Gait Analysis through a visual method to calculate temporal parameters: comparison of performance between the gait laboratory and the clinical setting

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***Abstract*— Analysis of human movement provides systematic and quantitative information of movement. The detection of events that occur during walking allows for the calculation of spatiotemporal parameters, commonly used for the characterization of gait. A method for visual detection of gait events was previously evaluated, showing promising results. The method should now be used in the clinical setting for estimation of gait parameters and symmetry. The aims of this study were then to compare the performance of the visual method in a clinical setting against its performance in a gait laboratory and to evaluate its behavior for calculation of gait symmetry in eight healthy subjects. Two gait events were detected and six temporal parameters (TP) were calculated. Also, a symmetry index (SI) was calculated for three TP. Results for the calculation of TP in the clinical setting were comparable to those obtained in the gait laboratory. Also, the values of TP and symmetry were within the range of those reported by other authors. These results suggest that the visual events detection method can be considered as an option for basic Analysis of Human Movement in the clinical environment.**

***Keywords*— clinical setting, event detection, gait analysis, gait parameters, gait laboratory, hospital environment, temporal parameters, symmetry index, video camera.**

***Resumen*— El análisis del movimiento humano proporciona información sistemática y cuantitativa del movimiento. La detección de eventos que ocurren durante la marcha permite el cálculo de parámetros espaciotemporales, comúnmente utilizados para la caracterización de la marcha. Se ha evaluado previamente un método para la detección visual de eventos de la marcha, mostrando resultados prometedores. El método podría utilizarse en el entorno clínico para la estimación de los parámetros y simetría de la marcha. Los objetivos de este estudio fueron comparar el uso del método visual en un entorno clínico con su uso en un laboratorio de marcha y evaluar su comportamiento para el cálculo de la simetría de la marcha en ocho sujetos sanos. Se detectaron dos eventos de marcha y se calcularon seis parámetros temporales (PT). Además, se calculó un índice de simetría para tres PT. Los resultados para el cálculo de PT en el entorno clínico fueron comparables a los obtenidos en el laboratorio de marcha. Además, los valores de PT y simetría estuvieron dentro del rango de los reportados por otros autores. Estos resultados sugieren que el método de detección de eventos visuales podría considerarse como una opción para el análisis básico del movimiento humano en el entorno clínico.**

***Palabras clave*— entorno clínico, detección de eventos, análisis de la marcha, parámetros de la marcha, laboratorio de la marcha, entorno hospitalario, parámetros temporales, índice de simetría, cámara de video.**

I. INTRODUCTION

A. Gait analysis

THE Analysis of Human Movement (AHM) provides systematic and quantitative information of the movement of people. It has been postulated that the evaluation of human movement is needed to assess the progress of rehabilitation treatments in patients with lower limb amputations [1], [2]. However, in clinical areas such as Rehabilitation Hospitals, the application of AHM is challenged by difficulties and it is virtually nonexistent [1], [3]–[8]. This could be due, in part to the complexity of selecting simple, practical, portable and inexpensive tools that had been validated for clinical evaluation; and in part to the lack of consensus about what are the most representative parameters for each group of patients [9], [10].

Spatiotemporal parameters are commonly used to evaluate the movement of unimpaired and impaired individuals [11]–[13]. They have also been proposed for the analysis of symmetry between the lower limbs and as an aid to evaluate the success of the rehabilitation process [9], [11], [13]. A recent review also showed that spatiotemporal parameters are the most common parameters used in research related to lower limb amputees [10]. And limb symmetry has been suggested as a way of characterizing the walk of lower limb amputees [14].

In order to calculate the parameters, it is necessary to detect some events that occur during walking: the initial contact of the foot with the floor (IC), and the break of contact or foot off (FO) [11], [12], [15]. The accuracy of the estimation of the parameters depends on the accuracy of the methods used for detection of gait event.

B. Methods for event detection

Force platforms are considered the gold standard for detection of gait events. However, they have some limitations for clinical environments, since they are relatively expensive and the number of steps that can be evaluated per trial is restricted by the number of platforms available [16], [17]. Alternative methods such as pressure sensors [18], [19] and kinematic methods using optical systems [18]–[24] have often been proposed.

Traditional video cameras are inexpensive when compared with force platforms, portable, small, light and easy to use, making them appealing for use in clinical settings [1].

A visual method based on conventional video cameras for detection of gait events was evaluated in a pilot study [25]. The results showed similar accuracy to other methods proposed in the literature [20], [23] (mean maximum difference when compared to the force platform of 32 ms for FO), repeatability and independence of the raters previous experience (inter rater ICC greater than 0.90).

In our last study [26] we evaluated the same method for calculation of temporal parameters, comparing the results to those obtained from a force platform in healthy subjects walking at different self-selected speeds. Results in the evaluation of step time, stance time, double support time and cadence, results showed an absolute mean difference smaller than 25 ms with the force platform. These differences are in the range of those reported by other authors [16]. These results suggest that the accuracy and inter-rater reliability of the method here proposed are comparable to other methods evaluated, when used in gait laboratories.

C. Application of gait analysis in clinical settings

Reid et al [7], discussed that although classically the validity of a method would be considered specific to the method regardless of the population to which it is applied, nowadays, a given instrument and the associated outcome measure are considered specific to a clinical context. So, the evaluation of such an instrument in the exact area where it will be used is of critical importance.

In fact, local rehabilitation clinics do not have a gait laboratory to perform a controlled gait analysis. Hence, the space used in gait laboratories, which are often 10 m long by 5 m wide, is not available. Instead, rooms allocated to other purposes may be used for the evaluation of gait. So, the first difference between the gait laboratory and the clinical setting is the confined space. If a method for detecting gait events and calculating spatiotemporal parameters is going to be used in the clinical setting, it should be feasible to work in space-limited rooms.

And in this respect, the evaluation of the visual method in the clinical setting is still pending.

Objectives

The aims of this work were then to evaluate the performance of a visual method for calculation of temporal parameters in a clinical setting, comparing it with the results obtained in a controlled environment as a gait laboratory and to evaluate its behavior for calculation of gait symmetry in healthy subjects.

II. MATERIAL AND METHODS

The study involved two groups of subjects from different environments: clinical setting and gait laboratory, geographically located in different countries. Although the participation of the same group of people for both conditions would have been ideal, it is considered that since both groups of healthy subjects had similar characteristics (age, gender distribution, etc) it is possible to compare their gait patterns.

A. Details of the study in the gait laboratory

The study in the gait laboratory [26] involved 10 healthy subjects (4 women and 6 men, 32.5±10.2 years of age, 1.7±0.1 m tall and 71.7±17.2 kg). The protocol for data collection was approved by the Local Ethics Committee. For each trial, the subjects walked for one minute at three self-selected speeds: normal, slow and fast. For each trial, the subject followed a 10 m straight path and walked in both directions. Data was collected from two platforms (AMTI model 400600HF-2000, sampling frequency 200 Hz), a video camera (Panasonic model NV DS 15, sampling frequency of 25 Hz), and an optical system (Qualisys Medical AB model ProReflex, sampling frequency 200 Hz). The video camera was placed on a tripod 1 m height and 3 m away from the walking path, perpendicular to the nominal sagittal plane of the lab.

B. Subjects and protocol in the Clinical Setting

Ten subjects were invited to participate but data from two of them had to be excluded due to technical problems with the videos. Data from 8 healthy subjects (3 women and 5 men, 38 ± 11 years of age, 1.7 ± 0.1m tall and 76 ± 17 kg) was analyzed. The data collection protocol was approved by the local ethics committee of the Faculty of Health Sciences, University of Entre Rios. Subjects walked on a walkway four meters long, in both directions, at a self-selected normal speed for one minute. The walkway was allocated in a multipurpose room of a local rehabilitation hospital and it was considered the most suitable room for the purpose. A video camera (Samsung WB36F, 30 Hz sampling rate) stood at 1.2 meters distance perpendicular to the walkway and recorded the gait of participants.

C. Analysis of the gait speed

The gait speed of subjects was calculated for three trials of each participant, using the hip as the reference and selecting the central part of the walkway for this calculation. The normalized velocity coefficient for each subject was calculated as the average of the three measurements of velocity divided by the height of the subject.

Using a Friedman test, the self-selected speed of the participants in the clinical setting was compared to those from participants walking in the the gait laboratory [26]. Then, a Sign post test was applied between the groups. For the statistical analysis, SPSS® software (version 23) was used.

D. *Calculation of temporal parameters*

Five trials for each subject were recorded, which accounted for a total of four initial contact events (IC) and three foot off events (FO). Visual detection of events was performed on the videos taken in the clinical setting, using the Virtual Dub (version 1.10.4) software. For event detection, the same protocol presented in our last study [26] was used. Then we proceeded to the calculation of the temporal parameters, using MATLAB® (version 2010) and considering all events detected. The temporal parameters calculated, and their equations are shown in Table 1.

The mean and the standard deviation of each of these parameters was calculated, to proceed to the comparison of results between the parameters in the clinical setting against those calculated in a gait laboratory and with data reported in the literature.

TABLE 1: TEMPORAL PARAMETERS CALCULATED AND THEIR EQUATIONS, WHICH INCLUDES THE IC AND FO OF THE FOOT THAT GOES ON (IC1 AND FO1) AND OF THE FOOT THAT GOES BEHIND (IC2 AND FO2).

Temporal Parameters	Calculation
Step time (starting with left and right foot)	$IC1 - IC2$
Stance time (from left and right foot)	$FO2 - IC2$
Double support time	$FO2 - IC1$
Cadence	$60/\text{step time}[s]$
Cycle time	$IC1 - IC1$
Swing time (from left and right foot)	$IC1 - FO1$

E. *Calculation of gait symmetry*

To measure symmetry between the lower limbs, George Marinakis [14], proposed the index of symmetry (IS), calculated as follows:

$$SI = 100 - \frac{100|P_R - P_L|}{0.5|P_R + P_L|}$$

Where P_R and P_L are the temporal parameters measured for the right and left limb respectively. The IS was calculated for step time, support time and swing time. For each, the mean value and standard deviation of IS was calculated using MATLAB® (version 2010) and the results were compared to those reported in the literature.

Analysis of data

The mean and the standard deviation of all parameters calculated (including speed, temporal parameters and symmetry index) were used for analysis of results. Also, statistical tests were performed. However, as the number of subjects included in the study is low (9 participants in the clinical setting), the generalization of the results is limited, and the statistical analysis should be considered with care.

Having said so, we believe that the number of participants, similar to other studies [17]–[20], [23]–[25], [27]–[29] is enough to show a tendency that could encourage further studies.

III. RESULTS AND DISCUSSION

A. *Analysis of gait speed*

Table 2 shows the mean speed values (M) and standard deviation (SD) of the averaged and normalized speed from subjects walking in the gait laboratory [26] (walking at three self-selected speeds: Fast (FS), Normal (NS) and Slow (SS)) and of the subjects walking in the clinical setting.

TABLE 2: COMPARISON OF SPEED IN A GAIT LABORATORY AND IN THE CLINICAL ENVIRONMENT

Gait laboratory					
Average speed M±SD [m/s]			Normalized speed M±SD [m/s]		
FS	NS	SS	FS	NS	SS
1.47±0.20*	1.14±0.15	0.85±0.20	0.87±0.12	0.67±0.09	0.50±0.12
Clinical setting					
Average speed M±SD [m/s]			Normalized speed M±SD [m/s]		
1.04±0.27			0.61±0.17		

All subjects were equally instructed regarding the speed o walking. However, from the results it is possible to see that the mean self-selected speed in the clinical environment falls in between the normal and slow speed of participants in the gait laboratory.

Friedman test was performed to compare the four groups of speeds. The results showed $p<0.001$, indicating a statistically significant difference among them. A Sign post test was then applied between the groups. The results indicated that the clinical gait speed is statistically different to the laboratory fast speed, but no statistically significant difference was found when compared to the normal and slow speeds from the gait laboratory.

Spatiotemporal parameters vary with walking speed [30]. Hence, and given that the objective of this study was to evaluate the performance of the method in the clinical setting when compared with its performance in a gait laboratory, it was important to establish the conditions that should be compared. The results obtained for the comparison of the self-selected speed were not definitive.

Therefore, the cadence parameter was also evaluated and compared in order to obtain more information.

Table 3 shows the mean values (M) and standard deviation (SD) of cadence of the subjects studied in a gait laboratory [26], walking at three self-selected speeds, and the cadence of the subjects studied in a clinical setting walking at self-selected speed.

TABLE 3: COMPARISON OF CADENCE IN A GAIT LABORATORY VERSUS THE CLINICAL ENVIRONMENT.

	Cadence M±SD [steps/min]		
Gait laboratory	FS	NS	SS
	125±14*	107±11*	92±15
Clinical setting	92±12		

Considering the mean value of the cadence, it can be noted that the results obtained in the clinical setting are identical to the cadence showed by the participants walking at slow speed in the gait laboratory.

A Friedman test was proposed between the four groups of cadences and $p<0.001$ value was obtained, showing that the four groups of cadence were statistically different.

The results of the Sign post test showed that the cadence of participants walking at self-selected speed in the clinical setting is statistically different to the cadence calculated for participants walking at fast and normal speed in the gait laboratory.

It is possible that this low walking speed and cadence in the clinical environment were due to insufficient length of the path in the room where the videos were recorded**.** In many studies it has been exposed that subjects in environments different to the gait laboratory show modifications in their gait speed [31]–[34] and other spatiotemporal parameters [33], [35].

B. Calculation of temporal parameters

The parameter calculation results are shown in Table 4.

TABLE 4: MEAN (M) AND STANDARD DEVIATION (SD) OF TIME PARAMETERS FOR SELF-SELECTED WALKING SPEED AND TOTAL NUMBER OF PARAMETERS (N).

	M±SD	**N**
Step time left foot[ms]	649±76	71
Step time right foot[ms]	668±92	64
Stance time left foot[ms]	895±119	71
%cycle time	69±3	
Stance time right foot[ms]	920±128	64
%cycle time	69±3	
Swing time left foot[ms]	405±47	45
%cycle time	30±2	
Swing time right foot[ms]	399±42	45
%cycle time	31±2	
Double support time[ms]	248±49	135
%cycle time	19±3	
Cadence [steps/min]	93±11	135
Cycle time[ms]	1311±158	80

For normal self-selected speed, the gait cycle is usually divided into stance time and swing time, lasting 60% and 40% of the cycle respectively. From Table 4, results in this study are more close to a 70-30% relationship, which agrees with the results reported in the literature for slow self-selected speed [36].

TABLE 5: COMPARISON OF THE RESULTS OBTAINED FOR THE DIFFERENT PARAMETERS CALCULATED IN CLINICAL SETTING WITH THE RESULTS OBTAINED IN A GAIT LABORATORY AND THOSE REPORTED BY THE LITERATURE. MEAN VALUES (M) ± STANDARD DEVIATION (SD).

M±SD	**Clinical setting**	**Gait lab. [26]**	**Cultip et. al [37]**	**Bilney et. al [38]**
Step time [ms]	658±84	617±117	730±30	-
Stance time [ms]	907±123	886±160	930±30	-
Swing time [ms]	402 ± 44.5	-	520±20	-
Double support time[ms]	248±49	216±56	-	-
%cycle time	19±3	-	-	27±3
Cadence [steps/min]	402±44	92±15	-	100±9
Cycle time [ms]	658±84	-	-	-

Table 5 shows the comparison of the results obtained in this study in the clinical setting, with those obtained at self-selected slow speed in the gait laboratory and with other authors. The values of step, stance and swing time of right and left leg were averaged for a direct comparison of the results. It is possible to see that the results are all within the range of those reported in the literature.

C. Calculation of gait symmetry

In Table 6, the results for the symmetry index (SI) calculated for each parameter are displayed.

TABLE 6: MEAN VALUES (M) AND STANDARD DEVIATION (SD) FOR THE SYMMETRY INDEX (SI), CALCULATED FOR THE PARAMETERS STEP TIME, STANCE TIME AND SWING TIME. (N=45)

SI	**M±SD**
Step time	93.6±4.5
Stance time	95.3±3.8
Swing time	93.3±5.5

This results are consistent with other reported in the literature, for which the symmetry in healthy subjects is greater than 90% [39].

IV. CONCLUSIONS

The performance of a method for estimation of temporal parameters and symmetry which had been previously evaluated in a gait laboratory was evaluated in the clinical setting. The method represents a portable, easy to use and a low-cost solution for basic gait analysis.

Results of this study showed that walking speed of the participants in the clinical setting was altered, probably due to a limited walkway. It is then necessary to note that when gait analysis is to be performed in the clinical setting, precautions should be taken in terms of space available for the movement of the subject and for positioning of the equipment used. In this way, we can guarantee the use of the data and the representativeness of the results.

As for the analysis of symmetry, if the study is extended to patients with pathological gait, such as lower limb amputees, it should be noted that the proposed calculation method presents the differences compared to their mean values and, if there is a large asymmetry, the resulting value may not reflect properly the performance of the extremities.

Finally, the visual events detection method gave comparable results in the calculation of temporal parameters and symmetry in the clinical setting to the gait laboratory setting. This suggests that it can be considered as an option for basic Analysis of Human Movement in the clinical environment.

ACKNOWLEDGMENT

We thank the participants who kindly gave of their time for participating in this study. Part of this study was funded by the Project PID 6151, UNER.

REFERENCE

[1] M. J. Cole *et al.*, "Bacpar Toolbox of Outcome Measures," 2014.
[2] P. Broomhead *et al.*, "Evidence Based Clinical Guidelines for the Physiotherapy Management of Adults with Lower Limb Prostheses," vol. 03, no. November, p. Section 3, 2012.
[3] P. D. E. L. A. Nacion, *Estandarización de Procesos Asistenciales*. .
[4] I. Gaunaurd *et al.*, "Use of and confidence in administering outcome measures among clinical prosthetists: Results from a national survey and mixed-methods training program," *Prosthet. Orthot. Int.*, vol. 39, no. 4, pp. 314–321, 2015.
[5] D. U. Jette, J. Halbert, C. Iverson, E. Miceli, and P. Shah, "Use of

standardized outcome measures in physical therapist practice: perceptions and applications.," *Phys. Ther.*, vol. 89, no. 2, pp. 125–135, 2009.
[6] R. a H. M. Swinkels, R. P. S. van Peppen, H. Wittink, J. W. H. Custers, and A. J. H. M. Beurskens, "Current use and barriers and facilitators for implementation of standardised measures in physical therapy in the Netherlands.," *BMC Musculoskelet. Disord.*, vol. 12, no. 1, p. 106, 2011.
[7] J. C. Reid, M. E. Kho, and P. W. Stratford, "Outcome Measures in Clinical Practice: Five Questions to Consider When Assessing Patient Outcome," *Curr. Phys. Med. Rehabil. Reports*, vol. 3, no. 4, pp. 248–254, 2015.
[8] D. Elliott, S. Berney, M. Harrold, and E. H. Skinner, "Key Measurement and Feasibility Characteristics When Selecting Outcome Measures," *Curr. Phys. Med. Rehabil. Reports*, vol. 3, no. 4, pp. 255–267, 2015.
[9] A. S. O. D. C. Soares, E. Y. Yamaguti, L. Mochizuki, A. C. Amadio, and J. C. Serrão, "Biomechanical parameters of gait among transtibial amputees: A review," *Sao Paulo Med. J.*, vol. 127, no. 5, pp. 302–309, 2009.
[10] Y. Sagawa Jr, K. Turcot, S. Armand, A. Thevenon, N. Vuillerme, and E. Watelain, "Biomechanics and physiological parameters during gait in lower-limb amputees: A systematic review," *Gait Posture*, vol. 33, no. 4, pp. 511–526, 2011.
[11] J. Perry, *Gait Analysis: Normal and Pathological Function.* Slack Incorporated, 1992.
[12] M. W. Wittle, *Gait Analisis an introduction*, 4th ed., vol. 53, no. 9. London: Heidi Harrison, 2007.
[13] M. W. Whittle, *Gait analysis: an introduction*, Third. Butterworth Heinemann ELSEVIER, 2003.
[14] G. N. S. Marinakis, "Interlimb symmetry of traumatic unilateral transtibial amputees wearing two different prosthetic feet in the early rehabilitation stage.," *J. Rehabil. Res. Dev.*, vol. 41, no. 4, pp. 581–590, 2004.
[15] R. Baker, "The History of Gait Analysis before the Advent of Modern Computers," *Gait Posture*, vol. 26, pp. 331–342, 2007.
[16] P. Catalfamo, R. Acevedo, S. Ghoussayni, and D. Ewins, "Comparison of kinematic and pressure measurement reference methods used in gait event detection," *Footwear Sci.*, vol. 6, no. 3, pp. 193–202, 2014.
[17] P. Catalfamo, D. Moser, S. Ghoussayni, and D. Ewins, "Detection of gait events using an F-Scan in-shoe pressure measurement system," *Gait Posture*, vol. 28, no. 3, pp. 420–426, 2008.
[18] I. P. I. Pappas, M. R. Popovic, T. Keller, V. Dietz, and M. Morari, "A reliable gait phase detection system," *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 9, no. 2, pp. 113–125, 2001.
[19] B. T. Smith, D. J. Coiro, R. Finson, R. R. Betz, and J. McCarthy, "Evaluation of force-sensing resistors for gait event detection to trigger electrical stimulation to improve walking in the child with cerebral palsy," *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 10, no. 1, pp. 22–29, 2002.
[20] E. Desailly, Y. Daniel, P. Sardain, and P. Lacouture, "Foot contact event detection using kinematic data in cerebral palsy children and normal adults gait," *Gait Posture*, vol. 29, no. 1, pp. 76–80, 2009.
[21] R. T. Lauer, B. T. Smith, and R. R. Betz, "Application of a neuro-fuzzy network for gait event detection using electromyography in the child with cerebral palsy," *IEEE Trans. Biomed. Eng.*, vol. 52, no. 9, pp. 1532–1540, 2005.
[22] C. M. O'Connor, S. K. Thorpe, M. J. O'Malley, and C. L. Vaughan, "Automatic Detection of Gait Events Using Kinematic Data," *Gait Posture*, vol. 25, no. 3, pp. 469–474, 2006.
[23] S. Ghoussayni, C. Stevens, S. Durham, and D. Ewins, "Assessment and validation of a simple automated method for the detection of gait events and intervals," *Gait Posture*, vol. 20, no. 3, pp. 266–272, 2004.
[24] J. Mickelborough, M. L. van der Linden, J. Richards, and A. R. Ennos, "Validity and Reliability of a Kinematic Protocol for Determining Foot Contact Events," *Gait Posture*, vol. 11, no. 1, pp. 32–37, 2000.
[25] M. V. Peterson, D. Ewins, A. Shaheen, and P. A. Catalfamo Formento, "Evaluation of methods based on conventional videography for detection of gait events," in *IFMBE Proceedings*, 2015, vol. 49.
[26] C. De Grucci, D. Ewins, A. Shaheen, and P. Catalfamo Formento, "Evaluation of a visual method to calculate temporal parameters.," *IEEE Argencon*, no. Ic, 2016.
[27] M. Hanlon and R. Anderson, "Real-time gait event detection using wearable sensors," *Gait Posture*, vol. 30, no. 4, pp. 523–527, 2009.
[28] P. Catalfamo, S. Ghoussayni, and D. Ewins, "Gait Event Detection on Level Ground and Incline Walking Using a Rate Gyroscope," *Sensors*, vol. 10, no. 6, pp. 5683–5702, 2010.
[29] H. Lau and K. Tong, "The reliability of using accelerometer and gyroscope for gait event identification on persons with dropped foot," *Gait Posture*, vol. 27, no. 2, p. 248, 2008.
[30] T. P. Andriacchi, J. A. Ogle, and J. O. Galante, "Walking speed as a basis for normal and abnormal gait measurements," *J. Biomech.*, vol. 10, no. 4, pp. 261–268, 1977.
[31] Y. Y. You, J. G. Her, T. Ko, J. Ko, H. Kim, and J. H. Woo, "The effects of measurement environment on the gait velocity and balance of stroke patients," *J. Phys. Ther. Sci.*, vol. 24, no. 9, pp. 873–876, 2012.
[32] D. Taylor, C. M. Stretton, S. Mudge, and N. Garrett, "Does clinic-measured gait speed differ from gait speed measured in the community in people with stroke?," *Clin. Rehabil.*, vol. 20, no. 5, pp. 438–444, 2006.
[33] K. Donovan, S. E. Lord, H. K. McNaughton, and M. Weatherall, "Mobility beyond the clinic: the effect of environment on gait and its measurement in community-ambulant stroke survivors.," *Clin. Rehabil.*, vol. 22, no. 6, pp. 556–563, 2008.
[34] S. E. Lord, L. Rochester, M. Weatherall, K. M. McPherson, and H. K. McNaughton, "The Effect of Environment and Task on Gait Parameters After Stroke: A Randomized Comparison of Measurement Conditions," *Arch. Phys. Med. Rehabil.*, vol. 87, no. 7, pp. 967–973, 2006.
[35] M. R. Patterson *et al.*, "Does external walking environment affect gait patterns?," *Conf. Proc. ... Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. IEEE Eng. Med. Biol. Soc. Annu. Conf.*, vol. 2014, pp. 2981–2984, 2014.
[36] M. H. Schwartz, A. Rozumalski, and J. P. Trost, "The effect of walking speed on the gait of typically developing children.," *J. Biomech.*, vol. 41, no. 8, pp. 1639–50, Jan. 2008.
[37] R. G. Cutlip, C. Mancinelli, F. Huber, and J. DiPasquale, "Evaluation of an instrumented walkway for measurement of the kinematic parameters of gait," *Gait Posture*, vol. 12, no. 2, pp. 134–138, 2000.
[38] B. Bilney, M. Morris, and K. Webster, "Concurrent related validity of the GAITRite® walkway system for quantification of the spatial and temporal parameters of gait," *Gait Posture*, vol. 17, no. 1, pp. 68–74, 2003.
[39] M. Blazkiewicz, I. Wiszomirska, and A. Wit, "Comparison of four methods of calculating the symmetry of spatial-temporal parameters of gait," *Acta Bioeng. Biomech.*, vol. 16, no. 1, pp. 29–35, 2014.

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