Ida et al. BMC Nutrition (2024) 10:126
https://doi.org/10.1186/s40795-024-00928-9

BMC Nutrition

RESEARCH

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The "vegetables first" dietary habit correlates with higher-level functional capacity in older adults with diabetes

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Abstract

Background Some studies suggest that the habit of eating vegetables may initially be correlated with maintenance of a higher-level functional capacity; however, such a correlation has not been demonstrated. This study aimed to correlate the habit of eating vegetables first and higher-level functional capacity in older adults with diabetes.

Methods Patients aged ≥ 60 years who were treated at Japanese Red Cross Ise Hospital on an ambulatory basis were included in this study. A self-administered questionnaire using the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) was used to evaluate higher-level functional capacity. Participants were instructed to answer the questionnaire regarding the order in which they consumed the mentioned food types, and based on their answers, they were classified into "no order of eating," "carbohydrates first," "protein first," and "vegetables first" groups. Multiple regression analyses with the TMIG-IC score as a dependent variable and the order of eating as explanatory variables were used to determine the partial regression coefficients of the "vegetables first" dietary habit with higher-level functional capacity.

Results This study included 346 patients. The adjusted partial regression coefficients of the "carbohydrates first," "protein first," and "vegetables first" dietary habits with the TMIG-IC score were 0.27 (95% confidence interval [CI], − 0.29 to 0.84), 0.17 (95% CI, − 0.54 to 0.90), and 0.77 (95% CI, 0.23 to 1.31), respectively.

Conclusions The habit of eating vegetables first was correlated with higher-level functional capacity in older adults with diabetes.

Keywords Older adults with diabetes, Nutrition, Activities of daily living

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Background

The number of older patients with diabetes has been increasing with the increase in the population of older adults [1]. Older adults with diabetes have been reported to likely experience a decline in activities of daily living (ADL) [2]. A 7-stage hierarchical model was previously proposed that categorized the living functions of older adults into the following categories in the order of simple to complex: life maintenance, functional health, cognition/perception, physical independence, instrumental independence, situational response, and social function [3]. In addition to basic ADL (BADL) (i.e., basic activities required for daily living), ADLs encompass instrumental activities of daily living (IADL) (i.e., complex daily activities) and higher-level functional capacities, including intellectual activity and social function. Of these ADLs, deterioration of the higher-level functional capacity begins early-on [3]. Furthermore, this deterioration has reported association with a decline in cognitive function, increased medical expenses, and mortality [4–6]. Therefore, higher-level functional capacity in older adults with diabetes is regarded as a clinically significant outcome.

Factors associated with a decline in higher-level functional capacity in older adults with diabetes include aging, sex, complications, and medication [7, 8]. Moreover, recent reports have indicated that postprandial hyperglycemia may be associated with the presence of disabilities and decline in ADL and physical function. Therefore, to maintain higher-level functional capacity in older adults with diabetes, controlling postprandial hyperglycemia is a critical factor in addition to the known relevant factors.

When considering glycemic control during the treatment for diabetes, dietary therapy is as crucial as exercise therapy. Several studies involving patients with diabetes have reported that maintaining an appropriate caloric intake was conducive to improving postprandial hyperglycemia and that eating orders, i.e., vegetables first, protein first, and carbohydrates last, also affected how an increase in postprandial blood sugar was suppressed [9–12].

These findings [7–12] suggest the possibility that “vegetables first” dietary habit is associated with the maintenance of higher-level functional capacity in older adults with diabetes; however, no previous studies have examined this association. Thus, this study aimed to correlate the habit of eating vegetables first and higher-level functional capacity in older adults with diabetes.

Methods

Study design and participants

This was a cross-sectional study targeting patients with diabetes aged ≥ 60 years who were treated at Japanese Red Cross Ise Hospital (Ise, Mie Prefecture) on an ambulatory basis. Before beginning this study, the participants provided their written consent, and the ethics committee of the hospital approved the study’s implementation. Patients with diabetes aged ≥ 60 years who received outpatient treatment at our hospital from July 2022 to December 2022 were included. Individuals with alcohol consumption disorder, with severe mental illness, who were admitted to a nursing home, and who were unable to independently cooperate in the survey were excluded.

Measurement of higher-level functional capacity

To evaluate higher-level functional capacity, a self-administered questionnaire using the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) was used [13]. The TMIG-IC is a widely used index for evaluating higher-level functional capacity in Japan, and its reliability and validity have been corroborated. This questionnaire comprised 13 questions, 5 of which were related to IADL (i.e., preparing meals, managing money, and using public transportation), 4 were regarding intellectual activity, and 4 were about social function. A respondent was asked to answer each question with “Yes” or “No.” Scores ranged from 0 to 13, with higher scores indicating higher higher-level functional capacity.

Evaluation of dietary habits based on eating order

Based on the self-administered questionnaires collected from the participants, their dietary habits concerning eating order were surveyed (Additional file 1). The participants were asked to select any one of the following answers: (1) “I make it a habit to eat vegetables first (vegetables first)”; (2) “I make it a habit to eat protein first (including dairy products) (protein first)”; (3) “I make it a habit to eat carbohydrates first (including rice, bread, and noodles) (carbohydrates first)”; and (4) “I follow no particular eating order (no order or eating).”

Measurement of other variables

Following factors were surveyed: age, sex, body mass index (BMI) (weight [kg]/height squared [m^2]), smoking habit, alcohol consumption habit, exercise habit, type of diabetes (type 1 or type 2), duration of diabetes, hemoglobin A1c (HbA1c), hypertension, hyperlipemia, diabetic retinopathy, diabetic neuropathy, diabetic nephropathy, cardiovascular disorder, social frailty, undernutrition risk, cognitive function, and antidiabetic medication. The types of diabetes were classified into type 1, type 2, and others as per the diagnostic criteria proposed by the Japan Diabetes Society [14]. Systolic and diastolic blood pressures were measured in a consultation room, and hypertension was diagnosed when any of the following criteria were satisfied: systolic blood pressure ≥ 130 mmHg, diastolic blood pressure ≥ 80 mmHg, and being on antihypertensive medication. Hyperlipemia was diagnosed when any of the following criteria were satisfied: triglyceride level (TG) of ≥150 mg/dl, high-density lipoprotein-cholesterol (HDL-c) of <40 mg/dl, low-density lipoprotein-cholesterol (LDL-c) of ≥120 mg/dl (if a coronary disorder was present, LDL-c of ≥100 mg/dl), and being on lipid-lowering medication. Presence or absence of diabetic retinopathy was judged by an ophthalmologist. Diabetic neuropathy was diagnosed when the following symptoms were observed: a decline in Achilles reflex, a decline in vibratory perception in the lateral malleolus, and abnormal nerve conduction findings. The cardiovascular disorder was diagnosed when the subject had underlying or previous ischemic cardiac diseases, including angina pectoris and myocardial infarction, or cerebrovascular diseases, e.g., cerebral infarction. A determination scale proposed by Makizako et al. [15] was used to measure social frailty. This scale consisted of the following five questions: (1) "Going out less frequently compared to last year (yes)"; (2) "Visiting the homes of friends (no)"; (3) "Feeling useful to your family and friends (no)"; (4) "Living alone (yes)"; and (5) "Conversing with someone every day (no)". Total scores ranged from 0 to 5. In this study, social frailty was diagnosed when the subject's total score was 2 or higher. Malnutrition risk was evaluated using the Mini Nutritional Assessment Short Form (MNA-SF) [16], an index whose reliability and validity have been demonstrated for assessing the nutritional state of older adults. This index comprises the following six items: a decrease in dietary intake, a decrease in body weight, athletic abilities (being bedridden, using a wheelchair, or being able to go out voluntarily), mental stress/acute disorder, dementia/depression, and BMI. Total scores ranged from 0 to 14, with scores of 0–7, 8–11, and ≥12 signifying undernutrition, suspected undernutrition, and favorable nutrition, respectively. In this study, undernutrition risk was diagnosed when the subject's total score was 11 or lower, i.e., when undernutrition or suspected undernutrition was observed. Each subject was questioned whether they had a habit of exercising at least once weekly, and the subject was considered to have a habit of exercising when they answered "Yes." Cognitive function was evaluated using a self-administered dementia checklist [17] comprising 10 items related to living and cognitive functions. Total scores ranged from 0 to 40, and cognitive decline was diagnosed when the subject scored 18 or above.

Statistical analysis

The patients were classified into the "no order of eating," "carbohydrates first," "protein first," and "vegetables first" groups and their background factors were listed. Intergroup comparison was performed using analysis of variance for the continuous variables (Bonferroni method for multiple comparisons) and the chi-square test for the dichotomous variables. The multiple regression analyses with the TMIG-IC score as a dependent variable and order of eating ("carbohydrates first," "protein first," and "vegetables first" dietary habits; dummy variables of 1 and 0 were assigned to those with and without the habit, respectively) as explanatory variables and moderators were used to determine the partial regression coefficients of the order of eating with higher-level functional capacity. Considering several previous studies [18–20] as well as some clinical considerations, the following variables were adjusted: age, sex, BMI, HbA1c, exercise habit, number of comorbidities (hypertension, hyperlipemia, diabetic retinopathy, diabetic neuropathy, diabetic nephropathy, and cardiovascular disorder), social frailty, undernutrition risk, cognitive decline, and antidiabetic medication. Previous studies have suggested that the nutritional status and cognitive function may be associated with ADL [7, 8]. Therefore, we conducted the analyses excluding these from moderators to confirm the effects of undernutrition risk and cognitive decline on the relationship between the order of eating and higher-level functional capacity. Furthermore, the relationship between the order of eating and higher-level functional capacity was also analyzed separately in men and women as a subgroup analysis [7, 8]. The significance level (two-tailed) was set at <0.05. STATA version 16.0 (Stata Corporation LP, College Station, TX) was used for statistical analysis.

Results

In the present study, 346 patients (204 men and 142 women) were investigated. Table 1 lists the characteristics of the analyzed population. The mean age of the study population was 72 years, mean HbA1c was 7.6%, and 59% of the participants were men. Overall, 67 participants (19.3%) followed no particular eating order, 99 (28.6%) would eat carbohydrates first, 43 (14.4%) would eat protein first, and 137 (39.7%) would eat vegetables first. The "carbohydrates first" group had the highest mean age, and the "vegetables first" group had the lowest male percentage. The TMIG-IC score in the "vegetables first" group was 11, which was the highest among all four groups.

Table 2 lists the results of the multiple regression analysis. The adjusted partial regression coefficients of the "carbohydrates first," "protein first," and "vegetables first" dietary habits with the TMIG-IC score were 0.27 [95% confidence interval (CI), −0.29–0.84], 0.17 (95% CI, −0.54–0.90), and 0.77 (95% CI, 0.23–1.31), respectively (Model 2).

In the analysis of a model including moderators other than undernutrition risk and cognitive decline (Table 2, Model 1), the adjusted partial regression coefficients of

Table 1 Sample characteristics based on eating habits among older Japanese adults

	No order of eating $n=67$ (19.3%)	Carbohydrates first $n=99$ (28.6%)	Protein first $n=43$ (12.4%)	Vegetables first $n=137$ (39.7%)	*p*
Age (years), mean (SD)	70.2 (6.6) [b]	74.4 (7.0) [a, c,d]	71.0 (6.4) [b]	71.8 (7.2) [b]	< 0.001*
Men, %	67.1	68.4	58.5	48.8	0.013*
BMI (kg/m^2), mean (SD)	24.8 (4.3)	23.9 (3.8)	24.9 (4.9)	23.8 (5.2)	0.358
T1DM/T2DM, %	6.4/93.6	10.1/89.9	5.0/95.0	16.7/83.3	0.014*
Duration of diabetes (years), mean (SD)	17.0 (11.1)	20.4 (11.6)	18.4 (9.8)	18.1 (13.1)	0.320
HbA1c (%), mean (SD)	7.7 (1.6)	7.5 (1.0)	7.6 (0.9)	7.6 (1.2)	0.907
Alcohol consumption, %	23.6	32.1	26.4	22.0	0.426
Smoking, %	54.5	41.6	18.1	32.7	0.003*
Exercise habit, %	92.4	91.9	85.7	92.6	0.543
Hypertension, %	58.0	66.6	65.0	61.0	0.688
Dyslipidemia, %	66.1	70.7	62.5	55.7	0.124
Retinopathy, %	32.8	30.3	32.5	32.1	0.985
Neuropathy, %	31.3	32.3	25.5	33.5	0.805
Nephropathy, %	49.2	57.5	51.1	40.1	0.065
Cardiovascular disease, %	17.9	32.3	23.2	18.9	0.070
Social frailty, %	41.5	41.4	53.6	38.5	0.395
Risk of undernutrition, %	49.2	46.3	42.5	52.2	0.683
Cognitive function decline,%	19.6	21.4	12.5	12.0	0.200
Oral hypoglycemic agents, %	89.3	88.6	90.6	75.7	0.010*
Insulin, %	79.1	77.3	74.4	81.6	0.736
TMIG-IC score (point), mean (SD)	9.7 (2.8) [d]	10.2 (2.9)	10.0 (2.3)	11.1 (2.3) [a]	0.001*

SD, standard deviation; BMI, body mass index; T1DM/T2DM, type 1/type 2 diabetes mellitus; HbA1c, hemoglobin A1c; TMIG-IC, Tokyo Metropolitan Institute of Gerontology Index of Competence; *$p<0.05$

[a] Significantly different from "No order of eating"

[b] Significantly different from "Carbohydrates first"

[c] Significantly different from "Protein first"

[d] Significantly different from "Vegetables first"

Table 2 Multiple regression with higher-level functional capacity as the outcome

	Univariate analysis (Adjusted r2: 0.038; $p<0.001$)		Multivariate analysis (Model 1) (Adjusted r2: 0.331; $p<0.001$)		Multivariate analysis (Model 2) (Adjusted r2: 0.538; $p<0.001$)	
	Coefficient (95%CI)	*p*	Coefficient (95%CI)	*p*	Coefficient (95%CI)	*p*
Age, per year increase			−0.01 (− 0.05–0.02)	0.446	0.02 (0.01–0.05)	0.115
Men (vs. women)			−0.22 (− 0.74–0.30)	0.404	−0.50 (− 0.95–−0.05)	0.026*
BMI, per 1 kg/m^2 increase			0.02 (− 0.03–0.08)	0.382	−0.01 (− 0.06–0.04)	0.617
HbA1c, per 1% increase			−0.04 (− 0.24–0.15)	0.660	−0.13 (− 0.29–0.02)	0.108
Exercise habit (vs. no)			2.20 (1.26–3.15)	< 0.001*	1.56 (0.78–2.34)	< 0.001*
Numbers of comorbidity, per 1 increase			−0.19 (− 0.36–−0.02)	0.024*	−0.07 (− 0.21–0.06)	0.293
Social frailty (vs. no)			−2.30 (− 2.83–−1.77)	< 0.001*	−1.62 (− 2.07–−1.16)	< 0.001*
Risk of undernutrition (vs. no)					−0.12 (− 0.59–0.34)	0.602
Cognitive function decline (vs. no)					−3.67 (− 4.28–−3.06)	< 0.001*
Insulin (vs. no)			−0.55 (− 1.20–0.08)	0.088	0.00 (− 0.53–0.53)	0.998
Eating order						
Carbohydrates first (vs. no)	0.47 (− 0.27–1.22)	0.215	0.23 (− 0.46–0.94)	0.505	0.27 (− 0.29–0.84)	0.348
Protein first (vs. no)	0.24 (− 0.65–1.15)	0.591	0.39 (− 0.46–1.24)	0.368	0.17 (− 0.54–0.90)	0.627
Vegetables first (vs. no)	1.38 (0.69–2.07)	< 0.001*	1.00 (0.33–1.66)	0.003*	0.77 (0.23–1.31)	0.005*

CI, confidence interval; BMI, body mass index; HbA1c, hemoglobin A1c; *$p<0.05$

the "carbohydrates first," "protein first," and "vegetables first" dietary habits with the TMIG-IC score were 0.23 (95% CI, −0.46–0.94), 0.39 (95% CI, −0.46–1.24), and 1.00 (95% CI, 0.33–1.66), respectively.

Results of the subanalysis based on sex are presented in Table 3. In the analysis of male patients, the adjusted partial regression coefficients of the "carbohydrates first," "protein first," and "vegetables first" dietary habits with the TMIG-IC score were 0.49 (95% CI, −0.27–1.25), 0.28 (95% CI, −0.74–1.30), and 1.29 (95% CI, 0.56–2.03), respectively. In the analysis of female patients, the adjusted partial regression coefficients of the "carbohydrates first," "protein first," and "vegetables first" dietary habits with the TMIG-IC score were −0.06 (95% CI, −0.94–0.81), −0.05 (95% CI, −1.11–0.99), and −0.04 (95% CI, −0.84–0.75), respectively.

Discussion

Our study on older adults with diabetes revealed an association between the "vegetables first" dietary habit and higher-level functional capacity. Moreover, the sex-based subanalysis reveals that this association was significant in men. To the best of our knowledge, this is the first study that demonstrated a correlation between these two factors.

Previous studies targeting patients with diabetes reported that the "vegetables first" eating order contributed to the suppression of postprandial hyperglycemia [10], attenuation of the mean amplitude of glycemic excursions (MAGE, a measure of glycemic variability) [21], and suppression of arteriosclerosis [10]. Postprandial hyperglycemia and blood sugar spikes induce inflammatory cytokines, oxidative stress, and insulin resistance, causing vascular complications and organ disorders [22–24]. Additionally, inflammatory cytokines and oxidative stress may be attributed to decline in physical function and ADL [7, 25]. Oxidative stress and inflammation may be implicated in the association between the "vegetables first" dietary habit and higher-level functional capacity in this study; however, these mechanistic details require further elaborations. In their study on older adults with diabetes, Ogama et al. [18] reported that postprandial hyperglycemia (mean peak value ≥ 180 mg/dL) may be correlated with declines in physical function and muscular strength. Moreover, Chung et al. [26] performed a study involving older adults with diabetes and reported that postprandial hyperglycemia (≥ 180 mg/dL) and blood sugar spikes might be correlated with frailty. In these reports, postprandial hyperglycemia was suggested to be associated with white matter lesions, which are believed to be responsible for reducing higher-level functional capacity [27]. Furthermore, recent large-scale investigations [19, 20] indicated that not only diabetes but also prediabetes might be involved in causing disabilities. Prediabetes is a blood sugar abnormality primarily characterized by postprandial hyperglycemia; the episodes of which may have contributed to the onset of certain disabilities [7, 19]. In the present study, besides the known ADL-related factors (age, sex, complications, exercise habit, and diabetes treatment), the "vegetables first" dietary habit was demonstrated to be significantly correlated with higher-level functional capacity via a multivariate analysis where HbA1c, an index for the chronic hyperglycemic state, was adjusted. This may suggest that suppressing chronic hyperglycemia and postprandial hyperglycemia to reduce blood sugar variability is essential in maintaining higher-level functional capacity in older adults with diabetes. Furthermore, previous studies involving patients with diabetes [10, 28] suggested that eating vegetables first might be conducive to achieving healthy dietary habits, including more dietary fiber consumption, less eating between meals, and less salt intake. Therefore, a habit of eating vegetables first might have led to a behavioral change, which might have affected higher-level functional capacity.

Results of multivariate analyses of Models 1 and 2 in this study demonstrate that adjustment for undernutrition risk and cognitive decline decreased the partial regression coefficient of the "vegetables first" dietary habit. This result suggests the involvement of

Table 3 Multiple regression with higher-level functional capacity as the outcome (analysis based on sex)

Eating order	**Coefficient (95%CI)**	***p***	**Coefficient (95%CI)**	***p***
Men	(Adjusted r2: 0.065; $p < 0.001$)		(Adjusted r2: 0.508; $p < 0.001$)	
Carbohydrates first (vs. no)	0.77 (−0.17–1.71)	0.110	0.49 (−0.27–1.25)	0.205
Protein first (vs. no)	0.59 (−0.61–1.81)	0.331	0.28 (−0.74–1.30)	0.589
Vegetables first (vs. no)	1.96 (1.02–2.90)	< 0.001*	1.29 (0.56–2.03)	0.001*
Women	(Adjusted r2: 0.012; $p = 0.045$)		(Adjusted r2: 0.614; $p < 0.001$)	
Carbohydrates first (vs. no)	−0.08 (−1.45–1.28)	0.903	−0.06 (−0.94–0.81)	0.883
Protein first (vs. no)	−0.50 (−2.01–1.00)	0.507	−0.05 (−1.11–0.99)	0.914
Vegetables first (vs. no)	0.28 (−0.9–1.47)	0.635	−0.04 (−0.84–0.75)	0.912

CI, confidence interval; BMI, body mass index; HbA1c, hemoglobin A1c; *$p < 0.05$

Adjustment variables: Age, BMI, HbA1c, exercise habits, number of comorbidities, social frailty, risk of low nutrition, cognitive decline, insulin undernutrition risk and cognitive decline as mediators in the association between the “vegetables first dietary” habit and higher-level functional capacity [7, 8]. Moreover, the sex-bases analysis revealed an association between the “vegetables first” dietary habit and higher-level functional capacity only in male patients. Women tend to have healthier eating habits than men [7–11]. Moreover, the prevalence of the “vegetables first” dietary habit in this study was 31.9% in men and 48.8% in women (result not shown). Although this is merely a speculation, the higher prevalence of healthy dietary habits in women with diabetes is a possible reason why the “vegetables first” dietary habit was not associated with higher-level functional capacity in women.

The results of the multivariate analysis in this study revealed that cognitive decline, social frailty, and exercise habit were correlated with higher-level functional capacity. Cognitive function, social involvement, and exercise habit are as important as dietary therapy for maintaining higher-level functional capacity [7, 29, 30]. The adjusted partial regression coefficients for exercise habits and “vegetables first” were 1.56 and 0.77, respectively. This suggests that not only exercise but the “vegetables first” dietary habits are also important when considering higher-level functional capacity in older adults with diabetes.

One advantage of this study is that the previously demonstrated factors were adjusted to correlate with higher-level functional capacity (including age, sex, complications, social factors, and cognitive function) before revealing the correlation between the habit of eating vegetables first and the maintenance of higher-level functional capacity. The clinical findings obtained from this study showed that the habit of eating vegetables was correlated with the maintenance of higher-level functional capacity in older adults with diabetes, implying the importance of this dietary habit. The habit of eating vegetables first is relatively easy to adopt and have potentially high persistence rate [10, 28]. We believe that practicing this easy to follow dietary habit, i.e., eating vegetables first, for an extended period contributed to the maintenance of higher-level functional capacity, which is of exceptional clinical importance.

This study has several limitations. First, the participants were outpatients examined at a department specializing in diabetes treatment and, accordingly, had relatively severe diabetic symptoms. Therefore, it is necessary to carefully consider whether the results can be applied to patients with stable blood sugar levels or patients receiving treatment from a general practitioner. Second, the sample size in this study was relatively small. Performing further studies to gather data from more case reports is warranted. Third, this study did not factor in the patients’ educational background, body composition, and caloric intake, which might have had an unforeseen effect on the results. Finally, this was a cross-sectional study, i.e., it was impossible to discuss the causal relationships. Longitudinal studies on older adults with diabetes should be performed to evaluate the causal relationships.

Conclusion

Despite the limitations, the results of this study on older adults with diabetes showed that the “vegetables first” dietary habit was associated with higher-level functional capacity. Moreover, the association was of significance in men. Considering the perspective of maintaining higher-level functional capacity in older adults with diabetes, we believe that the dietary habit of eating vegetables first is of utmost importance.

Abbreviations

TMIG-IC	Tokyo Metropolitan Institute of Gerontology Index of Competence
ADL	Activities of daily living
BADL	Basic ADL
IADL	Instrumental activities of daily living
BMI	Body mass index
HbA1c	Hemoglobin A1c
TG	Triglycerides
HDL-c	High-density lipoprotein-cholesterol
LDL-c	Lipoprotein-cholesterol (LDL-c)
MNA-SF	Mini Nutritional Assessment Short Form
MAGE	Mean amplitude of glycemic excursions

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40795-024-00928-9.

Additional file 1: Questionnaire.

Acknowledgements

The authors would like to thank the staff members of the Department of Metabolic Diseases at the Ise Red Cross Hospital for their cooperation in this study. This study received no funding.

Author contributions

SI carried out the design of the study and drafted the manuscript; KM worked on giving advice and reviewing from a medical point of view; KI, and SM helped to draft the manuscript. All authors read and approved the final manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Review Board of the Ise Red Cross Hospital (Approval number: ER2022-36) and conducted in accordance with the Helsinki Declaration. Written informed consent was obtained from all participants before enrolment.

Consent for publication
The participants included in this study provided their written informed consent.

Competing interests
The authors declare no competing interests.

Received: 5 December 2023 / Accepted: 3 September 2024
Published online: 27 September 2024

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