ORIGINAL

Usefulness of 2D Video Analysis for Evaluation of Shoulder Range of Motion during Upper Limb Exercise in Patients with Psychiatric Disorders

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Abstract : Aging and its associated problems related to movement impacts the care of people with psychiatric disorders. This study sought to clarify the usefulness of 2D video analysis for evaluating shoulder range of motion (ROM) during upper limb exercises in patients with psychiatric disorders. Subjects (N=54) were patients with psychiatric disorders categorized as the following : having either a high or low activities of daily living (ADL) score using the Barthel Index ; experiencing shoulder ROM limitation, and whether or not compensatory movements were exhibited. Compensatory movement was also considered in patients with Parkinsonism, cerebrovascular disease, and cognitive dysfunction. Shoulder joint ROM was measured using a goniometer and active ROM was captured using ImageJ. No significant difference between passive ROM measured by a goniometer and active ROM measured by ImageJ considering disease groups, ADL level, and shoulder ROM limitation was found. Factoring in compensatory movements, however, significant differences were found between passive and active ROM : existence compensatory movement group, left side (z=-2.30, p=0.02) ; nonexistence compensatory movement group, right side (z=-2.63, p<0.001). Image-evaluating devices help assess ROM in patients with psychiatric disorders, enhancing the development of physical rehabilitation programs to regain critical ADL, sustaining self-care capabilities. J. Med. Invest. 69 : 70-79, February, 2022

INTRODUCTION

Japan continues to experience a burgeoning aging population with the largest percentage of total population over 65 (1). It was reported that higher levels of cognitive and physical activity in midlife were independently associated with reduced risk of dementia (2). Moreover, aging and its associated problems impacts not only the care of persons with dementia (3), but also of other people with mental illnesses such as schizophrenia (4). Orthopedic signs and symptoms involving skeletal and joint disorders, such as in broken hips, along with mental health issues and cognitive impairments have the greatest probabilities of causing difficulties in performing activities of daily living (ADL) (5).

Physical exercise is considered beneficial for patients with schizophrenic conditions because of its valuable effects of impacting clinical signs, quality of life, and depressive symptoms (5). In addition, with patients diagnosed with schizophrenia, maintaining physical health remains a major concern (6). It appears that these patients have higher levels of cardiac and metabolic indisposition than the overall population because of poor physical health, and because of a chronic inactive lifestyle (7). For patients with psychiatric disorders related to motor symptoms such as disuse syndrome are common outcomes of poor physical health related to a chronic inactive lifestyle (8). In patients with

schizophrenia, motor symptoms induce reduced muscular activities, such as decreased hand gestures and shoulder mobility (9). Dyskinesia due to extrapyramidal symptoms such as tremor and muscle rigidity often appears, which greatly affects their ADL (10).

Functional mobility is the ability to use movements such as standing, bending, walking and climbing, and moving within safe environments in order to perform ADL. The most common risk factors for mobility impairments are old age, low physical activity, obesity, impaired muscle power, strength and balance, and chronic diseases such as diabetes or arthritis (11). One of the significant goals for therapists treating patients aims to increase their level of physical activity, by overcoming or improving the barriers toward engaging in active bodily activities (12).

With the joint the range of motion (ROM) study, a reduction in normal ROM in any joints is known as limited ROM. Joint ROM naturally declines with age (13), but it can also occur with several conditions. As persons get older, muscle mass decreases and the extent of ROM as well (14). When this occurs, a state of physical dysfunction known as disuse syndrome follows (15). This syndrome comprises a constellation of signs and symptoms that occur because of physical inactivity consequent to moderate to severe disease-causing impairment, leading to prolonged or forced rest (16). Sarcopenia, defined as a loss of whole-body muscle mass associated with aging, is one of the factors contributing to accelerated frailty, and is reportedly associated with conditions such as malnutrition and disuse syndrome (17). For example, in an earlier study of patients with schizophrenia, dysfunction of the shoulder joints during ROM exercises of the upper limb has been reported (18). Arm function shows a significant role in the performance of daily activities. Most daily

activities require using two hands, so that the performance of two-handed activities receives significant attention in rehabilitation programs (19). People with musculoskeletal disorders of the shoulder commonly experience pain, decreased strength, and restricted ROM that limit participation in meaningful occupational activities (20). The limited joint ROM in the upper extremities affects delay in ADL, especially for activities related to feeding and dressing (21). The shoulder complex, composed of the clavicle, scapula, and humerus, is an intricately designed combination of four joints, the Glenohumeral Joint, the Acromioclavicular Joint, the Sternoclavicular Joint, and a "floating joint," known as the Scapulothoracic Joint (22, 23). The shoulder is known as dynamic stabilization, which depends on active force or dynamic muscle control rather than passive stabilization by articular surface configuration, capsules, ligaments, which shows a unique functional balance between mobility and stability due to active force (22, 23). In the shoulder complex, muscle force is the main mechanism that holds the shoulder girdle to the thorax and provides stable support for upper limb movement.

Compensatory movement is defined as the performance of an 'extra' movement close to the original operation used consistently to attain efficient motor skills when no usual movement configuration has been recognized or is not available (24, 25). During rehabilitation, appropriate evaluation of compensatory patterns is critical for improving functional outcomes (26).

Evidence has shown that ROM, strengthening exercises and joint mobilizations can improve function and decrease pain (20). Before beginning therapeutic physical activities for persons with musculoskeletal activity problems, the therapist evaluates ROM using a goniometer, an instrument that establishes the widest angle at which the joint can move. Similarly, the therapist determines whether restricted mobility and motion result from muscular tightness or from tight ligaments and tendons (27). All factors relevant to impaired functioning need to be assessed and incorporated into a well-informed treatment plan. Such a plan involves predictive potentials for functional improvements and for subsequent discharge planning and rehabilitation care (28).

One of the major constraints of rehabilitative care in Japan is the dependence of staffing patterns on the medical fee classification system. The medical services payment system allows for one therapist to be assigned to provide medical services for approximately 25 patients in a chronic psychiatric unit (29). Conversely, based on the long-term care insurance system, one therapist is assigned to care for roughly 100 patients receiving elderly care or services in the chronic psychiatric unit of a Long-Term Care Health Facility (30). Given the restrictive nature of staffing standards, there are limits to the number of patients that can be evaluated as to their ROM, as they engage in group exercises under the supervision of qualified therapists.

It is important to clarify the patient's condition under actual clinical conditions to accurately provide rehabilitation support. Task-oriented repetitive movements can improve muscle strength and movement coordination in patients with impairments due to neurological lesions (31, 32). Traditional clinical assessment of patient progress is often based on a clinician's visual observation or their experience with patient movement or exercise performance (33). ROM movements include passive and active rehabilitation exercises. To accurately measure patient performance, it is important to evaluate the ROM during active exercise. The goniometer cannot measure ROM during exercise, while the ImageJ, a photograph-based goniometry tool (34), can measure the angle using images or videos during these exercises. Thus, the evaluation of patients with psychiatric disorders exhibiting limited mobility and compensatory movements, utilizing image-evaluating devices during exercise is a viable option.

This study sought to clarify the usefulness of 2 dimensional (2D) video analysis for evaluating shoulder range of motion during upper limb exercise in patients with psychiatric disorders.

MATERIALS AND METHODS

Research period and patient characteristics

The study took place from August 2, 2019 to December 24, 2019. A total of 54 patients met the inclusion criteria : patients diagnosed with psychiatric disorders who were hospitalized in a psychiatric hospital, older adults with dementia who have attended day care at the geriatric healthcare facility, or residents of a geriatric healthcare facility attached to the psychiatric hospital. Subjects were conversant with the Japanese language and did not have changes in their clinical psychiatric symptoms reflective of schizophrenia/dementia. These patients had been consistently following their pharmacological treatment regimens during the past three months. On the other hand, patients excluded from the study were those under treatment for alcohol or drug abuse, showing aggressive or violent behavior, suffering from a terminal illness, those with severe co-morbidity, severe stroke, cerebral palsy, or severe auditory impairment.

Analytical framework

In this study, it was important to illustrate how the shoulder joints moved with the upper limbs and the maximum extent of the shoulder joint ROM during the exercise. Thus, this study measured the active ROM during exercise using ImageJ and evaluated it by comparing passive and active ROM.

Passive ROM is performed without the "active" participation of the patient, and, the therapist can measure or test the tolerated the extent of the patient's joint capability.

On the other hand, active ROM is the range in which patient moves a part of his/her body by using muscles without outside help. With active ROM, the extent of the movement is arbitrarily but consciously performed by the patient. Active ROM includes other anatomical structures such as muscles, and the gravitational influence on the performance of the movements. However, it is difficult for patients to maintain active ROM activities when they are in pain.

ROM limitations may not depend on the effects of the disease condition, but secondary syndromes such as motion frequency, including disuse (35), can cause difficulty in starting motion, for example in Parkinsonism (36). Therefore, in this study, it was confirmed that there is no difference in ROM limitation depending on the disease name.

In this study, patients with schizophrenia or dementia were divided into two groups ; those having high ADL scores and those with low ADL scores as determined using the Barthel Index (BI) (Less than or greater than 60 points) ; Passive shoulder ROM limitation (Less than or greater than 130 degrees) ; and whether or not the patient exhibited compensatory movements. Moreover, disease-related factors were also assessed as components of the diagnostic profile along with personal characteristics such as the patient's age, results on the Drug-Induced Extrapyramidal Symptoms Scale (DIEPSS), Hasegawa's Dementia Scale-Revised (HDS-R) score, the presence of comorbid disease, and length of psychiatric hospital stay (LOS).

In actual clinical rehabilitation at psychiatric hospitals or at elderly rehabilitation sites, patients with various psychiatric disorders and comorbid diseases perform exercise therapies together. Therefore, this study considered these practice activities and used statistical tests according to data collected during these clinical situations.

Statistical analysis and sample size calculation

Wilcoxon signed-rank test (Table 1 and 3) was used to confirm the following measurement-method differences in goniometer as compared to ImageJ. Differences among diseases were determined by use of the Kruskal-Wallis test (Table 3). Data were expressed as mean, ± standard deviation (SD), and percentage (Table 2). To clarify the characteristic of patients exhibiting (or not exhibiting) compensatory movements whose active ROM values are less than passive for left or right shoulder flexion, use of descriptive statistics indicated that patients whose ImageJ data measured values (Active ROM) were lower than Goniometer values (Passive ROM), by 21 degrees or more were extracted (Table 4). Statistical analysis used Microsoft Excel and SPSS 21.0 statistical software (IBM Corporation). The statistical significance was set at $p < 0.05$.

Evaluation of drug-induced Parkinsonism

Patients selected were those with Parkinson's syndrome due to long-term use of antipsychotic medications rather than dementia and motor dysfunction due to Parkinson's disease, itself. The severity of the extrapyramidal symptoms was assessed by the DIEPSS (37). A total score of 5 or higher in the five items (gait, bradykinesia, sialorrhea, rigidity, and tremor) indicates Parkinsonism (38). Evaluation of drug-induced movement disorders focused on impaired upper limb movement was conducted only for patients taking antipsychotic drugs. As detailed in their medical records, except those taking antipsychotic medications none of the subjects in this study had been diagnosed with Parkinsonism.

Evaluation of dementia

Changes in cognitive abilities were assessed by conducting the HDS-R test (39). The total score range of the nine items on the HDS-R score is from 0 to 30, with lower scores indicating more severe cognitive deficits. The cut-off point for screening dementia is set between 20 and 21 (39). Kato, *et al*. reported that the degree of dementia is as follows : Non-dementia : 24.27 ± 3.91, Mild : 19.10 ± 5.04, Moderate : 15.43 ± 3.68, Relatively severe : 10.73 ± 5.40, Severe : 4.04 ± 2.62 (39). HDS-R was utilized to measure changes in cognitive abilities for only those patients diagnosed with dementia.

Procedure for data collection

The "Rajio taisō" radio calisthenics program was started in Japan in 1928. The recorded "Rajio taisō Dai-ichi" and corresponding instructional video with music broadcast by NHK (NIPPON HOSO KYOKAI) radio for calisthenics activities was used to support active ROM exercises. The total duration of the exercise program was approximately three minutes. This exercise consisted of swinging the upper limbs forward and backward, and from left to right, and bringing the maximum shoulder ROM flexion forward and in abduction during the calisthenics (18).

Procedure for measuring shoulder joint ROM

1) Measurement method for passive ROM before the calisthenics exercises using a goniometer

The physical therapist measured shoulder ROM of patients using a goniometer before starting the Radio calisthenics program. These procedures were based on the methods identified by the Japanese Orthopedic Association, and the Japanese Association of Rehabilitation Medicine (40). In forward flexion, the normal range is from 0 to 180 degrees. In abduction, the normal range is from 0 to 180 degrees (41). The angle of forward flexion and abduction of the left and right shoulder joints' passive ROM before calisthenics was measured using the goniometer (Figure 1. (a), (b)), by a physical therapist with seven years of clinical experience.

To accurately evaluate the basic axis and the movement axis, the bones (acromion, humerus head, distal humerus/near the humeroradial joint) were palpated over the individual's clothes. Trunk shape was confirmed before the measurement so that the margin of clothes was excluded in the measurement.

2) Measurement method using ImageJ during active ROM exercises

Three-dimensional motion capture systems, such as Vicon, have been widely used with increased accuracy (42). However, as these technologies can be costly and are unavailable in many clinical settings (43), the ImageJ open-source software is considered particularly for measuring the ROM of the upper limbs during exercise (44). An experiment showing measurement accuracy using ImageJ and visual estimation and goniometry indicated that general digital photography can display similar accuracy and precision as that of optical approximation and goniometry (45).

3 dimensional (3D) motion capture is considered the "gold standard" for motion recording and analysis. However, analysis results using 3D motion capture and 2D video analysis show a moderate to strong correlation between sagittal measurements, despite the lack of accuracy and ability to capture rotations (46). Thus, 2D video analysis is a reasonable and inexpensive option for kinematic assessment during exercise.

Shoulder joint ROM while exercising was measured by ImageJ, a public domain image processing and analysis program developed by the Research Services Branch (RSB) of the National Institute of Mental Health (NIMH), which is part of the National Institutes of Health (NIH) (47), an open-source image-processing platform intended for scientific multidimensional images. Therefore, ImageJ was selected for this experiment because the software is also available without cost.

Three digital video cameras were used for collecting images during the calisthenics program. These cameras were strategically positioned to take three views : 1. front, 2. left, and 3. right.

1. The front still image was used to evaluate the left and right shoulder joint abduction, 2. The left still image was used to evaluate the left shoulder joint flexion, and 3. The right still image was used to evaluate the right shoulder joint flexion. The still image taken from digital video recording that the author judged to be the maximum ROM for both shoulder flexion and abduction was retained. Subsequently, using this image, the joint angle for maximum ROM of the forward flexion and abduction was measured by ImageJ (Figure 1. (c), (d)).

Measurement accuracy of passive ROM

In measuring the accuracy of passive ROM, a range of measurement errors can occur due to variability of measurements when performed by different therapists, neurosurgeons, and/or psychiatrists. These measures can fluctuate from 0.5 to 11.1 degrees because of variation in human measurements (48). In comparison, the measurement of shoulder flexion using a digital application has the potential for error (approximately 6 to 11 degrees), which exceeds that taken by therapists (49, 50).

Validity in values of the shoulder joint ROM in ImageJ

The passive and active ROM of each was measured using a goniometer for flexion and abduction. The validity of the agreement of the measurements obtained using ImageJ with those obtained using a goniometer utilizing the Wilcoxon signed-rank test.

There was no significant difference between the values measured by the therapist using a goniometer and values measured by ImageJ for the left shoulder flexion (z=-0.94, p=0.35) and

right shoulder forward flexion (z=-0.32, p=0.75). However, significant differences were observed in the left shoulder abduction (z = -4.35, p < 0.001) and right shoulder abduction (z = -3.09, p < 0.01). When the laterality of the measured values with ImageJ was confirmed, no laterality was observed either in forward flexion (z = -0.97, p = 0.33) or in Abduction (z = -1.9, p = 0.06) (Table 1). Thus, this study decided to examine only the measured data of shoulder forward flexion.

Evaluation of compensatory movement on shoulder joint low ROM

Direct factors causing upper limb compensatory motion include shoulder pain (51) : psychiatric disorders such as schizophrenia (52) ; dementia (53) ; and cerebral infarction (54).

Indirect factors also contribute to the development of joint disorders. These include continued long-term symptoms that lead to poor alignment of the body, eventually emerging into dysfunctions of the shoulder joint, causing compensatory movements such as upper limb motion condition by ADL level (55). Also included is upper limb compensatory motion condition due to diabetes mellitus (56) and upper limb compensatory motion condition by vertebral compression fracture (57).

Normally, healthy people can use their full elbow flexion (150 degrees) for personal care, eating, and doing other manual tasks. The normal shoulder flexion and abduction of about 130 degrees are necessary for everyday tasks (58). Therefore, those with disuse syndrome and limited ROM with shoulder flexion/abduction of 130 or less are presumed to use some kinds of compensatory movement in their daily lives.

In this study, compensatory movements were those that were confirmed using measured passive ROM by the therapist.

Physical performance in ADL evaluated by the Barthel Index

The chief nurses of the psychiatric ward and of the nursing home evaluated patients utilizing BI, a commonly used assessment tool for appraising somatic performance in ADL. The tool includes ten activities : eating, toileting, showing, grooming, putting-on clothes, bowel and bladder control, transferring to a chair, climbing stairs and walking. With higher BI scores, a higher level of ADL of patients is illuminated (59). Most of the former studies apply the 60/61 cutting point (60, 61). Therefore, in this study, the patients were grouped into High ADL with BI scores of 60 and greater (or the Partly Support Needs or Independent Activities group), and Low ADL with BI scores of less than 60 (or the Completely Dependent Level group).

Ethical considerations

Approval to conduct the study was obtained from the Ethics Committee of the Tokushima University Hospital (#3046) and the Mifune Hospital Clinical Research Ethics Review Committee, where the study was conducted (#20180502). Informed consent was acquired from patients and their guardians as required before the start of the study. All patients and their guardians were informed regarding the purpose and methods used in the study assuring them that their personal information would be protected and kept in a secure location within the researchers' office under lock and key ; and that the results will be reported as an aggregate. The participants were informed that the data generated would be used only for research purposes.
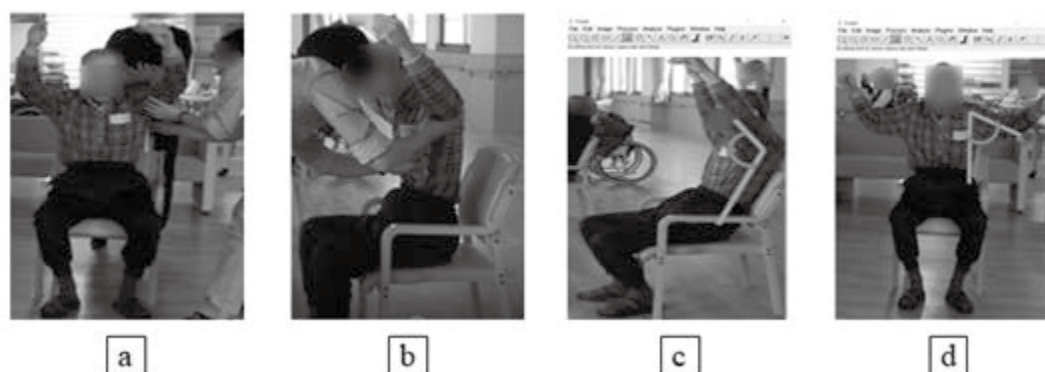

Figure 1.   The measurement method of patients' shoulders joint ROM. Notes : A physical therapist measured passive ROM of the shoulder joint (a) forward flexion and (b) abduction angle of the shoulder joint using a goniometer. In addition, active ROM of the shoulder joint (c) forward flexion and (d) abduction angle was measured using ImageJ during exercise.

Table 1.   The validity of the shoulder joint ROM by the measurement methods : goniometer vs ImageJ (N = 54).

Shoulder joint		Measured by goniometer			Measured by ImageJ			z	p
		Minimum	Median	Maximum	Minimum	Median	Maximum		
Forward flexion	Left	45°	120°	165°	24°	127°	167°	-0.94	0.35
	Right	15°	120°	155°	20°	120°	166°	-0.32	0.75
Abduction	Left	40°	135°	180°	12°	121°	174°	-4.35	***
	Right	40°	140°	175°	25°	130°	168°	-3.09	**
Laterality		Measured by ImageJ (Left)			Measured by ImageJ (Right)			z	p
		Minimum	Median	Maximum	Minimum	Median	Maximum		
Forward flexion		24°	127°	167°	12°	121°	174°	0.97	0.33
Abduction		20°	120°	166°	25°	130°	168°	1.9	0.06

Note : Wilcoxon signed-rank test, measured by a goniometer : Passive shoulder ROM measured by the therapist using a goniometer before exercise, measured by ImageJ : Active shoulder ROM measured by ImageJ during exercise, z : z value, ** p < 0.01, *** p < 0.001.

RESULTS

Patients' characteristics

Demographic data are shown in Table 2 : average age (N = 54) (mean± standard deviation) 75.72 ±11.30 years old ; BI (N = 54) 51.85 ± 31.42 points ; HDS-R (N = 17) 10.65 ± 3.60 points ; DIEPSS (N = 31) 3.81 ± 2.60 points ; Length of psychiatric hospital stay (N = 31) 36.13 ± 19.84 years ; Men (N = 20) (37.04 %) and Women 34 (62.96%).

Patients' primary diagnoses were schizophrenia, 26 (48.15 %), dementia 17 (31.48 %), and other diseases 11 (20.37%). Thirty-three out of 54 patients (61.11%) exhibited a compensatory movement. Physical problems were classified into the Low ADL group (BI < 60) 37 (68.52%) and High ADL group (BI > 60) 17 (31.48%).

Table 2.   Primary and comorbid diseases, compensatory movements, and activities of daily living (N = 54).

Items	Value	
Average age	75.72 ± 11.30	years old
Barthel Index (BI)	51.85 ± 31.42	points
DIEPSS for **Schizophrenia** (N = 26) (a)	10.65 ± 3.60	points
HDS-R for **Dementia** (N = 17)	3.81 ± 2.60	points
Length of psychiatric hospital stay (N = 31) (b)	36.13 ± 19.84	years
Gender	Men (N = 20) (37.04 %)	Women (N = 34) (62.96%)
Diagnosis	**N (%)**	**ICD-10 code**
Primary disease		
Schizophrenia	**26 (48.15)**	F20
Dementia	**17 (31.48)**	F00-F03
Alzheimer's disease	9 (16.67)	F00
Senile dementia	4 (7.41)	F02
Cerebrovascular disease	3 (5.56)	F01
Mixed dementia	1 (1.85)	F02
Other diseases (c)	**11 (20.37)**	
Depression	3 (5.56)	F32
Organic mental disorder	2 (3.70)	F09
Epileptic mental disorder	1 (1.85)	F44
Organic personality disorder	1 (1.85)	F07
Intellectual disability	1 (1.85)	F79
Cerebral hemorrhage	1 (1.85)	I61
Hypertension	1 (1.85)	I10
Angina pectoris	1 (1.85)	I209
Comorbid diseases (c)		
Hypertension	20 (37.04)	I10-I15
Diabetes mellitus	11 (20.37)	E11
Parkinsonian syndrome	10 (18.52)	20052619
Shoulder pain	5 (9.26)	20060301
Vertebral compression fracture	5 (9.26)	20067079
Cerebrovascular disease	4 (7.41)	I60-I69
Angina pectoris	3 (5.56)	I20
Chronic obstructive pulmonary disease	2 (3.70)	J44.9
Mental retardation	2 (3.70)	F70-F79
Delirium	2 (3.70)	F05
Bipolar disorder	2 (3.70)	F31
Depressive illness	2 (3.70)	F32
Manic psychosis	1 (1.85)	F30
Severe mental retardation	1 (1.85)	F72
Myocardial infarction	1 (1.85)	I20-I25
Cardiac insufficiency	1 (1.85)	I50
Existence compensatory movement	**33 (61.11)**	
No existence compensatory movement	**21 (38.89)**	
Low ADL	**37 (68.52)**	
High ADL	**17 (31.48)**	

Abbreviations : N : Number, ICD-10 : Tenth revision of the International statistical Classification of Diseases and related health problems. ADL : Activities of daily living. DIEPSS : Drug-Induced Extrapyramidal Symptoms Scale, HDS-R : Hasegawa's Dementia Scale-Revised. Note : (a) 6 patients did not receive DIEPSS or HDS-R. (b) 23 patients were older adults with dementia who have attended day care of a geriatric healthcare facility, or older adult residents of a geriatric healthcare facility attached to this psychiatric hospital. (c) One patient had several diseases.

Differences due to attributes in shoulder joint ROM forward flexion : goniometer vs ImageJ.

There was no significant difference between the passive ROM measured by a goniometer and the active ROM measured by the ImageJ related to the disease group, ADL level, and shoulder ROM limitations.

However, analysis using compensatory movements as a factor, identified a significant difference between the passive and active ROM : existence group, left side ($z = -2.30$, $p = 0.02$) ; nonexistence group, right side ($z = -2.63$, $p < 0.001$) (Table 3).

Characteristics of patients exhibiting or no exhibiting compensatory movements whose active ROM values are smaller than passive for left or right shoulder flexion

Table 4 (a) shows data of patients (N = 3/33) exhibiting compensatory movements whose active ROM values are lower than passive ROM with left shoulder flexion. Table 4 (b) shows patients not exhibiting compensatory movements (N = 7/21), and patients whose active ROM values are lower than the passive ROM of the right shoulder flexion.

Characteristics of patients have included age, primary disease, comorbid disease, DEIPSS, Length of psychiatric hospital stay (LOS), HDS-R, and BI values.

DISCUSSION

In this study, the average age of patients was 75.72 years, and the average BI was 51.85 points. The percentage of BI in the Low ADL group was 68.52% and persumed to have limited physical activity and reduced physical function. It was considered that the factors related to compensatory movements, their comorbid disease, were "Parkinsonism syndrome (18.52%)," and "shoulder joint pain (9.26%)." As an indirect factor, disuse syndrome accounted for 69.70%, which is considered a large effect. For patients with dementia, the average HDS-R score was 10.65 points, indicating relatively severe dementia.

Several studies have shown that persons diagnosed with psychiatric disorders in particular with schizophrenia and dementia often have ROM issues (6, 7, 11, 62). Therefore, it is important to assess ROM in these persons, particularly for determining rehabilitation outcomes.

Sophisticated and cost-effective clinical measurement tools are needed to provide accurate and dependable assessment of the ROM of patients with psychiatric disorders. When the values measured by the therapist using a goniometer and the values measured by ImageJ were compared, no significant difference was observed between the left and right shoulder joint flexion. Moreover, the laterality of the measured values with ImageJ was confirmed ; no laterality was observed in either forward flexion ; there was no difference between the left and right ROM

Table 3. Differences due to attributes in shoulder joint ROM forward flexion : goniometer vs ImageJ.

			Measured by goniometer Passive ROM			Measured by ImageJ Active ROM				
			Min	Med	Max	Min	Med	Max	z	p
Disease group (d)	Schizophrenia (N = 26)	Left	70°	120°	165°	90°	131°	167°	-1.69	0.09
		Right	15°	118°	155°	20°	124°	166°	-0.90	0.37
	Dementia (N = 17)	Left	45°	120°	140°	24°	126°	161°	-0.21	0.83
		Right	70°	120°	145°	51°	117°	152°	-0.73	0.46
	Others (N = 11)	Left	80°	115°	135°	60°	104°	160°	-0.31	0.75
		Right	105°	120°	140°	73°	108°	161°	-1.33	0.18
Barthel Index for Activities of Daily Living	Less than 60 (N = 37)	Left	45°	115°	140°	24°	120°	161°	-0.11	0.92
		Right	15°	115°	145°	20°	113°	161°	-0.74	0.46
	Greater than 60 (N = 17)	Left	70°	135°	165°	97°	145°	167°	-1.85	0.07
		Right	105°	135°	155°	103°	140°	166°	-0.73	0.46
Range of motion limitation	Less than 130	Left (N = 37)	45°	110°	125°	24°	116°	160°	-0.05	0.96
		Right (N = 38)	15°	115°	125°	20°	112°	152°	-0.00	1.00
	Greater than 130	Left (N = 17)	130°	135°	165°	114°	147°	167°	-1.91	0.06
		Right (N = 16)	130°	140°	155°	101°	142°	166°	-0.47	0.64
Exhibiting compensatory movements	Existence (N=33)	Left	45°	115°	145°	24°	129°	167°	-2.30	0.02
		Right	15°	115°	150°	20°	122°	166°	-1.41	0.16
	Nonexistence (N=21)	Left	105°	125°	165°	64°	123°	165°	-1.93	0.05
		Right	105°	125°	155°	58°	115°	151°	-2.63	0.00

Note : Wilcoxon signed-rank test, measured by a goniometer : Passive shoulder ROM measured by the therapist using a goniometer before exercise, measured by ImageJ : Active shoulder ROM measured by ImageJ during exercise, Min : Minimum, Med : Median, Max : Maximum, z : z value. Note : (d) Differences among diseases were not significant differences, by Kruskal-Wallis test (Passive ROM Left : H = 1.02, p = 0.60, Right : H = 0.73, p = 0.69, Active ROM Left : H = 3.23, p = 0.20, and Right : H = 3.98, p = 0.14).

Table 4.   Characteristics of patients exhibiting or no exhibiting compensatory movements whose active ROM values are smaller than passive for left or right shoulder flexion.

#	Age	Primary disease	Comorbid disease	DIEPSS	LOS	HDS-R	BI
(a) Exhibiting compensatory movements (N=3/33), Left							
1	92	Senile dementia	Parkinsonian syndrome, Cerebrovascular disease	6	5	13	10
2	72	Cerebrovascular dementia	Hypertension			6	25
3	78	Schizophrenia	Parkinsonian syndrome	1	63		15
(b) Nonexistence compensatory movements (N=7/21), Right							
4	67	Schizophrenia	Parkinsonian syndrome	7	29		50
5	89	Senile dementia	Cardiac insufficiency			13	40
6	89	Alzheimaer's disease	Hypertension, Vertebral compression fracture			13	20
7	64	Organic mental disorder		9	18		15
8	94	Depression	Hypertension, Delirium				10
9	80	Schizophrenia	Parkinsonian syndrome	5	50		10
10	60	Schizophrenia		1	36		100

Abbreviations : DIEPSS : Drug-Induced Extrapyramidal Symptoms Scale score. DIEPSS total score of 5 or higher in the five items (gait, bradykinesia, sialorrhea, rigidity, and tremor) indicate Parkinsonism. LOS : Length of psychiatric hospital stay. HDS-R : Hasegawa's Dementia Scale-Revised points. BI : Barthel Index score.

during exercise. Thus, ImageJ measuring technology was found to be capable of meeting these requirements, thus becoming a valuable measuring device.

As noted in Table 3, the active ROM on the left side of the compensatory movement group increased significantly during exercise when compared to before exercise. On the other hand, on the right side of the non-compensatory movement group, active ROM was significantly reduced during exercise. This confirmed that the group with compensatory movements performed such movements during exercise with the left upper limb.

During active exercise of left and right shoulder joint forward flexion, as measured by ImageJ, some patients exhibited less than 130 degrees. Focusing on the group with measurement differences of minus 21 degrees or more shown in Table 4, the possibility of factors such as extrapyramidal and dementia symptoms the influence of compensatory movement and upper limb-lifting movement was considered. The findings revealed that four patients had Drug-Induced extrapyramidal symptoms of tremor and muscle rigidity, four patients with dementia had 6 to 13 points of HDS-R, and patients with psychiatric disorders had from 1 to 9 points of DIEPSS score. For two subjects with DIEPSS of 4 points or less, for whom muscle rigidity, tremor and bradykinesia were confirmed. It was considered since their influence on upper limb-lifting exercise is large, which indicates those patients were having difficulty performing their daily life activities.

To fully grasp the significance of these findings, it is critical to consider the effect of complications such as shoulder joint pain, Parkinsonism, and cerebrovascular accidents, which were confirmed to be direct factors of compensatory movement. Patients with the extrapyramidal symptoms shown in Table 4 were those who had exceptionally long hospital stays ranging from five to fifty years. In addition, with long-term drug use, drug-induced side effects greatly influence the upper limb-lifting exercise (63). Patient numbers (# 1, 4, 7, 9) in Table 4, who had a DEIPSS score of 5 points or more, were considered as being affected by drug-induced Parkinson's syndrome. The HDS-R scores of patient numbers (# 1, 2, 5, 6) were 6 to 13, in particular the patient with

dementia (#2), whose HDS-R scored of 6 points was evaluated as severe dementia, confirming that dementia affected differences in passive and active ROM exercises.

Patient numbers (# 1-9) have BI scores of 50 or less, meaning they require physical assistance. Therefore, physical effects could be considered as a cause in determining the differences between passive and active ROM. The patient number (# 10), whose BI score was 100 points, DIEPSS score was 1 point (Muscle Rigidity 1 point), and LOS was 36 years. Despite the long hospitalization period, there was no notable effect of physical or drug-induced Parkinson's syndrome, or negative symptoms or cognition due to schizophrenia. Therefore, it was believed that dysfunction affected differences in both passive and active ROM.

Additionally, it is possible that patients with psychiatric disorders cannot cope with hasty movements during exercise due to the effects of drug-induced Parkinsonism, and the same may be true for patients with cerebrovascular accidents due to abnormal muscle activation (64). Moreover, the effects of cognitive impairment and decreased motivation should be considered in this group since patients with schizophrenia suffer from cognitive dysfunction (65). Cognitive decline is also associated with manic-depressive illness, depression, and mania (66). Delirium symptoms are also a factor leading to cognitive decline (67) as well as dementia (68).

Apathy is broadly defined as a loss of incentive to do anything manifested as behaviors such as reduced commencement, poor resolution, lack of attention, meaninglessness, low social commitment, blunted the emotional reaction, and lack of intuition (69). Motivational deficits play a critical role in determining functional outcomes in schizophrenia spectrum disorders (70). Tam and Lam (71) suggested that executive dysfunction, depressive symptoms, apathy, and mild Parkinsonian signs were associated with functional disability. Forsell, *et al*. (72) pointed out that motivation symptoms increased sharply along with a decrease in cognitive function in older adults' sample.

Considered comprehensively, it is difficult to estimate the ROM and compensatory movements of the shoulder joints of the upper limbs with only the ADL evaluated by BI. Therefore,

DIEPSS or HDS-R evaluation must be conducted together with BI, and imaging results during exercise to assess the upper limb motor function of patients with psychiatric disorders. This integrated data set suggests that it is possible to accurately predict patients' ADL level and contribute to the formulation of a more specific rehabilitation plan.

Importantly, in psychiatry, physical rehabilitation, such as continuous physical activity of patients with schizophrenia and dementia shows an effective association not only with the maintenance and improvement of physical function but also with the improvement of cognitive function (16, 73). As reported in other studies, in order for patients with dementia to continue to exercise, it is necessary to attract their interest and maximize the ability of the exercise to entertain (74). In addition, enhancing motivation can lead to improvements in cognitive function of persons diagnosed with dementia (70). To maximize ROM in these patients, when performing group exercise therapy, subjects' cognitive function, motivation, evaluation of compensatory movement for rehabilitative intervention as well as their extrapyramidal symptoms require the utmost consideration.

LIMITATIONS

To extrapolate and then generalize results for all patients with psychiatric disorders in the Japanese population with schizophrenia and dementia, a larger sample should be recruited in the study. Methodological limitation was small sample sizes. In future research, a comparative study with normal older adults will be needed.

Moreover, a decline in patients' motivation to perform ROM because of their psychiatric disorders may affect outcome measurements. Compensatory movements associated with upper limb movements, especially shoulder movements include trunk movements, anterior-posterior flexion, lateral flexion, and cervical anterior-posterior flexion. From the viewpoint of image analysis, ImageJ is a two-dimensional analysis, and there is an implied limit to its measurement accuracy compared to a three-dimensional analysis.

CONCLUSION

This study clarified the usefulness of 2D video analysis for the evaluation of shoulder ROM during upper limb exercise in patients with psychiatric disorders. There was no significant difference between passive ROM measured by a goniometer and active ROM measured by ImageJ related to the disease group, ADL level, or shoulder ROM limitations. In analysis using compensatory movements as a factor, however, a significant difference was found between the passive and active ROM on the left side in the existence group and the right side in the nonexistence group. This factor included Parkinsonism, cerebrovascular disease, and cognitive dysfunction. Thus, compensatory movements should be seen as principal concerns. The findings revealed that the evaluation of compensatory movements together with video imaging, is useful in developing rehabilitation plans for patients with chronic mental disorders.

CONFLICT OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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