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Prediction of changes in functional ability of inpatients with schizophrenia using logarithmic and linear regression modelling

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Abstract

Background/Objective: Few studies have addressed the type of time course regression that can predict changes in functional ability in inpatients with schizophrenia. This study investigated the possibility of predicting changes in functional ability by logarithmic and linear regression modelling when treating schizophrenia.

Methods: This longitudinal study included two analysis rounds. Analysis 1 comprised 40 inpatients (male/female: 16/24, mean age: 39.7 ± 13.5 years) for the identification of the time course of changes in functional ability based on the Activity Profile Scale for Patients with Psychiatric Disorders score from the group data. Analysis 2 comprised 17 inpatients (male/female: 9/8, mean age: 38.5 ± 9.4 years) to ensure correlation of the group data with the prediction of each individual's degree of functional ability.

Results: In Analysis 1, Activity Profile Scale for Patients with Psychiatric Disorders score was assessed at the initial occupational therapy visit, one week and one month thereafter, and at discharge; logarithmic modelling using the scores at the initial visit, one month later and at discharge was more suitable ($R^2 = .506$, $p < .001$) than the logarithmic and linear regression models using other score combinations. In Analysis 2, the individual's predicted Activity Profile Scale for Patients with Psychiatric Disorders scores at discharge, as calculated by logarithmic modelling using scores from the initial visit and one month later, correlated moderately with actual Activity Profile Scale for Patients with Psychiatric Disorders scores ($R^2 = .574$, $p < .001$; ICC = .747, $p < .001$).

Conclusion: Logarithmic modelling based on Activity Profile Scale for Patients with Psychiatric Disorders score accurately predicted changes in the functional ability of inpatients with schizophrenia and is sufficiently uncomplicated to be adopted in daily clinical practice.

Keywords

Functional ability, longitudinal study, predictive model, occupational therapy, schizophrenia

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Introduction

Predicting change in functional ability as an underlying index of everyday functioning is important to obtain information regarding social adjustment for inpatients with schizophrenia. Everyday functioning indicates functional outcome of the community life of people with schizophrenia and involves three functional domains: social functioning (the ability to interact

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with others), vocational functioning (the ability to solve problems at work), and community functioning (the ability to perform daily activities) (Bowie et al., 2010, 2008; Mantovani, Teixeira, & Salgado, 2015). To measure everyday functioning, previous studies focused on consideration of the following two points in the assessment: (1) assessment of real-world functioning (what a person does in the community), which directly measures the degrees of the three domains of everyday functioning in real-life situations; and (2) assessment of functional ability (what a person does when performing key parts of everyday activities, measured by the performance of simulated activities in the clinic or examination room), which is a single domain of everyday functioning (Green et al., 2008; Mantovani et al., 2015).

To assess real-world functioning, some assessment scales are composed of self-reported questionnaires or assessments based on information from an informant regarding social, vocational, and community functioning aspects of everyday functioning (Harvey et al., 2011; Rosen, Hadzi-Pavlovic, & Parker, 1989; Schneider & Struening, 1983; Wallace, Liberman, Tauber, & Wallace, 2000); others are composed of interviews with patients or caregivers, following standard instructions for examining outcomes of everyday functioning (Birchwood, Smith, Cochrane, Wetton, & Copestake, 1990; Heinrichs, Hanlon, & Carpenter, 1984). However, assessment instruments for measuring real-world functioning might be inadequate for accurately predicting outcomes of everyday functioning relative to individual environmental factors or within the subjective experience of patients or caregivers, even though measurements of everyday functioning traditionally focus on the endpoint of real-world functioning (Green et al., 2008; Mantovani et al., 2015).

In contrast, assessment instruments for measuring functional ability largely comprise direct observational measures based on patient performance in simulated real-life situations and have methodological advantages in that quantitative results of objective assessments can be obtained (Mantovani et al., 2015). The Activity Profile Scale for Patients with Psychiatric Disorders (APS) (Kawaguchi et al., 2015) and other instruments (Atsumi & Ohbuchi, 2002; Margolis, Harrison, Robinson, & Jayaram, 1996; Ohata et al., 2010) can be used to assess task processing skills and interpersonal skills of patients participating in occupational therapy. Similar measurements are conducted by direct observation of patient performance in role-play situations to assess processing skills and social skills within daily activities (Green et al., 2008; Patterson, Goldman, McKibbin, Hughs, & Jeste, 2001a) or social problem-solving skills (Bellack, Brown, & Thomas-Lohrman, 2006; Donahoe et al., 1990; Patterson, Moscona, McKibbin, Davidson, & Jeste, 2001b).

Many previous long-term follow-up studies in schizophrenia focused on functional outcomes or recovery of cognitive function after treatment (Milev, Ho, Arndt, & Andreasen, 2005; Rund, 1998). Functional ability might relate more closely with improvements in cognitive function that strongly predict the outcomes of everyday functioning (Leifker, Bowie, & Harvey, 2009; Menendez-Miranda et al., 2015) and be reflected earlier in functional recovery after treatment, rather than in real-world functioning (Mantovani et al., 2015). Furthermore, competence in social and living skills related to functional ability was reported as a mediator between cognitive functions and the three domains of everyday functioning when functional abilities and neuropsychological function typified by symptoms and cognitive function in schizophrenia were involved as factors in constructing predictive models of everyday functioning (Bowie et al., 2008; Bowie, Reichenberg, Patterson, Heaton, & Harvey, 2006). Moreover, functional ability determined through performance-based measures provides more comprehensive information, via assessment of everyday functioning, than any single measurement of cognitive function (Heinrichs, Ammari, Miles, & McDermid Vaz, 2010; Mantovani et al., 2015). Hence, assessment of functional ability provides an alternative to the co-primary measurement of everyday functioning in schizophrenia (Green et al., 2008).

However, few studies have addressed whether the prognosis for functional ability can be predicted by assessment during early stages of treatment or whether time course regression can predict changes in functional recovery in schizophrenia. If the time course of changes in the functional ability of patients with schizophrenia is revealed by logarithmic and linear regression modelling, as in other diseases (Koyama, Matsumoto, Okuno, & Domen, 2005; Suzuki et al., 2013; Watanabe et al., 2016), we can obtain useful and highly practical information regarding how patients with schizophrenia might recover in clinical situations. Comparison between logarithmic and linear regression models is necessary to determine which model is better suited for schizophrenia as previous studies have shown the applicability of both logarithmic and linear regression models (Suzuki et al., 2013; Watanabe et al., 2016).

In the present study, to predict the recovery of functional ability of inpatients with schizophrenia, we used the APS (Kawaguchi et al., 2015) as a simple and comprehensive observation measure with elements of task processing skills and interpersonal skills, and as an outcome measure that reflects changes in the degree of functional ability during rehabilitation. In comparison with other assessment scales (Atsumi & Ohbuchi, 2002; Margolis, Harrison, Robinson, & Jayaram, 1996; Ohata et al., 2010), the APS was determined to be suitable for this study at the points that it can be used in the context of Japanese, it is easy to apply clinically as there are few items, and it is not affected by differences in recovery period between inpatients with schizophrenia. We hypothesised that (a) the time course of the initial phase of change in the recovery of functional ability could be approximated in a logarithmic model, as in previous studies (Koyama et al., 2005; Suzuki et al., 2013; Watanabe et al., 2016), and (b) recovery of functional ability could be accurately predicted by a logarithmic model. Therefore, we conducted a longitudinal study to investigate the possibility of predicting recovery of functional ability over time by logarithmic and linear regression modelling of changes during the treatment of schizophrenia.

Material and methods

Participants

We used consecutive sampling to collect data. The eligibility criteria included patients with schizophrenia, hospitalisation for >1 month, and participation in a programme of psychiatric occupational therapy. The diagnosis of schizophrenia was based on the ICD-10 diagnostic criteria. Patients who satisfied the eligibility criteria were randomly divided by random number table into two analysis rounds (Analysis 1 and 2) to analyse data for predicting the recovery of functional ability. Data in Analysis 1 were analysed to identify the time course of recovery of functional ability within the group data and to construct predictive models. Data in Analysis 2 were analysed to predict individual scores by logarithmic or linear regression modelling, based on the individual slope of the early phase of change of functional ability, and to ensure that the correlation of the group data applied to the prediction of each individual's degree of functional ability.

Sample size in Analysis 1 was based on a desired 90% statistical power to detect a 0.5 effect size (r) in the APS score, with a two-sided α of 5%. A sample size of 38 was derived by insertion of 1-power (0.90), α (0.05), and effect size (0.50) values in the Hulley, Cummings, Browner, Grady, and Newman (2013) matrix. In addition, we adopted a stricter sample size estimation in Analysis 2 for accurate prediction. Sample size in Analysis 2 was based on a desired 90% statistical power to detect a 0.7 effect size (r) in the APS score, with a two-sided α of 5%. A sample size of 17 was derived by insertion of 1-power (0.90), α (0.05), and effect size (0.70) values in the Hulley et al. (2013) matrix. We therefore planned to recruit approximately more than 38 and 17 patients for Analysis 1 and 2, respectively.

All patients received standard psychotherapy and psychopharmacologic treatment. This study was approved by the Kitasato University Medical Ethics Organization (KMEO B13-45). All participants were given a brief explanation of the study aims and testing procedure prior to participation. Written informed consent was obtained from each participant. This study was performed in accordance with the Declaration of Helsinki.

Assessment of functional ability

To predict the recovery of functional ability of inpatients with schizophrenia, we used the APS as a simple observational measure. The APS contains six domains of task processing skills and interpersonal abilities that were found useful for the comprehensive evaluation of functional capabilities in a previous study (Gladsjo et al., 2004; Vesterager et al., 2012): Motivation, Comprehension, Concentration, Performance skill, Social interaction, and Conformity. Each domain is rated on a 5-point scale (1: Severe disability, 2: Moderately severe disability, 3: Moderate disability, 4: Slight disability, 5: No significant disability) by occupational therapists. APS scores range from 6 to 30, with higher scores indicating higher functional abilities. Previous research verified the internal consistency reliability (Cronbach's $\alpha = .84$), test–retest reliability (intraclass correlation coefficient (ICC) = .85), and simple factor structure of the APS (Kawaguchi et al., 2015). This assessment scale based on the observation of inpatients was used to assess functional ability in occupational therapy programmes. Compared with other assessments of functional ability (Bellack et al., 2006; Donahoe et al., 1990; Patterson et al., 2001a, 2001b), APS assessment does not require special simulated situations, and it can be measured on the basis of patient performance in conventional rehabilitation programmes.

Procedure

Assessments with the APS were performed on four occasions each for Analysis 1 and Analysis 2: initial assessment at the time occupational therapy began (first assessment), at one week (second assessment) and one month (third assessment) after the first assessment, and at patient discharge (fourth assessment). All patients participated in occupational therapy programmes consisting of leisure activities, personal activities of daily living, sports, and psycho-education and social skills training for 2–5 days per week. Each programme contained performance scenes that could be evaluated for assessment of the APS domains. The assessment of APS was conducted by two occupational therapists. In addition, assessment with the Global Assessment of Function scale was carried out by the attending psychiatrist at patient hospitalisation and discharge.

Modelling and data analysis

To assess the inter-rater reliability of APS assessment scores between the two occupational therapists in this study, ICC values were determined to compare the APS scores at the initial assessment with those at one week using the data from 13 participants.

We conducted statistical analysis for the following purposes using patient data that were randomly divided into the Analysis 1 and Analysis 2 rounds. In Analysis 1, Friedman's test was used to compare time course differences in APS scores. For post hoc analyses, significant differences in APS score between the initial assessment and each time point assessment were analysed using the Shirley–Williams multiple comparison test. In addition, to identify the time course of recovery of functional ability in the group data and to construct predictive models, logarithmic (Koyama et al., 2005; Suzuki et al., 2013; Watanabe et al., 2016) and linear regression analyses (Suzuki et al., 2013; Watanabe et al., 2016) were performed with the group data using the following formulae: $f(t) = a + b\ ln\ (t)$ and $f\ (t) = a + b\ (t)$, where t is the number of days since the beginning of the occupational therapy programme, a is the APS score at the first assessment, and b is the slope of the changes in functional ability at three time points (first, second, and fourth assessments, or first, third, and fourth assessments). We used the APS scores at one week and at one month because functional recovery in schizophrenia requires substantial time (Robinson, Woerner, McMeniman, Mendelowitz, & Bilder, 2004). Thus, we analysed the appropriateness of the timing of the assessment by comparison with the second and third assessment scores. Therefore, four logarithmic and linear regression models using the group data of APS scores at the initial, one-week, and discharge assessments, or at the initial, one-month, and discharge assessments, were mutually compared. To assess the fit of the predictive model for the time course of recovery of functional ability and to choose the most applicable model, we tested the fit between actual APS scores and predicted APS scores according to the linear regression analysis and the coefficient of determination (R^2).

In Analysis 2, to investigate the predictive possibility of each individual's degree of functional ability based on the applicable models chosen in Analysis 1, and to assess the applicability of the predictive models based on the individual slope of the early phase of change of functional ability, we calculated the predicted APS score at discharge (fourth assessment) by using APS scores at two time points (first and second assessments or first and third assessments). For each patient, the change in their score between these two measured time points was used as the basis for the scaling coefficient in the equation, using the following formulae: $a_{log} = a_1 + (a_{2or3} - a_1)\ [ln\ (t_2/t_1)]^{-1}\ ln\ (t_4/t_1)$ and $a_{lin} = a_1 + (a_{2or3} - a_1)\ (t_2 - t_1)^{-1}\ (t_4 - t_1)$, where a_{log} is the predicted APS score by the logarithmic model, a_{lin} is the predicted APS score by the linear regression model, a_i is the APS score at the ith assessment, and t_i is the number of days since the beginning of the occupational therapy programme at the ith assessment. Thus, these equations could be tailored by substituting APS scores and the days of the two sampling points in the predictive model equation to forecast the functional ability of each patient. Further, they could calculate an individual's predicted APS score on the discharge date. To assess the applicability of the predictive model on an individual basis, the linear regression analysis, R^2, and ICC values for variance estimation were determined to compare the actual APS scores obtained (from the fourth assessment) with the predicted APS scores at discharge (derived from the model formula). Bland–Altman analysis was also performed in which plots with means and standard deviations (SDs) of the differences between actual and predicted APS scores were created. Plotting the difference against the mean allowed investigation of any possible relationship as measurement bias between actual and predicted APS scores. If the mean difference is zero and 95% of the values lie within two SD of the mean difference, it can be judged that the predicted APS scores have few errors and that the predictive model is applicable.

Statistical analyses were conducted using SPSS Statistics 19 software (IBM, New York, USA) for regression and reliability analyses and Excel Statistics version 2.0 for Macintosh (Esumi Co., Ltd, Tokyo, Japan) for the Shirley–Williams multiple comparison test. A p value of $< .05$ was considered statistically significant.

Results

Characteristics of the participants

Between January and December 2011, 57 consecutive schizophrenia inpatients who met the eligibility criteria were enrolled from the participating hospital; patients were randomly divided into two analysis groups, Analysis 1 and Analysis 2, to analyse data for predicting recovery of functional ability. Analysis 1 included 40 inpatients and Analysis 2 included 17 inpatients to satisfy the sample size calculations described in the 'Material and methods' section. APS scores and other characteristic data from Analysis 1 and Analysis 2 are shown in Table 1.

Identification of the time course of functional ability

The inter-rater reliability between the two occupational therapists was shown by analysis based on the assessment data of 13 participants (ICC = .840; 95% confidence interval (CI), .556–.948]; $p < .001$), indicating good reliability. In addition, the medians of the APS score on each occasion in the participants of Analysis 1 and in those divided into improved, maintained, and worsened inpatients at discharge are shown in Table 2. To confirm the capacity for constructing predictive models in Analysis 1, Friedman's test showed significant differences in APS score between the four occasions ($p < .001$). In addition, the Shirley–Williams multiple comparison test showed that APS score increased significantly over time compared with the initial APS score ($p < .05$; Figure 1).

In Analysis 1, to identify the time course of recovery of functional ability and to construct predictive models, we

Table 1. Participants characteristics of Analysis 1 and Analysis 2.

Characteristic	Analysis 1 ($n = 40$)	Analysis 2 ($n = 17$)
Age (years)	39.7 ± 13.5	38.5 ± 9.4
Male/female	16/24	9/8
Educational level (years)	12.4 ± 2.6	13.5 ± 2.3
(College/high school/junior high school)	(9/19/12)	(5/9/3)
Employment history (years)	5.7 ± 7.0	4.9 ± 5.2
(Full time/part time/no employment)	(24/9/7)	(12/2/3)
Marital status (Married/divorced/not married)	12/2/26	3/3/11
Years since onset (years)	10.7 ± 11.0	14.1 ± 11.3
Number of hospitalisations at this time	3.4 ± 2.7	4.0 ± 4.9
Duration of hospitalisation (days)	131.9 ± 85.6	123.6 ± 110.0
Number of days from admission to start of OT First assessment (day)	37.0 ± 39.7	51.5 ± 83.2
GAF score on admission	30.0 (25.0–45.0)	35.0 (22.5–40.0)
GAF score at discharge	55.0 (50.0–65.0)	60.0 (50.0–65.0)

Values are mean ± SD, n or median (interquartile range),
College: graduated from regular four-year college or junior college; GAF: Global Assessment of Functioning; high school: graduated from high school or vocational school; junior high school: graduated from junior high school; OT: occupational therapy.

Table 2. Values of APS scores on four assessment occasions and coefficient of determination for identification of the time course of APS scores (Analysis 1).

	At the initial day of OT	At one week	At one month	At discharge
APS score (total, $n = 40$)	21.5 (20.0–23.0)	22.5 (22.0–23.5)	23.0 (21.5–24.0)	23.0 (22.0–24.1)
Improved inpatient ($n = 31$)	21.5 (19.5–22.0)	22.0 (21.5–23.0)	23.0 (22.0–24.0)	23.5 (22.5–25.0)
Maintained inpatient ($n = 5$)	23.0 (22.0–23.5)	22.5 (22.0–25.0)	21.5 (21.0–23.0)	23.0 (22.0–23.5)
Worsened inpatient ($n = 4$)	24.5 (24.0–25.1)	23.5 (22.8–24.5)	22.5 (21.9–23.1)	22.3 (21.9–22.6)

	One week[a]		One month[b]	
Model	R^2	p	R^2	p
Logarithmic model	.087	.064	.506	< .001
Linear regression model	.005	.658	.155	.012

Values are median (interquartile range).
APS: Activity Profile Scale for Patients with Psychiatric Disorders; OT: occupational therapy; R^2: coefficient of determination.
[a]One week: analysis using the group data of APS scores at initial, one-week, and discharge assessments.
[b]One month: analysis using the group data of APS scores at initial, one-month, and discharge assessments.

compared the coefficient of determination between the following four models of logarithmic and linear regression formulae in the group data. The results of linear regression analyses and R^2 for the four models of logarithmic and linear regression formulae in the group data of all 40 participants are shown in Table 2 and Figure 2.

Logarithmic modelling using the group data of APS scores at the initial, one-month, and discharge assessments (first, third, and fourth assessments) revealed moderate R^2 values (.506, $p < .001$) and accurately estimated prediction of the recovery of functional ability (Figure 2(c)). Linear regression modelling using the group data of APS scores at the initial, one-month, and discharge assessments (first, third, and fourth assessments) revealed low R^2 values (.155, $p = .012$). In contrast, linear regression analysis based on scatterplots for linear regression modelling demonstrated floor/ceiling effects (Figure 2(d)). However, logarithmic and linear regression modelling using the group data of APS scores at the initial, one-week, and discharge assessments (first, second, and fourth assessments) revealed non-significant R^2 values; linear regression analysis based on scatterplots of these data also demonstrated floor/ceiling effects (Table 2, Figure 2(a) and (b)).

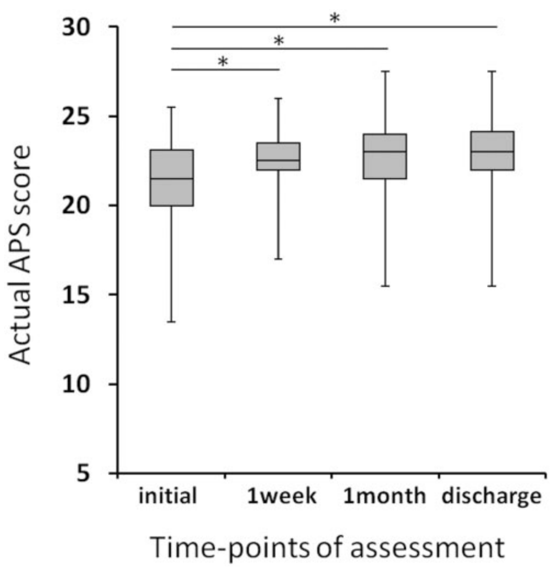

Figure 1. Time course of APS score. Box plots of APS score for each assessment point are shown. The middle line in the box: median; the ends of the box: interquartile range of the median; the T bars: ranges of data distribution; asterisk: $p < .05$ for difference in comparison with the initial APS score (the Shirley–Williams multiple comparison test). The APS scores increased significantly compared with the initial APS score (Friedman's test, $p < .001$). APS: Activity Profile Scale for Patients with Psychiatric Disorders.

Assessment of model fit

In Analysis 2, to investigate the predictive capacity of each individual's degree of functional ability based on applicable models, logarithmic and linear regression modelling using APS scores at the initial and one-month assessments (first and third assessments) was adopted because the R^2 of these models was statistically significant in Analysis 1. In addition, we used these models to calculate each individual's predicted APS score at discharge and assessed the applicability of the predictive models by comparing the coefficient of determination, variance estimation, and measurement bias between actual and predicted APS scores. The results of linear regression analyses, R^2, ICC determinations, and Bland–Altman plots for the agreement of the logarithmic and linear regression models of all 17 participants are shown in Table 3 and Figure 3.

Despite various time courses of change in individual APS scores, the R^2 value between actual and predicted APS scores at discharge (fourth assessment) was moderate for the logarithmic model using APS scores at initial and one-month assessments (first and third assessments) ($R^2 = .574$, $p < .001$). In addition, the

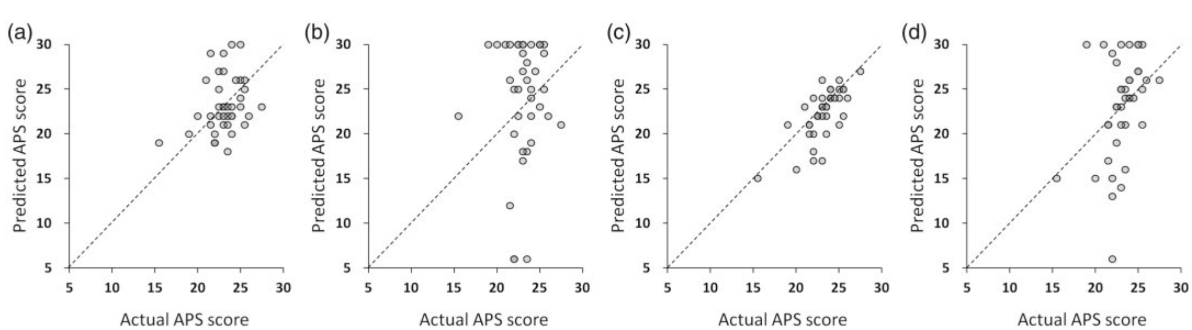

Figure 2. Scatterplots showing the relationship between actual and predicted APS scores in Analysis 1. Logarithmic model (a) and linear regression model (b) using group data of APS scores at initial, one-week, and discharge assessments. Logarithmic model (c) and linear regression model (d) using group data of APS scores at initial, one-month, and discharge assessments. APS: Activity Profile Scale for Patients with Psychiatric Disorders.

ICC value between actual and predicted APS scores at discharge was high for the logarithmic model (ICC = .747, $p < .001$). Furthermore, the Bland–Altman plots of actual and predicted APS scores showed that all data were included within the 95% CI (Figure 3(b)). In contrast, linear regression modelling using APS scores at initial and one-month assessments (first and third assessments) revealed non-significant R^2 values and ICC. Linear regression analysis and Bland–Altman plots of actual and predicted APS scores showed that the predicted APS score in the linear regression model exhibited proportional bias and varied more widely than the predicted APS score in the logarithmic model (Figure 3(d)).

Discussion

Predicting recovery of functional ability is important because functional ability is strongly involved in the prediction of mediators that determine the performance of community activities by people with schizophrenia (Bowie et al., 2006). The present results suggest that (a) the time course of change in the recovery of functional ability was more similar logarithmically than linearly regressive for the group data, and (b) APS scores sampled at two time points (initial and one-month assessments) by logarithmic modelling could be used to predict the pattern of individual recovery of comprehensive functional ability. These findings support the applicability of the logarithmic model for determining the predicted value of functional ability at discharge by estimating the trajectory of recovery of functional ability. In contrast, prediction based on linear regression modelling might be less useful for schizophrenia patients because the predicted APS score in this model increased without limit in association with an increase in the number of hospitalisation days.

We were able to predict functioning using logarithmic modelling based on observation of an assessment scale as in previous studies (Koyama et al., 2005; Watanabe et al., 2016) that showed the applicability of logarithmic modelling for predicting activities of daily living and behavioural functions in stroke and dementia patients. The present study also found that functional ability in inpatients with schizophrenia could be predicted by logarithmic modelling. We showed that logarithmic modelling can predict functioning of an individual with schizophrenia at discharge over various hospitalisation periods, whereas the predictive model in previous studies (Koyama et al., 2005; Suzuki et al., 2013; Watanabe et al., 2016) was used to assess applicability for all participants in a specific period. Furthermore, the present study showed that logarithmic modelling using the APS score based on brief observation assessments could predict recovery of functional ability for inpatients with schizophrenia during individual rehabilitation

Table 3. Coefficient of determination and variance estimation regarding assessment of model fit (Analysis 2).

Model	R^2	*p*	ICC	*p*
Logarithmic model	.574	<.001	.747	<.001
Linear regression model	.126	.162	.271	.138

ICC: intraclass correlation coefficient (indicates coefficient to quantify agreement between actual assessed APS score and predicted APS score using the predictive modelling); linear regression model: analysis using individual data of APS scores at initial and one-month assessments; logarithmic model: analysis using individual data of Activity Profile Scale for Patients with Psychiatric Disorders (APS) scores at initial and one-month assessments; R^2: coefficient of determination.

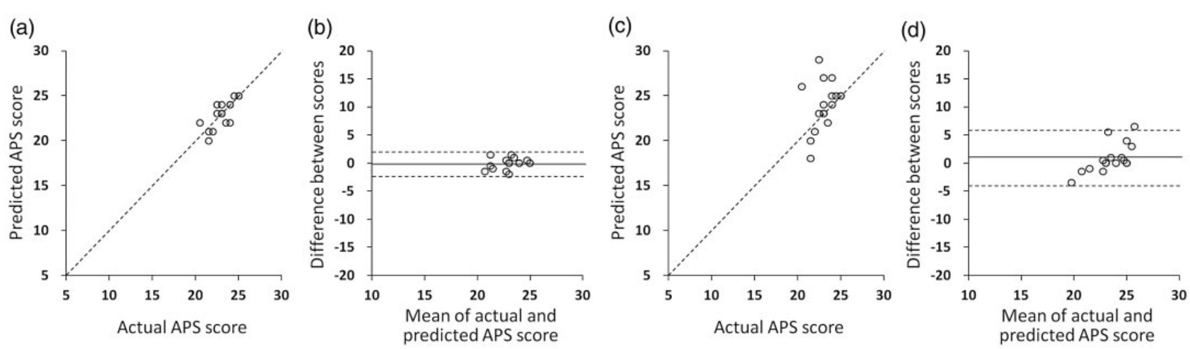

Figure 3. Scatterplots showing the relationship between actual and predicted APS scores, and associated Bland–Altman plots in Analysis 2. Linear regression analysis based on scatterplots (a) and Bland–Altman plots (b) in the logarithmic model using individual APS scores at the initial and one-month assessments. Linear regression analysis based on scatterplots (c) and Bland–Altman plots (d) in the linear regression model using individual APS scores at the initial and one-month assessments. Range between dashed lines in the Bland–Altman plots (b, d) represents ± 2 SD, which indicates the 95% confidence interval. APS: Activity Profile Scale for Patients with Psychiatric Disorders.

without the need for a simulated scene, as required with most conventional rating scales. This is important to individualised occupational therapy provided at the inpatient stage in order to reducing the rehospitalisation rate of patients with schizophrenia (Shimada, Nishi, Yoshida, Tanaka, & Kobayashi, 2016).

Studies of predictors of functional outcome in schizophrenia have reported that cognitive function is an important predictor of everyday functional outcome (Bowie et al., 2008, 2006; Green, Kern, Braff, & Mintz, 2000; Green, Kern, & Heaton, 2004; Harvey et al., 1998). Thus, assessment of schizophrenia-related functional ability may be appropriate (McClure et al., 2007) because functional ability is closely related to cognitive function, which strongly predicts outcomes of everyday functioning (Leifker et al., 2009; Menendez-Miranda et al., 2015). The development of a concrete measurement of prognostic prediction is important in the treatment of schizophrenia. The APS score, based on observation by medical professionals, consists of domains related to factors of cognitive function that are associated with functional ability in patients with schizophrenia (Gladsjo et al., 2004). It allows functional ability to be assessed through performance-based measures, which provide more comprehensive information based on everyday functioning than any single measurement of cognitive function (Heinrichs et al., 2010; Mantovani et al., 2015).

In the future, to reveal the sensitivity of the APS score to clinical changes and to obtain quantitative information regarding the recovery of functional ability in schizophrenia, the relationship between APS score and the effects of each programme will require investigation. The precision of prediction must be improved by adding variables such as disease severity to the predictive modelling based on the APS score. Analysis based on the estimation of minimal clinically important difference is required to determine the practicability of the predictive model. Further investigation is also required to determine whether the predictive model can be applied to inpatients receiving therapies other than occupational therapy. Furthermore, a larger number of participants are necessary to investigate more detailed information on the reproducibility and responsiveness of predictive modelling as the number of participants in the present study was small and the number of hospitalisation days varied widely in the data used for Analyses 1 and 2. However, after we included a variable (t_i) for the number of days in the model, high versatility of the mathematical model with regard to the APS was proven by recruiting both short- and long-term hospitalised participants. In addition, the predictive model constructed in the present study has unique characteristic such as being able to predict not only the inpatients with improved but also maintained or worsened functional ability.

Although recent studies (Bowie et al., 2008, 2006) have shown that assessment focused on functional ability is more sensitive to therapeutic interventions and less dependent on nonspecific environmental factors, sufficient consensus has not been obtained regarding the recovery of functional ability during the rehabilitation of individuals with schizophrenia. Importantly, logarithmic modelling with simple mathematical formulas may contribute to the prediction of recovery of functional ability by using APS scores determined at the initial and short-term stages of hospitalisation. In addition, it was possible to evaluate determinants of treatment success and to judge whether to change the intervention process by calculating an individual's predicted score of functional ability at an early stage.

Conclusion

The predictive model reported here can contribute widely to the drafting of goals and treatment plans for the rehabilitation of patients with schizophrenia and may serve as a tool for predicting recovery of functional ability as a basic index predictive of the outcome of everyday functioning after discharge. Logarithmic modelling based on the APS score accurately predicted changes in the recovery of functional ability in patients with schizophrenia and is sufficiently simple for adoption in daily clinical practice.

Declaration of conflicting interests

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