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ORIGINAL ARTICLE

Relationship between objective cognitive functioning and work performance among Japanese workers

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Abstract

Objectives: We aimed to explore the relationship between objective cognitive functioning and work performance among Japanese workers.

Methods: From February to November 2019, this cross-sectional study enrolled workers aged 18–65 years from 10 companies located in a metropolitan area of Japan. We emailed invitations to participate to employees of companies that had agreed to cooperate with the study. We measured work performance with the question, "How would you rate your performance (compared with your optimum performance) over the past 4 weeks?" Responses were made via a visual analog scale (range: 0–100). Cognitive functioning was assessed using the THINC-integrated tool (THINC-it®). THINC-it® is a brief, objective computerized cognitive assessment battery. Associations between work performance and cognitive functioning tests were examined using logistic regression analysis.

Results: In total, 353 individuals provided e-consent to participate, of whom 276 were included in the analysis (after omitting those with missing values). The median work performance was used to divide participants into high- (scoring ≥ 80%) and low- (scoring < 80%) performing groups. The *P*-values for trends indicated that association between cognitive domains, such as attention, executive functioning and working memory was significant ($P < .05$). Work performance was significantly associated with cognitive function for the two tests that assess attention, executive functioning, and working memory in general workers.

Conclusions: Our results suggest that objective cognitive functioning may be related to work performance. Longitudinal investigations may allow for the establishment of causality.

KEYWORDS
cognition, mental health, resilience, sleep disorders, work performance

1 | INTRODUCTION

Mental health in the workplace has emerged as a major concern because of the increasing prevalence of mental health problems. Over the past several decades, economic costs and lost workplace productivity related to mental health disorders have increased worldwide.[1] The National Institute of Population and Social Security Research provided statistics showing that the loss of gross domestic product due to suicide and depression in Japan amounted to about 2.7 trillion yen in 2010.[2] Moreover, an estimated 775.4 billion yen would be saved if depression could be prevented.[2]

Work performance is a critical issue in occupational mental health.[3] Recent studies have reported that workers with good mental health show superior work performance,[4] whereas poor mental health can negatively impact performance.[5] Although the relationship between mental health and work performance has been well documented, knowledge of how workers' mental health affects work performance is still insufficient.

Mental health is described by the World Health Organization as "a state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community."[6] Mental health is multifaceted, that is, is determined by multiple interacting social, psychological, and biological factors. Thus, researchers have developed various operational definitions. For example, Montano et al.[5] define mental health as a continuum of neurophysiological and cognitive states related to thinking, mood, and emotion, along with behaviors related to negative and positive mental health states. Although these elements may not be completely independent from each other, identifying their individual contributions to work performance may allow us to effectively mitigate the negative impact of poor mental health on work performance.

Cognitive function, which is one of the elements of mental health,[7] can be divided into objective and subjective subtypes. Usually, objective cognitive function is measured by neuropsychological test batteries, whereas subjective cognitive function is assessed using self-report questionnaires about cognitive function in the real-world setting. Subjective cognitive impairment was related to work performance in general adult workers.[8] Moreover, a relationship between subjective cognition and work performance was reported in patients with depression.[9,10] As subjective cognitive function is "contaminated" by the effects of metacognition, it is susceptible to changes in mood states. People in a depressive state tend to underestimate their cognitive function, while those with an elevated mood tend to overestimate theirs. Therefore, objective cognitive measures are more reliable and also serve as feasible targets for interventions. In addition, objective measures of cognitive impairment make it easier for occupational health professionals to understand employees' mental conditions when considering aspects of employment such as placements.

This study aimed to investigate the cross-sectional relationship between objective cognitive function and work performance among general Japanese workers. Our hypothesis was that objective cognitive function would be related to work performance in general workers, similar to patients with mental illness. Based on this hypothesis, objective measures of cognitive impairment will enable early intervention for workers with mental disorders. Other mental health problems that may affect cognition and work performance, such as psychological distress,[11] sleep,[12] resilience,[13,14] and neurodevelopmental tendencies,[15,16] were included as potential confounding factors. A cross-sectional relationship between work performance and objective cognitive function, even with consideration of confounding factors, would indicate that more care should be taken with objective cognitive function when evaluating the mental condition of workers to aid monitoring and promote improvement of their work performance.

2 | MATERIALS AND METHODS

We analyzed data from a prospective cohort study, in which assessments were conducted three times with a 24-week interval. The data were obtained from a cross-sectional dataset of baseline assessments.

2.1 | Participants

The participants were Japanese workers recruited from 10 companies located in a metropolitan area of Japan between February and November 2019. All participants were aged 18–65 years. We emailed invitations to participate in the responsible department of each company that had agreed to cooperate with this study. These companies included manufacturing, retail, electronic commerce, and independent administrative corporations. Company staff were free to decide which department the invitation email should be sent to. A document including the URL of the study was distributed to potential participants. Furthermore, an invitation email was sent containing the URL for a web page, through which those consenting to take part in the study could register their email addresses. Self-administered questionnaires were distributed to all individuals consenting to participate. We sent an email reminding the participants to respond within 2 weeks of receiving the email containing the web survey URL. We imposed a deadline of 1 month to complete the web-based, self-administered questionnaire; cognitive function tests were conducted during that period. Because the cognitive testing had to be done in person, we informed each participant individually (by email) of the dates of testing. We visited the participating companies and conducted cognitive function tests in conference rooms and other locations on their premises. Participants whose schedules were not convenient for the inspections were contacted individually and visited on different days.

The study protocol was approved by the Institutional Review Board of the Japan Organization of Occupational Health and Safety.

2.2 | Measures

2.2.1 | Outcome measure: work performance

The primary outcome measure was self-reported work performance, which was evaluated using a single question (with responses made using a visual analog scale; range: 0–100): "How would you rate your performance (compared with your optimum performance) over the past 4 weeks?" We aimed to measure presenteeism regardless of the presence or absence of illness. Using the Stanford Presenteeism Scale as a guide, four psychiatrists, two industrial physicians, and a clinical psychologist created questions via which workers could self-assess their labor productivity, regardless of illness status.[17]

2.2.2 | Exposure variable: cognitive functioning

The exposure variable of cognitive functioning was assessed using THINC-it®. This tool was used because it is simple and easy to administer. THINC-it® comprises a brief computerized battery of cognitive tests available for use on personal computers and touch screen tablet devices. The tests measure multiple domains of cognitive performance, with a subjective evaluation of cognitive functioning conducted separately. THINC-it® has been validated and is widely used for assessing cognitive function in patients with mood disorders.[18,19] THINC-it® has been translated into multiple languages, including Japanese, and can be downloaded for free. Completing all THINC-it® components takes 10–20 min, and the task instructions are designed to minimize administrative requirements.[18] We considered 10–20 min acceptable for a survey conducted in the workplace.

The tests were administered in the following order: The self-reported Perceived Deficits Questionnaire for Depression-5 item (PDQ-5-D), Spotter, Symbol Check, Codebreaker, and Trails.[18] Of these five tasks, the latter four test objective cognitive function (working memory, visuospatial coordination, set shifting, and psychomotor speed, respectively). A validation study of THINC-it® demonstrated that subjective and objective cognitive functioning were impaired in patients with depression relative to healthy controls.[19] Under the guidance of a psychiatrist, psychologist, and occupational physician, participants completed the THINC-it® cognitive function tests using a 9.7-inch tablet computer.

The PDQ-5-D is a self-report questionnaire comprising five questions that assess attention, planning, organization, and concentration during the previous 7 days. Participants rate the difficulty experienced in each domain on a Likert scale ranging from 1 (*Never*) to 5 (*Very often*). Higher PDQ-5-D scores indicate greater subjective cognitive impairment.

Spotter is a reaction time test of attention and executive function inspired by the Choice Reaction Time Task. Participants are presented with a left- or right-pointing arrow, and are required to select the left or right direction as quickly as possible depending on the direction of the arrow. The latency to cue presentation varies among trials, and the cue may appear on the left or right side of the screen; this can give rise to an interference effect. The test comprises 40 trials and takes 2 min to complete. Participants are assessed according to their mean correct reaction time. Responses made before 100 ms were treated as erroneous (anticipatory) responses.

Symbol Check evaluates working memory, executive function, and attention/concentration. Participants are presented with a continuously moving sequence of symbols, equivalent to an n-back task. As the sequence moves to the left of the screen, the symbols are hidden in a specific order. Participants are required to recall each hidden symbol as quickly as possible and press one of the five symbols presented at the bottom of the screen accordingly. The test consists of 40 trials and takes 2 min to complete. The number of correct responses is the outcome measure.

Codebreaker requires participants to match a list of symbols to corresponding numbers based on the legend. This task was inspired by the Digit Symbol Substitution Test and can identify deficits in the domains of executive function, processing speed, and attention/concentration. This test also takes 2 min to complete. A legend comprising numbers ranging from 1 to 6 and corresponding symbols is provided at the top of the screen. The number of correct symbols matched within 2 min is considered to represent cognitive performance.

Trails, inspired by the Trail Making Test, evaluate executive function and comprise 18 connecting points. Subjects must trace a line between letters and numbers alternatively, beginning with the letter "A" and proceeding to number "1" as quickly as possible; they continue until all letters and numbers have been connected. If the line touches a letter or number that is not the next one in the sequence, participants must restart from the last correct digit. A shorter completion time represents better cognitive performance.

2.2.3 | Potential confounders and effect modifiers

Possible confounders in the statistical analysis were age, sex, education, marital status, mental/physical treatment status, depression, sleep disorder, autism spectrum disorder (ASD) traits, attention-deficit/hyperactivity disorder (ADHD) tendencies, and resilience. Participants completed all items of a web-based self-administered questionnaire. Effect modifiers in the statistical analysis were job role (manager or non-manager), employment status (full- or part-time worker), and quality of life (QoL). Participants completed all items on a web-based, self-administered questionnaire.

Depression

Mood symptoms were assessed using the Kessler Psychological Distress Scale (K6), which is a screening questionnaire for depressive symptoms.[20] The K6 comprises six questions, with responses made using a Likert scale ranging from 0 (*Never*) to 4 (*Very often*). Participants scoring ≥5 points were considered to have a tendency toward depression.[21]

Sleep disorder

The Athens Insomnia Scale (AIS) is a self-report questionnaire designed to quantify sleep difficulty based on International Classification of Diseases, 10th Revision criteria.[22] The first five AIS questions pertain to sleep induction, awakenings during the night, final awakening, total sleep duration, and sleep quality. The last three questions cover well-being, functional capacity, and sleepiness during the day. Participants scoring ≥6 points were considered to have a sleep problem.[23]

Autism spectrum disorder and attention-deficit/hyperactivity disorder tendencies

Autism spectrum disorder tendencies were assessed using the Japanese version of the Autism Spectrum Quotient (AQ-J), which is a self-assessment tool.[24] We used the short version of the AQ-J (AQ-J-10), which comprises 10 items responded to via a Likert scale ranging from 1 to 4. Participants who scored ≥7 points were considered to have autistic traits. To assess ADHD tendencies, we used the Adult ADHD Self-Report Scale (ASRS) v.1.1. Part A of the ASRS is a self-reported screening questionnaire that includes six questions about the frequency of recent symptoms of adult ADHD according to the Diagnostic and Statistical Manual of Mental Disorders (4th ed.) criteria.[25] If four or more items met the criteria, then this was considered highly consistent with an ADHD diagnosis.

Resilience

Resilience, which should be assessed based on the number of risk and protective factors, refers to the ability to withstand adversity and work through emotional pain and suffering. Higher resilience at work has been associated with better work performance in individuals from various backgrounds.[13,14] To evaluate resilience in this study, we used the short version of the Resilience Scale (RS), which consists of 14 items pertaining to protective personality factors, that is, factors associated with healthy development and resistance to psychosocial stress. Responses to RS items are made via a 7-point Likert scale ranging from 1 (*Strongly disagree*) to 7 (*Strongly agree*).[26]

Quality of life

To assess QoL, we used the 26-item World Health Organization Quality of Life Questionnaire, which is the shorter version of a widely used QoL assessment instrument.[27] This tool comprises 26 questions, the first 2 of which are related to overall QoL; the remaining questions (questions 3–26) are related to QoL in four domains: physical, psychological, social relationships, and environment. Responses are made using a 5-point Likert scale, with higher scores indicating higher QoL.

2.3 | Statistical analyses

We used SPSS software (version 25.0; IBM Corp.) for the analysis of complete cases. Cases with missing values were excluded from the analysis. Participants were divided into high and low (median split) work performance groups. Logistic regression analysis was performed with self-reported work performance (high- or low-performing) as the dependent variable and age, sex, employment status, job role, presence/absence of sleep difficulties, tendency toward depression, resilience score, autistic traits, ADHD tendencies, and cognitive subtest terciles (low, moderate, or high) as potential confounders or effect modifiers. Because we were concerned that treatment for physical or mental illness might affect cognitive function, we also performed a logistic regression analysis that excluded participants undergoing treatment for physical or mental illness. Because most measures failed to show a normal distribution, we calculated terciles under the assumption of non-linearity. Using the "low" THINC-it® group as a reference, we performed logistic regression to estimate odds ratios (ORs) for membership in the moderate and high THINC-it® groups; 95% confidence intervals (CIs) were also calculated for participants reporting low or high levels of work performance. Age, gender, job role, and employment status were used as covariates. $P < .05$ was considered statistically significant.

3 | RESULTS

In total, 353 individuals provided e-consent to participate in this study, 308 of whom completed both the questionnaires and the cognitive screening. We included 276 subjects in the analysis after omitting those with missing data (Figure 1).

The participants' demographic and clinical characteristics are compared between the high- and low-performing groups in Table 1. Most participants were full-time male workers with an education level above high school graduates. As the work performance data did not show a normal distribution, we performed a median split (median = 80%; mean (SD) = 79.5% (17.4)) to obtain a dichotomous variable. The participants with a performance score above the median were classified as high-performing.

The results of the binary logistic regression model are presented in Table 2. The ORs of moderate and high levels based on low levels in Spotter and Symbol Check were as follows: Spotter, OR of moderate level 0.45 (95% CI: 0.45–2.08); OR of high level 0.34 (95% CI: 0.15–0.78); Symbol Check, OR of moderate level 0.97 (95% CI: 0.20–1.01); OR of high level 2.44 (95% CI: 1.01–5.87). The *P*-value for trends indicated that the association of Spotter and Symbol Check with work performance was significant but no other indicators, such as Codebreaker, Trails, and PDQ-5D. As for confounders, high resilience scores (OR = 1.03, 95% CI: 1.01 to 1.06) and sleep difficulties (OR = 0.32, 95% CI: 0.17–0.65) and sex (OR = 2.24, 95% CI: 1.16–4.37) were associated with work performance. Specifically, female workers with high resilience who slept well tended to report higher work performance.

After excluding workers being treated for mental or physical illness, the analysis suggested a significant association between Spotter and Symbol Check and work performance. The ORs of moderate and high levels based on low levels in Spotter and Symbol Check were as follows: Spotter, OR of moderate level 0.54 (95% CI: 0.21–1.40); OR of high level 0.38 (95% CI: 0.14–0.98), and Symbol Check, OR of moderate level 0.81 (95% CI: 0.32–2.00); OR of high level 2.26 (95% CI: 0.76–6.68).

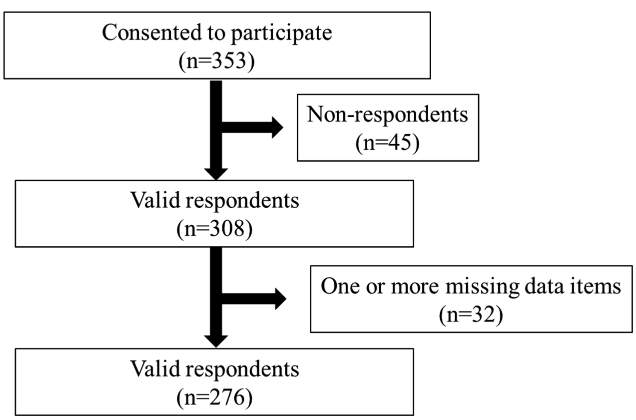

FIGURE 1 Flow of study participants based on the study exclusion criteria

4 | DISCUSSION

To our knowledge, this is the first study to investigate the relationship between objective cognitive functioning and work performance in general workers in Japan. According to the multivariable logistic regression analysis, work performance was significantly associated with attention and executive function, as evaluated by Spotter and Symbol Check in general workers, along with gender, resilience, and sleep disorders. In univariate analyses, there were significant differences in the proportions of participants with sleep difficulties, mental illnesses currently being treated, a tendency toward depression, ADHD tendencies, and autistic traits, as well as differences in resilience and QoL scores, between the high- and low-performing groups.

Spotter is designed to test for interference effects, in addition to attention and processing speed, while Symbol Check is similar to the n-back task. In Symbol Check, interference effects can arise from the presented stimuli when recalling hidden symbols.[18] In other words, interference effects are a feature of both tests. Performance on the other attention- and processing speed-related tests did not differ significantly between the high- and low-performing groups in this study, and the results suggest that executive functioning, which is related to the suppression of interference effects, may be a key factor in subjective work performance. Although objective cognitive impairment was associated with presenteeism in psychiatric populations,[28–30] it has been indicated that an association exists between work performance deficits and subjective, but not objective, cognitive impairment in general workers.[8] A previous study

TABLE 1 Sociodemographic characteristics

					High performing group (n = 187)				Low performing group (n = 89)			
	n = 276	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD
Age (years)			45.2	10.2			45.1	10.1			45.4	10.4
Sex												
Male	178	64.5			113	60.4			65	73.0		
Female	98	35.5			74	39.6			24	27.0		
Other	0	0.0			0	0.0			0	0.0		
Educational years												
≤12	0	0.0			0	0.0			0	0.0		
13–16	81	29.3			56	29.9			25	28.1		
≥17	195	70.7			131	70.1			64	71.9		
Marital status												
Married (including living with common-law partner)	193	69.9			132	70.6			61	68.5		
Single (including divorced and widowed)	83	30.1			55	29.4			28	31.5		
Employment status												
Full-time worker	230	83.3			154	82.4			76	85.4		
Part-time worker	46	16.7			33	17.6			13	14.6		
Employment position												
Manager	77	27.9			53	28.3			24	27.0		
Non-manager	199	72.1			134	71.7			65	73.0		
Sleep difficulties (AIS)												
≥6	117	57.6			59	31.6			58	65.2		
≤5	159	68.4			128	68.4			31	34.8		
Physical disease treatment status												
Under treatment	65	23.6			47	25.1			18	20.2		
Not treated	211	76.4			140	74.9			71	79.8		
Mental illness treatment status												
Under treatment	16	5.8			5	2.7			11	12.4		

TABLE 1 (Continued)

					High performing group ($n = 187$)				Low performing group ($n = 89$)			
	$n = 276$	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD
Not treated	260	94.2			182	97.3			78	87.6		
Depression tendency (K6)												
≥5	124	44.9			65	34.8			30	66.3		
≤4	152	55.1			122	65.2			59	33.7		
ADHD tendency (ASRS v.1.1 part A)												
+	35	12.7			16	8.6			19	21.3		
−	241	87.3			171	91.4			70	78.7		
Autistic traits (AQ-J)												
≥7	18	6.5			9	4.8			9	10.1		
≤6	258	93.5			178	95.2			80	89.9		
Resilience (RS-14			65.3	14.7			68.8	12.5			58.0	16.4
QOL (WHOQOL 26)			3.3	0.6			3.2	0.8			2.8	0.8
Cognitive functioning (THINC-it®)												
Spotter (ms)			554.93	135.8			543.5	123.6			578.9	156.6
Symbol check (number)			28.717	10.0			29.4	9.9			27.3	10.2
Codebreaker (number)			60.812	15.2			60.7	14.6			61.2	16.6
Trails (s)			26	11.7			25.9	10.9			26.3	13.4
PDQ-5D (point)			4.13	2.9			3.9	2.7			4.6	3.2
Spotter (ms)												
Low (344.73–485.62)	92	33.3			69	36.9			23	25.8		
Moderate (485.63–595.38)	91	33.0			62	33.2			29	32.6		
High (595.39–1490.00)	93	33.7			56	29.9			37	41.6		
Symbol check (number)												
Low (0–26)	95	34.4			61	32.6			34	38.2		
Moderate (27–35)	91	33.0			57	30.5			34	38.2		
High (36–40)	90	32.6			69	36.9			21	23.6		
Codebreaker (number)												
Low (3–56)	94	34.1			59	31.6			35	39.3		

(Continues)

TABLE 1 (Continued)

	n = 276	%	Mean	SD	High performing group (n = 187)				Low performing group (n = 89)			
					n	%	Mean	SD	n	%	Mean	SD
Moderate (57–67)	91	33.0			70	37.4			21	23.6		
High (58–108)	91	33.0			58	31.0			33	37.1		
Trails (s)												
Low (11.05–20.47)	92	33.3			64	34.2			28	31.5		
Moderate (20.48–27.37)	92	33.3			61	32.6			31	34.8		
High (27.38–103.07)	92	33.3			62	33.2			30	33.7		
PDQ-5D (points)												
Low (0–3)	123	44.6			86	46.0			37	41.6		
Moderate (4, 5)	69	25.0			45	24.1			24	27.0		
High (5–15)	84	30.4			56	29.9			28	31.5		

Note: Spotter (Choice Reaction Time) = mean latency for correct response.

Symbol check (N-back) = total number of correct responses.

Codebreaker (Digit Symbol Substitution Test) = total number of correct responses.

Trails (Trail Making Test) = total time taken for completion.

PDQ-5D (Perceived Deficits Questionnaire for Depression-5 item) = total score (points).

Abbreviations: ADHD, attention deficit hyperactivity disorder; AIS, Athens Insomnia Scale; AQ-J, Autism-Spectrum Quotient-Japanese version; ASRS, Adult ADHD Self-Report Scale v.1.1 part A; K6, Kessler Psychological Distress Scale; QOL, quality of life; SD, standard deviation.

TABLE 2 Relationship between objective cognitive functioning and work performance among Japanese workers ($n = 276$)

	Model 1[a]			Model 2[b]		
	OR	95%CI	*P* value	OR	95% CI	*P* value
Spotter						
Low	Ref.			Ref.		
Moderate	0.62	0.32–1.21		0.45	0.20–1.01	
High	0.45	0.23–0.90		0.34	0.15–0.78	
Test for linear trend[c]			<.05			<.05
Symbol check						
Low	Ref.			Ref.		
Moderate	0.79	0.42–1.49		0.97	0.45–2.08	
High	1.96	0.94–4.08		2.44	1.01–5.87	
Test for linear trend[c]			.08			<.05
Codebreaker						
Low	Ref.			Ref.		
Moderate	1.66	0.83–3.32		2.87	1.24–6.65	
High	0.69	0.34–1.40		0.75	(0.33–1.68	
Test for linear trend[c]			.36			.48
Trails						
Low	Ref.			Ref.		
Moderate	0.96	0.50–1.86		1.04	0.48–2.29	
High	1.23	0.61–2.49		1.37	0.58–3.25	
Test for linear trend[c]			.70			.57
PDQ-5D						
Low	Ref.			Ref.		
Moderate	0.75	0.39–1.45		1.27	0.60–2.68	
High	0.82	0.44–1.54		1.80	0.83–3.91	
Test for linear trend[c]			.53			.19

Note: Spotter = mean latency for correct response.
Symbol check = total number of correct responses.
Codebreaker = total number of correct responses.
Trails = total time taken for completion.
PDQ-5D = total score (points).
Abbreviations: CI: confidence interval, OR: odds ratio, PDQ-5D: Perceived Deficits Questionnaire for Depression-5 item.
[a]Unadjusted logistic regression model.
[b]Fully adjusted logistic regression model: adjusted for sex, age, employment position, employment status, attention deficit hyperactivity disorder tendency, autism spectrum disorder trait, resilience, sleep difficulty, tendency for depression.
[c]Test for linear trends was performed by modeling the group scores (1–3) of each THINC-it result as one variable.

found that at-work performance deficits (presenteeism) were associated with both mental and physical conditions (e.g., depression, anxiety, allergy, migraine, and arthralgia).[31] Future studies should aim to identify the cognitive functions that have the greatest effect on work performance.

Confounding factors such as sex, resilience scores, and sleep difficulties were statistically significant between high and low performance. The women in this study showed better subjective work performance than the men. In a previous study, women scored significantly higher than men in terms of autonomy orientation.[32] Higher levels of autonomy orientation often occurred with intrinsic motivation in women, and greater intrinsic motivation was in turn associated with better work functioning.[33] Further studies are needed to confirm the circumstances under which women's work performance is higher than that of men. The resilience scores were related to work performance in this study, which was in line with a previous study suggesting that higher resilience scores have significant positive correlations with work performance and engagement in nurses.[13] Furthermore, our findings regarding the relationships of work performance with sleep difficulties as well as cognitive functioning were consistent with a previous study focused on patients with remitted depression,[34] which suggests that the relationships are not disease-specific. Our results were consistent with previous studies suggesting that healthy sleep is essential for high-level work performance.

The present study had several limitations. First, staff members of participating companies were responsible for sending the participation email, and the number of people to whom it was sent is unknown. Given that the response rate is unknown, assessing selection bias is difficult. However, the participants who completed the web-based questionnaire only, those who completed the cognitive function tests only, and those who completed both showed no significant performance differences, suggesting a lack of systematic error. Furthermore, we took measures to avoid information bias: the examiners were blinded to the participants' responses on the web questionnaire, and the cognitive function tests were conducted according to a standardized manual. Therefore, any misclassification would have been non-differential.

Second, as we recruited participants by email, people who do not routinely check their email messages may have been less likely to participate. Moreover, the participating companies were located within the suburbs of a metropolitan area, so the results may not generalize to all workers in Japan. Although we invited many firms to cooperate with our research, those that ultimately did so were all either large firms or conglomerates. Therefore, the results may not generalize to small- and medium-sized enterprises, which account for most of the companies in Japan. Large firms typically have more manpower than small- and medium-sized firms, and workers in large firms may have a tendency to rate their own labor productivity more highly because they are monitored more closely. Furthermore, our participants were highly educated, and the proportion of full-time employees was high; this is another reason why caution is required when generalizing the results of this study.

Third, the logistic regression analysis included individuals who are currently receiving treatment for psychiatric or physical illnesses as well as those who were not. However, a secondary analysis excluding those with psychiatric and physical illnesses yielded similar results, although the effects of medications could not be controlled for because these data were not available.

Finally, because of the cross-sectional study design, our ability to infer causality was limited. Therefore, further longitudinal studies are needed to establish causal relationships between objective cognitive functioning and work performance.

In conclusion, our findings suggest the importance of assessing cognitive function in workplace mental health measures. There is also a survey result that the volume of the hippocampus of London taxi drivers who learned and memorized the map of the city increased.[35] It is expected to play an important role in lifelong learning methods and neurorehabilitation in clinical settings. By taking into account not only the subjective reports of workers with mental disorders but also objective evaluations of their cognitive functions, it is expected that the diagnosis accuracy of attending physicians will be improved and a smooth return to work will be realized. Our results suggest that cognitive functioning is related to work performance and could be used as one indicator of mental health in the workplace, although longitudinal research is required to establish causality between these factors.

AUTHOR CONTRIBUTIONS

M. Shibaoka, S. Ikezawa, M. Masuda, H. Eguchi, and K. Nakagome conceived the idea for the study; M. Shibaoka and M. Masuda collected the data; M. Shibaoka, S. Iwasawa, H. Eguchi, S. Ikezawa, and K. Nakagome analyzed the data; and S. Iwasawa, H. Eguchi, S. Ikezawa, and K. Nakagome led the writing.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are not available due to privacy or ethical restrictions.

DISCLOSURE

Approval of the research protocol: The Research Ethics Committee of Japan Organization of Occupational Health and Safety reviewed and approved the aims and procedures of this study.

Informed consent: Online informed consent was obtained from all participants after full disclosure of the purpose and the methods of this study.

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