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TITLE:

Motor Dual-tasks for Gait Analysis and Evaluation in Post-stroke Patients

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KEYWORDS:

Stroke, three-digital gait analysis, dual-tasks, motor task, assessment, dual-task gait cost

SUMMARY:

This paper presents a protocol specifically for dual motor task gait analysis in stroke patients with motor control deficits.

ABSTRACT:

Eighteen stroke patients were recruited for this study involving the evaluation of cognition and walking ability and multitask gait analysis. Multitask gait analysis consisted of a single walking task (Task 0), a simple motor dual-task (water-holding, Task 1), and a complex motor dual-task

(crossing obstacles, Task 2). The task of crossing obstacles was considered to be equivalent to the combination of a simple walking task and a complex motor task as it involved more nervous system, skeletal movement, and cognitive resources. To eliminate heterogeneity in the results of the gait analysis of the stroke patients, the dual-task gait cost values were calculated for various kinematic parameters. The major differences were observed in the proximal joint angles, especially in the angles of the trunk, pelvis, and hip joints, which were significantly larger in the dual motor tasks than in the single walking task. This research protocol aims to provide a basis for the clinical diagnosis of gait function and an in-depth study of motor control in stroke patients with motor control deficits through the analyses of dual-motor walking tasks.

INTRODUCTION:

The restoration of independent walking function is one of the requisites for the participation of post-stroke patients in community life[1]. The recovery of walking ability requires not only the interaction of the perception and cognitive systems, but also motor contro[2-4]. Furthermore, in real community life, people require higher abilities such as performing two or more tasks at the same time (*e.g.*, walking while holding objects or crossing obstacles). Therefore, studies have begun to focus on the interference of dual-tasks in gait performance[5,6]. Previous dual-task studies were mostly targeted to elderly and cognitively impaired patients owing to the difficulty in motor performance and heterogeneity in stroke patients; the gait function in stroke patients was mostly evaluated by a single walking task[7-9]. However, further research on dual-task gait analysis, especially motor dual-tasks related to motor control, is required.

This study introduces a methodology for dual motor task gait analysis and evaluation. This protocol not only includes clinical assessment of the walking ability in stroke patients, but also focuses on two dual-motor tasks: the holding-water-and-walking task (a simple dual motor task) and the crossing-obstacle walking task (a complex dual motor task). The aim of this study was to explore the effects of dual motor tasks on the gait of stroke patients and to employ the dual-task gait cost (DTC) values[10] of dual-task parameters (the difference between a single task and dual-task) to exclude the heterogeneity among stroke patients. The design of the experimental tasks facilitated an in-depth discussion of the motor control function of stroke patients, which provided new ideas for the clinical diagnosis and evaluation of the gait function of stroke patients.

PROTOCOL:

NOTE: The clinical study was approved by the Medical Ethics Association of the Fifth Affiliated Hospital of Guangzhou Medical University (NO. KY01-2019-02-27) and has been registered at the China Clinical Trial Registration Center (No. ChiCTR1800017487 and entitled, “The multiple modal tasks on gait control and motor cognition after stroke”).

1. Recruitment

1.1. Recruit stroke patients with the following inclusion criteria: patients meeting the diagnostic criteria for cerebrovascular disease of the Neurological Branch of the Chinese Medical Association (2005); cerebral infarction confirmed by computed tomography or magnetic resonance imaging; damage to the unilateral cortex or with a subcortical lesion; ability to walk independently, Brunnstrom stage ≥ 4 stages; Modified Ashworth Scale[11] ≤ 2 points; meeting the requirements of three-dimensional (3D) gait analysis and the ability to tolerate the whole process; and the ability to give informed consent.

1.2. Ensure the following exclusion criteria are met: congestive heart failure, deep vein thrombosis of the lower extremities, malignant progressive hypertension, respiratory failure or other diseases, and serious risk of falling.

1.3. Obtain written informed consent from all patients before beginning the study.

2. Clinical evaluation

2.1. Record the demographic characteristics of the patient including the name, gender, date of birth, level of education, chief complaint, current medical history, past history, medical treatment, and current medications.

2.2. Cognitive function assessment

2.2.1. Ask the patient to complete the Mini-Mental State Examination (MMSE)[12]: record the patient's responses to a 30-question scale with a total score of 30 points for cognition evaluation, which involves the following seven aspects: time orientation, position orientation, instant memory, attention and computing power, delayed memory, language, and visual space.

NOTE: The scores of MMSE are closely related to the level of education. The normal cognitive standard is illiteracy > 17 points, primary school > 20 points, and junior high school > 24 points[13].

2.2.2. Ask the patient to complete the Montreal Cognitive Assessment (MoCA)[14]: record the patient's responses to an 11-question scale with a total score of 30 points for cognition evaluation, which involves the following eight aspects: attention and concentration, executive function, memory, language, visual structure skills, abstract thinking, calculation, and orientation.

NOTE: The normal cognitive standard is ≥ 26 points. If the subject has been educated for less than 12 years, they should add 1 point to the score[15].

2.3. Walking ability assessment

2.3.1. Conduct the 10-m walk test (10 MWT)[16]. Ask the patient to perform three consecutive trials at a self-selected pace for safety, comfort, and higher speed, respectively. Record the time taken to walk to the middle 6 m in each trial (to exclude acceleration and deceleration effects).

2.3.2. Conduct the timed up and go test (TUGT)[17]. Ask the patient to perform three consecutive TUG trials (stand up, walk 3 m, turn, walk back, and sit down) at a self-selected pace for safety and comfort[18].

3. 3D gait analysis

3.1. Patient preparation

3.1.1. Inform the patient about the precautions and the purpose of the experiment.

3.1.2. Ask the patient to wear tight underwear to fully expose the neck, shoulders, waist, and lower limbs.

3.1.3. Record the values of various anthropometric indicators including height, weight, bilateral width of the ankle joints, bilateral knee diameter, pelvic width, bilateral pelvic depth, and bilateral leg length.

3.1.4. Place 22 markers on key points of the patient based on the Davis protocol[19]: three markers on the trunk (7th cervical vertebrae, shoulders on both sides); three markers on the pelvis (both sides of the anterior superior iliac spine and ankle joint); six markers on the thigh (bilateral femoral greater trochanter, femoral condyle, and middle point of femoral greater trochanter and femoral condyle on the same side); six markers on the calf (bilateral humeral head, lateral ankle joint, and middle point of humeral head and lateral ankle joint on the same side); four markers on the foot (the fifth metatarsal head and the heel on both sides) **(Figure 1)**.

3.1.5. Click on the **Start** button of the 3D gait analysis system, and make a new profile for the patient.

3.1.6. Enter basic patient information and previously measured parameters.

3.2. Standing data acquisition

3.2.1. Instruct the patient to maintain an upright position on the force plate for at least 3–5 s to gather the baseline data.

3.2.2. Click on the **Proc_Davis_Standing** button to quickly check the position of the marker.

3.3. Walking task data acquisition

3.3.1. Determine the random order of three walking tasks by drawing lots.

3.3.2. Ask the patient to walk on the walking pass for five trials at a self-selected comfortable speed, which is marked as **Task 0** (consider the single walking task as the Baseline task).

3.3.3. Ask the patient to walk while holding a bottle of water on the walking pass for five trials at a self-selected comfortable speed, which is marked as **Task 1** (simple dual-motor task).

NOTE: Ask the patient to hold a 550 mL bottle of water in the unaffected hand while holding the arm position of the shoulder joint at 0° and elbow flexion at 90°.

3.3.4. Ask the patient to walk across the line in the middle of the walking pass for five trials at a self-selected comfortable speed, which is marked as **Task 2** (complex dual-motor task).

NOTE: Place a soft ruler in the middle of the walking pass before **Task 2** data acquisition.

4. Data processing and analysis

4.1. Select the middle three trials of each walking task to be processed to ensure the patient is stable.

4.2. Identify each gait cycle with two consecutive heel stride points on the same side.

4.3. Mark the toe-off point in each gait cycle[20].

4.4. Click on the **Proc_DavisHeel+GI_AE** button to compute the kinematic parameters of gait, as well as the computation of the Gait Performance Score (GPS) index.

5. Data extraction and statistical analysis of interest

5.1. Select region of interest parameters from the processed data, which include special-temporary parameters (stance phase, swing phase, single stance, double stance, cadence), joint angle parameters (trunk obliquity (frontal plane), trunk tilt (sagittal plane), trunk rotation (transversal plane), pelvic obliquity (frontal plane), pelvic tilt (sagittal plane), pelvic rotation (transversal plane), hip flex-extension, hip ab-adduction, hip rotation, knee flex-extension, ankle dorsi-plantarflexion, and GPS index.

5.2. Calculate DTC values based on the following formula[10]:

([single-task gait velocity – dual-task gait velocity]/ single-task gait velocity) × 100 (**1**)

5.3. Perform the statistical analysis (see the **Table of Materials**) using the methodology described previously[20,21].

5.3.1. Present parametric data as means and standard deviation if normally distributed or as medians if not.

5.3.2. Use the paired *t*-test to compare the differences in kinematic parameters between patients in **Task 1** and **Task 2** conditions.

5.3.3. Use one-way analysis of variance to compare three different tasks (**Task 0**, **Task 1**, and **Task**

2) of the kinematic parameters. Set statistical significance at $P < 0.05$.

REPRESENTATIVE RESULTS:

Eighteen patients with hemiplegia after stroke were recruited in this study. The average age of the participants was 51.61 ± 12.97 years; all were males. The proportion of left and right hemiplegia was 10/8; the average Brunnstrom stage was 4.50 ± 0.76. The average of MMSE and MoCA were 26.56 ± 1.67 and 20.06 ± 2.27, respectively. Other demographic characteristics (including stroke type and time of onset) are shown in **Table 1**. For the original data of gait dual-tasks (Task 1 and Task 2), there was no statistical difference in the spatiotemporal parameters (Table 2). However, in the joint angle parameters, the bilateral trunk rotation (transversal plane) was larger in Task 2 than in Task 1 (left side: Task 1, 18.40 ± 5.76 *vs*. Task 2, 26.35 ± 14.92, P = 0.004; right side: Task 1, 18.39 ± 7.04 *vs*. Task 2, 24.08 ± 18.18, P = 0.001). Bilateral pelvic rotation (transversal plane) was larger in Task 2 than in Task 1 (left side: Task 1, 20.71 ± 7.97 *vs.* Task 2, 21.31 ± 6.96, P = 0.024; right side: Task 1, 27.56 ± 9.71 *vs.* Task 2, 29.264 ± 11.17, P = 0.006). The differences were statistically significant (**Table 3**).

For the DTC values of gait dual-tasks (Task 1 and Task 2), the bilateral trunk obliquity (frontal plane) was higher in Task 2 than in Task 1 (left side: Task 1, 2.60 ± 36.38 *vs.* Task 2, -23.4 ± 40.62, P = 0.006; right side: Task 1, -10.82 ± 47.58 *vs.* Task 2, -11.42 ± 30.10, P = 0.013). The bilateral pelvic rotation (transversal plane) was higher in Task 2 than in Task 1 (left side: Task 1, -2.75 ± 36.20 *vs.* Task 2, -23 ± 40.36, P = 0.011; right side: Task 1, 1.66 ± 43.72 *vs*. Task 2, -31.89 ± 58.50, P = 0.006). All differences were statistically significant (**Table 4** and **Figure 2**). At the same time, the right Cadence was significantly decreased in Task 2 relative to that in Task 1 (right side: Task 1, 18.40 ± 5.76 *vs*. Task 2, 26.35 ± 14.92, P = 0.044), and the right GPS was significantly decreased in Task 2 relative to that in Task 1 (right side: Task 1, 20.71 ± 4.87 *vs.* Task 2, 24.24 ± 10.33, P = 0.047) (**Table 5** and **Figure 3**).

FIGURE AND TABLE LEGENDS:

Figure 1: The gait analysis settings are based on the Davis protocol.

Figure 2: Comparing the DTC values of trunk and joint angle parameters of the simple motor dual-task (Task 1) and complex motor dual-task (Task 2). (**A**) Trunk obliquity (frontal plane); (**B**) trunk rotation (transversal plane); (**C**) pelvic rotation (transversal plane). Abbreviation: DTC = dual-task gait cost.

Figure 3: Comparing the DTC values of spatiotemporary parameters of the simple motor dual-task (Task 1) and the complex motor dual-task (Task 2). Percentages of (**A**) stance phase and (**B**) swing phase are shown for one gait cycle. Percentages of (**C**) single stance phase and (**D**) double stance phase are shown for one gait cycle. (**E**) The cadence and (**F**) GPS index are shown. Abbreviations: DTC = dual-task gait cost; GPS = Gait Performance Score.

Table 1: Basic characteristics of study subjects. Values are presented as a number or mean ± standard deviation. Abbreviations: MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; 10MWT = 10-meter walk test; TUGT = timed up and go test; SD = standard

deviation; LE = lower extremity; s = second.

Table 2: Differences in spatiotemporary parameters of the simple motor dual-task (Task 1) and complex motor dual-task (Task 2). Values are presented as a number or mean ± standard deviation. Statistical significance was set as *P* < 0.05 and marked in bold. Abbreviations: GPS = Gait Performance Score; min = minute.

Table 3: Differences in trunk and joint angle parameters of the simple motor dual-task (Task 1) and complex motor dual-task (Task 2). Values are presented as a number or mean ± standard deviation. Statistical significance was set as *P* < 0.05 and marked in bold.

Table 4: Differences in dual-task gait cost values of trunk and joint angle parameters of the simple motor dual-task (Task 1) and complex motor dual-task (Task 2). Values are presented as a number or mean ± standard deviation. Statistical significance was set as *P* < 0.05 and marked in bold.

Table 5: Differences in dual-task gait cost values of spatiotemporary parameters of the simple motor dual-task (Task 1) and complex motor dual-task (Task 2). Values are presented as a number or mean ± standard deviation. Statistical significance was set as *P* < 0.05 and marked in bold. Abbreviations: GPS = Gait Performance Score; min = minute.

Supplementary Table 1: Differences in trunk and joint angle parameters of single motor tasks (Task 0), simple motor dual-task (Task 1), and complex motor dual-task (Task 2) (degree). Values are presented as a number or mean ± standard deviation. Statistical significance was set as *P* < 0.05 and marked in bold.

Supplementary Table 2: Differences in spatiotemporary parameters of single motor tasks (Task 0), simple motor dual-task (Task 1), and complex motor dual-task (Task 2). Values are presented as a number or mean ± standard deviation. Statistical significance was set as P < 0.05 and marked in bold. Abbreviations: GPS = Gait Performance Score; min = minute.

DISCUSSION:

This study describes a protocol for the clinical assessment of dual motor task gait analysis in stroke patients with motor control deficits. The design of this protocol was based on two main points. First, most previous studies used a single walking task to assess the gait function of stroke patients, and the related discussions on motor control were inadequate, especially because the principles of complex motor movements were rarely involved[22,23]. Therefore, in this study, in addition to the single walking task as the baseline, the authors mainly focused on the comparison of two dual-tasks of motor performance and walking, including the task of water-holding (simple motor dual-task) and the task of crossing obstacles (complex motor dual-task)[24]. The water-holding task was identified as being equivalent to a combination of a simple walking task and a simple motor task.

Because the cross-obstacle walking task involved more nervous system, skeletal muscle movement, and cognitive resources in participating in motor control (including motor planning, motor coordination, and motor feedback) than the simple motor dual-task of holding water while walking, it was identified as being equivalent to a combination of a simple walking task and a complex motor task. Thus, the motor control function deficit after stroke could be closely examined based on this experimental task design. Previous dual-task gait analyses in the elderly and in patients with cognitive impairment have reported decreased velocity and cadence in dual-task walking compared with single-task walking[25].

However, the results of this study in stroke patients show that there were no significant differences in spatiotemporal parameters in dual motor tasks compared with those of the single motor task. The major changes were only observed in the proximal joint angles, especially the angles of the trunk, pelvis, and hip joints, which were significantly larger in dual motor tasks than in single walking tasks. This might be related to the obvious motor deficit of recruited stroke patients compared with the elderly or cognitively impaired patients (their basic motor function is preserved). There might be similar difficulties while performing a simple motor task and a complex motor task in stroke patients with existing impaired motor function, which could explain why the spatiotemporal parameters and distal joint angle were not sensitive parameters for the comparison between single and dual motor tasks in stroke patients. Additionally, these results suggest that rehabilitation training to increase trunk and large joint control might help stroke patients improve their ability to perform complex daily motor activities.

The heterogeneity of stroke patients has always been the main obstacle in many investigations[26]. A previous study had explored the use of the DTC value (the dual-task consumption ratio as the difference between a single task and double tasks) to eliminate the heterogeneity between stroke patients[10]. Indeed, the representative results demonstrate that the bilateral joint angle parameters of the large proximal joints in the complex dual walking task are significantly larger than those in the simple motor dual-task, indicating the advantages of using the DTC values in dual-task gait assessment for stroke patients.

This study has three main limitations. First, as this study is mainly a methodological demonstration of dual-motor tasks, the representative data only included data of 18 male stroke patients. In addition, previous studies have suggested that both gender and age impact gait and balance function. For example, as age increases, the ability to control posture decreases, and women are more affected than men. Moreover, the lack of significant difference in spatiotemporal parameters found in this study might be simply because of the sample size. Hence, further studies are needed to increase the sample size and include female subjects to extend the clinical application of this assessment. In conclusion, through dual-motor walking tasks and the calculation of DTC values, this research protocol aims to provide a basis for the clinical diagnosis of gait function and an in-depth study of motor control in stroke patients.

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DISCLOSURES:

The authors have nothing to disclose.

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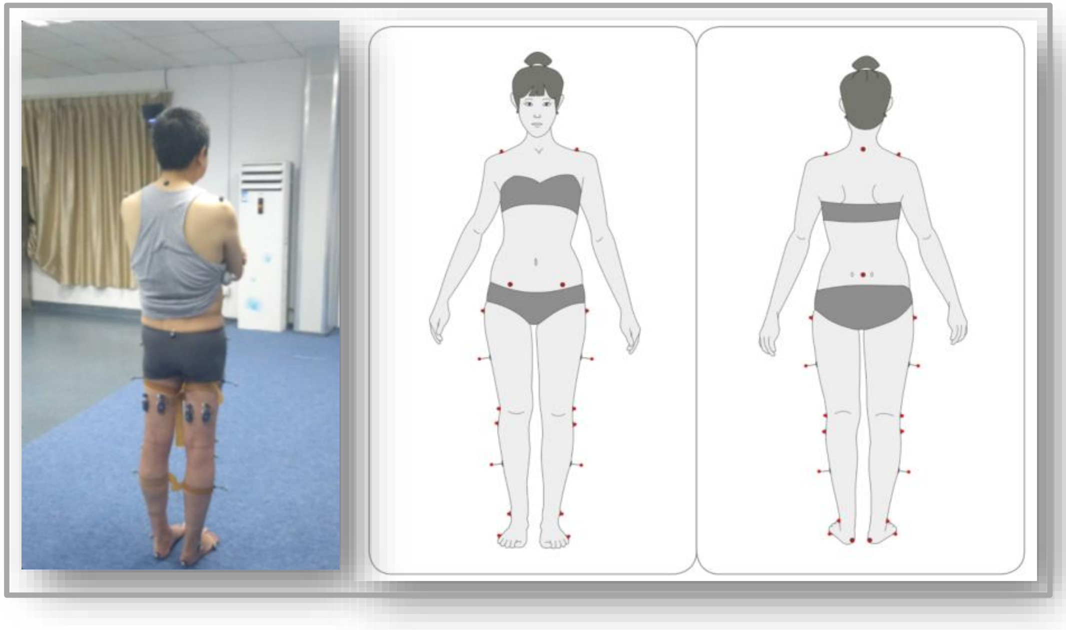
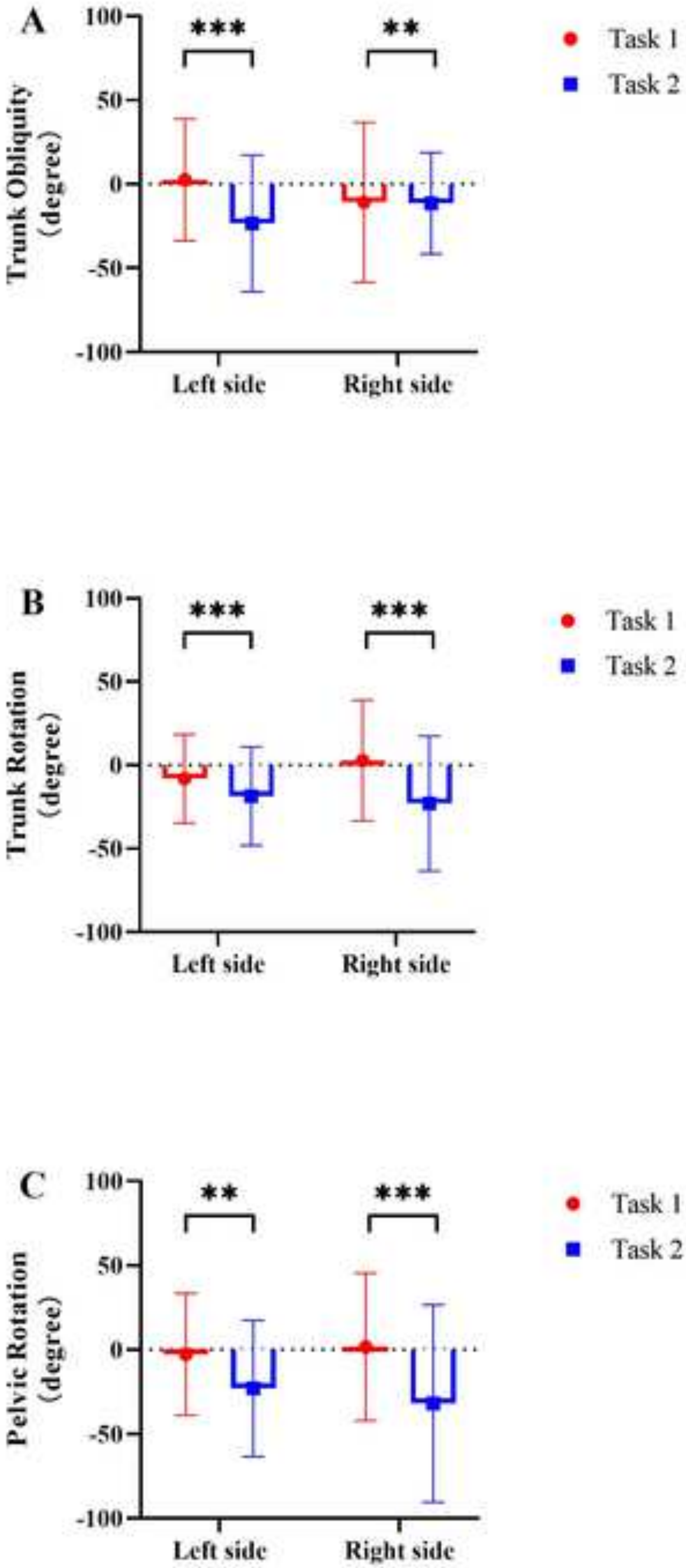
Figure 1.




A
100
50
0
-50
-100
Trunk Obliquity
(degree)
***
**
Left side
Right side
Task 1
Task 2
B
100
50
0
-50
-100
Trunk Rotation
(degree)
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***
Left side
Right side
Task 1
Task 2
C
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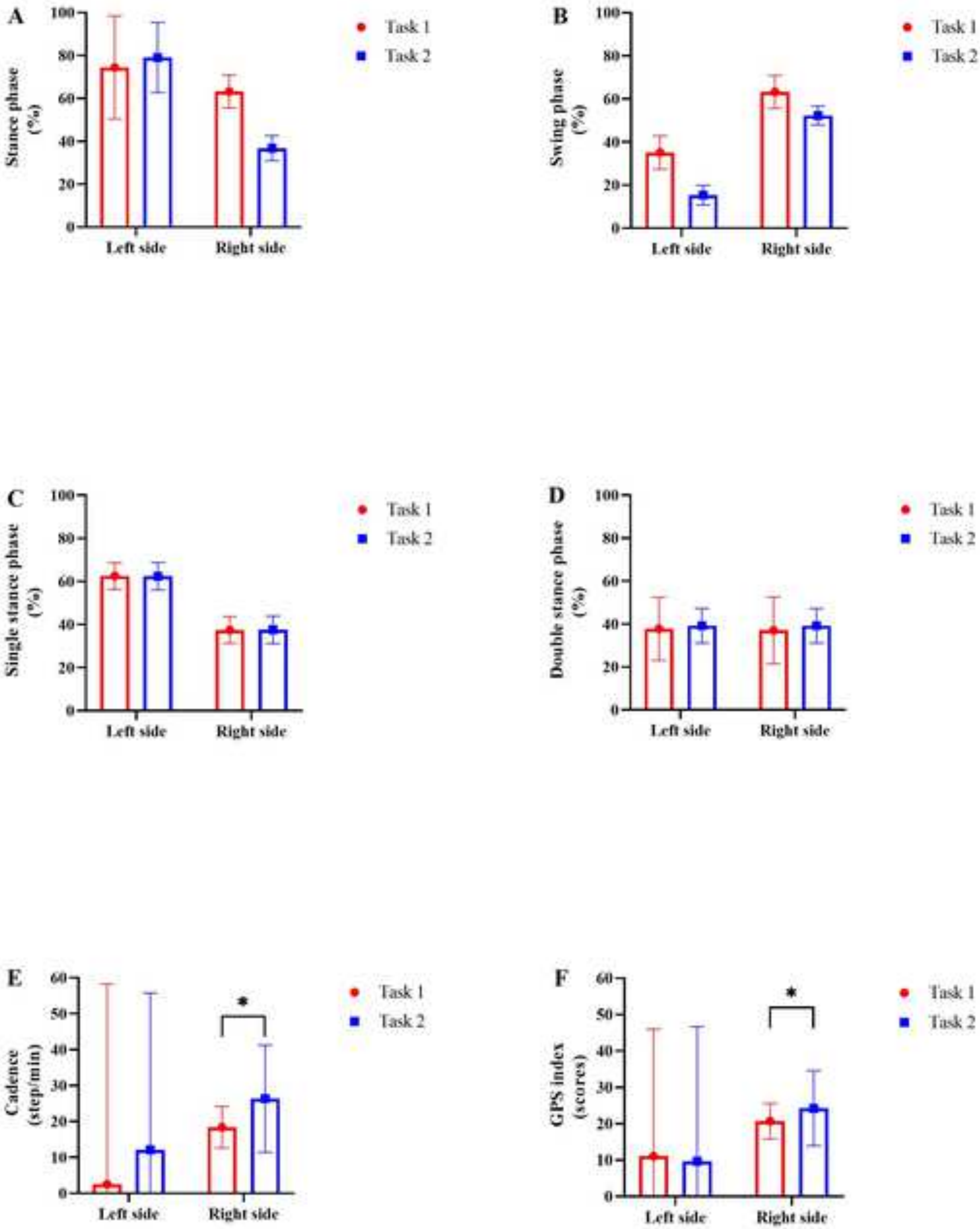
0
-50
-100
Pelvic Rotation
(degree)
**
***
Left side
Right side
Task 1
Task 2

Figure 3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Stance phase (%)
100
80
60
40
20
0
Left side
Right side
Task 1
Task 2
B
Swing phase (%)
100
80
60
40
20
0
Left side
Right side
Task 1
Task 2
C
Single stance phase (%)
100
80
60
40
20
0
Left side
Right side
Task 1
Task 2
D
Double stance phase (%)
100
80
60
40
20
0
Left side
Right side
Task 1
Task 2
E
Cadence (step/min)
60
50
40
30
20
10
0
*
Left side
Right side
Task 1
Task 2
F
GPS index (scores)
60
50
40
30
20
10
0
*
Left side
Right side
Task 1
Task 2

Table 1 Click here to access/download;Table;Table 1 (5).xlsx

Table 1

Subject	Sex	Age (years)	Hemorrhage/ infarct	Hemiplegic side	Stroke onset (months)	Brunnstrom-stage (LE)	MMSE	MoCA	10MWT (customized speed)	10MWT (fast speed)	TUGT (s)
001	male	30	Hemorrhage	right	29	5	25	18	0.52	0.62	26
002	male	59	Infarct	left	26	6	30	23	0.43	0.52	36
003	male	27	Infarct	left	26	5	24	19	0.46	0.48	48
004	male	54	Hemorrhage	right	23	5	26	18	0.56	0.61	58
005	male	63	Infarct	left	23	4	29	23	0.62	0.72	28
006	male	45	Infarct	left	23	5	25	19	0.56	0.63	33
007	male	67	Hemorrhage	left	22	4	28	17	0.59	0.67	45
008	male	42	Infarct	left	21	3	29	23	0.67	0.73	27
009	male	38	Infarct	right	18	4	28	20	0.52	0.67	26
010	male	70	Infarct	left	31	4	26	23	0.64	0.68	30
011	male	49	Hemorrhage	left	17	4	24	20	0.46	0.53	45
012	male	42	Infarct	left	19	3	27	16	0.43	0.56	49
013	male	45	Infarct	right	26	5	26	24	0.56	0.74	29
014	male	45	Hemorrhage	right	28	4	26	19	0.64	0.73	27
015	male	54	Infarct	right	18	5	25	21	0.52	0.65	33
016	male	68	Infarct	right	14	5	27	20	0.57	0.59	42
017	male	69	Infarct	left	15	5	26	18	0.52	0.63	38
018	male	62	Infarct	right	24	5	27	20	0.61	0.72	31
mean±SD		51.61±12.97	NA	NA	22.39±4.70	4.50±0.76	26.56±1.67	20.06±2.27	0.55±0.07	0.64±0.08	36.17±9.29

Table 2

	Left side				Right side			
	Task 1	Task 2	Difference	*P* value	Task 1	Task 2	Difference	*P* value
Stance phase (%)	20.71±7.97	21.31±6.96	0.60±10.58	0.916	18.02±4.86	20.66±7.41	2.64±8.86	0.254
Swing phase (%)	27.56±9.71	29.26±11.17	1.70±14.80	0.285	23.68±6.74	29.88±12.19	6.20±13.93	0.916
Single stance (%)	26.91±5.41	31.09±11.67	4.18±12.86	0.519	31.16±9.27	27.80±10.67	-3.36±14.13	0.583
Double stance (%)	24.72±7.10	31.31±5.99	6.59±9.29	0.291	37.55±17.79	44.10±12.60	6.55±21.80	0.369
Cadence	18.40±5.76	26.35±14.92	7.95±15.99	0.521	18.39±7.04	24.08±18.18	5.79±19.50	0.720
GPS (scores)	17.91±7.24	23.09±9.49	5.18±11.94	0.580	20.71±4.87	24.24±10.33	3.53±11.42	0.058

Table 3 Click here to access/download;Table;Table 3 R1.xlsx

Table 3

	Left side				Right side			
	Task 1	**Task 2**	**Difference**	***P* value**	**Task 1**	**Task 2**	**Difference**	***P* value**
Trunk Obliquity (Frontal plane)	27.86±7.45	24.63±4.08	-3.23±8.49	0.263	37.91±4.76	48.89±7.56	10.98±8.93	0.114
Trunk Tilt (Sagittal plane)	31.43±12.69	34.25±12.69	2.82±17.95	0.238	24.64±7.53	29.85±16.93	5.21±18.53	0.582
Trunk Rotation (Transversal plane)	18.40±5.76	26.35±14.92	7.95±15.99	**0.004**	18.39±7.04	24.08±18.18	5.69±19.50	**0.001**
Plevic Obliquity (Frontal plane)	16.99±6.07	25.05±15.43	8.06±16.58	0.277	20.66±7.41	18.02±4.86	-2.64±8.86	0.937
Plevic Tilt (Sagittal plane)	23.68±6.74	29.88±12.19	6.20±13.93	0.282	34.94±18.29	39.31±12.86	4.37±22.36	0.689
Plevic Rotation (Transversal plane)	20.71±7.97	21.31±6.96	0.60±10.58	**0.024**	27.56±9.71	29.26±11.17	1.70±14.80	**0.006**
Hip Ab-Adduction	20.71±4.87	24.24±10.33	3.53±11.42	0.148	17.91±7.24	23.09±9.49	5.18±11.94	0.238
Hip Flex-Extension	37.55±17.79	44.10±21.60	6.55±27.98	0.544	13.00±2.59	19.87±10.16	6.87±10.48	0.531
Hip Rotation	27.69±11.17	28.27±13.78	0.58±17.74	0.323	31.16±9.27	27.80±10.67	-3.36±14.13	**0.006**
Knee Flex-Extension	26.91±5.41	31.09±11.67	4.18±12.86	0.475	23.37±7.75	29.16±18.66	5.79±20.21	0.791
Ankle Dors-Plantarflex	21.75±11.07	27.54±13.41	5.79±17.39	0.213	25.87±10.71	25.87±11.50	0±15.71	0.112

Table 4.

	Left side				Right side			
	Task 1	**Task 2**	**Difference**	***P* value**	**Task 1**	**Task 2**	**Difference**	***P* value**
Trunk Obliquity (Frontal plane)	2.60±36.38	-23.4±40.62	-26.00±54.53	**0.006**	-10.82±47.58	-11.42±30.10	-0.60±56.30	**0.013**
Trunk Tilt (Sagittal plane)	15.34±7.74	13.40±8.22	-1.94±11.29	0.260	16.28±5.12	36.62±5.20	20.34±7.30	0.489
Trunk Rotation (Transversal plane)	-8.15±26.55	-18.56±29.54	-10.41±39.72	**0.004**	2.75±36.20	-23.00±40.36	-25.75±54.22	**0.001**
Pelvic Obliquity (Frontal plane)	15.34±7.74	13.40±8.22	-1.94±11.29	0.153	62.51±4.53	64.40±6.19	1.89±7.67	0.962
Pelvic Tilt (Sagittal plane)	37.49±6.36	37.60±6.19	0.11±8.88	0.097	12.89±6.36	14.32±3.79	1.43±7.43	0.510
Pelvic Rotation (Transversal plane)	-2.75±36.20	-23±40.36	-20.25±54.22	**0.011**	1.66±43.72	-31.89±58.50	-30.23±73.03	**0.006**
Hip Ab-Adduction	83.15±7.21	78.49±5.91	-4.66±9.32	0.125	84.18±8.81	92.56±6.51	8.38±10.95	0.242
Hip Flex-Extension	37.49±6.36	37.60±6.19	0.11±8.88	0.392	12.89±6.36	14.32±3.79	1.43±7.40	0.583
Hip Rotation	37.64±6.87	36.98±6.21	-0.66±9.26	0.549	49.6±8.52	56.52±4.52	6.92±9.65	0.004
Knee Flex-Extension	50.68±4.89	67.63±4.87	16.95±6.90	0.343	78.54±7.92	57.95±7.16	-20.59±10.68	0.673
Ankle Dors-Plantarflex	27.86±7.45	24.63±4.08	-3.23±8.50	0.263	37.91±4.76	48.89±7.56	10.98±8.93	0.114

Table 5

	Left side				Right side			
	Task 1	**Task 2**	**Difference**	***P* value**	**Task 1**	**Task 2**	**Difference**	***P* value**
Stance phase (%)	74.44±31.37	79.08±16.36	4.64±35.38	0.916	63.24±7.60	36.76±5.84	-26.48±9.58	0.236
Swing phase (%)	35.15±7.74	15.34±4.53	-19.81±8.97	0.980	63.24±7.61	52.28±4.36	-10.96±8.77	0.654
Single stance (%)	62.51±6.19	62.40±6.36	-0.11±8.88	0.348	37.49±6.19	37.60±6.36	0.11±8.88	0.671
Double stance (%)	37.78±14.71	39.19±8.05	1.41±16.77	0.164	37.03±15.55	39.19±8.05	2.16±17.51	0.406
Cadence (steps/min)	2.53±55.72	12.13±43.62	9.60±70.76	0.087	18.40±5.76	26.35±14.92	7.95±15.99	**0.044**
GPS (scores)	11.1±34.86	9.65±37.01	-1.45±50.84	0.681	20.71±4.87	24.24±10.33	3.53±11.42	**0.047**

Name of Material/Equipment	Company	Catalog Number	Comments/Description
BTS Smart DX system	Bioengineering Technolc	1	Temporospatial data collection
BTS SMART-Clinic software	Bioengineering Technolc	2	Data processing
SPSS software (version 25.0)	IBM Crop., Armonk, NY, USA		Statistical analysis

RE: JoVE62302: Manuscript Revision Required

Dear Editor,

Thanks for the editor board interested in this manuscript (ID: JoVE62302) and gave us the opportunity to address editor's and reviewers' recommendations. All points in the comments have been addressed in the manuscript and revisions. The manuscript was kept with marks in Microsoft Word. Please also see the attachment of response to reviewer's comments.

We would like to submit the revised version for your consideration to be published soon.

Yours sincerely,

Editorial comments:

1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues.

Response to the comments: Thank you for the comment. We polished the language again and revised some grammatical errors with text highlighting grey. We keep the marks in our revised manuscript.

2. Please provide an institutional email address for each author.

Response to the comments: Thank you for the comment. We have added the institutional email address for each author on the title page.

3. Please revise the text to avoid the use of any personal pronouns (e.g., "we", "you", "our" etc.).

Response to the comments: Thank you for the comment. We have changed the personal pronouns as marked in our manuscript-R1.

4. JoVE cannot publish manuscripts containing commercial language. Please remove all commercial language from your manuscript and use generic terms instead. All commercial products should be sufficiently referenced in the Table of Materials: e.g., BTS Smart. We must maintain our scientific integrity and prevent the subsequent video from becoming a commercial advertisement.

Response to the comments: Thank you for the comment. We have deleted the commercial in our manuscript.

5. Please include an ethics statement before the numbered protocol steps, indicating that the protocol follows the guidelines of your institution's human research ethics committee.

Response to the comments: Thank you for the comment. We have added ethics statement and the ethics number at the beginning of the protocol as follow:

"The clinical project was approved by the Medical Ethics Association of the Fifth Affiliated Hospital of Guangzhou Medical University (NO. KY01-2019-02-27)"

6. Line136: For SI units, please use standard abbreviations when the unit is preceded by a numeral. Abbreviate liters to L to avoid confusion. Examples: 10 mL, 8 µL, 7 cm^2.

Response to the comments: Thank you for the comment. We have changed "550ml" into "550mL".

7. Please highlight up to 3 pages of the Protocol (including headings and spacing) that identifies the essential steps of the protocol for the video, i.e., the steps that should be visualized to tell the most cohesive story of the Protocol. Remember that non-highlighted Protocol steps will remain in the manuscript, and therefore will still be available to the reader.

8. Please include an Acknowledgements section, containing any acknowledgments and all funding sources for this work.

Response to the comments: Thank you for the comment. We have added the Acknowledgements section in our manuscript-R1.

9. Please include a Disclosures section, providing information regarding the authors' competing

financial interests or other conflicts of interest. If authors have no competing financial interests, then a statement indicating no competing financial interests must be included.

Response to the comments: Thank you for the comment. We have added the Disclosures section in our manuscript-R1.

10. Please ensure that the references appear as the following: [Lastname, F.I., LastName, F.I., LastName, F.I. Article Title. Source. Volume (Issue), FirstPage – LastPage (YEAR).] For more than 6 authors, list only the first author then et al. Please do not use any abbreviations for journal titles and book titles. Article titles should start with a capital letter and end with a period and should appear exactly as they were published in the original work, without any abbreviations or truncations.

Response to the comments: Thank you for the comment. We revised the form of all the references as JOVE required.

11. Figure 2/ Figure 3: Please consider rearranging the graphs to form a multi paneled image and define each graph in the Figure Legend. Please label the Y axis.

Response to the comments: Thank you for the comment. We have revised Figure 2 and Figure 3. We also defined each graph in the Figure Legend.

Reviewers' comments:

Reviewer #1:

Manuscript Summary:

1. Text needs serious edits, including grammar and bullet points numbering, e.g. bullet point 2.2.1 jumped to 2.1.2.

Response to the comments: Thank you for the comment. We went through the manuscript carefully and corrected all the grammar mistakes we found. And we also corrected the bullet point "2.1.2" in Line 92.

2. Please use standard error instead of standard deviation for boxplot to easily see the significant difference.

Response to the comments: Thank you for the comment. On the one hand, we preferred to use SD to reflect the fluctuation of data points in the statistics of three-dimensional gait analysis data (SE might be mainly used to reflect the fluctuation of the mean value). On the other hand, SD using in the figures could also be consistent with SD using in the tables.

3. Tables with mean and standard deviation, why is the mean of difference different from subtracting task1 from task2 mean? Specially if you have the same number of patients for task 1 and 2.

Response to the comments: Thank you so much for the comment. We corrected all the difference data in table 2, table 3, table 4 and table 5.

4. Suggest using paired t-test for normally distributed factors to remove heterogeneity, since patients are actually performing different tasks before and after. Also, please provide adjusted pvalue for multi comparisons.

Response to the comments: Thank you so much for the comment. The paired t-test has been used to compare the differences of kinematic parameters between patients in Task 1 and Task 2 conditions in our study.

5. Please discuss the limitation of the study, e.g. the no significant difference in spatiotemporal parameters might be simply because of the sample size or the unpaired t-test.

Response to the comments: Thank you for the comment. We added more limitations in our limitation section as follow.

"This study also has three main limitations.... Moreover, the no significant difference in spatiotemporal parameters found in this study might be simply because of the sample size."

6. Main results are showing difference in proximal joint angles comparing dual to single task, so is this something that should happen but not found by single task or is it false positive? Please clarify and make the conclusion clearer on the usage of the dual task protocol.

Response to the comments: Thank you for the comment. We added more explanation as follow:

"Meanwhile, these results also suggested that rehabilitation training strategy increasing trunk and large joint control might help stroke patients improve their ability to perform complex daily motor activities. Another reason is that we studied relatively few stroke subjects. Larger sample sizes might provide better insight into mechanism of motor control after stroke during multiple-level motor tasks."

Reviewer #2:

Manuscript Summary:

In this manuscript, the authors Ou et al. provide a methodology protocol for dual motor task gait analysis in subjects with stroke. They recruited 18 subjects with stroke and evaluated them using clinical assessments (including MMSE, MoCA, 10MWT, and TUG) and three-dimensional gait analysis. The major findings of this study showed that there were no significant differences in spatiotemporal parameters in dual motor walking task as compared with the single motor walking task. The difference between dual task and single task conditions was only observed for proximal joint angles, which were markedly greater in dual task condition compared with single task condition. While the topic is interesting, there are some major concerns with this study.

Major Concerns:

- A major problem with the design was that only 5 trials were collected for each experimental condition without any practice trial. There is likely to be substantial within-subjects variability in the performance of the task, particularly with dual-tasking.

Response to the comments: Thank you for the comment. We thought the motor tasks used in this study, especially the dual task of holding water, were relatively simple. If the subject performed the practice trial, the learning factor might be considered and discussed for the result. Second, the middle three trials were used in the final statistical analysis for excluding unstable performances of recruited subjects. Finally, one of mainly innovations of this study was the use of DTC algorithm for excluding within-subjects heterogeneity in stroke group.

- "Crossing-obstacle walking task" was considered as a "complex dual motor task". However, it seems a complex motor task rather than a complex dual motor task. Please provide a justification based on a reference (s) for choosing this task as a complex dual motor task.

Response to the comments: Thank you for the comment. Crossing-obstacle task was seemed as complex dual motor task mainly based on Bloem BR's study as follow. We also added this paper as one of our references. And other references could also be used to support this concept.

1. Bloem BR, Valkenburg VV, Slabbekoorn M, Willemsen MD. The Multiple Tasks Test: development and normal strategies. Gait Posture. 2001 Dec;14(3):191-202. doi: 10.1016/s0966-6362(01)00141-2. PMID: 11600322.
2. Gagné Marie-Ève,McFadyen Bradford J,Ouellet Marie-Christine,Performance during dual-task walking in a corridor after mild traumatic brain injury: A potential functional marker to assist return-to-function decisions.[J] .Brain Inj, 2021, undefined: 1-7.
3. Ambike Satyajit,Penedo Tiago,Kulkarni Ashwini et al. Step length synergy while crossing obstacles is weaker in patients with Parkinson's disease.[J] .Gait Posture, 2021, 84: 340-345.

- The authors calculated some spatiotemporal gait parameters for left and right side. It has been shown that spatiotemporal gait parameters are different between the paretic and non-paretic lower extremities in individual's post-stroke. Thus, considering that both right and left hemiplegic patients were included in this study, I wonder what is the rational of providing results for right and left sides.

Response to the comments: Thank you for the comment. This study did not further divide recruited subjects into left-sided hemiplegia and right-sided hemiplegia, mainly because of the following three aspects. First, one of the highlights of this methodology was adapting DTC algorithm for eliminating heterogeneity. Moreover, we also used the paired-t test in statistical analysis to explore the difference under two conditions on the same stroke subject. Finally, because this study protocol focused on presenting methodology and just the representative results were present in result section, so the number of recruited subjects was relatively small. In the future original study, patients with left hemiplegia or right hemiplegia would be specifically recruited.

The authors are recommended to report the results for the paretic and non-paretic sides separately.
- The authors should acknowledge that cognitive impairment significantly affect dual-task function. None of the participants of this study had normal cognitive function based on MoCA (None of participants obtained MoCA score≥ 26).
Response to the comments: Thank you for the comment. The MoCA scores of all the recruited stroke patients were from 18 to 24, which were all ranked into mild cognitive impairment based on previous study (Hong H, Su Y, Su R, Yu Z, Xia Y. MoCA and MMSE scales in series for the screening of patients with mild cognitive impairment. Chinese Journal of Gerontology 2018, 38(19): 4815-4817.). The recruited stroke patients with MCI could be capable of performing all the tasks in our study protocol, including single walking, walking with holding water, and walking with crossing obstacle. Moreover，calculating DTC values in our study protocol was designed to eliminate the heterogeneity between stroke patients.

- One of the major limitations of this study is lack of control healthy group.
Response to the comments: Thank you for the comment. Calculating DTC values in our study protocol was designed to eliminate the heterogeneity between stroke patients. Meanwhile the purpose of our study protocol was mainly designed to compare the different motor dual task effect on the stroke patients with paired-t test statistical analysis.

Minor Concerns:
- Page 3, line 99-100: the authors stated that 10MWT was performed at self-selected speed while the results are provided for both 10MWT (customized speed) and 10MWT (fast speed) in Table 1.
Response to the comments: Thank you for the comment. We rewrote this part as follow:
"The patient is asked to perform three consecutive trials at a self-selected pace for safety and comfort and fast speed, respectively".

- Page 7, lines 226: what did the author mean by "simple exercise task?"
Response to the comments: Thank you for the comment. We changed "simple exercise task" into "simple motor task" for more appropriate expression.

- Page 7, lines 225-232: This part of discussion is speculative and confusing. Which part of the results of this study led to this interpretation?
Response to the comments: Thank you for the comment. This type of JOVE paper is more about methodology protocol presenting. So, for this part, we were mainly explaining the design of our

study protocol. We also added the specific purpose of this design as follow:
“Thus, the motor control function deficit after stroke could be deeply implored based on this in experimental task design.”

Supplementary Table 1.

	Left side				Right side			
	Task 0	**Task 1**	**Task 2**	***P* value**	**Task 0**	**Task 1**	**Task 2**	***P* value**
Trunk Obliquity (Frontal plane)	9.93±4.08	9.43±3.12	11.69±3.46	0.586	8.25±4.48	7.83±4.11	7.71±4.09	0.734
Trunk Tilt (Sagittal plane)	8.08±4.39	9.82±5.80	8.54±2.60	0.995	12.43±5.74	11.70±5.52	14.55±5.31	0.991
Trunk Rotation (Transversal plane	5.13±1.56	5.31±2.13	6.06±2.30	0.621	6.29±2.62	6.00±2.17	9.78±5.40	0.793
Plevic Obliquity (Frontal plane)	9.90±4.38	10.15±2.98	12.85±4.21	0.347	7.14±4.77	6.07±3.64	7.72±4.12	0.138
Plevic Tilt (Sagittal plane)	8.08±4.39	9.81±5.80	8.53±2.59	0.557	12.36±4.80	9.97±2.25	13.61±4.37	0.095
Plevic Rotation (Transversal plane)	8.30±6.38	8.52±6.54	8.33±2.40	0.193	6.75±3.07	6.78±2.45	6.94±3.53	0.785
Hip Ab-Adduction	5.04±1.78	4.88±2.46	5.75±2.12	0.567	12.37±4.28	9.10±2.56	12.12±3.41	0.196
Hip Flex-Extension	5.14±1.55	5.30±2.12	6.05±2.30	0.671	7.13±5.08	5.87±3.48	7.20±4.44	0.730
Hip Rotation	9.90±4.40	10.15±2.98	12.86±4.20	0.631	6.75±3.08	6.78±2.45	6.93±3.53	0.913
Knee Flex-Extension	9.94±4.09	9.43±3.12	11.69±3.46	0.190	6.29±2.61	6.00±2.18	9.80±5.39	0.775
Ankle Dors-Plantarflex	26.60±10.9[illegible]	25.25±8.86	31.58±14.56	0.817	7.15±5.08	5.85±3.49	7.20±4.44	0.820

Supplementary Table 2.

	Left side				Right side			
	Task 0	**Task 1**	**Task 2**	***P* value**	**Task 0**	**Task 1**	**Task 2**	***P* value**
Stance phase (%)	76.74±20.55	69.00±40.07	82.36±18.59	0.381	73.45±17.23	81.25±15.20	74.98±13.09	0.574
Swing phase (%)	12.13±5.41	12.59±3.43	12.26±5.01	0.512	66.20±8.33	62.42±6.66	64.73±9.14	0.648
Single stance (%)	58.26±10.82	60.07±5.30	60.40±5.29	0.577	33.80±8.33	37.58±6.66	35.28±9.14	0.648
Double stance (%)	39.74±6.49	39.93±5.30	39.60±5.29	0.975	16.17±4.49	18.79±11.16	14.83±3.65	0.549
Cadence (steps/min)	15.15±8.72	12.19±2.43	13.23±4.62	0.992	67.00±4.46	65.56±6.16	64.89±7.02	0.774
GPS (scores)	82.22±12.59	88.46±7.70	85.65±10.16	0.414	80.02±14.01	82.31±7.96	76.07±15.71	0.837