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Original Article

Benefit of "rysis": A Wheelchair Seated Posture Measurement Based on ISO 16840-1.

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Abstract: This article is of a measurement method of wheelchair seated posture. First, we have reported a brief outline of ISO 16840-1 world standard regarding posture while seated in a wheelchair; the standard specifies a global coordinate system. We also introduced measurement tools based on ISO 16840 and the current Japanese clinical works using the tools. Secondly, we have reported how to use "rysis" , the ISO standard-based wheelchair seated posture measurement (WSPM) software, which was invented by one of the authors Takashi Handa innovated in 2008. Since 2009, we have been promoting clinical application of "rysis" . As of June 2014, the number of distribution facilities of the "rysis" was over 300 in the world. Thirdly, we have reported how to conduct a survey using "rysis" and have stated the results of the research. We have presented our research booth during the Barrie Free Trade Show (BF), which has annually held with almost one hundred thousand visitors at Intec Osaka, Osaka, Japan. From BF visitors in the past six years, a total of 266 daily wheelchair users participated in the research. Our measurement results can directly visualize their wheelchair seated posture. We have been developing skills and knowledge for clinical application and improving the software usability. Finally, we concluded the benefit of "rysis" that include empowerment of people with disability and the educational impact on both consumers and students.

Key Words: Wheelchair, Seated Posture, ISO16840-1, Measurement Software, rysis

1 Introduction

1.1 ISO 16840-1

Seated posture is one of the major factors in the development of pressure sores, and it has significant effects on the comfort, function, physiology, mobility and alignments of the spine. Therefore, it is necessary to measure the seated posture. Currently, therapists use joint

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motion terms to describe the sitting posture. The standards, ISO 16840 Wheelchair seating Part 1: Vocabulary, was formally adopted in 2006. The standards include reference axis convention and measures for body segments, posture, and the postural support surface. It specifies the global coordinate system that permits the determination and recording of a person's posture while seated in a wheelchair. The global coordination system involves the 0° –360° measurement, where the vertical Line (0°) is considered as the norm of the system, and the movement is measured in a clockwise direction, i.e., 90° - 180° - 270° - 360° .

It should be noted that an important difference between the local coordinate and the global coordinate systems is the gravity of earth as the norm of the system. ISO has defined the 0° –360° measurement in the global coordinate system for the description of the posture of a wheelchair-seated person. The angular orientations of the global and local coordinate systems are called absolute angle and relative angle, respectively.

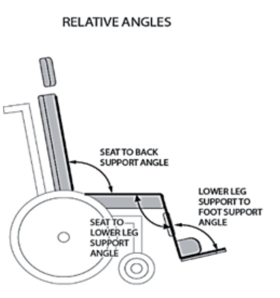

Figure 1

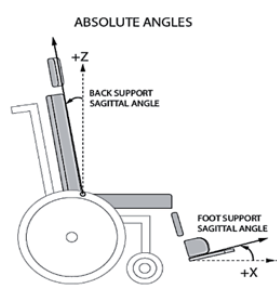

Figure 2

The ISO guidelines have also state the minimum number of body segments required to define the seated posture and have defined the landmarks for each segment, representing each segment by a line. The lines that join these body landmarks are called body segment lines, which can be located in each of the three views, i.e. sagittal, frontal, and transverse views. The body segment lines enable the orientation of body segments to be measured. The below figures (Figures 3-8) show some of the defined body segment lines and body landmarks in each of the three views.

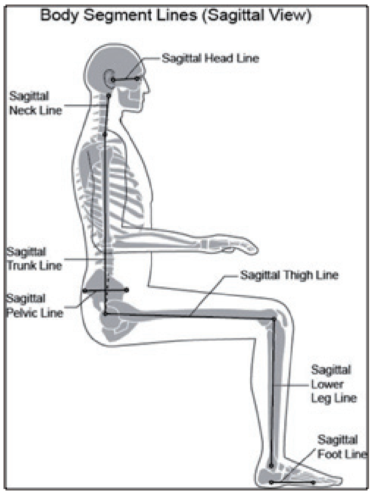

Figure 3

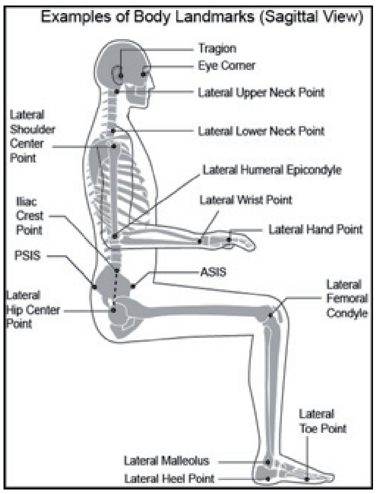

Figure 4

Figures 3 and 4 represent the sagittal views of the segment lines the body landmarks, respectively. Sagittal plane landmarks included right lateral eye corner, tragion: notch just above tragus, mastoid process, C7 vertebra spinous process, upper and lower sternal notch, anterior superior iliac supine (ASIS), iliac crest point, and posterior superior iliac supine (PSIS).

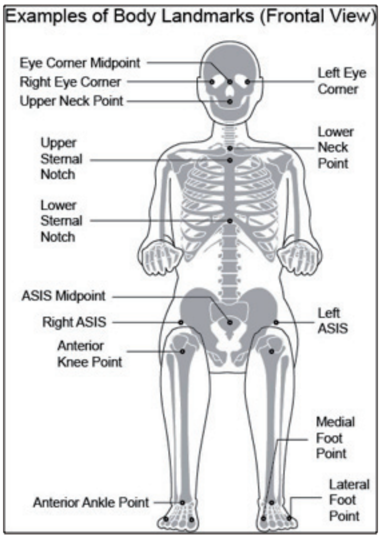

Figure 5

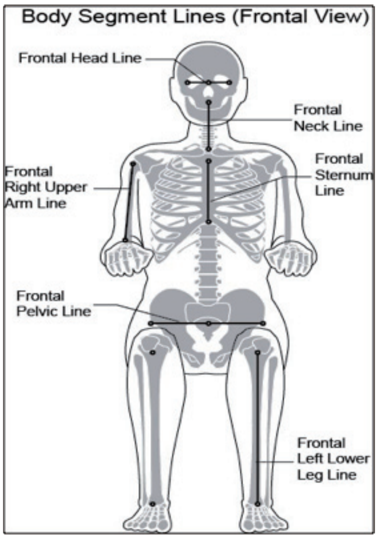

Figure 6

The ISO has provided guidelines regarding the number of body segment lines to be included in the frontal plane and has defined land marks for each segment. Figure 5 shows frontal plane landmarks, including eye corners and base of the nose, upper and lower sternal notch, ASISs. Figure 6 shows the segment lines in the frontal plane.

Figures 7 and 8 show the body landmarks and body segment lines, respectively in the transverse plane. The transversal plane landmarks include lateral eye corners, acromion, and ASISs. [1)]

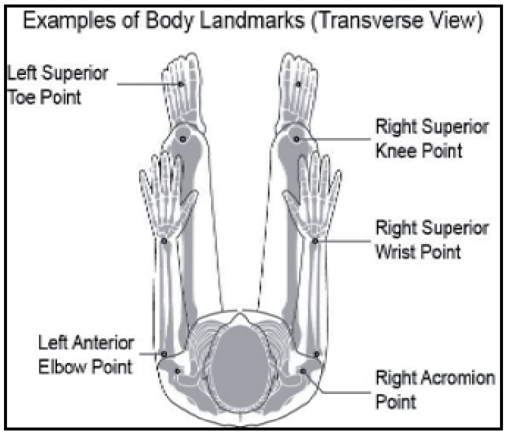

Figure 7

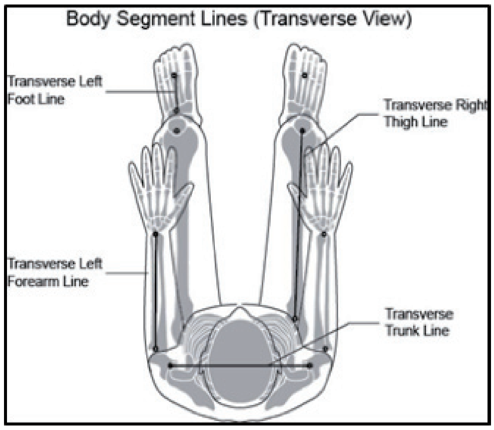

Figure 8

To measure the selected body segment angles while the individual is seated in the wheelchair, the body landmarks should be palpable when the client is seated against a back support and seat. This is challenging in the trunk and pelvis segment as the spine and posterior pelvis constitute the most easily palpable bony landmarks that are often not accessible when seated in a wheelchair. Thus, although the measurement rule of seated posture was defined, how to measure an aspect of the standard was not established. Hence, one of the authors Takashi Handa developed a software that could measure the seated posture according to ISO 16840-1 and presented our development result at the 22nd and 23rd RESJA [2-4].

1.2 “Horizon” and “rysis”, tools used to measure absolute angles

Since absolute angles are determined by comparing a line on the body segment or support surface to an external reference line, it becomes necessary to identify the external reference line. For angles in the sagittal and frontal planes, the orientation of the body segment or support surface is compared to either the vertical or horizontal aspect. Therefore, the measurement device must be able to identify the gravitational horizontal and/or vertical aspect. An inclinometer, also known as an “angle finder”, automatically measures the degrees off of either the horizontal or vertical; therefore, this is the most straightforward tool to use for sagittal and frontal angles. Digital inclinometers are easier to read and indicate both positive and negative values. However, inclinometers cannot be used to measure absolute angles in the transverse plane because these angles are not referenced to the horizontal or vertical aspect. Absolute angles in the transverse plane are referenced to the wheelchair, specifically either the X or Z axis of the Wheelchair Axis System; therefore, for these measures, it will be necessary to locate a line along or parallel to these axes. Two tools, i.e., Horizon tool [5] and the other is “rysis” software [2-4], have been developed in Japan for measuring the absolute body segment angles in order to quantify the seated posture according to the ISO 16840-1:2006 standard. The Horizon is a device similar to a digital inclinometer; however, it can measure absolute angles in all the three planes. Based on ISO 16840-1 standards, the "HORIZON" was developed [5] (Kenmoku, Handa, Sano, et al. 2009) that includes an acceleration sensor, gyroscope, and a microcomputer. "HORIZON" can measure the angle of the gradient of the body segments. It has three modes, i.e., horizontal, vertical, and rotation modes. The horizontal mode can measure pelvic obliquity, the vertical mode measures pelvic tilt in sitting position, and rotation mode measures pelvic rotation in the supine position. The vertical mode has two axes (X and Y), which measure the sternum obliquity and tilting simultaneously and in supine position pelvic tilting and rotation at the same time. The rotation mode needs calibration of the zero axes of the transverse plane prior to the measurement based on the ISO 16840-1 standard.

The developers of “HORIZON" conducted the field test with the help of physical and occupational therapists and showed higher satisfaction for accurate angle detection, good visibility, good operability, and good design.

2 ISO-Based Software “rysis”

2.1 Body segment angle calculation using “rysis”

“rysis” is two-dimensional digitizing software that can measure the gradient angles of body segment lines defined in the ISO 16840-1. It is a free software developed by Handa, who established the seated posture measurement study group (http://seating.web.fc2.com/). In this methodology, the clinicians can mark body landmarks of interest using ½" diameter adhesive markers and then capture a digital image. This digital image is then analyzed using computer-based image analysis software, which prepares a report of the absolute body segment angle values that describe a person's posture. As stated earlier, the ISO 16840-1 standard defined the list of measures but did not describe any specific measurement methods. Hence, Hirose and Handa proposed the "Simple measurement" of the ISO 16840-1 standard to establish the measurement method based on the standard [3, 4, 6].

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

2.2 Application of seated posture analysis system "rysis"

"rysis" is an affordable and valid posture measurement tool. Handa and his colleagues evaluated the reliability of the software by using a metal model representing the human seated posture and calculating the standard deviation of within- and between-examiner measurements. They also evaluated validity by comparing their results with a contact three-dimensional measurement device. From their results, the software seemed to be practical and well-suited measurement tool for daily clinical use [6-9].

2.3 ISO-based measurement research : what is going on in Japan?

As mentioned earlier, Japan is the leading country in the development of measurement tools based on new ISO 16840 standards. However, due to "language barrier" , many

Table 1: Body Segment lines in "Simple Measurement"

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

Three segment lines we measured were shown in bold font out of 15 segment lines for "Simple Measurement" works of Japanese researchers were not recognized in the international seating community. Hence, we summarized the current research using new tools and methods based on ISO 16840-1 standards. Specifically, we focused on works written in Japanese, which have not been published in English yet. We aim to share this knowledge with over 67 million people who need a wheelchair globally. The search strategy was as follows. The keywords used for web searching were seated posture measurement, “rysis”, “Horizon”, and wheelchair seating. We included both academic and conference papers published during 2004 to 2012. These papers were on the introduction of a tool, introduction of the usage, reliability tests, applications for clients, and benefit of the tool. The search results showed 28 studies (Table 2).

Table 2:　ISO based measurement research in Japanese

Survey	6
Introduction	11
Reliability Study	5
Experimental study	6
Total	28

The clinical application can be conducted in many settings and objectives, such as seating clinics and measurements for clinical prevention. The first example is a paper from a seating clinic at Taito Rehabilitation for Elderly [10], which was presented at the 1st Seminar of Seated Posture Measurement. The subjects included in the study were elderly people in the nursing home, and the objective of the study was to improve their sitting posture. Before the intervention, the patient's trunk was inclined to the right in Depot-chair with losing sling-seat. The chair was modified into a modular type chair, with trunk support and adjusted heights of arm supports. The pelvic obliquity and frontal sternum line were measured by “Tenmoku angular meter”. The results helped the patients improve their posture to a more upright posture, and it was confirmed quantitatively by an angle of body segment lines in the three orthogonal planes such as sagittal, frontal, and transverse planes.

The second example is a case report by Yoshida[11] that reported the repeated incidence of pressure ulcer in a person with SCI at the 1st Seminar of Seated Posture Measurement and in the seating clinics at the National Rehabilitation Center for the Disabled. The objective of the study was to identify the factors responsible for developing PU and its prevention. They found the patients were bottoming out at his left buttock without any trunk support. They accommodated back seating unit for supporting trunk. The outcomes of the study were pelvic oblique and sternum oblique using “rysis”.

The third example is a study by Onodera [12] that focused on preventing low back pain (LBP) among outpatients with Parkinson disease (PD) in a university hospital. The inclusion criteria of the study were patients with PD whose Hoehn & Yahir Stage was from 1 to 3, those who can stand independently for 30 seconds or longer, and those had or did not have LBP. They analyzed trunk functional factors related to Visual Analog Scale (VAS) for LBP and Unified PD Rating Scale. To evaluate patients' trunk function, they measured a pelvic range of motion using “HORIZON” . They found strong correlations between pain and pelvic anterior tilt, and between pain and rigidity (Table 3).

Table 3: Onodera's results

Correlation	r	p-value
Pain /Pelvic Anterior Tilt	0.61	0.06
Pain /Pelvic Obliquity	0.57	0.08
Pain/ Rigidity	0.70	0.02

All of these works above have clinical relevance in some conditions regardless of nationality and implicated using ISO based tools can be universal strategies.

3 “rysis” Survey Protocol

In the past six years (from 2010 to 2015), we presented “seated posture measurement booth” in the annual “Barrier Free tradeshow” , which has annually held with almost one hundred thousand visitors at Intec Osaka, Osaka, Japan [13-16]. From BF visitors in the past six years, a total of 266 daily wheelchair users were recruited. We used a convenience sampling method to recruit participants using flyers and posters around our booth each year. Inclusion criteria of this study were people who use the same wheelchair daily. Only those who gave a written consent were recruited. The procedure of data collection was as follows: 1) basic information questionnaire; 2) Taking photographs from three orthogonal planes at one time; 3) only the frontal plane images were analyzed by “rysis” on site; and 4) clinical consultation using printed results.

3.1 Analytic method

At later date of data collections in our surveys, we analyzed the following:

A) The 5 degree or higher between two raters, inter-class rater reliability between two raters using same photographs, and a total of 586 segment lines from 40 participants from BF2013 survey.

B) An exploratory study of the source of error.

C) An experimental study for the pointing procedure.

3.2 Results and findings

A total of 266 wheelchair users visited us for past four years, including 111 prop sitters, 32 hand supported sitter, and 123 hands-free sitters.

A total of 44% participants commented to satisfy their interest in understanding their seated posture and to become convinced in the importance of ergonomic seating. This result indicates that our clinical consultation allowed the majority of subjects to satisfy their interest in understanding their seated posture. This knowledge made a difference in not only satisfying these interests but also motivating them to improve their quality of lives. For example, one lady with cerebral palsy, Ms. Yuko Kanazawa, broke the barrier on the system to provide powered tilt' s space, seat elevation chair, after continuing negotiations over 2 years with the local government. During the negotiating process, she referred the results of her “rysis” measurement as scientific evidence [17]. She wrote the six pages article as the disability report in “Japanese journal for the problems of the handicapped” vol 42 issue 2, 2015. In the same issue, her effort was highly regarded as “Disability rights pioneer to equality” by Professor Naoko Nakamura, a renowned sociologist at Risho University.

Every year from 2011 to 2015, more than a couple of cases have been motivated to improve their seating after participating our survey.

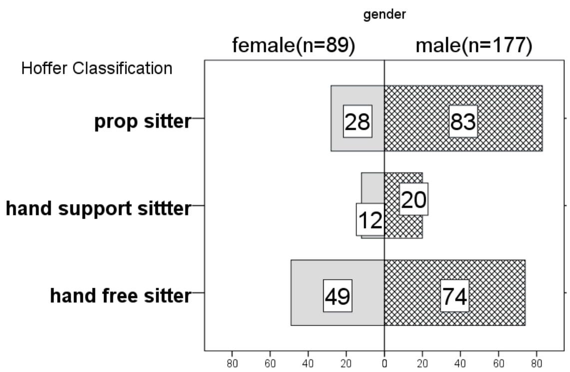

Figure 9

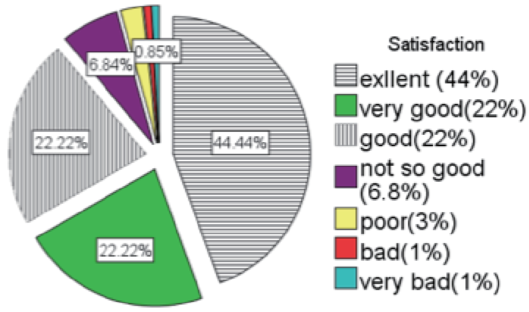

Figure 10

3.2.1 Inter-rater reliability

A total of 586 segment lines from 40 participants from BF2013 were analyzed by two raters. In addition, 98 body segment lines out of 586 lines were excluded due to a difference of 5° or higher between two raters. All segment lines showed high reliability by intra-class correlation coefficient (Table 4) [18].

3.2.2 Exploratory study of the source of error

While we analyzed seated posture using

Table 4: Intra-class Correlation Coefficient by each body segment line

Body segment Lines	n	ICC	95% Confidence Interval Lower Bound	Upper Bound
Transverse Pelvic Line	41	0.992	0.985	0.996
Transverse Trunk Line	41	0.996	0.993	0.998
transverse Head Line	41	0.998	0.996	0.999
Frontal Sternum Line	34	0.981	0.962	0.99
Frontal Neck Line	37	0.989	0.979	0.994
Frontal Pelvic Line	37	0.969	0.941	0.984
Frontal Trunk Line	37	0.965	0.931	0.982
Frontal Head Line	33	0.993	0.987	0.996
Frontal Abdominal Line	35	1.000	1	1
Sagittal Sternum Line	31	0.990	0.98	0.995
Sagittal Neck Line	15	0.987	0.962	0.996
Sagittal Pelvic Line	22	0.992	0.97	0.997
Sagittal Trunk Line	15	0.973	0.89	0.992
Sagittal Head Line	15	0.991	0.981	0.996
Sagittal Abdominal Line	38	0.995	0.99	0.997

"rysis" , we faced difficulties in taking pictures of the subjects' consistently, handling angular results for statistics, and irregular angular results of "rysis" . We explored the causality of 98 disagree as follows [18] .

1) Forty-four lines had no external markers; 2) Twenty lines had an error of insufficient triangle pointer; 3) Invisible external body markers; 4) Eleven lines had in sufficient pointing configuration; 5) Six lines had different pointing order of triangle pointer; and 6) Five lines seemed to be systematic errors. From the results above, the preventing errors are as follows (Table 5).

Table 5: Check list for preventing error in each phase

Data collection phase	Check
· All the body landmarks had external markers? · Triangle pointers did not warp or bending? · Two legs of the triangle pointer were visible? · All the external markers were visible? · Make sure external markers and triangle legs in different colored from the closest?	
"rysis" analysis phase	Check
· Same way to point the same landmark? · Pointing appropriate order on the legs of triangle pointer? · Make sure the operating error did not include in the angler results?	

3.2.3 An experimental study for the pointing procedure

During our "rysis" analysis, we faced irregular angular results; therefore, we conducted pointing experiment and extensively reviewed the making paper of the software "rysis" . We found out how to Miss-pointing happened. As results, appropriate pointing procedures were only the following three-way [19].

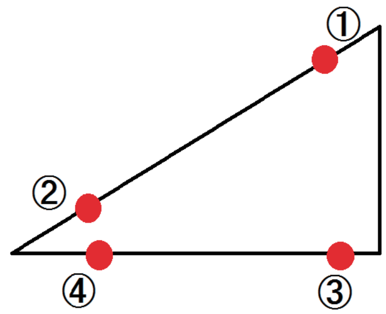

Figure 11

①→②→③→④ (Click from outside to corner of triangle)

②→①→④→③ (Click the corner to outside in each leg of triangle)

③→④→①→② (No matter where you began to click from upper edge or lower edge, the results angle was the same among the three pointing way)

3.3 Other improvements

3.3.1 Camera Frame

For the consistency of the pictures, we developed simultaneously photographing system from three orthogonal planes and developed an original camera for the transversal view. Transversal view camera should have the function of remote capture to ensure the consistency in pictures and possibly remote power supply [20].

3.3.2 Software Update

Considering the yearly feedback from the front line of survey, one of the authors (Handa) has updated “rysis” (version 4DF) to changing the result outputs into 0-180-degree format from 0-360-degree original form according to ISO 16840-1. Due to this update, we can handle angular results directly for statistics.

3.4 Summary of students’ significance

A total of 32 students contributed to this work for past six years. Among their contributions, the significant topics are presented as follows (Table 6).

4 Discussions and Conclusion

We, along with the faculty of the university, researchers in institutions, and clinicians in hospitals, have been working together with students at consumer trade shows during the

Table 6: Students’ significant contributions by years (from 2009 to 2015)

Student's name	Year	Comparison
M. Sakai	2009	Preliminary data collection.wheelchair.
Five students	2010	Research booth designing and setting up, recruitment of 56 subjects, data collection, constructing database.
M. Kagatani	2010	Japanese translation of Wheelchair Discomfort Questioner.
M. Kagatani	2010	Proving the benefit of movable joystick mount.
Five students	2011	New designed research booth, recruitment of 58 subjects, updating data collection, updating database.
R. Fukumoto	2011	Designing a new camera flame.
C. Kameoka	2011	An experimental study for the pointing procedure with a review on the background of the rysis click point protocol.
Four students	2012	New research booth setting up, recruitment of 38subjects, data collection, updating Database.
Y. Yoshid	2012	Comparison between pelvic rotation angles and head rotation angles.
K. Okamoto	2012	Comparison between the sitting postures at plat home and the postures in their own wheelchair.
Four students	2013	Improving research booth set-up, 30subjects recruitment, data collection, updating database, reliability study of the data.
H. Kanda	2013	Reliability on data collection of “rysis” , and making a checklist.
Y. Murata	2013	Problems of 360° reference system in ” rysis” analysis.
Five students	2014	Improved research booth with pressure mapping, 34subjects recruitment, data collection, updating the database, and follow up.
M. Kishi	2014	A longitudinal case reports by follow-up home visit.
H. Shiraishi	2014	Comparison between seat to back angle and trunk anterior-posterior tilting angle.
Eight students	2015	Improved booth setting up, 41subjects recruitment, affordable data collection, improving database reliability, follow up.
S. Nakanishi	2015	Analysis on the free text of additional feedback comments in wheelchair discomfort questioner.
S. Fujita	2015	Comparison between the simple observation and “rysis” analysis according to pressure mapping results.
K. Jinbo	2015	A case report of seating intervention home visits after the survey.
R. Yamaguchi	2015	Common seat back angle in some diagnosis, in comparison of professional estimations and our survey data.

past six years. We have analyzed 266 daily wheelchair users using the “rysis” seated posture measurement software, which was designed based on ISO standards. We have found that over 70% people who were on their wheelchair for a very long time stated pain and discomfort.

Our measurement results, which are based on ISO 16804-1, can directly visualize users’ wheelchair seated posture. These findings can have an educational impact on consumers and stakeholders to provide appropriate wheelchairs. This may also help students, who may become clinicians in future, to know the world standards in the field [21].

It should be noted that observational visibility has potential relevance on providing evidence of good practice in many clinical and community settings. For example, when Ms. Yuko Kanazawa, with her struggle for over two years, challenged that the wheelchair providing system required improvement, the “rysis” results had supported her by providing scientific evidence. Inoue, a wheelchair provider, reported that the “rysis” results and the images were a strong evidence of good practice when he submitted a claim to local government with the authority of national wheelchair providing system [22].

An on-going 2015 study listed in the last line in Table 6 is challenging to another clinical relevance of observational visibility. Reina Yamaguchi is now challenging to substantiate the previous research by Inoue and his colleagues regarding clinician's estimated optimal angles of a wheelchair [23]. Inoue and his colleagues had investigated using questioner regarding the angle of the seat to back angle and lower leg to thigh angle. They had asked clinicians who were taking care of different diagnosis, divided to the three group based on JCCA Hoffer's classification. Yamaguchi compared their estimations and our BF survey data in each group of different diagnosis. Her obtained results imprecates the previous professional estimation as a predictor of reasonable accommodation in each group of our participants.

Observational visibility also has a promising power on clinical education in many settings. For example, when we investigated the key factors of simple observation in the screening process of seating interventions, the observational information by expert clinicians and the results of “rysis” on their subjects’ images revealed the focus of the experts. This notion can emerge from an on-going 2015 study by Shiori Fujita, who conducted a comparison study on her simple observation and “rysis” analysis by supporting with pressure mapping results.

Feedback information from individual researchers and clinicians at different settings and different conditions might have valuable implications to improve our systems and software, guiding us to the more accessible affordable useful measurement of wheelchair-seated posture. Easily-visualized underlying information of person's posture seated in a wheelchair is still challenging. Like all other clinical device development, learning from someone's error as we reported in this article might be a valuable source of knowledge for the clinician to apply “rysis” to clients as a common practice.

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