RELIABILITY OF A TRUNK MOUNTED ACCELEROMETER WHEN DETERMINING GAIT PARAMETERS IN PEOPLE WITH STROKE

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Wearable sensors and accelerometers can objectively and reliably assess gait parameters in both healthy individuals and stroke patients. The purpose of this study was to determine whether a wireless tri-axial accelerometer is reliable when measuring spatio-temporal gait parameters in patients with stroke. Thirty-one chronic stroke patients (age: 59.5±13.6 years; time since stroke: 28.1±17.8 months) completed three repeated walks along a 10m flat walkway whilst wearing a trunk mounted accelerometer (BTS G-Walk) secured around the waist of the participant over the L5 vertebrae. Outcome measures included cadence, speed, stride length, %stride length/height, gait cycle duration, step length, stance and swing phase duration, single and double support duration for both symptomatic and asymptomatic lower limbs where relevant. Reliability was assessed via intraclass correlation coefficient (ICC), standard error of the mean (SEM) and smallest detectable change (SDC) values. ICCs were > 0.75 for all parameters, excluding step length on the asymptomatic side (ICC = 0.70). SEM and the SDC were marginally larger for the symptomatic limb than the asymptomatic limb for gait cycle duration and step length, but smaller for all other outcomes. The study showed that the BTS G-Walk is a reliable tool for measuring spatio-temporal parameters in patients with stroke. Physiotherapists and clinicians often prefer detailed information on gait ability. As advanced technologies could help with specific goals relating to gait performance, such devices could be reliably implemented as an alternative to the gold standard in clinical and community settings to monitor patients outside of a lab-based environment.

KEYWORDS: accelerometer, gait, rehabilitation, stroke.

INTRODUCTION: Gait recovery is a major objective in the rehabilitation of stroke patients (Beldo-Lois et al., 2011) with gait analysis frequently implemented in clinical practice to identify impairments, and determine appropriate treatments (Yavuzer et al., 2008). Many clinicians include the observation of an individual's gait as part of their examinations by using simple and reliable scales to assess walking ability and speed (e.g., Dynamic Gait Index [DGI]) (Jonsdottir et al., 2007). These measures are a useful tool to form an idea of a patient's ability, however, do not have the capability to comprehensively identify more specific areas of improvement (Faulkner & Wright, 2018). Physiotherapists and clinicians often prefer more detailed information on gait ability (Papi et al., 2016), while for participants, measurable outputs from more advanced technologies could help with specific goals relating to gait performance. Optical 3D motion analysis systems are the gold-standard method of collecting objective, accurate, and repeatable gait data, providing 3D spatio-temporal, kinematic and kinetic gait parameters (Carse et al., 2013). Yet routine clinical use of instrumental gait analysis can be complex, costly, inconvenient, and require technical expertise and tend to be limited to laboratory-based settings located in universities or specialized research hospitals (Carse et al., 2013).
Wearable sensors and accelerometers have been shown to be a useful method for objective and reliable assessment of gait in both healthy and stroke patients (Kavanagh et al., 2006; Saremi et al., 2006). These are an alternative gait analysis tool which are small, lightweight, non-invasive, cost effective and can be used to measure many spatio-temporal gait parameters (Mizuike et al., 2009). The BTS G-Walk (BTS Bioengineering, Quincy, USA), one such commercially available device, is a small wireless accelerometer which acquires, interprets and reports gait parameters almost instantaneously. The G-Walk has been shown to have excellent inter-trial reliability (Intra-class correlation coefficient [ICC] values ≥ 0.84) when measuring several spatio-temporal gait variables in healthy subjects aged 20-56 years (De Ridder et al., 2019). Despite these encouraging findings, research is needed to explore

whether the G-Walk can reliably measure gait parameters in a stroke population and provide further insight into the spatio-temporal measures of the symptomatic versus asymptomatic limbs than traditional observations (i.e., DGI).

The purpose of this study was to determine whether the BTS G-Walk, a wireless trunk tri-axial accelerometer, is reliable when measuring spatio-temporal gait parameters in patients with stroke.

METHODS: Thirty-one participants with chronic stroke (> 3 month post stroke) were recruited from a neuro-physiotherapy practice (Table 1). Participants Functional Ambulation Classification (FAC) (Mehrholz et al., 2007) was to be between 3 and 5 and a Modified Rankin Scale (MRS) (Banks et al., 2007) score between 2 and 4. Participants were able to walk either independently with supervision or with an assistive walking device. Written informed consent was obtained from all participants prior to the start of the study. The study protocol received institutional ethical approval [BLS/16/16].

Table 1. Participant Demographics (n=31)

Demographic	Total
Sex (M/F)	27/4
Age (years)	59.5 ± 13.6
Stroke diagnosis; Ischaemic/Haemorrhagic	27/4
Affected side (R/L)	19/12
Functional Ambulation Classification	3.7 ± 0.9
Modified Rankin Scale	3.1 ± 0.7
Orthotic* (Y/N)	16/15
Walking aid** (Y/N)	20/11
Time since stroke (months)	28.1 ± 17.8

Note: Age and time since stroke are shown as mean ± SD
**Orthotic refers to a soft or hard foot and/or ankle brace*
*** Walking aid refers to use of a walking stick, tripod or quadrupod*

The G-Walk is a small wireless inertial sensor equipped with a tri-axial accelerometer, gyroscope and magnetometer and uses Bluetooth to collect spatio-temporal data in real-time sampled at 100Hz. The G-Walk was placed in an elasticated belt and secured around the waist of the participant over the L5 vertebra. Participants stood upright and still for approximately five seconds whilst the G-Walk calibrated. Participants were instructed to walk in a straight line along a 10m flat walkway at a self-selected speed wearing their own shoes. Each participant completed a minimum of six trials. The first three trials were discounted due to potential 'cautious gait', a specific gait pattern with reduced stride length and gait velocity, compromising data interpretation in the adaptation phase (Boudarham et al., 2013). Parameters of interest included cadence, speed, stride length, %stride length/height, gait cycle duration, step length, stance and swing phase duration, single and double support duration for both legs where relevant.

Data was collected through G-studio and were exported to Excel for analysis of intra-class coefficients (ICC) to attain values to determine the reliability of the device. ICC ≥ 0.75 is considered good to excellent (Koo et al., 2016). In addition, standard error of measurement (SEM) and smallest detectable change (SDC), which symbolises a minimal change in score which cannot be attributed to measurement error (Serbetar, 2015), was also recorded. Where possible symptomatic and asymptomatic limbs were analysed independently. Means and standard deviations for each parameter are also reported.

RESULTS: As demonstrated in table 2, ICCs were > 0.75 for all parameters, excluding step length on the asymptomatic side (ICC = 0.70). SEM and the SDC were marginally larger for the symptomatic limb than the asymptomatic limb for gait cycle duration and step length, but smaller for all other outcomes.

Table 2: Means, standard deviation, ICC, SEM and SDC values from the G-walk for symptomatic and asymptomatic side.

Gait parameter	Limb	Mean ± SD	ICC	SEM	SDC
Gait cycle duration (s)	Symptomatic	2.53 ± 1.43	0.90	0.40	1.10
	Asymptomatic	2.46 ± 1.26	0.96	0.26	0.71
Step length (%)	Symptomatic	49.20 ± 2.03	0.97	1.39	3.85
	Asymptomatic	50.51 ± 2.39	0.70	1.08	3.01
Stance phase (%)	Symptomatic	64.01 ± 8.83	0.84	3.20	8.88
	Asymptomatic	69.66 ± 8.18	0.80	3.43	9.51
Swing phase (%)	Symptomatic	35.99 ± 8.77	0.84	3.20	8.88
	Asymptomatic	30.01 ± 8.00	0.80	3.43	9.51
Double support phase (%)	Symptomatic	16.59 ± 7.54	0.84	2.67	7.40
	Asymptomatic	17.43 ± 7.16	0.79	2.96	8.20
Single support phase (%)	Symptomatic	30.53 ± 8.07	0.80	3.26	9.05
	Asymptomatic	35.65 ± 8.77	0.81	3.48	9.65
Cadence (steps/min)	n/a	61.81 ± 28.41	0.98	4.39	12.19
Speed (m/s)	n/a	0.73 ± 0.35	0.98	0.06	0.15
Stride length (m)	n/a	1.42 ± 0.34	0.98	0.05	0.14
%stride length/height (%)	n/a	86.90 ± 19.99	0.97	3.44	9.54

DISCUSSION: The purpose of this study was to determine whether the BTS G-Walk is a reliable tool when measuring spatio-temporal gait parameters in individuals with stroke. Reliability is important when establishing the consistency of measurements and is important for the clinical application of outcome evaluation tools in a rehabilitation environment (Kim et al., 2012). In this study ICC values for cadence, speed, stride length, %stride length/height, gait cycle duration on both symptomatic and asymptomatic limb, and step length on the symptomatic limb were excellent (≥ 0.90) for the BTS G-Walk. All other measures were found to have good reliability (0.79 - 0.84), apart from step length on the asymptomatic limb which showed moderate reliability (0.70). Lower reliability scores for some measures on the asymptomatic limb could be due to the inconsistent movement pattern that occurs when in stance on the symptomatic side. Our study findings are comparable to a young healthy population using the same device (0.84 - 0.99) (De Ridder et al., 2019), and similar tri-axial accelerometers (FITMETER; 0.84 – 0.90) in older adults (Byun et al., 2016). Accordingly, our study demonstrates encouraging evidence as the G-Walk can reliably explore gait patterns in stroke for general variables such as speed, but also in more detail for the symptomatic or asymptomatic limbs.

The SDC is an additional benchmark for interpreting changes in outcome measures (Serbetar, 2015). When taking into account the SDC, on an individual patient-based level, changes in each measurement should exceed those seen in table 2 to show that an individual has undergone real change in the measured gait parameter for this particular population. For example, an increase of 0.15m/s in speed and 0.14m in stride length would be considered a meaningful improvement for this particular population (table 2). This may also be of benefit for clinicians when interpreting symptomatic and asymptomatic limbs.

To better contextualise the study findings, the strengths and limitations should be addressed. Firstly, the present study only examined a self-selected walking speed. Although ICCs were excellent for walking speed (0.98), exploring the effect of set slow, moderate and fast walking speeds would be beneficial as this would help to reflect the ecological utility of the G-Walk. Secondly, within this study participants could ambulate independently without the need for manual contact (FAC 3 - 5). However, future research may need to explore whether the G-Walk is reliable when assessing a less able stroke population (FAC 1 - 2). Despite these limitations, the BTS-G-Walk is portable and more accessible than 3D gait analysis and could help clinicians determine appropriate treatments and evaluate interventions in more depth outside of the laboratory.

CONCLUSION: In conclusion, this study demonstrated that the BTS G-walk is a reliable tool for measuring spatio-temporal parameters in participants with stroke. Further work is needed to investigate the validity of this device within a stroke population to prove its accuracy against the gold standard. This could help to determine whether such a device could be used within community and/or clinical settings in the future to help monitor patients outside of a laboratory-based environment.

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