shows the swing phase.
 • An "x" mark on the left indicates no significant difference in stance phase, and an "x" mark on the right indicates no significant difference in swing phase.

Conclusion

❖ This study confirmed a significant relationship between FAC levels in stroke patients and the duration of stance and swing phases during gait. Particularly, higher FAC levels systematically corresponded with decreased affected stance and swing phase durations. Additionally, as FAC increased, changes in stance phase duration reflected the level of gait function more sensitively than swing phase duration. These results suggest that the temporal characteristics of gait phases, especially the gait phase proportion, may serve as an important indicator for assessing functional ambulation capacity in stroke patients.

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