Dietary Behaviors, Nutrient Intake, and Rowing Performance in Collegiate Athletes: From a National Champion Team in Japan

Original Research

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Abstract

Introduction: Competitive rowers train at high volumes and intensities and therefore require well-structured nutritional support. However, it remains unclear how everyday dietary behaviors and habitual dietary intake patterns relate to rowing performance.
Methods: In this cross-sectional study, 33 male collegiate rowers from a national champion team in Japan completed a food frequency questionnaire and additional items assessing nutrition-related behaviors and awareness. Performance outcomes included personal-best 2,000-m rowing ergometer time and official competition ranking at a national university championship.
Results: Four behaviors, use of low-fat milk, frequent legume/soy consumption, seeking nutrition information, and perceived dietary adequacy, were significantly associated with faster 2,000-m ergometer times (ρ = 0.35–0.40, p = 0.032–0.044). In addition, a higher plant-protein ratio was associated with better official competition ranking (ρ = -0.48, p = 0.017).
Conclusions: These findings suggest that both everyday nutrition-related behaviors and habitual dietary intake patterns were associated with rowing performance and underscore the potential value of nutrition education and support in this population.

Key Words: plant protein, nutrition knowledge, ergometer time

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Introduction

Endurance sports require sustained skeletal-muscle activity during training phases and competition periods. As a result, dehydration and depletion of stored carbohydrates (muscle glycogen) have been identified as a primary factor of fatigue [1]. It is important to establish nutritional strategies that enable appropriate replenishment of water and energy during training phases and competition periods to maintain long-term muscle activity.

Rowing is an endurance sport in which athletes compete over a 2,000-meter straight course, and the training is aimed at developing aerobic and anaerobic capacity [2,3]. Rowing ergometers are widely used for performance evaluation because they eliminate variables associated with outdoor environments and enable highly reproducible time trials. In fact, ergometer is used in national training centers and rowing federations worldwide [4-6] and is strongly correlated with on-water rowing performance [7-9]. In well-trained rowers, the between-trial error for a 2,000-m ergometer time trial is approximately 2%, supporting its validity for estimating physiological capacity [4].

The energy expenditure during training for lightweight rowers participating in the World Championships has been reported to be approximately 4,125 kcal/day, indicating that competitive activities require substantial energy [10]. This suggests that frequent and appropriate nutritional intake is required in rowing athletes. Recently, Lewis et al. demonstrated that nutritional interventions improve athletic performance in an international rower diagnosed with unexplained underperformance syndrome (UUPS, or overtraining syndrome) [11]. However, nutrition research focused on competitive rowers remains limited, and nutritional guidance is lacking.

Furthermore, several factors contribute to athletic performance; dietary behaviors are also considered one of the crucial factors. Indeed, in other sports such as hockey, it has been reported that athletes' dietary choices (one of dietary behaviors) can affect their performance [12]. However, a narrative review revealed that the number of studies investigating dietary behaviors in athletes compared to non-athletes is limited, and most studies focused on athletes in specific sports [13]. Dietary behaviors are closely linked to alterations in body composition and physical performance [14-16]. Thus, it is possible that high performance athletes have obtained better dietary behaviors compared to low performance athletes. Despite several studies focusing on energy intake and expenditure [17-21], research on the relationship between dietary behaviors and rowing performance remains scarce, except for our own research [22].

This study aimed to examine, in elite male collegiate rowers, the relationships between nutrition and performance, as assessed by ergometer score results and competition ranking.

Methods

Study Protocol

This study employed a cross-sectional observational design involving a single collegiate rowing team (University A) that won the overall team championship at the All-Japan University Rowing Championships in both 2019 and 2020. Following the 48th All-Japan University Rowing Championships (2021), all eligible rowers were invited to complete a self-administered survey assessing dietary behaviors, nutrition-related awareness, and habitual dietary intake, as well as basic demographic and training information. The study protocol prespecified two performance outcomes: personal-best 2,000-m rowing ergometer time achieved during university enrollment up to October 31, 2021, and official competition ranking at the 48th All-Japan University Rowing Championships. Accordingly, the 2,000-m ergometer time was treated as an individual performance indicator, whereas competition rank reflects team (crew) performance and race context in addition to individual fitness. All questionnaire responses and performance records were collected once for each athlete, and no intervention or experimental manipulation was introduced. The sample size was determined by the number of rowers available on the championship team and thus represents a convenience sample of elite collegiate athletes.

Participants

The participants were 33 male rowers from University A, whose team secured the overall championship title at the All-Japan University Rowing Championships in both the 2019 and 2020 seasons. None of the participants had injuries limiting training or performance at the time of the survey, and all were training to improve their rowing performance. Rowers in the position known as coxswain, who steer the boat, were excluded. The team engaged in 11 training sessions per week (approximately 2h each session), primarily focusing on long steady-state rowing and circuit training aimed at developing both aerobic and anaerobic capacities.

The study protocol was approved by the Ethics Committee of Sendai University (Approval no. 2021-17). All participants provided written informed consent. The study was conducted in accordance with the Declaration of Helsinki and the Ethical Guidelines for Medical and Biological Research Involving Human Subjects in Japan.

Ergometer score

Ergometer score was obtained on a rowing ergometer (Concept2; Concept2 Inc., Morrisville, VT, USA). The time-trial distance was 2,000-m, which is the standard competition distance at the World Championships and Olympic Games. The analysis utilized personal-best times for the 2,000-m distance achieved from the start of university enrollment through October 31, 2021. Times were collected via self-report on the study questionnaire.

Competition performance

Competition performance was assessed by competition rank at the 48th All-Japan University Rowing Championships, with lower ranks indicating better performance. Competition rank was collected via self-report on the study questionnaire.

Dietary behaviors

Dietary behaviors were assessed using specific items in the Food Frequency Questionnaire (FFQ) that queried eating behaviors, attitudes, knowledge, and food choices (Table 1). The dietary behavior items were selected a priori from the FFQ to capture practical, modifiable nutrition-related behaviors and awareness that have been hypothesized in the sports nutrition literature to influence training quality, recovery, and thus performance (e.g., food choices, recovery-oriented habits, and information-seeking/perceived adequacy) [13, 14, 17, 20, 21]. All items listed in Table 1 were examined in an exploratory manner as potential correlates of performance.

Table 1. Survey questions and response options.

Question	Choices
1. Do you try to stay physically active in your daily life to maintain your health?	1. Yes | 2. No
2. Do you feel that you don't get enough exercise?	1. Yes | 2. No
3. Do you exercise regularly?	1. Yes | 2. No
4. Do you know what your appropriate body weight is?	1. Yes | 2. No
5. Are you aware of your appropriate body weight and trying to maintain it?	1. Yes | 2. Not sure | 3. No
6. Do you smoke?	1. Currently smoke | 2. Used to smoke but quit | 3. Never smoked
7. Do you drink more alcohol than you think is appropriate?	1. Often | 2. Sometimes | 3. Rarely
8. Do you have trouble sleeping?	1. Often | 2. Sometimes | 3. Rarely
9. Do you find it hard to get up even after waking?	1. Often | 2. Sometimes | 3. Rarely
10. Do you often feel stressed or fatigued?	1. Often | 2. Sometimes | 3. Rarely
11.Does your appetite change when you are stressed or tired?	1. Decreases | 2. No change | 3. Overeats
12. Have you ever received abnormal results from a health checkup?	1. Within the past year | 2. More than a year ago | 3. No
13. Do you think about nutrition and diet for your health?	1. Often | 2. Sometimes | 3. Rarely | 4. Never
14. Do you prepare balanced meals that include staple foods, main dishes, and side dishes?	1. Always | 2. Often | 3. Sometimes | 4. Rarely
15. Do you check nutrition information when buying food or eating out?	1. Always | 2. Sometimes | 3. Never
16. Do you check expiration or best-before dates when purchasing food?	1. Always | 2. Sometimes | 3. Never
17. Do you believe your meals provide the necessary nutrients?	1. Sufficient | 2. Adequate | 3. Not enough
18. How often do you take dietary supplements?	1. Nearly every day | 2. 4-5 days a week | 3. 2-3 days a week 4. Once a week or less | 5. When I remember
19. Do you try to stay informed about health and nutrition?	1. Yes | 2. No
20. Have you ever taken part in health- or nutrition-related activities or education in your community, workplace, or school?	1. Currently participating | 2. Participated within the past year 3. Participated more than a year ago | 4. Never participated
21. Are you familiar with local specialties and dishes?	1. Yes | 2. No
22. Do you make efforts to reduce food waste by cooking and storing food properly?	1. Yes | 2. No
23. Do you enjoy your meals?	1. Always | 2. Sometimes | 3. Rarely
24. Do you often eat alone?	1. Always | 2. Sometimes | 3. Rarely
25. Do you take time to enjoy your meals?	1. Yes | 2. Not sure | 3. No
26. How often do you cook meals?	1. Always | 2. Sometimes | 3. Rarely
27. Do you eat meals at regular times?	1. Yes | 2. No
28. Do you sometimes skip meals?	1. Nearly every day | 2. 4-5 days a week | 3. 2-3 days a week 4. Once a week or less | 5. Never
29. How often do you drink alcohol?	1. Nearly every day | 2. 4-5 days a week | 3. 2-3 days a week 4. Once a week or less | 5. Never
30. Do you often eat after 9 p.m.?	1. Nearly every day | 2. 4-5 days a week | 3. 2-3 days a week 4. Once a week or less | 5. Never

31. Do you often eat until you feel completely full?	1. Almost always | 2. Sometimes | 3. Rarely
32. How often do you eat out (excluding store-bought boxed meals)?	1. Nearly every day | 2. 4-5 days a week | 3. 2-3 days a week 4. Once a week or less | 5. Never
33. How often do you buy boxed meals from convenience stores or takeout shops?	1. Nearly every day | 2. 4-5 days a week | 3. 2-3 days a week 4. Once a week or less | 5. Never
34. How often do you eat ready-made foods prepared outside the home?	1. Nearly every day | 2. 4-5 days a week | 3. 2-3 days a week 4. Once a week or less | 5. Never
35. How often do you eat instant or frozen foods?	1. Nearly every day | 2. 4-5 days a week | 3. 2-3 days a week 4. Once a week or less | 5. Never
36. How often do you have snacks?	1. Nearly every day | 2. 4-5 days a week | 3. 2-3 days a week 4. Once a week or less | 5. Never
37. Do you consider your snack portions appropriate?	1. Appropriate | 2. Too much | 3. Not sure
38. Do you think your current dietary habits are good?	1. Very good | 2. Good | 3. Not sure 4. Minor issues | 5. Major issues
39. Do you eat enough grains such as rice?	1. Yes | 2. No
40. Do you make an effort to eat dairy products (milk, yogurt, cheese, etc.)?	1. Always | 2. Sometimes | 3. Rarely | 4. Never
41. Do you make an effort to eat beans, tofu, or other soy products?	1. Always | 2. Sometimes | 3. Rarely | 4. Never
42. Do you make an effort to eat vegetables?	1. Always | 2. Sometimes | 3. Rarely | 4. Never
43. How many servings of vegetables do you eat per day (including side dishes)?	1. 5 or more servings | 2. 3-4 servings 3. 1-2 servings | 4. Rarely eat vegetables
44. Do you make an effort to eat fruit?	1. Always | 2. Sometimes | 3. Rarely | 4. Never
45. Do you add soy sauce to foods such as pickles?	1. Always | 2. Sometimes | 3. Rarely
46. Do you try to limit your salt intake?	1. Always | 2. Sometimes | 3. Rarely | 4. Never
47. Do you prefer foods with mild flavors or strong flavors?	1. Prefer mild flavors | 2. Slightly prefer mild flavors | 3. Unsure 4. Slightly prefer strong flavors | 5. Prefer strong flavors
48. Do you often eat fried or stir-fried foods?	1. Often | 2. Sometimes | 3. Rarely | 4. Never
49. Do you use low-fat milk?	1. Yes | 2. No
50. Do you often eat fatty meat?	1. Often | 2. Sometimes | 3. Rarely | 4. Never

List of questionnaire items extracted from the Food Frequency Questionnaire (FFQ) and administered to collegiate rowers.
The original items were developed in Japanese and translated into English. Response options were presented in binary (Yes/No) or Likert-scale format (n = 33).

Dietary intake
Dietary intake was assessed by the larger 172-item Food Frequency Questionnaire (long-FFQ), which was developed for the Japan Public Health Center-based prospective Study for the Next Generation (JPHC-NEXT) [23]. Food and nutrient intake were calculated on designated computer software (FFQ NEXT, Kenpakusha, Tokyo, Japan) based on Standard Tables of Food Composition in Japan 2020 (eighth revised edition).

Statistical Analysis
Associations between dietary intakes and competition rank were assessed using Spearman's rank correlation coefficient (ϱ), given the non-normal distributions. Associations between dietary behavior items (ordinal variables) and ergometer score were also examined using Spearman's ϱ, a non-parametric method suitable for ordered data. For group comparisons, independent t-tests (or Mann–Whitney U tests when normality was violated) were performed. Along with p-values, effect sizes were reported (Spearman's ϱ for correlations, Cohen's d or rank-biserial correlation for group comparisons). Statistical significance was defined a priori as two-sided $p \leq 0.05$. All analyses were conducted in R (version 4.4.1; R Foundation for Statistical Computing, Vienna, Austria). Given the exploratory nature of screening multiple dietary behavior items, p-values were interpreted cautiously alongside effect sizes, without formal adjustment for multiple comparisons.

Results
Participant characteristics and ergometer score

Participant characteristics and subgroup summaries by 2,000-m ergometer score and competition rank are shown in Tables 2 and 3. The full sample included 33 male collegiate rowers, and 24 of these athletes had an official rank at the 48th All-Japan University Rowing Championships and were included in the competition-rank subgroup analyses. Participant characteristics were generally similar across these analytic subsets.

Table 2. Physical characteristics and 2,000-m ergometer time of the participants.

	mean ± SD	max	min
Height (cm)	172.7 ± 3.9	180	163
Weight (kg)	71.4 ± 4.5	80	63
Age (yo)	20.5 ± 1.8	26	18
Experence (y)	6.2 ± 1.9	11	3
Ergometer time (sec)	403.0 ± 10.8	424	376

Values are presented as mean ± SD, maximum, and minimum (n = 33).
Ergometer time was obtained from each participant's personal best 2,000-m trial during the study period.

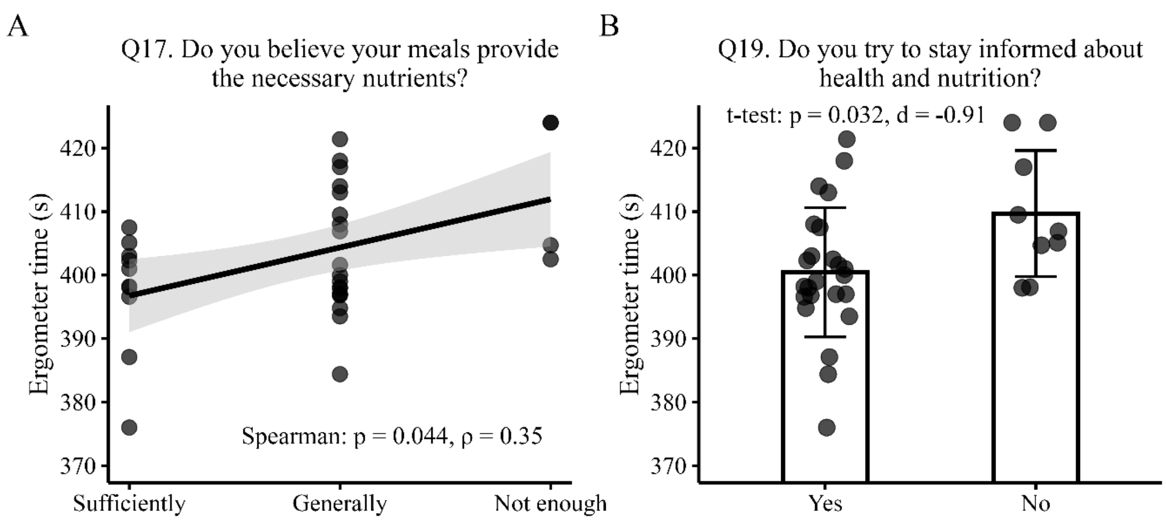
Table 3. Physical characteristics and 2,000-m ergometer time of rowers with official competition ranking.

	mean ± SD	max	min
Height (cm)	174.1 ± 2.9	180	168
Weight (kg)	72.1 ± 4.0	80	64
Age (yo)	21.0 ± 1.7	26	18
Experence (y)	6.3 ± 2.0	11	3
Erogometer time (sec)	398.8 ± 8.4	414	376

Values are presented as mean ± SD, maximum, and minimum (n = 24).
Competition rank was obtained from the 48th All-Japan University Rowing Championships.

Dietary behaviors and ergometer score

Several dietary behaviors showed significant associations with 2,000-m ergometer time (Figure 1). Greater perceived dietary adequacy, stronger engagement with nutrition/health information, more frequent soy product intake, and low-fat milk use were each associated with faster times. The effect sizes ranged from moderate correlations (Spearman's ϱ



≈ 0.35–0.36) to large between-group differences (Cohen's d ≈ −0.9).

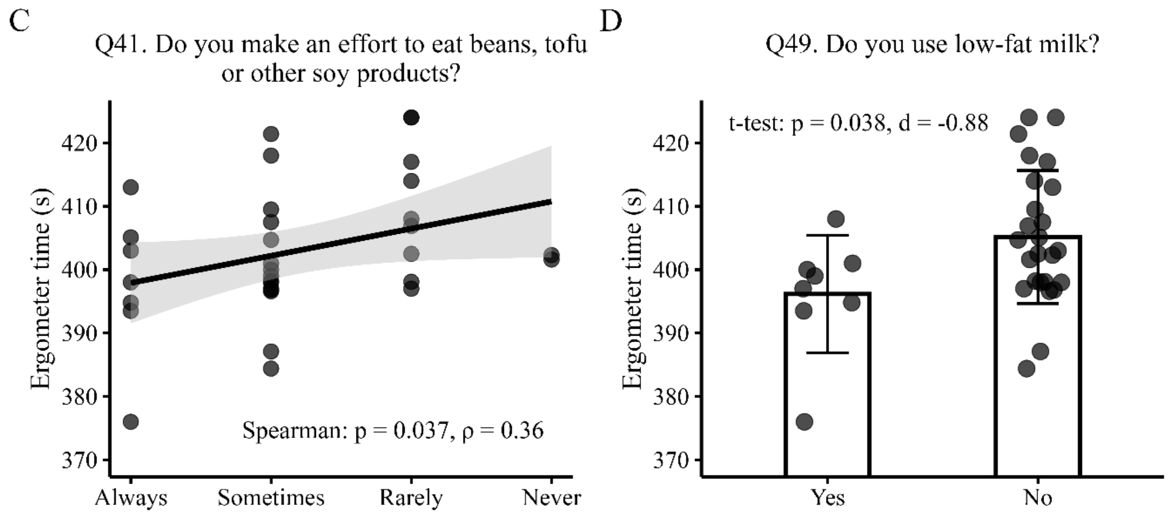


Figure 1. Associations between dietary behaviors and 2,000-m ergometer time
Scatter/summary plots show associations between self-reported dietary behaviors and 2,000-m ergometer time (lower values indicate better performance). Regression lines with 95% confidence intervals (shaded areas) are displayed where applicable. Statistics: Spearman (Q17, Q41), two-group tests (Q19, Q49).

Competition rank and dietary intake

Daily nutrient intakes are summarized in Table 4. The proportion of plant protein to total protein intake exhibited a slight inverse association with competition rank ($\varrho = -0.48$, $p = 0.017$; Figure 2), indicating that a higher plant-protein ratio aligned with better (lower) competition rank.

Table 4. Daily nutrient intake of the participants.

Nutrients	mean ± SD	max	min
Energy (kcal)	2717.69 ± 820.19	4748.13	1423.06
Water content (g)	1328.75 ± 360.82	2051.69	603.20
Protein (g)	109.56 ± 40.7	214.06	53.40
Fat (g)	88.32 ± 32.34	190.87	35.61
Carbohydrate (g)	359.42 ± 106.02	604.96	213.89
Ash (g)	22.39 ± 6.76	40.90	6.80
Sodium (mg)	5034.69 ± 1872.41	9790.83	1237.49
Potassium (mg)	3306.39 ± 1114.15	5577.21	1184.00
Calcium (mg)	624.56 ± 225.61	1046.81	286.25
Magnesium (mg)	359.34 ± 118.33	632.56	127.93
Phosphorus (mg)	1466.34 ± 481.60	2643.24	711.65
Iron (mg)	11.40 ± 3.66	18.02	4.53
Zinc (mg)	13.01 ± 4.53	25.13	6.18
Copper (mg)	1.63 ± 0.50	2.69	0.77
Manganese (mg)	3.69 ± 1.19	6.36	1.96
Iodine (μg)	936.97 ± 681.99	2574.15	144.25
Selenium (μg)	99.91 ± 46.43	218.36	55.40
Chromium (μg)	8.94 ± 3.59	18.74	1.65
Molybdenum (μg)	241.10 ± 86.42	494.74	138.49
Retinol (μg)	263.00 ± 132.54	567.91	102.93

β-Carotene (μg)	4618.79 ± 3475.96	16250.14	955.41
β-Carotene Equivalent (μg)	5347.52 ± 3916.13	18452.23	1134.48
Retinol Activity Equivalent (μg)	716.52 ± 352.03	1740.92	206.33
Vitamin D (μg)	7.60 ± 3.88	18.59	3.16
α-Tocopherol (mg)	9.52 ± 2.92	15.33	4.53
Vitamin K (μg)	311.57 ± 146.73	672.96	85.96
Vitamin B1 (mg)	1.81 ± 0.80	4.34	0.60
Vitamin B2 (mg)	1.80 ± 0.68	3.24	0.87
Niacin (mg)	25.53 ± 12.11	55.76	10.86
Niacin Equivalent (mg)	45.84 ± 18.61	93.76	21.09
Vitamin B6 (mg)	1.91 ± 0.76	3.68	0.73
Vitamin B12 (μg)	7.77 ± 4.03	18.94	3.12
Folic Acid (μg)	384.42 ± 137.93	706.10	152.61
Pantothenic Acid (mg)	8.83 ± 2.89	15.85	4.35
Biotin (μg)	49.51 ± 20.03	102.61	27.98
Vitamin C (mg)	119.10 ± 53.72	242.47	34.53
Saturated Fatty Acid (g)	27.77 ± 11.82	68.24	10.48
Monounsaturated Fatty Acid (g)	32.36 ± 12.97	75.26	12.11
Polyunsaturated Fatty Acid (g)	16.47 ± 5.16	28.00	7.07
Cholesterol (mg)	640.33 ± 306.44	1491.91	308.09
Soluble Dietary Fiber (g)	4.03 ± 1.52	7.33	1.18
Insoluble Dietary Fiber (g)	12.67 ± 4.20	21.44	4.48
Total Dietary Fiber (g)	18.23 ± 6.08	29.60	6.34
Salt Equivalent (g)	12.75 ± 4.76	24.78	3.14
Alcohol Amount (g)	0.77 ± 0.95	3.08	0.00
Total Fatty Acid (g)	76.64 ± 29.14	171.56	29.67
n-3 Polyunsaturated Fatty Acid (g)	2.55 ± 0.86	4.69	1.47
n-6 Polyunsaturated Fatty Acid (g)	13.89 ± 4.52	25.36	5.53
Protein Energy Ratio (%)	15.96 ± 2.24	21.13	11.95
Fat Energy Ratio (%)	29.03 ± 4.10	36.18	22.00
Saturated Fatty Acid Ratio (%)	9.05 ± 1.67	12.93	6.63
Carbohydrate Energy Ratio (%)	55.01 ± 5.56	64.65	45.79
Alcohol (%)	0.02 ± 0.08	0.40	0.00
Cereal Energy Ratio (%)	38.67 ± 10.44	59.79	26.03
Plant Protein Ratio (%)	39.78 ± 9.35	60.50	24.76
Green and Yellow Vegetable Ratio (%)	41.99 ± 13.51	85.01	20.41
n-6 Fatty Acid / n-3 Fatty Acid (ratio)	5.57 ± 1.29	9.68	3.64

Values are presented as mean ± SD, maximum, and minimum (n = 24).
Nutrient intake was estimated using the Food Frequency Questionnaire (FFQ).

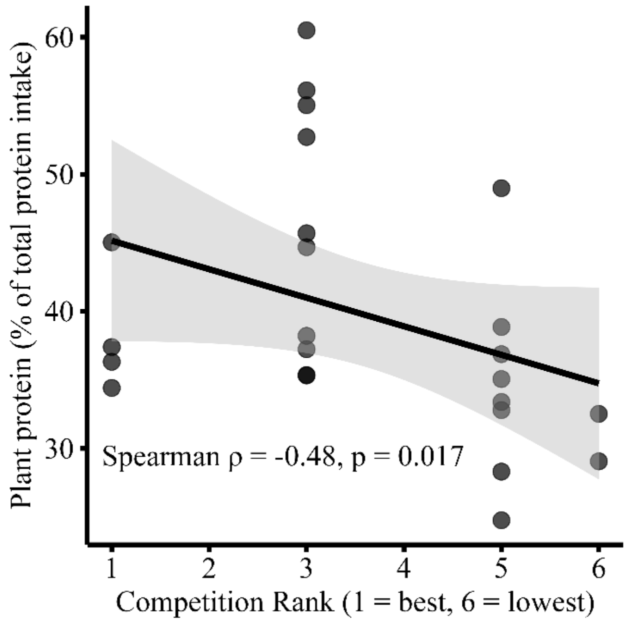


Figure 2. Association between the proportion of plant protein in total protein intake and competition rank
Scatter plot and regression line with 95% confidence interval (shaded) illustrate the relationship between plant protein ratio (%) within total protein intake and competition rank (1 = best, 6 = lowest). Spearman's correlation coefficient (ϱ) and p-value are shown.

Discussion

In this study, we conducted a cross-sectional analysis of dietary behaviors (self-administered questionnaire) and dietary intake (estimated by FFQ) in relation to rowing performance indicators among 33 male collegiate rowers in Japan. The findings revealed that specific dietary behavior factors were significantly associated with rowing performance. Regarding ergometer score, athletes who reported higher adherence to "use of low-fat milk," "frequent consumption of legumes and soy products," "active engagement with nutrition/health information," and "awareness of sufficient nutrient intake from their own meals" tended to record faster (shorter) ergometer times ($p = 0.032$–0.044). Moreover, competition ranking was inversely associated with the proportion of protein intake derived from plant sources, suggesting that athletes with higher plant protein ratios achieved better official competition results (Spearman's $\varrho = -0.48$, $p = 0.017$). From a practical perspective, the between-group effects ($d \approx 0.9$) correspond to a difference on the order of ~10 s in a 2,000-m ergometer test in this cohort, which may be meaningful for competitive selection and seat racing.

The four dietary behavior items significantly correlated with faster ergometer times can be categorized into nutritional behavior and nutritional awareness. From the behavioral perspective, the use of low-fat milk and frequent consumption of legumes/soy products were associated with faster ergometer score. Athletes who consciously consume low-fat milk achieved faster ergometer times compared to athletes with lower intake. Low-fat milk is a high-quality protein source known to facilitate muscle glycogen resynthesis and muscle protein synthesis following exercise [24]. Choosing low-fat dairy allows athletes to efficiently obtain protein and calcium while minimizing saturated fat intake, representing a strategic nutritional behavior. Such practices may be a marker of more performance-oriented dietary management and could be linked to better recovery and training adaptation, which may be associated with faster ergometer times. Similarly, frequent consumption of legumes and soy products (e.g., natto, tofu, soy milk) was also linked to better ergometer score. These foods provide plant protein along with fiber and micronutrients, and their regular intake may be a marker of a more nutrient-dense, balanced dietary pattern. In this cohort, more frequent consumption of legumes/soy products was associated with faster ergometer times, potentially reflecting better overall diet quality and recovery-oriented food choices. This interpretation is consistent with recent evidence suggesting that plant-forward dietary patterns can support endurance-related performance without compromising strength/power outcomes [25].

In terms of nutritional awareness, both engagement with nutrition/health information and greater perceived dietary adequacy were associated with faster 2,000-m ergometer times. These associations may indicate that nutrition literacy and proactive information-seeking co-occur with more performance-oriented dietary practices. Indeed, athletes who are enthusiastic about gathering information are considered to possess greater knowledge regarding dietary improvement strategies and ergogenic aids, and to incorporate such knowledge into their daily dietary behaviors [26]. Furthermore, athletes who perceived that their own diet provided sufficient nutrients also recorded faster ergometer times. This subjective sense of nutritional adequacy likely reflects the athletes' confidence in their dietary management and nutritional balance. Athletes with such awareness are likely to monitor and adjust their intake of energy and macronutrients in preparation for training, which may contribute to enhanced performance. Moreover, confidence in one's own nutritional management may provide psychological reassurance and help prevent performance decline due to nutrition-related concerns.

Collectively, these findings suggest that higher nutritional awareness and proactive information-seeking tend to co-occur with dietary practices that are associated with faster 2,000-m ergometer times.Importantly, the observed effect sizes were in the medium-to-large range (e.g., $\rho \approx 0.35–0.40$; Cohen's $d \approx 0.9$), suggesting that these associations are not only statistically significant but also practically meaningful in the context of rowing performance.

The correlation between dietary intake patterns and competition results were also examined. An intriguing finding was that a higher plant-protein–to–total-protein ratio was associated with better official competition rank. This ratio likely reflects a more balanced intake of protein sources (e.g., legumes, grains, and nuts) rather than heavy reliance on animal protein, and such plant-forward patterns are typically lower in saturated fat while providing more fiber, vitamins/minerals, and antioxidant-rich foods [25]. In endurance sports such as rowing, these features may support recovery, energy availability, and metabolic efficiency [27]. Taken together, the plant-protein ratio may function as a practical proxy for overall diet quality and variety that is linked to competitive outcomes.

This study has several limitations. First, the cross-sectional design precludes causal inference; for example, better performers may be more motivated to manage their diet. Second, the sample size was modest ($n = 33$) and restricted to elite male collegiate rowers, which limits statistical power and generalizability. Third, dietary behaviors, nutrient intakes, and performance outcomes (personal-best ergometer time and competition rank) were self-reported, introducing potential recall and reporting biases. Fourth, competition rank reflects crew-level performance and race context, which may dilute associations with individual dietary habits.
Despite these limitations, studies that combine detailed dietary assessment (FFQ plus behavioral items) with sport-specific performance measures are scarce in rowing. Prospective and interventional studies are needed to determine whether nutrition education and behavioral modification lead to improvements in rowing performance, and future work should include female athletes and other sports to clarify the broader applicability of these findings.

Conclusions

Among top-level collegiate rowers, higher nutrition knowledge/awareness and favorable eating practices (e.g., use of low-fat milk, active intake of legumes/soy, seeking nutrition information, and confidence in dietary adequacy) were associated with faster ergometer times. A higher plant-protein ratio was exploratorily associated with better competition rank. These findings support the importance of both day-to-day nutritional behaviors and habitual dietary intake patterns as potential correlates of rowing performance and provide a rationale for targeted nutrition support in this population.

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Conflict of Interest

The authors declare no conflicts of interest.

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