Minimal detectable change of kinematic and spatiotemporal parameters in patients with chronic stroke across three sessions of gait analysis

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Abstract

Three-dimensional gait analysis is the gold standard for gait-assessment in patients with stroke. This technique is commonly used to assess the effect of treatment on gait parameters. In clinical practice, three gait analyses are usually carried out (baseline, after treatment and follow-up), the objectives were to define the reproducibility and the Minimum Detectable Change (MDC) for gait parameters in stance and swing measured using 3D-gait analysis, and to assess changes in MDC across three repeated 3D-gait analyses. Three gait analyses (V1, V2 and V3) were performed at 7-day intervals in twenty-six patients with chronic stroke. Kinematic data (in the sagittal plane, during swing and stance) and spatiotemporal data were evaluated for the paretic limb. Reliability was tested using repeated measures ANOVA with a Tukey post hoc test, and the MDC values were calculated for each parameter. Only the range of hip motion during swing changed significantly between V1 and V2, but no other kinematic parameters changed. No significant differences were observed for the spatiotemporal parameters. MDC values were always higher during the V1vsV2 comparison for both kinematic and spatiotemporal parameters. This is the first study to evaluate the MDC for kinematic and spatiotemporal parameters during stance and swing. Reliability of kinematic and spatiotemporal data across sessions was very good over the three sessions. MDC values were the lowest between V2 and V3 for most parameters. Use of the MDC will allow clinicians to more accurately determine the effect of treatments.

Key Words: stroke, gait analysis, reproducibility, minimum detectable change.

1 Introduction

Stroke-related hemiparesis alters the gait pattern (Pélissier, Pérennou, & Laassel, 1997; Pinzur, Sherman, DiMonte-Levine, & Trimble, 1987), and medical and surgical treatments and rehabilitation often focus on improving gait (Bleyenheuft et al., 2009; Boudarham et al., 2014; Flansbjer, Downham, & Lexell, 2006; Roche, Zory, et al., 2015). The effects of treatment can be measured using three-dimensional gait analysis (3D-gait analysis) (Bleyenheuft et al., 2009; Pittock et al., 2003; Roche, Zory, et al., 2015), the gold standard for gait assessment. 3D-gait analysis systems provide precise measurements of spatiotemporal, kinematic and kinetic gait parameters (McGinley, Baker, Wolfe, & Morris, 2009). The reliability of these system has been shown to be good in patients with stroke. Reliability is high for kinematic parameters in the sagittal plane (Kadaba et al., 1989; McGinley et al., 2009; Schwartz, Trost, & Wervey, 2004) and for spatiotemporal parameters (Oken, Yavuzer, Ergöçen, Yorgancioglu, & Stam, 2008; Yavuzer, Oken, Elhan, & Stam, 2008), the reliability has been mainly assessed using the intraclass coefficient correlation (ICC) and the standard error measurement (SEM). However, another very important psychometric parameter to consider is the minimal detectable change (MDC). MDC relates to measurement bias. If the change following treatment is greater than the MDC, it is therefore likely due to the treatment. (Weir, 2005).

MDC values have been calculated for certain parameters evaluated during 3D-gait analysis in patients with stroke, including gait profile score and gait deviation index (Correa et al., 2017; Devetak et al., 2016), ground reaction forces (Campanini & Merlo, 2009) and kinematic (such as peak ankle angle during swing or peak knee flexion during swing) and spatiotemporal (such as step length) parameters and ground reaction forces during treadmill gait (Kesar, Binder-Macleod, Hicks, & Reisman, 2011). However, treatment often aims to improve kinematic parameters during a specific phase of the gait cycle to improve locomotion of patients with stroke (i.e botulinum toxin injection (BTI) in the rectus femoris muscle to increase peak knee flexion in swing phase, or surgery to the triceps surae to improve ankle dorsiflexion in swing phase). It is thus important to determine the MDC for specific kinematic parameters during stance and swing in patients with chronic stroke-related hemiparesis to better analyses results from studied using gait analysis to assess effect of a given treatment in a specific gait

phase.. Furthermore, hemiparetic gait is characterized by an asymmetry between duration of swing and stance phase, knowing the MDC of these parameters could also be relevant to better analyses results of studied aiming to restore the symmetry of phases (Bohannon, 1987; Pinzur et al., 1987; Sheffler & Chae, 2015).

The effect of treatment is often evaluated over three 3D-gait analyses: baseline, mid-treatment and end of treatment, or baseline, end of treatment and after a wash out period to determine if the effect is maintained. It is therefore important to assess the MDC over three sessions.

The aim of this study was thus to define the MDC for hip, knee and ankle angles in the sagittal plane during both stance and swing and the MDC of spatiotemporal parameters and to assess changes in MDC across three repeated 3D-gait analyses. To that end, the kinematic and spatiotemporal parameters of patients with chronic stroke-related hemiparesis were compared over three 3D-gait analyses performed at 7-day intervals. We hypothesized that performance would be most variable during the first 3D-gait analysis, inducing a larger MDC than during the second and third analyses. If this was confirmed, it would imply that an initial 3D-gait analysis should be carried out simply for familiarization purposes prior to the data collection.

2 Methods

2.1 Sample

Twenty-six -patients with chronic stroke were included in the study (n=19 men; mean age 58.2±13.1 years; mean time since stroke 9.7±7.1 years; n=14 right hemiparesis). They were recruited during routine follow-up visits in the physical medicine and rehabilitation department of a university teaching hospital. Subjects were eligible for inclusion if they: i) were over eighteen years old, ii) had hemiparesis due to a single stroke more than six month previously, and iii) were able to walk 10 minutes independently with or without walking aids. Subjects were excluded if they had: i) bilateral cortical lesions, ii) cerebellar syndrome, iii) severe comprehensive deficit or severe aphasia, iv) apraxia or v) musculoskeletal surgery less than six months ago. All subjects gave written informed consent before participation. The study was performed in accordance with the ethical codes of the

World Medical Association (Declaration of Helsinki) and was approved by the local Ethics Committee.

2.2 Study design

Each subject participated in 3 visits at 7-day intervals (V1, V2 and V3). One 3D-gait analysis was carried out at each visit.

2.2.1 Gait analysis

At least three trials were performed before the beginning of the recording in order to familiarise the patient with the experimental conditions, since it has been shown that the first three trials of a gait analysis session differ from subsequent trials (Boudarham, Roche, et al., 2013). A minimum of 4 trials were then recorded at a spontaneous walking speed in a 10-meter-long corridor. To balance the influence of each visit, the same number of gait cycles was analysed for each subject (based on the visit with the least number of gait cycles). We manually deleted the gait cycles in excess. Therefore, the number of gait cycles analyzed varied across subjects (from 5 to 18). Seven optoelectronic cameras (Motion Analysis Corporation, Santa Rosa, CA, USA, 100 Hz sampling frequency) recorded the trajectories of 30 reflective markers, positioned on the skin of the subjects according to the Helene Hayes model. The trajectories were manually processed using Cortex 1.3 and OrthoTrack 6.5 software (Motion Analysis Corporation, Santa Rosa, CA, USA) to extrapolate joint kinematics and spatiotemporal parameters.

The same operator positioned all the markers for each patient at each visit and carried out the whole 3D-gait analysis in order to limit extrinsic variability (McGinley et al., 2009).

2.3 Data Analysis

2.3.1 3D gait analysis

Kinematic data in the sagittal plane (peak hip and knee flexion and extension, ankle dorsiflexion and plantarflexion and total range of motion (RoM) during the stance and swing phases) were calculated for the paretic lower limb. Spatiotemporal gait parameters (gait speed, cadence, stride length, step

length, step width and duration of stance phase) were also calculated. Values for each parameter were averaged across all the gait cycles for each patient and the mean was used for the analysis.

2.3.2 Analysis of raw differences, reliability and minimal detectable change

Mean values of the kinematic and spatiotemporal parameters were compared to determine if there were significant differences between each visit. Reproducibility of measures is often evaluated by comparing two datasets with different indices. The most common and relevant indices are the ICC and the SEM, the MDC is then derived from the SEM. ICC is useful to observe the correspondence between two measures, however it is dependent on the standard deviation in the sample (Weir, 2005). To give more weight to the reliability of the data assessed by the ICC, it is necessary to concomitantly evaluate the SEM and the MDC. Low SEM and MDC values signify that changes observed are likely due to the treatment and not the measurement (Correa et al., 2017; Devetak et al., 2016; Flansbjer, Holmbäck, Downham, Patten, & Lexell, 2005; Kadaba et al., 1989; McGinley et al., 2009; Weir, 2005).

Reliability was thus evaluated using two methods, the ICC and the SEM. ICC was calculated using custom software written by Arash Salarian (Copyright 2016) in MATLAB (Mathworks). The $ICC_{3,k}$, was used because the data were acquired over three sessions by the same operator and the trials within each session were averaged (Shrout & Fleiss, 1979; Weir, 2005). The formulae used to calculate the ICC was:

$$\frac{MS_S - MS_E}{MS_S}$$

Where MS_S is the subjects mean square and MS_E is the error mean square of the 2-way ANOVA used to compare the data (Weir, 2005). The ICC varies between 0 and 1; the higher the $ICC_{3,k}$ the higher the reproducibility. There is no real consensus regarding "cut-off" values, however, it has been suggested that values <0.59 reflect “poor reproducibility”, 0.60-0.79 “moderate reproducibility” and > 0.80 “high reproducibility” (Bushnell, Johnston, & Goldstein, 2001). The SEM can be calculated using two formulae : $SEM = SD\sqrt{1 - ICC}$, or SEM=$\sqrt{MS_E}$, MS_E being the square root of the within-subjects

error of the repeated measures ANOVA (Weir, 2005). $\sqrt{MS_E}$ was chosen because the ICC depends on the standard deviation of the data, thus for two sets of data with the same means and two different standard deviations, data with a low standard deviation will have a lower ICC than data with a large standard deviation. $\sqrt{MS_E}$ takes this into account (Weir, 2005).

The MDC was calculated using the following equation: $MDC = SEM * 2.056 * \sqrt{2}$. The value 2.056 corresponds to the student-t distribution with a 95% confidence interval for the study sample size (n=26) (Beckerman et al., 2001). SEM and MDC are expressed in raw units and not in percentages to facilitate future comparisons with other studies. However, the mean MDC and SEM values for the spatiotemporal parameters are presented as percentages in order to compare parameters with different units (McGinley et al., 2009). The MDC% was calculated using the following formula: $MDC\% = \left(\frac{MDC}{\bar{X}}\right) * 100$, $\bar{X}$ being the mean value of the parameter compared between 2 sessions (either V1/V2 or V1/V3 or V2/V3) (Flansbjer et al., 2005). The SEM% was calculated using the same technique.

2.4 Statistical analysis

The statistical analysis was based on the recommendations of Weir et al. (2005) (Weir, 2005). If the data followed a normal distribution (according to the Shapiro-Wilk test), a one-factor (time), repeated measures ANOVA was performed (sessions V1, V2 and V3). If the results of the repeated measures ANOVA were significant, a post hoc Tukey HSD test was performed to determine which visits differed: (V1vsV2 or V1vsV3 or V2vsV3). If the data did not follow a normal distribution, a Friedman test was performed. Significant differences were analysed using a Wilcoxon test to identify which visits differed significantly from each other. Simultaneously, the $ICC_{3,k}$, SEM and MDC were calculated for each parameter between V1 and V2, V1 and V3; V2 and V3.

3 Results

3.1 Kinematics

Table 1 shows the kinematic values (mean and SD) for each parameter studied during each visit. The details of the repeated measures ANOVAs are available in S1 appendix Table A.

Table 1: Kinematic parameters during the swing (SwP) and stance phases (StP) of gait cycle. Positive values denote flexion and negative values denote extension.

--Table 1--

The only parameter that changed significantly was hip RoM in swing, which increased significantly (p=0.045) from V1 to V2 (Tables 1 and table A).

3.1.1 ICC and SEM

The mean ICC values were high for all parameters between all visits (from 0.96 to 0.97). The reliability was higher between V2 and V3 than between the other visits as showed by higher ICC (0.97) and lower SEM (2.01°) in V2vsV3 than in V1vsV2 and V1vsV3 (see Table 2).

3.1.2 MDC Values

The mean MDC was lowest between V2vsV3 (5.86°) than in V1vsV2 (7.20°) and V1vsV3 (6.48°) (Table 2).

Table 2: ICC, SEM and MDC of kinematic parameters of the paretic lower limb during the swing (SwP) and stance phases (StP) of gait cycle. The lowest MDC values are in bold

--Table2--

3.2 Spatiotemporal parameters

Table 3 presents the values (means and SD) of spatiotemporal parameters during the three visits. All the results of the ANOVAs are available in appendix S1 Table A.

Table 3: Spatiotemporal parameters with mean and SD at each visit.

--Table3--

There were no significant differences between the values of the spatiotemporal parameters for the three visits.

3.2.1 ICC and SEM

Mean ICC values were high for all parameters between all visits (0.96 to 0.97). The reliability was higher between V2 and V3 than between the other visits as showed by higher ICC (0.97) and lower %SEM (3.90%) in V2vsV3 than in V1vsV2 and V1vsV3 (see Table 4).

3.2.2 MDC values

The mean %MDC was lowest between V2vsV3 (11.45%) than in V1vsV2 (13.75%) and V1vsV3 (13.10%) (Table 4).

Table 4: ICC, SEM and MDC of spatiotemporal parameters in paretic lower limb. The lowest MDC values are in bold. The mean values of SEM and MDC are presented as percentages in order to rationalize and compare the different units.

--Table 4--

4 Discussion

The purpose of this study was to determine the MDC for paretic-limb kinematic and spatiotemporal parameters in both swing and stance phase, evaluated during 3D gait analysis, in order to improve interpretation of the results of treatments in patients with hemiparesis following stroke. Reliability was higher between the second and third visits than between the first and second and first and third visits: ICC values were higher and mean SEM and MDC values were lower. However, the differences in reliability across sessions were small, likely because of the lack of differences in kinematic values across sessions that resulted in high ICC values. This result is in accordance with previous studies that have also found a high reliability of raw kinematic data in a similar population of patients (Correa et al., 2017; Devetak et al., 2016).

The aim of treatment is often to improve peak hip extension in stance, and peak knee and ankle flexion in the swing phase of the gait cycle (Pomeroy, King, Pollock, Baily-Hallam, & Langhorne, 2006). The MDC values for these three parameters were lowest between V2 and V3. There was a difference of 1° to 3° in the MDCs depending on the visits compared. This is highly relevant considering the small, but

statistically significant changes reported in the literature following various treatments (Bonnyaud et al., 2014; Boudarham, Hameau, et al., 2013; Novak, Olney, Bagg, & Brouwer, 2009; Pradon et al., 2011; Robertson et al., 2009; Roche, Boudarham, Hardy, Bonnyaud, & Bensmail, 2015). Some changes reported in studies of patients with stroke are close to, or sometimes lower than, the smallest MDC defined in the present study. Roche et al, (2015) found a significant improvement in peak hip flexion during swing of 4.2° (MDC=9.1°) after BTI in the rectus femoris (Roche, Boudarham, et al., 2015); Roche et al, (2015), Robertson et al, (2009) and Boudarham et al, (2013) found significant improvements in peak knee flexion in swing of respectively 6.5°, 8° and 3.4° (MDC=6.5°) after BTI in the rectus femoris (Boudarham, Hameau, et al., 2013; Robertson et al., 2009; Roche, Boudarham, et al., 2015). Pradon et al, (2011) found a significant increase in peak ankle dorsiflexion in stance of 4° (MDC=5.4°) and a significant increase in peak knee flexion in swing of 6° to 10° (MDC=6.5°) after BTI in the triceps surae (Pradon et al., 2011). Novak et al, (2009) found a significant decrease in plantarflexion at the end of the swing phase of 2.5° (MDC=5.8°) after BTI in the triceps surae (Novak et al., 2009). Bonnyaud et al, (2014) found a significant increase in peak knee flexion during swing of 2.5° (MDC=6.5°) after a single Lokomat session (Bonnyaud et al., 2014). Thus, it is not possible to know how much the change relates to the treatment and how much to the repetition of the measurements. Treatment also aims to improve gait speed, stride length and step length. The MDCs for the former two parameters were lowest between the second and third visits, while the MDC for step length was lowest between the first and third visits. The changes in spatiotemporal parameters reported in patients with stroke following treatments are often close to or below the MDC values found in this study. Wallard et al (2015) found an increase in gait speed of 35 cm/s (MDC=14.6 cm/s) and a 2 cm increase step length (MDC=6.3 cm) after 20 intensive sessions of lokomat training (Wallard, Dietrich, Kerlirzin, & Bredin, 2015). After a single session of Lokomat training, Bonnyaud et al, (2014) found a significant increase in gait speed of 5.4 cm/s (MDC=14.6 cm/s), of 3.1 step/min in cadence (MDC=8.6 step/min) and 3.6cm in step length (MDC=6.3 cm). Pradon et al, (2011) found a significant increase in gait velocity of 17 cm/s (MDC=14.6 cm/s), and a 7 cm increase in step length (MDC=6.3 cm) and 15 cm in stride length (MDC=11.9 cm) after BTI in the triceps surae (Pradon et al., 2011).

Thus, statistically significant improvements in kinematic and spatiotemporal parameters are often close to, or even below, the lowest MDC values found in the present study. The purpose of these comparisons is not to diminish the scientific impact of these studies, far from it. We believe that our study supports the need to decrease CMD values in studies using the 3D gait-analysis to evaluate the effects of a treatment. This familiarization visit seems important to reduce as possible the MDC values, but comparisons are only possible between populations with similar characteristics such as walking speed, thus this does not apply to all studies, so these comparisons should be used sparingly. Indeed, in our study the average gait speed of patients was 0.77 m/s; in Roche et al., (2015) it was 0.58 m/s, in Robertson et al., (2009) it was 0.52 m/s, in Boudarham et al., (2013) it was 0.61 m/s, in Pradon et al., (2011) it was 0.55 m/s, in Novak et al., (2009) it was 0.50 m/s, in Bonnyaud et al., (2014) it was 0.76 m/s, in Wallard et al., (2015) it was 0.84m/s.

In contrast with our hypothesis, kinematic data were very reliable across visits as shown by the ANOVAs results (only one parameter shown a significant modification between V1 and V2) and ICC values (0.95 to 0.97). This is in accordance with the literature (Awad, Kesar, Reisman, & Binder-Macleod, 2013; Correa et al., 2017; Devetak et al., 2016; Kadaba et al., 1989; McGinley et al., 2009). Only hip RoM during swing differed between visits one and two. Spatiotemporal data were also highly reliable across visits as shown by the ANOVAs results (none significant ANOVAs) and ICC values (0.96 to 0.97). This is also in agreement with the literature (Cho, Lee, & Lee, 2015; Kesar et al., 2011).

A study of five 3D-analyses of treadmill gait found no changes in mean peak knee and ankle angles or standard deviations across sessions. The authors therefore did not recommended the use of a familiarization session (Awad et al., 2013). However, gait on a treadmill is different from gait over-ground (Bayat, Barbeau, & Lamontagne, 2005; Brouwer, Parvataneni, & Olney, 2009; Kautz, Bowden, Clark, & Neptune, 2011). The results of the present study indicate that for over-ground gait analysis, a familiarization session would increase the reliability of the data, particularly for hip extension in swing and stance, as well as ankle RoM in swing which showed the greater decreased of MDC value because of the familiarization visit.

5 Conclusion

In conclusion, kinematic and spatiotemporal data recorded during three 3D-gait analyses at intervals of 7 days were reliable. However, the MDC was lowest between the second and third visits, suggesting that patients should attend a familiarization session prior to carrying out the actual evaluations. This would ensure changes measured are related to the treatment and are not an effect of the repeated evaluations.

6 Limitations

The results of this study may not be generalizable to the whole population of patients with stroke since the patients included all had moderate to good functional recovery (based on mean gait speed) (Beyaert, Vasa, & Frykberg, 2015). In clinical practice, gait analyses may be carried out at intervals greater than 7 days. It is possible that the reliability and MDC may differ for intervals of 1 month for example. Further studies are required to test this.

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8 Disclosure

None.

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10 Appendix

Supporting Information

S1 Table A: Results of statistical analyses for kinematic and spatiotemporal parameters.

--Table A--

11 Tables

Table 1: Kinematic parameters during the swing (SwP) and stance phases (StP) of gait cycle. Maximum values denote flexion/dorsiflexion and minimum values denote extension/plantarflexion.

Kinematic Parameters	Gait Cycle Phases	Description (degrees)					
		V1		V2		V3	
		mean	SD	mean	SD	mean	SD
Hip Maximum Angle	SwP	33.42	9.03	33.29	8.72	32.19	9.62
	StP	29.35	9.13	28.81	9.09	27.91	9.1
Hip Minimum Angle	SwP	7.95	9.52	6.36	10.35	6.23	10.75
	StP	-2.05	9.92	-3.14	10.22	-3.54	10.63
Hip RoM	SwP*	25.47	9.99	26.93	11.36	25.96	10.4
	StP	31.4	11.97	31.95	12.64	31.45	12.43
Knee Maximum Angle	SwP	43.97	15.07	43.2	14.28	44.25	15.2
	StP	31.91	9.95	30.67	9.1	31.83	9.47
Knee Minimum Angle	SwP	12.21	9.65	11.36	8.91	11.19	9.32
	StP	1.74	10.01	0.77	9.39	0.98	9.53
Knee RoM	SwP	31.76	16.13	31.85	15.41	33.05	16.52
	StP	30.17	9.14	29.9	7.97	30.85	8.82
Ankle Maximum Angle	SwP	-0.2	6.22	-0.13	5.84	-0.07	6.12
	StP	10.73	4.75	10.75	4.71	11.59	4.63
Ankle Minimum Angle	SwP	-10.33	6.68	-10.28	5.94	-9.59	6.72
	StP	-9.29	6.01	-8.95	5.69	-8.75	6.45
Ankle RoM	SwP	10.13	5.53	10.14	5.05	9.52	4.78
	StP	20.02	4.26	19.7	4.18	20.34	4.42

SwP: swing phase, StP: stance phase, RoM: range of motion. *indicate a significant modification revealed by the ANOVA.

Table 2: ICC, SEM and MDC of kinematic parameters of the paretic lower limb during the swing (SwP) and stance phases (StP) of gait cycle. The lowest MDC values are in bold.

Kinematic Parameters	Gait Cycle Phase	ICC			SEM (degrees)			MDC (degrees)		
		V1vsV2	V1vsV3	V2vsV3	V1vsV2	V1vsV3	V2vsV3	V1vsV2	V1vsV3	V2vsV3
Hip Maximum Angle	SwP	0.93	0.94	0.94	3.21	3.09	3.12	9.36	**9.01**	9.12
	StP	0.95	0.95	0.96	2.92	2.58	2.50	8.54	7.52	**7.28**
Hip Minimum Angle	SwP	0.93	0.94	0.97	3.58	3.22	2.59	10.44	9.39	**7.56**
	StP	0.94	0.95	0.98	3.26	2.96	2.22	9.53	8.63	**6.48**
Hip RoM	SwP	0.98	0.99	0.99	1.87	1.61	1.66	5.47	**4.69**	4.85
	StP	0.99	0.99	0.99	1.55	1.41	1.37	4.53	4.13	**4.01**
Knee Maximum Angle	SwP	0.98	0.99	0.99	2.61	2.43	2.24	7.61	7.10	**6.54**
	StP	0.96	0.97	0.98	2.46	2.40	1.69	7.19	7.01	**4.93**
Knee Minimum Angle	SwP	0.96	0.97	0.98	2.61	2.24	2.02	7.62	6.53	**5.90**
	StP	0.97	0.98	0.98	2.17	2.12	1.87	6.34	6.18	**5.47**
Knee RoM	SwP	0.98	0.99	0.98	2.80	2.20	2.91	8.16	**6.43**	8.49
	StP	0.96	0.98	0.96	2.44	1.80	2.23	7.12	**5.25**	6.52
Ankle Maximum Angle	SwP	0.92	0.93	0.95	2.38	2.22	1.87	6.93	6.49	**5.47**
	StP	0.91	0.91	0.92	1.94	1.83	1.71	5.65	5.33	**4.99**
Ankle Minimum Angle	SwP	0.92	0.95	0.95	2.43	2.00	1.95	7.10	5.84	**5.69**
	StP	0.9	0.95	0.94	2.57	2.01	2.14	7.50	**5.86**	6.24
Ankle RoM	SwP	0.92	0.89	0.99	2.08	2.33	0.70	6.08	6.80	**2.05**
	StP	0.93	0.93	0.94	1.51	1.53	1.35	4.40	4.48	**3.95**
Mean		0.95	0.96	0.97	2.47	2.22	2.01	7.20	6.48	5.86

Table 3: Spatiotemporal parameters with mean and SD at each visit.

Spatiotemporal Parameters	Description					
	V1		V2		V3	
	mean	SD	mean	SD	mean	SD
Gait speed (cm/s)	77.44	23.03	80.17	26.56	80.03	23.25
Stride length (cm)	97.02	19.04	98.29	21.58	98.32	18.96
Cadence (step/min)	94.44	12.69	96.12	15.13	96.52	14.35
Step length (cm)	50.48	8.94	51.34	9.68	51.36	8.19
StP (%)	60.41	5.41	60.53	5.37	60.35	5.05
SwP (%)	39.59	5.41	39.47	5.37	39.65	5.05
Width (cm)	19.99	4.79	19.96	4.89	20.38	4.45

Table 4: ICC, SEM and MDC of spatiotemporal parameters in paretic lower limb. The lowest MDC values are in bold. The mean values of SEM and MDC are presented as percentages to rationalize and compare the different units.

Spatiotemporal Parameters	ICC			SEM			MDC		
	V1vsV2	V1vsV3	V2vsV3	V1vsV2	V1vsV3	V2vsV3	V1vsV2	V1vsV3	V2vsV3
Gait speed (cm/s)	0.96	0.96	0.98	6.38	6.08	5.03	18.54	17.67	**14.61**
Stride length (cm)	0.98	0.98	0.98	4.38	4.13	4.11	12.73	12.02	**11.96**
Cadence (step/min)	0.95	0.95	0.98	4.06	4.09	2.95	11.81	11.9	**8.58**
Step length (cm)	0.96	0.97	0.96	2.42	2.18	2.42	7.02	**6.33**	7.02
StP (%)	0.96	0.97	0.97	1.52	1.30	1.24	4.42	3.79	**3.60**
SwP (%)	0.96	0.97	0.97	1.52	1.30	1.24	4.42	3.79	**3.60**
Step width (cm)	0.97	0.96	0.98	1.03	1.12	0.85	3.00	3.25	**2.47**
Mean (% for SEM and MDC)	0.96	0.97	0.97	4.66	4.32	3.90	13.75	13.10	11.45

Table A: Results of statistical analyses of all the spatiotemporal and kinematics parameters during swing phase (SwP), stance phase (StP). RoM means Range of Motion (amplitude total between flexion and extension).

Normal Distribution						Non Normal Distribution					
Variable	Phase	P Anova	HSD Tukey			Variable	Phase	P Friedman	Wilcoxon		
			V1VSV2	V1VSV3	V2VSV3				V1VSV2	V1VSV3	V2VSV3
Hip RoM	SwP	0.01*	0.01*	0.58	0.12	Minimum Hip Angle	SwP	0.36	-	-	-
	StP	0.33	-	-	-	Minimum Knee Angle	SwP	0.75	-	-	-
Maximum Hip Angle	SwP	0.32	-	-	-	Maximum Knee Angle	StP	0.03*	0.68	0.81	0.53
	StP	0.16	-	-	-	Knee RoM	SwP	0.11	-	-	-
Minimum Hip Angle	StP	0.17	-	-	-		StP	0.22	-	-	-
Maximum Knee Angle	SwP	0.29	-	-	-	Minimum Ankle Angle	StP	0.84	-	-	-
Minimum Knee Angle	StP	0.22	-	-	-	Ankle RoM	SwP	0.11	-	-	-
Maximum Ankle Angle	SwP	0.97	-	-	-	Stride		0.12	-	-	-
	StP	0.17	-	-	-	Cadence		0.08	-	-	-
Minimum Ankle Angle	SwP	0.39	-	-	-	StP		0.33	-	-	-
Ankle RoM	StP	0.31	-	-	-	SwP		0.33	-	-	-
Gait speed		0.18	-	-	-	Width step		0.08	-	-	-
Step length		0.32	-	-	-						