IDENTIFYING GAIT ASYMMETRY USING DIGITAL SENSORS

Yin-Shin Lee[1], Tsan-Yang Chen[2], Chia-Hsiang Chen[3], Tzyy-Yuang Shiang[2]
Department of Physical education, National Taiwan Normal University, Taipei, Taiwan[1]
Department of Athletic Performance, National Taiwan Normal University, Taipei, Taiwan[2]
Department of Athletic Performance, National University of Kaohsiung, Kaohsiung, Taiwan[3]

The purpose of this study was to determine which phases and kinematics were easier to identify gait asymmetry by using digital sensors. Sixteen participants were recruited in this study. The participants were requested to walk naturally under two conditions (with or without asymmetrical load). Four digital sensor sets were attached on 4 limbs to collect kinematics data. The results showed that only the ASI of Medial-Later acceleration of upper limb on the stance phase significantly different between unloading and loading conditions; on the lower limb were ASI of Superior-Inferior acceleration and Flex/Extension angular velocity on the swing phase. The digital sensors that attach on upper and lower limbs both can detect gait asymmetry, but the asymmetrical phase and kinematics are different on upper and lower limbs.

Key words: Kinematics, Acceleration, Angular velocity, Gyro, Accelerometer.

INTRODUCTION:

Gait is a common movement in daily life and been considered as the most universal human activity (Cappozzo, 1984). It is a complex skill and required coordinated movements of the body segment and muscles. The effect of asymmetrical gait may cause injury or impairing sports performance (Schache, Wrigley, Baker, & Pandy, 2009). Since the start of gait analysis, asymmetry issue is always a popular topic. Previous asymmetry studies had developed many methods and indexes to quantify asymmetry of individual variables, e.g. symmetry index (SI), asymmetry index (ASI), gait asymmetry (GA) (Robinson, Herzog, & Nigg, 1987; Sadeghi, Allard, Prince, & Labelle, 2000; Yogev, Plotnik, Peretz, Giladi, & Hausdorff, 2007). Most of those studies observed the asymmetric muscle strength, range of motion, or join angle. However, these observations require expensive experiment equipment (motion capture system or force plate) and must complete under laboratory conditions. In recent years, sensor technology is developed rapidly. Because of portability and low-cost, digital sensor has been wildly applied in biomechanical studies recently (Sprager & Juric, 2015). We can easily get the information of some kinematics parameters, e.g. acceleration and angular velocity of body segment through digital sensor. Therefore the purpose of this study was to use digital sensors as a new instrument to detect gait asymmetry and determining which phases and kinematics are easier to identify gait asymmetry.

METHOD:

Participants: Sixteen participants were recruited in this study (8 male, 8 female, 24.0±3.0 yrs, 168.4±8.3 cm, 64.7±12.8kg). Participants who had surgery history on upper/lower limbs, been diagnosed with limb length discrepancies (LLD), the quadriceps femoris (QF) muscle strength asymmetry (>10%) or injured in the previous 6 months and required medical treatment were excluded from this study.

Data acquisition: Four digital sensor sets including one tri-axial accelerometer (ADXL345, Analog Devices, USA) and one tri-axial gyroscope (MPU3050, InvenSense, USA) were attached on the lateral side of each limb (wrist and ankle). The sampling rate was set at 200 Hz. After 5 mins warm-up, walking on the treadmill at self-selected speed, participants were asked to perform 2 overground walking trials with or without unilateral ankle loading (5% body weight (Nessler, Gutierrez, Werner, & Punsalan, 2015) in the indoor stadium. Participants were requested to walk naturally at consistent self-selected speed in the distance of 50m. Two trials were performed randomly and separated by a 5 mins of rest.

Data analysis: Six strides (12 steps) in the middle of each trail were extracted for analysis. Stride duration was determined by gyro data on ankle (Gouwanda & Arosha Senanayake,

2011) and divided into 2 phases (stance/swing). The data of digital sensors were normalized by Eq. (1) which developed by Gouwanda and Arosha Senanayake (2011). The mean values of each axis of sensors during 2 phases were calculated for the asymmetry index (ASI). The asymmetry index were calculated by Eq. (2) (Robinson et al., 1987). Paired-sample t test was used to compare the difference of asymmetry index between unloading and loading. The significant level was set at α= .05.

$\theta_{norm(n)} = \frac{\theta_{(n)}-\theta_{min}}{\theta_{max}-\theta_{min}} + 1$..............Eq. (1)   (n) is the number of data points.

$\mathrm{ASI} = \left[\frac{|\theta r-\theta l|}{1/2(\theta r+\theta l)}\right] \times 100$................Eq. (2) θ r is the result of kinematics parameters of right side.

θ l is the result of kinematics parameters of left side.

RESULTS:

The asymmetry results of each kinematics parameter in different phases and limbs were shown in Table 1 & 2. In the results of upper limb, only the ASI of Medio/Lateral acceleration in stance phase showed significant difference between unloading and loading conditions. In the results of lower limb, more kinematics parameters showed significant difference between two conditions than the results of upper limb. Majority was shown in swing phase (e.g., Superior- Inferior acceleration, Inter/External rotation and Flex/Extension angular velocity).

Table 1
Asymmetry results for upper limb

	Stance phase			**Swing phase**		
ASI (%)	Unloading	Loading	Delta	Unloading	Loading	Delta
Superior/Inferior acceleration	18.45±6.54	17.40±3.43	-1.04%	16.50 ±6.49	17.33 ±4.98	0.83%
Anterio/posterior acceleration	18.67±6.01	19.79±3.88	-1.11%	19.94 ±6.84	19.47 ±5.94	-0.47%
Medio/lateral acceleration	20.32±4.74	25.91±5.44	6.00%*	19.31 ±6.93	22.44 ±6.28	3.13%
Inter/External rotation angular velocity	20.10±6.80	22.92±6.85	2.82%	27.31 ±8.91	27.60 ±7.58	0.29%
Abd/Adduction angular velocity	24.24±7.56	26.96±9.34	2.73%	34.69 ±12.17	23.71 ±8.42	-10.98%
Flex/Extension angular velocity	28.18±14.50	24.28±12.49	-3.90%	28.28 ±16.55	24.42 ±10.46	-3.86%

* significantly different between none-loading and loading (*p* < .05)

Table 2
Asymmetry results for lower limb

	Stance phase			**Swing phase**		
ASI (%)	Unloading	Loading	Delta	Unloading	Loading	Delta
Superior/Inferior acceleration	9.01±3.64	11.96±4.55	2.95%*	7.15±3.65	11.32±2.80	4.17%*
Anterio/posterior acceleration	10.11±3.92	11.34±3.27	1.23%	10.00±4.90	13.08±3.30	3.09%
Medio/lateral acceleration	16.38±3.41	14.47±2.12	-1.91%	18.41±4.42	15.59±4.67	-2.81%
Inter/External rotation angular velocity	23.35±4.99	20.55±5.41	-2.79%	20.39±4.54	24.05±2.89	3.70%*
Abd/Adduction angular velocity	16.41±2.80	22.84±5.55	6.43%*	22.46±7.91	26.07±7.31	3.62%
Flex/Extension angular velocity	4.71±3.35	9.21±9.72	4.50%	5.39±3.95	11.60±7.72	6.20%*

* significantly different between none-loading and loading (*p* < .05)

DISCUSSION:

There were more ASI results for lower limb showed significant difference between unloading and loading conditions. Meaning that is easier to identify gait asymmetry by using the kinematics parameter from lower limbs than upper limbs. Due to the different kinetic chain implement between upper and lower limbs while walking, we considered that upper limb movement was easier effected by the unilateral loading. And it was also proved by the results of lower limb in swing phase. Through additional unilateral loading on lower limb did not seem to affect the movement of upper limb. Maybe the loading or the walking speed was not heavy or fast enough to make the significant change on the upper limb movement. Previous study also showed that the asymmetry of arm-swing might be more complex and does not related to asymmetrical leg movements (Kuhtz-Buschbeck, Brockmann, Gilster, Koch, & Stolze, 2008).

The result of lower limb Superior/Inferior acceleration showed significant difference between two conditions in both stance and swing phases. We supposed that the loading made participants more difficult to raise their leg and land properly. Previous studies also pointed out that lower limb muscle strength asymmetry and unilateral loading could affect lower limb kinematics (e.g., stance/swing time, rang of motion) (Smith & Martin, 2007; Vagenas & Hoshizaki, 1991).

CONCLUSION:

The digital sensors that attach on upper and lower limbs both can detect gait asymmetry, but it is easier to identify gait asymmetry using the kinematics parameter from lower limbs. We considered that the superior/Inferior acceleration of lower limb is a better parameter to identify gait asymmetry. The asymmetrical phase and kinematics parameters which could identify the difference between unloading and loading were different on upper and lower limbs. In future study, inertial measurement units will attach on patients with asymmetry gait and the data could apply for clinical applications.

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