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ORIGINAL

RELIABILITY AND VALIDITY OF KINOVEA TO ANALYZE SPATIOTEMPORAL GAIT PARAMETERS

FIABILIDAD Y VALIDEZ DE KINOVEA PARA ANALIZAR PARÁMETROS ESPACIOTEMPORALES DE LA MARCHA

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ABSTRACT

The aims of this study are to evaluate test-retest ant inter-rater reliability of the software Kinovea® to obtain the spatiotemporal gait parameters, as well as to study the criterion validity with respect to a three-dimensional motion capture system. The results obtained are statically significant ($p < 0.05$) in all the parameters studied. The test-retest reliability shows an excellent correlation in the parameters of step length, stride length, step time and stride time (ICC > 0.90), and good in speed (ICC = 0.76-0.90). The inter-rater evaluation is excellent (ICC > 0.90) in all the spatiotemporal parameters studied in both raters. The criterion validity between Kinovea® and VICON Motion System® is excellent for the parameters studied ($r > 0.80$) in both raters. These findings support the use of Kinovea® as an accessible and easy-to-use tool with which to obtain objective gait data.

KEY WORDS: Gait Analysis; Psychometric Properties; Reliability; Spatiotemporal Parameters; Criterion Validity.

RESUMEN

Los objetivos del presente estudio son evaluar la fiabililidad test-retest e inter-observador del software Kinovea® para la obtención de los principales parámetros espaciotemporales de la marcha, así como, estudiar la validez de criterio respecto a un sistema tridimensional de análisis del movimiento. Los resultados obtenidos son significativamente estadísticos ($p < 0,05$) en todos los parámetros estudiados. La fiabilidad test-retest muestra una correlación excelente en los parámetros de longitud de paso, longitud de zancada, tiempo de paso y tiempo de zancada (CC I> 0,90), y buena en la velocidad (CCI = 0,76-0,90). La fiabilidad inter-observador es excelente (CCI > 0,90) en todos los parámetros espaciotemporales estudiados en ambos observadores. La validez de criterio entre Kinovea® y VICON Motion System® es excelente para los parámetros estudiados ($r > 0,80$) en ambos evaluadores. Estos hallazgos respaldan el empleo de Kinovea® como una herramienta accesible y de fácil manejo, con la que obtener datos objetivos de la marcha.

PALABRAS CLAVE: Análisis de la marcha; Propiedades psicométricas; Fiabilidad; Parámetros espaciotemporales; Validez de criterio.

INTRODUCTION

Gait disturbances represent one of the most common difficulties in people who present some pathology, be it neurological or musculoskeletal (1), as well as in older people, and they can negatively affect the participation and quality of life of these subjects.

The study of gait is an essential tool in the diagnosis of various pathologies, and it can be used to guide clinical decision-making, to monitor the progression of a pathological process, to personalise treatment, and/or to evaluate the efficacy of different therapeutic interventions carried out in patients (1–5). Furthermore, some spatiotemporal parameters of gait are considered predictive factors of quality of life, risk of falls, length of hospitalization, and even mortality in the population (6,7).

One of the most widely analyzed spatiotemporal parameters in clinical practice is speed, which is commonly assessed with stopwatch walking tests such as the 10-meter test. However, these methods have great limitations for the evaluation of parameters such as stride length and stride time (8,9), which are studied by visual observation. Despite their accessibility and easy handling, these tests are not exempt from some subjectivity on the part of the evaluator and from possible inter-rater and test–retest error.

Three-dimensional motion analysis systems are considered the gold standard or reference test since they provide objective and quantitative data in terms of kinematic, kinetic, and spatiotemporal parameters (10). However, these systems present several disadvantages, such as the high cost of the equipment, the need for trained personnel, the considerable processing times, and the space required for their installation, located in specific laboratories. It is for these reasons that they are not routinely available in clinical practice.

In order to obtain more objective data than the observational scales and to reduce the costs of three-dimensional motion capture systems, in recent years new low-cost motion analysis methods have been developed (11) based on obtaining videos through cameras or mobile devices for further analysis.
The free Kinovea® software can be used to carry out linear and/or angular kinematic analysis of the sporting gesture of dynamic or static actions through images or videos using different tools. In the study of gait, the use of tools such as the drawing of vectors and angles and the chronometer could be used to obtain objective and quantitative data with which to carry out a diagnostic approach in the case of detecting any alteration of the same (12). This software has been used by various authors for the analysis of movements during sports practices such as volleyball, running or vertical jump (13–18).

In 2017, Mathew et al. (19) used Kinovea® software in the analysis of the gait of older subjects, obtaining objective data used to record gait asymmetries, which could be used to predict the risk of falls. In 2019, García-Pinillos et al. evaluated the concurrent validity of two different inertial measurement units, RunScribe™ and Stryd™, to measure spatiotemporal parameters during running on a treadmill by comparing data with an analysis video for that they used Kinovea®. Despite the fact that both instruments were considered valid tools for the analysis of these parameters, the RunScribe™ system was more accurate at measuring step length and temporal parameters than Stryd™ (20).

In short, the literature consulted demonstrates the use of Kinovea® software in sports and clinical settings; although, there is an absence of studies, to our knowledge, that evaluate its psychometric properties for the analysis of the spatiotemporal parameters of human gait in subjects without pathology, which is the basis for using this measurement program in athletes and in people with pathology.

OBJECTIVES

The aims of the present study were 1) to evaluate the test–retest and inter-rater reliability of Kinovea® software to obtain the main spatiotemporal parameters of gait and 2) to analyse the criterion validity, comparing the spatiotemporal data obtained through Kinovea® software with those registered with a three-dimensional motion capture system.

MATERIALS AND METHODS

Participants

Voluntary participation of subjects was requested through informative talks.

The following inclusion criteria were established: older 18 years of age; absence of pathologies that cause alterations in gait and posture; and not using any orthosis or gait support products.

Participants were excluded if they had: osteoarticular, muscular or neurological pathologies involving gait alterations or lower limb injuries within six months prior to the study.

Ethical aspects

The present study was approved by the local ethics committee. Informed consent was obtained from all participants included in this study.

Instrumentation

A digital camera Nikon D3200 Full HD with 1280 × 720 pixels resolution and 50 frames per second was used for the recording of the gait. This was placed perpendicular to the participant at 2.5 m and 1 m above the floor.

The VICON Motion System® (Oxford Metrics, Oxford, United Kingdom) was used for the purpose of performing a three-dimensional motion analysis and an analysis of the criterion validity of Kinovea®. This system consists of eight 100 Hz infrared capture cameras, three AMTI® force platforms, two BASLER A601FC-2 video cameras and a data station where the information is recorded and processed.

Procedures

The research took place at the Laboratory of Movement Analysis, Biomechanics, Ergonomics and Motor Control (LAMBECOM), located in the Faculty of Health Sciences of the Rey Juan Carlos University (Alcorcón, Madrid, Spain). Two sessions were carried out, with a separation interval of one week between them.

The configuration of the Vicon system consisted of the placement of passive and reflective markers in specific anatomical areas of the lower limbs (anterior superior iliac spine, posterosuperior iliac spine, middle third of the thigh, external femoral condyle, middle third of the tibia, external malleolus, calcaneus, and second metatarsal head), according to the biomechanical models of Davis et al. (21) and Kadaba et al. (22).

Two marks were placed on the footbridge that the subjects had to walk, at a distance of two meters between them, in order to contrast the measurement in the video and to thus obtain the parameters of step length and stride length.

After the instrumentation was completed, the participants were asked to walk along the 11-meter walkway at a speed that was comfortable for them.

Five recordings of the gait per subject were made in each of the sessions for further analysis.

Analysis of data

For the data analysis, Kinovea® version 0.8.15 software was used (23). Two evaluators independently analysed the parameters of step length (distance between two successive heel strikes of one limb and the other limb), stride length (distance between two successive heel strikes of the same limb), step time and stride time of the gait of each of the subjects (Figure 1). The speed (V) was calculated, taking into account the stride length and the stride time, using the following formula: V = [distance (m)]/[time (s)]. This procedure was repeated for the videos acquired in both the first session and in the second session, allowing the study of test–retest and inter-observer reliability.

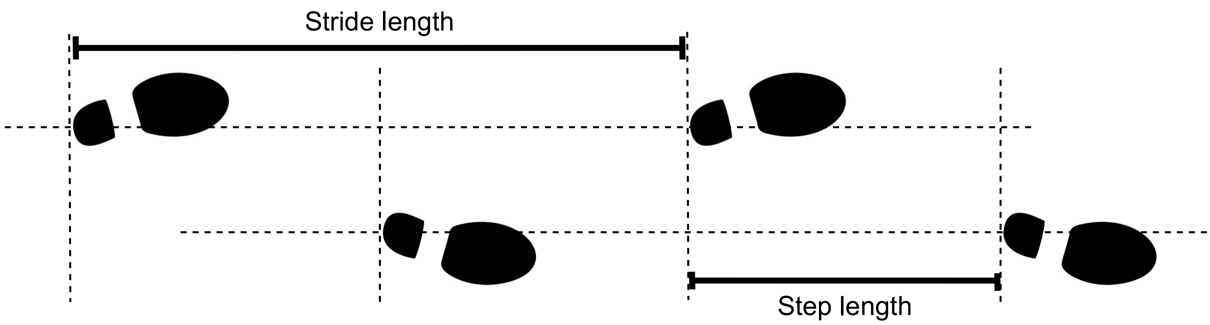

Figure 1. Step length and stride lenght (24).

The procedure for obtaining the spatiotemporal parameters began with the drawing of a line joining the two marks located on the walkway. Next, we contrasted its measurement in the program (2 meters), which allowed us to obtain the step length and stride length with the use of the “line” tool (Figures 2 and 3).

To obtain the step time and stride time parameters, the “chronometer” tool in the software was used. If it is activated from the initial contact of a foot to the initial contact of the contralateral, we will obtain the step time, and if we do it from the initial contact of a foot to the initial contact of the same, the stride time (Figures 2 and 3).

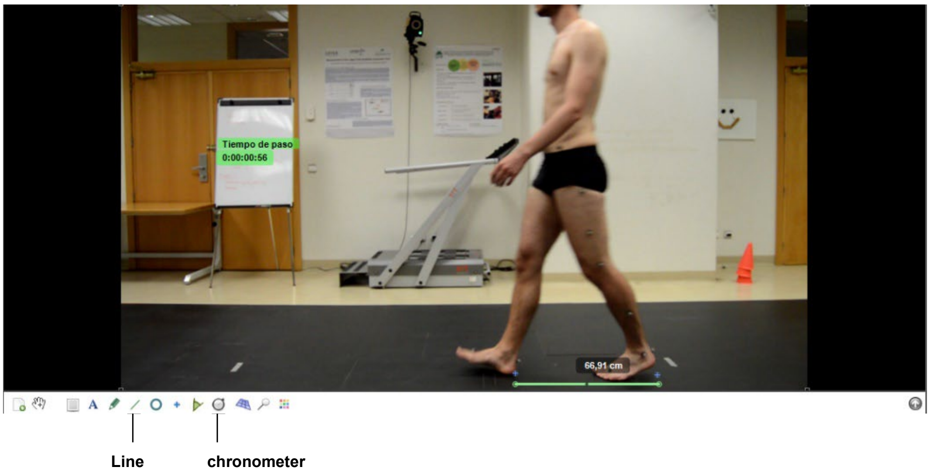

Figure 2. Step length and step time obtained using Kinovea® software.

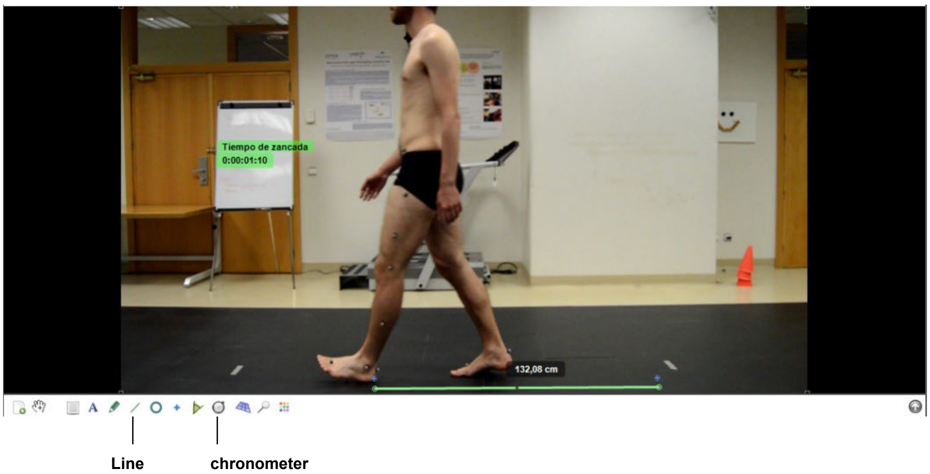

Figure 3. Stride length and stride time obtained using Kinovea® software.

For processing of trials obtained with VICON Motion System® (Oxford Metrics, Oxford, United Kingdom), which was carried out by a third evaluator, Vicon Nexus® 1.8.5 software was used. Considering that the exact moment analysed through the videos acquired for the analysis with Kinovea® coincided with the tread on one of the platforms, it was ensured that the third evaluator analysed the same step and the same stride in each of the videos. To process these, it was first necessary to label the markers in a static test, which provides the angular values corresponding to the standing position of the pelvis, hip, knee, and ankle in the three anatomical planes of movement. Then, in the walking test to be analysed (dynamic capture) and after labelling the markers, the lost trajectories of these were reconstructed and the foot strike and foot off events were detected. This process was used to obtain graphs and numerical values of the kinematic, kinetic, and spatiotemporal parameters of gait in Microsoft Excel files using the Vicon Polygon® program.

Sample Size Calculation

Sample size was calculuated based on Walter et al. (25). Considering a minimally aceptable Intraclass Correlation Coefficient (ICC) (p0) of 0.6, and expect ICC (p1) of 0.8, and 10% of attrition, 43 subjects are needed. Finally, the sample size consisted of 50 subjects.

Statistical Analysis

The SPSS 22.0 program for Windows (version 22.0, SPSS Inc., Chicago, IL, USA) was used.

The ICC and the 95% confidence interval (95% CI) were calculated to establish test–retest and inter-rater reliability. The ICC was calculated for the spatiotemporal parameters of the gait. ICC values of >0.90 indicate excellent reliability, values of 0.76–0.90 indicate good reliability, values of 0.50–0.75 indicate moderate reliability, and values of <0.5 indicate low reliability (26).

Absolute reliability was determined by estimating the standard error of the measurement (SEM) and the minimum detectable change (MDC). This required the calculation of the standard deviation of the differences between the observers (SDdiff). SEM and MDC were calculated using the following equations: SEM = SDdiff * √1–CCI and MDC95 = 1.96 * √2 * SEM (27).

Pearson's correlation coefficient (r) was used to study the criterion validity between Kinovea® and the VICON Motion System®. Correlation coefficients from 0.00 to 0.49 were interpreted as poor, those from 0.50 to 0.79 were moderate, and those of 0.80 or higher were excellent (28).

The statistically significant *p value* was set at 0.05.

RESULTS

Fifty subjects participated in the study (26 women and 24 men; age of 21.62±2.62 years; weight of 65.74±12.94 kg; height of 167.49±25.57 cm) without alterations in gait.

The test–retest reliability showed an excellent correlation in the parameters of step length, stride length, stride time, and stride time (ICC>0.90) and good correlation in speed (ICC=0.76–0.90) (Table 1), with adjusted confidence intervals [less than 14 points (0.80–0.93)].

The ICC for inter-rater reliability was >0.90 in all the spatiotemporal parameters studied in both observers, indicating excellent inter-rater reliability (Table 2). Confidence intervals for inter-observer reliability were narrow, with intervals of less than 7 points (0.90–0.97).

Criterion validity between Kinovea® and the VICON Motion System® was excellent for the parameters studied (r>0.80) in both evaluators. Confidence intervals were adjusted [less than 12 points (0.81–0.93)] (Table 3).

Table 4 shows the SEM and the MDC test–retest of each observer and inter-observer of the analysed spatiotemporal parameters.

Table 1. Test-retest of the Kinovea spatiotemporal parameters.

	Observer 1					Observer 2				
	Session 1	**Session 2**	**ICC**	**95% CI**	***p*-value**	**Session 1**	**Session 2**	**ICC**	**95% CI**	***p*-value**
Step Length (m)	0.672 (0.51)	0.672 (0.52)	0.924.	0.867 to 0.957	< 0.01*	0.679 (0.53)	0.679 (0.54)	0.927	0.871 to 0.958	< 0.01*
Stride Length (m)	1.341 (0.1)	1.339 (0,1)	0.933	0.822 to 0.962	< 0.01*	1.367 (0.1)	1.369 (0.1)	0.941	0.896 to 0.966	< 0.01*
Step Time (s)	0.539 (0.03)	0.536 (0.03)	0.916	0.851 to 0.952	< 0.01*	0.538 (0.03)	0.536 (0.03)	0.904	0.830 to 0.945	< 0.01*
Stride Time (s)	1.068 (0.06)	1.059 (0.06)	0.922	0.863 to 0.956	< 0.01*	1.067 (0.06)	1.057 (0.06)	0.922	0.862 to 0.956	< 0.01*
V (m/s)	1.26 (0.12)	1.27 (0.12)	0.887	0.800 to 0.936	< 0.01*	1.285 (0.12)	1.3 (0.13)	0.893	0.812 to 0.939	< 0.01*

The values referring to Session 1 and 2 of Observer 1 and Observer 2 are expressed in mean and standard deviation.
V, velocity. ICC, Intraclass Correlation Coefficient. CI, Confidence Interval. m, meters. s, seconds * *p*-value< 0,05.

Table 2. Inter-rater reliability of the Kinovea parameters.

			Observer 1 Vs. Observer 2					
			Session 1			**Session 2**		
	Observer 1	**Observer 2**	**ICC**	**95% CI**	***p*-value**	**ICC**	**95% CI**	***p*-value**
Step Length (m)	0.672 (0.51)	0.679 (0.53)	0.961	0.932 to 0.978	< 0.01*	0.949	0.909 to 0.971	< 0.01*
Stride Length (m)	1.341 (0.1)	1.367 (0.1)	0.993	0.988 to 0.996	< 0.01*	0.993	0.988 to 0.996	< 0.01*
Step Time (s)	0.539 (0.03)	0.538 (0.03)	0.989	0.981 to 0.994	<0.01*	0.984	0.971 to 0.991	<0.01*
Stride Time (s)	1.068 (0.06)	1.067 (0.06)	0.996	0.993 to 0.998	<0.01*	0.995	0.991 to 0.997	<0.01*
V (m/s)	1.260 (0.12)	1.285 (0.12)	0.995	0.991 to 0.997	<0.01*	0.994	0.989 to 0.996	<0.01*

The values referring to Session 1 and 2 of Observer 1 and Observer 2 are expressed in mean and standard deviation.
V, velocity. ICC, Intraclass Correlation Coefficient. CI, Confidence Interval. m, meters. s, seconds * *p*-value< 0,05.

Table 3. Validity of the Kinovea parameters.

				Observer 1 Vs. Vicon			Observer 2 Vs. Vicon		
	Observer 1	Observer 2	Vicon	r	95% CI	*p*-value	r	95% CI	*p*-value
Step Length (m)	0.672 (0.51)	0.679 (0.53)	0.654 (0.04)	0.895	0.821 to 0.939	< 0.01*	0.948	0,909 to 0,970	< 0.01*
Stride Length (m)	1.341 (0.1)	1.367 (0.1)	1.306 (0.09)	0.964	0.937 to 0.979	< 0.01*	0.964	0.937 to 0.979	< 0.01*
Step Time (s)	0.539 (0.03)	0.538 (0.03)	0.534 (0.03)	0.894	0.819 to 0.938	<0.01*	0.909	0.844 to 0.947	<0.01*
Stride Time (s)	1.068 (0.06)	1.067 (0.06)	1.070 (0.06)	0.991	0.984 to 0.994	<0.01*	0.989	0.980 to 0.993	<0.01*
V (m/s)	1.260 (0.12)	1.285 (0.12)	1.223 (0.11)	0.978	0.961 to 0.987	<0.01*	0.973	0.952 to 0.984	<0.01*

The values referring to Session 1 and 2 of Observer 1 and Observer 2 are expressed in mean and standard deviation.
V, velocity. r, Pearson's correlation coefficient. CI, Confidence Interval. m, meters. s, seconds * *p*-value< 0,05

Table 4. Standard error of the measurement and minimal detectable change test-retest of observer 1 and observer 2 and inter-rater.

	TEST-RETEST OBSERVER 1		TEST-RETEST OBSERVER2		INTER-RATER	
	SEM	MDC	SEM	MCD	SEM	MCD
Step Length (m)	0.0069	0.0191	0.0071	0.0196	0.0050	0.0140
Stride Length (m)	0.0126	0.0351	0.0119	0.0332	0.0040	0.0112
Step Time (s)	0.0047	0.0131	0.0052	0.0145	0.0017	0.0047
Stride Time (s)	0.0087	0.0242	0.0090	0.0249	0.0019	0.0052
V (m/s)	0.0202	0.0560	0.0200	0.0554	0.0045	0.0126

SEM, *standard error of the measurement.* MDC, *minimal detectable change.* V, velocity. m, meters. s, seconds.

DISCUSSION

The purpose of the present study was to evaluate the test–retest and inter-observer reliability of Kinovea® software to obtain the main spatiotemporal parameters of gait. In addition, the criterion validity was analysed, comparing the spatiotemporal data obtained through Kinovea® software with those registered by the Vicon Nexus System®.

This work found that Kinovea® software is a valid and reliable system for evaluating step length, stride length, step time, stride time, and velocity in subjects without gait disturbances. The results obtained showed excellent test–retest and inter-observer reliability (ICC>0.90) in all the parameters analysed in both observers, except for velocity, whose test–retest reliability was good (ICC=0.76–0.90). Furthermore, the criterion validity between Kinovea® and the VICON Motion System® was excellent for the studied parameters (r>0.80) in both evaluators.

To improve assessments in clinical settings, there is a need to develop low-cost, portable gait analysis technology. Such technology should be evaluated to determine its validity and reliability (29) when analysing spatiotemporal parameters of gait. To our knowledge, there are no previous studies evaluating the psychometric properties of Kinovea® software for gait analysis. However, in 2019, García-Pinillos et al. carried out a study whose objective was to evaluate the agreement of two inertia measurement systems, Stryd ™ and RunScribe ™, to analyse the spatiotemporal parameters during running on a treadmill without end, using video analysis as a reference method (20). These videos were analysed using Kinovea® software, with which the authors obtained the spatiotemporal parameters of contact time, oscillation time, and gait time. The parameters of step length and step frequency were calculated by means of mathematical formulas, taking into account the previous ones.

Various authors have studied the psychometric properties of low-cost motion analysis systems for the study of human gait. One of the most analysed systems is Microsoft Kinect®, which is proposed as an accessible alternative without the need to use markers for movement analysis. In 2015, Mentiplay et al. studied its test–retest reliability and concurrent validity during comfortable and fast walking at two speeds using the VICON Motion System® as a reference test (30), which is the same system that was used in the present study. In line with the results obtained in this study, the authors found an excellent validity of Kinect® for the parameters of step length and step time and velocity ($r \geq 0.90$). However, they found a lower test–retest reliability, which was moderate for step time (ICC=0.70) and velocity (ICC=0.75) and good for step length (ICC=0.87). Similar results were obtained by in 2016 Dolatabadi et al., who studied the validity of Kinect® for the study of these parameters by comparing the results with another reference system, GAITRite, which consists of a portable gateway equipped with pressure sensors (31).

Other authors, such as Van Bloemendaal et al., have developed their own two-dimensional gait analysis system (SGAS) to measure spatiotemporal parameters in the sagittal plane using a single camera (32). In their study, they analysed the validity of SGAS with respect to GAITRite in healthy subjects who walked in different conditions: barefoot, in shoes, and imitating gait disorders typical of neurological or musculoskeletal diseases (such as on tiptoe or more slowly). The results of walking with footwear showed excellent validity for the parameters of step length and step time (ICC=0.97), which is in line with those found in the present study. In addition, they determined that a minimum of four steps was necessary to obtain a reliable evaluation of these parameters, in accordance with those recorded in our work.

Regarding the methodology to be followed for the analysis of videos with Kinovea® software, a standardized protocol has not been described in the existing literature (20). Previous studies using a video camera have determined that its position is essential to obtain parameters in a plane of space (20,32), standing perpendicular to the walkway or endless belt at a height of 80–92 cm. In the present study, the spatiotemporal parameters in the sagittal plane (30,32) and of a single lower limb (30) were evaluated, which were in agreement with other authors. Regarding the speed with which the subjects had to walk to perform the capture, it was evaluated at a single speed, in contrast to other authors who carried out the study at two speeds, comfortable and fast (30), and who even included dual-task mathematics (31).

The present study presents a series of limitations that should be pointed out. On the one hand, the analysis of the spatiotemporal parameters of gait at a single gait speed, through the use of a stationary camera and in a single plane of space, which prevents the evaluation of other parameters, such as the step width, it forces us to perform a careful reading of the results. In addition, it would be necessary to evaluate the usefulness of Kinovea® software in a clinical setting in groups of patients with gait disorders.

CONCLUSION

The use of the free Kinovea® software in the analysis of the spatiotemporal parameters of gait in subjects without pathology reflects excellent test–retest reliability, except for velocity, which is good, and inter-rater. The criterion validity with respect to a three-dimensional motion capture system was excellent in all the spatiotemporal parameters studied. Therefore, Kinovea® software could be an accessible and user-friendly tool to obtain objective data for clinical evaluation when more sophisticated systems, such as three-dimensional motion analysis systems, are not available.

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