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Original Article

APPLICATION OF ISO-BASED POSTURE MEASUREMENT SYSTEM “rysis” TO CLINICAL GAIT ASSESSMENT

: Reliability of body segment angles in the absence of external markers.

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Abstract: Whilst instrumented gait assessment is the gold standard for gait analysis, visual gait observation is commonly used to determine gait disorders and to evaluate treatment in clinical practice. Because the instrumented gait assessment is laboratory-based, expensive, and time and energy consuming, it is not commonly available in the context of routine clinical practice. The purpose of this study was to examine the reliability of therapist observations in the gait assessment process using the quantitative measurement tool “rysis” which is based on ISO 16840-1 standard. Inter-rater reliabilities of 12 physical therapists were assessed and compared under two conditions: with (ICC=0.970) and without (ICC=0.902) externally placed visible body landmark markers. In addition we explored potential power of the application of “rysis” in clinical gait analysis performed by physical therapists.

Key Words: Observation, Gait assessments, Marker, Body segment line, Reliability, ISO 16840-1, rysis.

1.0 INTRODUCTION

1.1 Science of Gait Assessment

Human locomotion is a kind of art which has fascinated many scientists for a long time. Perry [1)] and Sutherland [2)] provide thorough descriptions of a typical gait cycle. A complete gait cycle is defined as the movement from one foot strike to the successive foot strike on the same side. The stance phase, which begins with a foot strike and ends with toe-off usually lasts for about 62% of cycle; the swing phase, which begins with toe-off and ends with foot strike, lasts for the final 38%. During each cycle, a regular sequence of events occurs. Chambers stressed that the older terms "heel strike" and "foot flat" should not be used because these events may be absent in subjects with pathologic gait[3)].

For common use in clinical settings, the stance phase is divided into five major periods;

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first is Initial Contact (IC), second is Loading Response (LR), third is Mid Stance (MSt), fourth is Terminal Stance (TSt), fifth is Pre-Swing (PSw). The defining events for IC are foot strike on standing leg. The defining events for LR are weight loading phase. MSt is single limb support from LR to TSt. Terminal stance is last of single limb support phase. PSw is double limb support with opposite limb and continuing swing phase (Table 1).

1.2 Limitations of Naked Eye Observation

Many researchers pointed that observational gait analysis should be limited because it is relatively subjective in nature, demonstrates poor validity, reliability, sensitivity and specificity, and is not helpful in determining the biomechanical causes of an abnormal gait[3,4,5].

In clinical settings, therapists diagnose pathologic gait patterns from patient observation. However, the same gait pattern can have multiple etiologies, such as tibialis anterior spasticity with at tibialis posterior pattern. In addition, rotational abnormalities in the transverse plane may be confused with sagittal or frontal plane problems. The gait laboratory study can provide much more information such as muscle activity, kinematic forces, joint kinematics, energy consumption, and other biological valiables[3,6,7].

1.3 Unfamiliar Gold Standard

Laboratory-based gait analysis is commonly used in research, and has aided the development of the science on gait. Kinematics measures the dynamic range of motion of a joint or segment[2]. Kinetics describes the forces acting on a moving body, including analysis of the electrical activity of muscles, these quantitative measurements are well-known to be a gold standard for gait assessment[6, 7].

However, instrumented gait analysis is expensive and not available in all hospitals and rehabilitation centers. In younger age groups (less than 6 years of age) instrumented gait analysis is also not always appropriate due to the children's size and varying levels of cooperation, as Boyd, et al., pointed in1999[8]. In addition, incorrect marker placement and excessive skin movement affects the validity and reliability of the results of the analysis as Della Croce, Coppozzo, and Kerringan, stated in 1999[9].

Toro and her colleagues conducted a survey

Period	% Cycle	Function	Contralateral Limb
Initial Contact (IC) Loading Response (LR)	0-12	Loading, weight transfer	Unloading and preparing for swing (preswing)
Mid Stance (MSt)	12-50	Support of entire body weight; center of mass moving forward	Swing
Terminal Stance (TSt), Pre-Swing (PSw),	50-62	Unloading and preparing for swing (preswing)	Loading, weight transfer
Initial Swing,	62-75	Foot clearance	Single-limb stance
Mid Swing	75-85	Limb advances in front of body	Single-limb stance
Terminal-Swing	85-100	Limb deceleration, preparation for	Single-limb stance

Table 1 :Gait Cycle: Periods and Function

among 1826 physiotherapists in the United Kingdom 2003. They reported only 23.1% of all respondents had a patient assessed in a gait laboratory study, despite almost all respondents (93.6%) treating patients with gait impairments. Clinicians indicated that they need training in gait assessment (66.4%) and desire guidance at a national level[10]. Most clinicians in the world do not conduct instrumented gait analysis, because the analysis is not always available or considered clinically reasonable.

1.4 Potential application of seated posture analysis system "rysis"

"rysis" is the free software developed by Handa et. al, [11] who established the seated posture measurement study group (http://seating.web.fc2.com/). "rysis" is two-dimensional digitizing software that can measure the gradient angles of body segment lines defined in the ISO16840-1 standard formally adopted in 2006. Handa and his colleagues evaluated the reliability of the software by using a metal model representing human seated posture and by calculating the standard deviation of within- and between- examiner measurements[1]. They also evaluated validity by comparing their results with a contact three-dimensional measurement device. From their results, the software seems to be practical and well suited measurement tool for daily clinical use[1]. Therefore, we attempted to apply this software for the static measurement of one phase of the gait cycle.

If "rysis" can calculate body segment line angles from static image capture from a patient gait video, it will provide us more detailed information in evaluating the orientation of the head, neck, trunk, and pelvis in some critical phase of the gait cycle.

1.5 Study Question

In both the "rysis" posture measurement and high-tech instrumented gait analysis, accurately placing external markers on body landmarks is the key for quantitative measurement. Markers must be placed quickly and accurately on body landmarks, which is a very challenging task for many clinicians. For this reason, we felt it necessary to examine the reliability of gait posture measurement with and without externally placed markers (Figure 1).

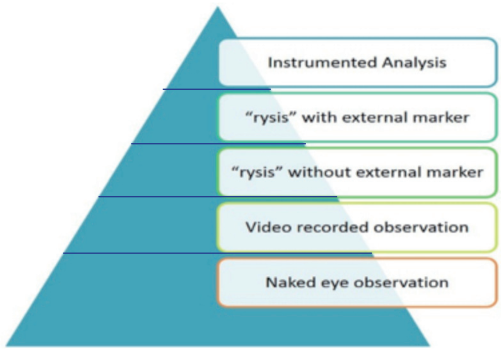

Figure 1: Hypothetic hierarchy for reliable gait assessment

To facilitate "rysis" application in clinical practice, four study questions emerged as follows:

1. Can a marker be placed accurately and repeatedly?
2. Is there a difference in observational accuracy of each body segment angle?
3. Is there a difference based on the rater's prior clinical experience?
4. What range of error does simple observation potentially have?

We hypothesize that markers placed on body landmarks may contribute to the quantitative accuracy of determining body segment angles such as sternum angles, and pelvic angles in the frontal plane. We also expected that a retouched image to eliminate markers may result in lower inter-rater reliability. And also, body landmarks of the head can be used as the control data of each measurement because these landmarks are visible and potentially do not require externally placed markers.

2.0 METHODOLOGY

2.1 Design

A reliability experimental study was conducted. In this pilot study, image data were captured from a gait observation video in the frontal plane recorded prior to the study: 1) frame captured at the beginning of the left loading response, 2) we eliminate the markers from the captured image, and 3) compare the raters' results between the marker present conditions and marker absent conditions.

2.2 Raters and subject

We recruited raters for this study from the Yoshieikai hospital. We included physical or occupational therapists who worked in our department at the time. We excluded any therapists who were already familiar with "rysis" and therapists who did not have at least one year of clinical experience at the time of the investigation. A total of 12 physical and occupational therapists including six males and six females participated in this study(Table 2). The participants had clinical experience ranging from one year up to five years. The mean of age of raters was 25 years with a standard deviation of two years and 9 months. We also recruited a 26 year old male subject who has no impairment and whose height was 177cm, weight was 68kg, and BMI was 21.7. Prior to the "rysis" protocol, we asked the subject to walk on a 10m pathway and recorded it for use as our gait observation video.

2.3 Body segment angle calculation using "rysis"

As we stated before, "rysis" is an affordable, valid posture measurement tool. To evaluate the body segment angles, we captured the image at the specific phase of the gait cycle from the patient gait video. "rysis" was not developed for the dynamic gait assessment, but for wheelchair seated posture measurement. When the ISO16840-1 standard was adopted in March 2006, the list of measures was defined but no specific measurement methods were described. That is why Hirose et al. proposed

	N	Minimum	Maximum	Mean	Std. Deviation
Age	12	22	31	24.9	2.46
experience	12	1	5	3.0	1.65
Male	6				
Female	6				

Table 2 : Raters Characteristics

"Simple measurement" of ISO16840-1 standard to establish the measurement method based on the standard[12].

They defined 15 body segment lines including six body segment lines in frontal plane, six body segment lines in sagittal plane, and three body segment lines in transverse plane for "Simple Measurement" of ISO 16840-1 (Figure1, 2). 15 body segment lines were defined from 25 body landmarks (Table 3).

For the current study, we chose the three segment line angles in the frontal plane: the head line angle, sternum line angle, and pelvic line angle.

2.4 Rating protocol

We captured an image of the loading response phase of the gait cycle from the gait observational video in which markers were placed on relevant body landmarks based on ISO 16840-1 body landmark descriptions for frontal sternum and frontal pelvic lines. We also retouched the image to eliminate all markers except head landmarks. The "rysis" pointing procedures were strategically

Body segment line	Related landmarks
Sagittal pelvic line	ASIS and PSIS
Frontal pelvic line	**Right ASIS and left ASIS**
Transverse pelvic line	Right ASIS and left ASIS
Sagittal upper truck line	C7, Iliac crest point and upper sternal notch
Frontal trunk line	Upper sternal notch, right ASIS and left ASIS
Transverse trunk/shoulder line	Right acromion point and left acromion point
Sagittal abdominal line	Lower sternal notch, right ASIS and left ASIS
Frontal abdominal line	Lower sternal notch, right ASIS and left ASIS
Sagittal sternum line	Upper sternal notch and lower sternal notch
Frontal sternum line	**Upper sternal notch and lower sternal notch**
Sagittal neck line	Upper neck point, C7 and upper sternal notch
Frontal neck line	Base of nose and upper sternal notch
Sagittal head line	Eye corner and tragus of the ear
Frontal head line	**Right eye corner and left eye corner**
Transverse head line	Right eye corner and left eye corner

Table 3 : Body Segment lines in "Simple Measurement"

Three segment lines we measured were shown in bold font out of 15 segment lines

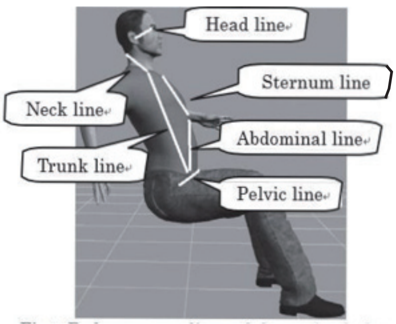

Figure 2: Body segment lines of the sagittal plar defined by "Simple measurement"

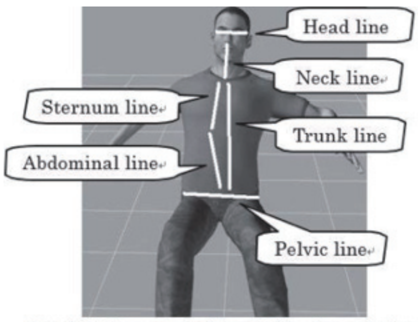

Figure 3: Body segment lines of the frontal plane defined by "Simple measurement"

allocated. The retouched photos were analyzed first, and the photos with visible external markers were analyzed next. The raters were asked to point three times on each image during both retouched and marked phases.

For intra-rater reliability of the clinical gait observation, after 10 months from the initial data collection, we asked the raters to assess the same sample video which had been captured images for the "rysis". Eastlack and her colleague developed "Videotaped Observational Gait-Analysis Assessments" (1991) and Read and his colleague developed "Video-Based Tools Edinburgh Visual Gait Score" (2003). All these studies used a three-point ordinal scale to quantify gait deviations, using slightly different descriptor terms. Similar to these systems, raters were asked to distinguish the orientation of each body segment line using a three grade rating systems (Left side, Upright or Level, Right side) in each phase of the observed gait cycle.

2.5 Statistic Analysis

To compare the reliability of "rysis" results of body segment lines between absence of marker (AOM), and presence of marker (POM), reliability levels were established by calculating the standardized Cronbach alpha, Intra-class Correlation Coefficient (ICC), and the 95% confidence intervals (CI), using a two-way random design and based on absolute agreement. To compare each result of body segment angles among the 12 raters, reliability levels were established by calculating Cronbach alpha, ICC, and 95% CI. As the summary of the results of body segment lines of both AOM and POM, the mean, standard error and 95% CI were calculated. To compare intra- and inter-rater agreement between video observation and "rysis" measurement, agreement ratios were calculated. The relationship between agreement ratio and clinical experience of each rater was evaluated by Spearman's rank-correlation coefficient. An alpha level of $p<0.05$ was used for all statistical tests and statistical analyses which were conducted using SPSS 20.0 (IBM 2012) software.

3.0 RESULTS

3.1 Inter-rater reliabilities

For inter-rater reliability, the standardized Cronbach alpha was 0.996 in presence of marker, and 0.999 in absence of marker, and both indicated a reliable result (Table 4).

Next, regarding the standardized Cronbach

	presence of external marker (n=12)	absence of external marker (n=12)
Cronbach alpha	0.998	0.993
The standardized Cronbach alpha	0.999	0.996
ICC (3.12)	0.97	0.902
95%Confidence interval		
Upper limit	0.992	0.972
Lower limit	0.931	0.792

Table 4 : Analysis of reliability

alpha of 12 raters among each body segment angle, head angle was 0.787, sternum angle was 0.901, and pelvic angle was 0.989. The inter-rater reliability of the head angle was lower than the others (Table 5).

Furthermore, the standard error of the sternum angle was 0.319 degrees in the absence of marker (AOM), and 0.078 degrees in the presence of marker (POM) (Table 6). The same tendency as a sternum angle, the pelvic angle had a standard error of 0.297 degrees or more in the absence of marker (AOM); it became 0.099 degree or less in the presence of marker (POM). The standard error of head angle was 0.202 degree as control. The markers contributed to limit the standard errors within 0.1 degree in both sternum angles and pelvic angles.

3.2 Observational agreement

There was no significant statistical relationship between raters' clinical experience and intra-tater agreement by Spearman's rank-correlation coefficient. Although the rating system is a broad classification, the agreements of the 12 raters were not so sufficiently in MSt and PSw (Table 7). The Pelvic angle had the poorest agreement throughout the three gait phase in both inter-rater agreement and intra-

	Sternum angle (n=12)	Pelvic angle (n=12)	Head angle (n=12)
Cronbach alpha	0.922	0.982	0.763
The standardized Cronbach alpha	0.901	0.989	0.787
ICC (3.12)	0.922	0.982	0.763
95%Confidence interval			
Upper limit	0.987	0.997	0.961
Lower limit	0.792	0.951	0.336

Table 5 : Analysis of reliability of each segment angles

	Mean	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
			Lower Bound	Upper Bound		
POM Sternum line	-.58	.078	-.74	-.42	-2	1
AOM Sternum line	-2.58	.319	-3.23	-1.93	-6	1
POM Pelvic line	7.55	.099	7.35	7.75	6	9
AOM Pelvic line	3.78	.297	3.18	4.38	1	8
Head line	-7.66	.202	-8.06	-7.26	-11	-4

Table 6: Body Segment Line Statistics

		Head angle	Sternum angle	Pelvic angle
Inter-Rater agreement				
	LR	91.67%	100.00%	50.00%
	MSt	66.67%	58.33%	50.00%
	PSw	58.33%	58.33%	50.00%
Intra-Rater agreement with "rysis"		91.67%	100.00%	8.33%

Table 7: Inter and Intra rater agreement of observation

rater agreement. Half of raters failed to agree on the frontal pelvic angle in the inter-rater agreement. Only one rater could agree with his “rysis” results, and others could not.

4.0 DISCUSSION

4.1 General Discussion of Method

To the best of our knowledge this is the first English publication attempting to extend the application of ISO 16840-1-based “rysis” tool to the field of clinical gait assessment. However, this experimental study was not free from the sampling bias due to the nature of the pilot study. We had only one healthy photographed subject. Raters were all asked to analyze the same picture. This might be the reason why 12 rater's “rysis” results of three body segment angles were concentrated around vertical or horizontal lines. For this reason, we could not control the positive effect of the functional central limit theorem. The daily clinical analysis might face a lot of difficult factors identifying each body landmark; Actual patients might have various body alignments such as regressive changes, lateral curvature, and tilting head and trunk for postural control during gait.

To promote the clinical application of “rysis”, we need more research with many subjects, various clothes, and different body types. In addition, low resolution of the image may also create potential bias, because “rysis” analyses were performed on a captured image from commercially available video camera. Furthermore, as raters were all clinicians, clinical imagination of specific captured phase in gait cycle can also create positive bias of concentrating data distribution.

4.2 General Discussion of Results and Implications

In spite of the potential limitations, the results of current study suggested that, regardless of marker absence, “rysis” can be used reliably to assess videotaped gait patterns compared with naked eye observation which is usually conducted in the clinic. Standard error of “rysis”, even in the absence of markers for frontal sternum and pelvic angles were 0.319 degree and 0.279 degree repeatedly. These ranges of standard errors are easily acceptable in daily clinical practice. High reliability (Cronbach alpha: 0.993) of retouched image analysis with markers removed indicates the clinical application of “rysis” can be helpful for every day practice of physical therapy.

4.3 Rater's Clinical Experience

Brunnekreef et al.[12] conducted reliability studies on videotaped gait patterns of thirty patients by using a structured gait analysis. Their 10 raters included four inexperienced students, and four experienced raters (who had successfully completed a gait training course and had at least ten years clinical experience), and two experts who were currently teaching therapists treating patients with orthopedic gait disorders. The inter-rater reliability among experienced raters was ICC = 0.42; 95% CI: 0.38–0.46, the inexperienced raters' reliability was ICC = 0.40; 95% CI: 0.36–0.44 and the expert raters' reliability was ICC =

0.54; 95% CI: 0.48–0.60. Their conclusion was that clinical experience is crucial in reliability of observational gait assessment.

Compared with our 12 raters (mean clinical experience of three years), their 10 raters seemed to have rich clinical experiences (over ten years) and skills (all of them were certificated clinical gait trainers). This might explain our inability to find any difference in our results due to the clinical experience of our raters. The only rater who failed to agree with observed head orientation and “rysis” result had only one year experience. And the only rater who agreed with frontal pelvic angle observation and “rysis” result had 5 years of clinical experience. These findings may support the notion of the importance of clinical experience, as Brunnekreef and others concluded[12].

Our resulting ICC values are higher than their results, and neither age nor clinical experience affected our subjects’ reliability.

4.4 Potential of “rysis”

Unexpectedly, we found the absence of markers did not have much impact on “rysis” results in videotaped gait analysis, so markers may not always be required when using this method. However, our pilot study had several limitations as noted previously.

This study had only one healthy photographed subject. He had a standard body type and was wearing a hospital gown with a vertically-striped pattern. All the raters might very easily have inferred the body alignment from the vertically striped gown during their observation in particular the sternum line observation; might be the easiest of all for raters because the sternum line goes vertically in the baseline. In contrast, the pelvic line goes horizontally throughout the baseline which is masked by the vertical stripe pattern of the subjects hospital gown. This might be the reason why the intra-rater agreement between the observation of pelvic line and “rysis” angle was the poorest (8.33% agreement) of all.

To identify the accurate body segment angles from observation, there are many possible limiting factors which we have to examine. The impact of these limiting factors on reliability is still somewhat unclear. In addition, actual patients in the daily clinical evaluation might have various body alignment changes such as regressive lateral curvature, and tilting the head and trunk for postural control during gait.

McGinley et al[13]. compared the measurements of peak ankle power generation at the push off and observational assessment rating among post stroke patients, and they found their therapists’ observations to be moderately reliable (ICC=.76). Because “rysis” showed excellent inter-rater reliability in this pilot study, “rysis” may be an excellent tool for judging the push off, foot strike, or other specific phases of a gait cycle using a captured image from videotaped gait assessment.

To improve accuracy and reliability of observational gait analysis, a more strategic examination for clinical application of “rysis” using our measurement protocol is required in the future.

5.0 CONCLUSIONS

Although simple gait observation is not always reliable, instrumented gait analysis is not always available. Video recorded gait analysis can be used as an alternative, and the posture measurement during gait assessment using "rysis" is promising for a quantitative posture evaluation regardless of the presence of external body markers (ICC=.98). A more strategic examination for clinical application of "rysis" is required for the future.

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