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Original

The Effect of Problem-Solving-Based Blood Glucose Management through Real-Time Self-Monitoring: A Case Study

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ABSTRACT *Background.* Understanding how daily habits affect blood glucose is challenging for many patients with type 2 DM, often leading to difficulties in sustaining self-management. This case study examined the impact of real-time glucose monitoring with the Free Style Libre on blood glucose control and behavioral change and introduced the concept of "problem-solving–based blood glucose self-management." *Methods.* A patient with type 2 DM and persistently poor blood glucose control was evaluated using continuous glucose data from the Free Style Libre, supported by lifestyle records and interview findings. *Results.* Use of the Libre enabled the patient to identify links between lifestyle behaviors and glucose fluctuations, prompting gradual lifestyle adjustments. HbA1c improved by 1.8% within three months, and glucose visualization enhanced motivation, self-efficacy, and active problem-solving. *Discussion.* The patient's process of identifying challenges and implementing solutions resembled a Project-Based Learning (PBL) approach, supporting the applicability of "problem-solving–based blood glucose self-management" as a patient-centered model. *Conclusion.* Real-time glucose monitoring facilitated significant short-term improvement in blood glucose control and promoted meaningful behavioral change. This approach may offer value for DM education and public health strategies, though further validation is needed.

Keywords: Self-management, Free Style Libre, HbA1c improvement, Problem-solving–based blood glucose management, public health significance

INTRODUCTION

Diabetes mellitus (DM) is classified into four main types: type 1 DM, type 2 DM, DM caused by specific diseases or conditions, and gestational DM (1). Both genetic and environmental factors play a role in its development. In Japan, most cases of DM are type 2, which is strongly influenced by lifestyle habits such as high-calorie diets, high-fat diets, and lack of exercise (1). When these unhealthy habits continue for a long time, the body produces less insulin, and insulin resistance increases, leading to DM (2). Patients with type 2 DM are required to control their blood glucose levels through dietary and exercise therapy to prevent severe complications. If blood glucose control is not sufficient, medications such as oral drugs or insulin injections may be necessary (2). Diet and exercise therapy usually start as soon as a person is diagnosed with DM or is suspected of having it. If these treatments are successful, blood glucose levels can be kept within a healthy range, and the need for medication may decrease (2). However, to achieve this, patients must make diet and exercise therapy a part of their daily routine. These are not a short-term effort but something that must continue for life. Since DM is a chronic disease with few noticeable symptoms, particularly in the early stages, patients often do not experience significant physical changes or disruptions to their daily activities. This makes it difficult for them to fully realize they have DM or feel a sense of urgency. It is often noted that, even

when individuals acquire knowledge and skills related to dietary and exercise therapy, they frequently struggle to maintain these practices in daily life, leading to poor blood glucose control and unsuccessful self-management of blood glucose (3). Schmitt et al. assessed the level of illness acceptance in a cohort of 320 patients with DM and found that those with lower acceptance demonstrated fewer self-management behaviors and had higher HbA1c levels. They reported that accepting one's condition and facing DM directly is closely linked to the continuation of effective blood glucose self-management, and that this factor plays a stronger role than psychological distress in influencing glycemic control. (4). This helps them stay motivated to learn about self-care, include treatment in their daily routines, and create a new lifestyle that supports better health (5,6).

Reports exist regarding the factors influencing the quality of blood glucose control and the support systems available for patients (5,7,8,9,10); however, there are few studies that detail specific methods for achieving good blood glucose control. Okui et al. conducted an intervention study involving ten employed patients with type 2 DM, using systematic self-monitoring of blood glucose (SMBG). Although participants experienced a shift in their awareness toward improving their lifestyle habits, the study also revealed the difficulties of conducting blood glucose monitoring in work environments. Consequently, the authors emphasized the need for a simpler and more practical approach (11). There is an urgent demand for methods that allow blood glucose fluctuations to be recorded without the need to consider specific times, places, or conditions for measurement.

In this study, we report a case of a type 2 DM patient who had been experiencing poor blood glucose control and a continuous rise in HbA1c levels, but who achieved significant improvement in blood glucose control over a relatively short period through self-management using the Free Style Libre Flash Glucose Monitoring System. Although personal experiences and self-collected data related to one’s own health or illness may hold significant academic value, such information is often underrepresented in scholarly literature and rarely reaches formal publication. This study presents data voluntarily contributed by an individual who sought to address this limitation. By documenting these insights in an academic format, the study aims to contribute to the literature and pursue publication in this journal.

Furthermore, the insights gained from this case extend beyond the management of a single individual and hold significant implications from a public health perspective. The demonstration of a simple and sustainable method of self-monitoring for blood glucose control not only contributes to improving the quality of life of patients with DM but also has the potential to strengthen DM prevention and management at the community and workplace levels. Importantly, in the current context where DM is becoming an urgent global public health challenge, the findings of this study may serve as practical evidence that can be shared across countries and regions. Such outcomes are expected to support the advancement of preventive interventions and health education both domestically and internationally, while also informing health policy development and contributing to global strategies for DM control. Thus, this case report transcends an individual success story, offering meaningful insights for broader societal health strategies and for the international public health framework.

METHODS

Participant (Self-initiated data provider) The patient is an elderly man who is currently working. He was diagnosed with non-insulin dependent DM (type 2 DM) in 2013. He has no complications and continues outpatient treatment at a hospital in Tokyo. He takes oral medication but does not use insulin injections. He lives with his wife. Since February 2024, he has been using the Free Style Libre flash glucose monitoring system, manufactured by Abbott, for self-monitoring of blood glucose levels.

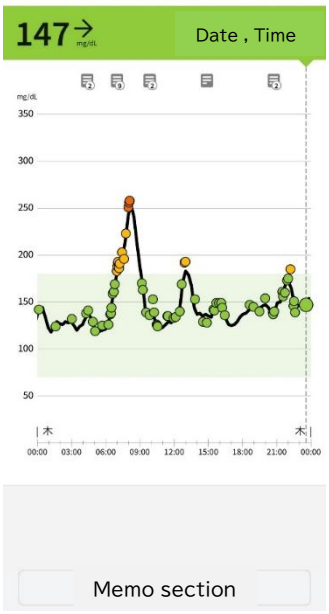
Following a diagnosis of type 2 DM, the patient had continuously adhered to dietary and exercise therapies; however, blood glucose control remained challenging, and HbA1c levels continued to rise. In response, the patient began using the Free Style Libre system to monitor blood glucose fluctuations in real time while reassessing lifestyle habits. This resulted in improved blood glucose control and a marked reduction in HbA1c levels. Believing that this personal experience could offer valuable insights into DM management, the patient expressed a strong desire for these findings to be published in the form of an academic paper. The research team deemed this request appropriate, carefully

reviewed the data provided by the patient to confirm its authenticity, and submitted the research protocol for ethical review to the Jumonji University Research Ethics Committee, as described below. Upon receiving approval, the study was compiled into a research manuscript. The patient was fully informed of the purpose and content of the study, as well as the intended use and handling of the provided data. After fully understanding and accepting these conditions, the patient voluntarily consented to provide personal data in support of this research. In this study, the patient is referred to as the “Self-initiated data provider.”

Blood Glucose Self-Monitoring Tool Used by the Self-initiated data provider The self-initiated data provider uses the Free Style Libre flash glucose monitoring system (hereinafter referred to as "Libre") as a tool for self-monitoring blood sugar levels. Libre is a flash glucose monitoring system that continuously measures glucose levels in the interstitial fluid under the skin. It has a disposable sensor attached to the upper arm, which is scanned using a dedicated Reader to display glucose readings. The system can also be used with a smartphone app called Free Style Libre Link instead of the Reader. This app can be easily downloaded from the Google Play Store or App Store, and the self-initiated data provider in this study uses the app. The sensor is a white, disk-shaped device measuring 35 mm in diameter and 5 mm in thickness, and it is capable of continuously measuring glucose levels for two weeks with a single sensor. During the monitoring period, the sensor remains attached to the body without removal, allowing the user to continue daily activities, including bathing. Even for individuals who are employed, glucose monitoring is not restricted by the time, location, or type of work performed. While strong pressure on the sensor may cause slight discomfort, under normal conditions, it does not produce pain or irritation to the skin.

When the sensor is scanned, the smartphone screen displays a diurnal variation graph. The light green area represents the target blood sugar range (70–180 mg/dL). Circular markers on the line graph indicate individual glucose measurements, with color variations depending on the glucose concentration: green if within the target range, yellow for 181–240 mg/dL, orange for above 240 mg/dL, and red for below 70 mg/dL. The graph also shows the daily average blood sugar level. Additionally, a memo section at the bottom of the screen allows users to record information such as meals, exercise, bathing, sleep, and commuting (Figure 1).

a. Sensor attached to the left upper arm



b. Example of a diurnal variation graph in blood glucose levels

Figure 1 Sensor and a diurnal variation graph

a: The sensor is a white, disk-shaped device that continuously measures glucose levels for up to two weeks while worn on the body, permitting normal daily activities. It generally causes no pain or skin irritation.

b: The screen displays the daily mean glucose level, date and time, and a glucose profile. The light green area indicates the target glucose range (70–180 mg/dL), and measured glucose values are shown as color-coded circles according to glucose level. A memo field below the graph allows users to record daily activities such as meals and exercise.

By continuously tracking glucose levels in the interstitial fluid, Libre helps users understand how their daily habits affect blood sugar. This supports better self-management and helps prevent high and low blood sugar levels.

Interview Survey In June 2024, two face-to-face interviews were conducted. The self-initiated data provider was asked to share his thoughts about DM and self-management. The goal was to understand how his feelings and attitudes changed before and after using Libre.

Medical Record Review Medical data from the self-initiated data provider's hospital visits were used in this study. The basic data for this study were laboratory details, types of prescribed oral medications, daily average blood glucose levels recorded by Libre, and a blood glucose diurnal variation graph. The self-initiated data provider voluntarily provided these materials. It should be noted that no intervention was made by the research team toward the self-initiated data provider during the course of the study, including the process of preparing the manuscript for publication.

Ethical Considerations A detailed explanation of this study was provided to the self-initiated data provider, both in writing through the research protocol and verbally. Among the items described in the protocol, particular emphasis was placed on the following points.

- The data provided must be authentic, and the self-initiated data provider assumes full responsibility should any information prove otherwise.
- The data will be used solely for research purposes, and any information disclosed in publications will be processed to prevent the leakage of personal information.
- Any figures or tables created on the basis of the provided data must be authentic.
- Participation as a self-initiated data provider in this study is entirely voluntary, and refusal to participate carries no disadvantage or penalty.

Consent was considered established upon submission of a signed consent form. Through this process, the ethical soundness of the study—particularly with respect to the protection of personal information and the assurance of research quality—was confirmed, and ethical approval was subsequently obtained from the Jumonji University Research Ethics Committee (Approval No. JEC2024043).

RESULTS

Diabetes Mellitus Treatment Plan at Diagnosis Table 1 shows the dietary and exercise guidance the self-initiated data provider received from his doctor when he was diagnosed with type 2 DM (non-insulin-dependent DM). At first, his treatment only included dietary and exercise therapy, but because he had difficulty managing his blood glucose levels, oral medication was later added. He has never used insulin injections.

Table 1 Diabetes mellitus treatment plan

Treatment	Guidance Details
Dietary therapy	- Maintain a stable weight. - Avoid overeating and finish dinner at least two hours before bedtime. - Reduce high-carbohydrate foods and eat more fiber-rich vegetables. - Make sure to get enough protein.
Exercise therapy	- Walk for about one hour during weekday commutes. - Engage in alternative physical activities on non-working days.
Oral medication	- Oral hypoglycemic agents (Suglat 1 tablet/day, Metoana HD 2 tablets/day, Twymeeg 4 tablets/day, Metformin 1 tablet/day). - Lipid-lowering agent (Lotriga granules 1 packet/day). - Gout and hyperuricemia treatment (Allopurinol 2 tablets/day). - Vasodilator (Amlodipine OD 1 tablet/day). - Hypercholesterolemia treatment (Livalo 1 tablet/day).

Dietary and exercise guidance provided at the time of diagnosis with type 2 DM; oral medication agents were added later due to poor blood glucose self-management.

Even with these treatments, his HbA1c levels kept rising, making him increasingly worried about complications. In search of a way to lower HbA1c levels, he learned about Libre, a self-monitoring blood glucose tool, and decided to incorporate it into his management plan. Libre is covered by insurance for DM patients requiring insulin therapy; however, since the self-initiated data provider did not qualify, he bore the full cost (7,000 yen per two weeks).

Impact of Libre on Blood Glucose Levels The self-initiated data provider started using Libre in January 2024. At first, his blood glucose and HbA1c levels kept rising, but from March 2024 onward, both began to decrease. Notably, the self-initiated data provider's HbA1c level decreased by 1.8% within three months, demonstrating a significant improvement (Figure 2).

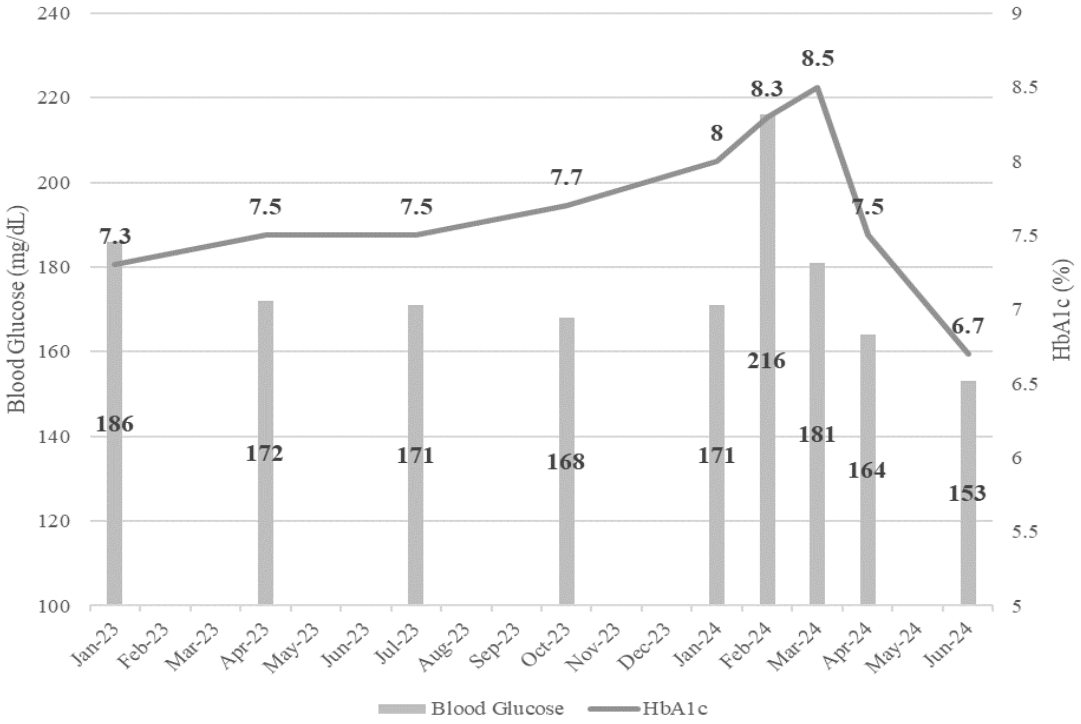


Figure 2 Changes in blood glucose levels and HbA1c during routine hospital visits
Left y-axis: blood glucose (mg/dL); right y-axis: HbA1c (%).
The x-axis shows measurements from routine checkups between January 2023 and June 2024. Use of the Free Style Libre began in January 2024.
Bars represent blood glucose levels, and the line represents HbA1c.

Key Observations from Libre Data Five days between March and May 2024, blood glucose monitoring data obtained via Libre were analyzed, including average daily blood glucose levels and diurnal variation graph (Figure 3). Details for the five days example are provided below:

a: workday (business event) On this day, the self-initiated data provider attended a work-related event where dining was unavoidable. After consuming a bento meal provided at the event, his blood glucose levels rose sharply. He realized that white rice and traditional Japanese sweets (which contain sugar) caused a big spike.

b: hospital checkup day (no work) On this day, the self-initiated data provider did not go to work because he had a hospital checkup. He had a fasting blood test in the morning and ate a late lunch. His blood glucose spiked sharply after eating. He discovered that blood glucose could rise even without eating and that having a full meal after fasting caused an even bigger spike than usual.

c: weekend (at home) While at home on a weekend, the self-initiated data provider ate half a pizza for lunch, which caused a sharp blood glucose increase. Worried about this, he tried exercise bike, which effectively lowered his blood glucose. Through this experience, he discovered that exercise bike was beneficial for blood glucose control. This realization provided him with reassurance that even foods typically considered unfavorable for DM management, such as pizza, could occasionally be enjoyed if paired with appropriate physical activity. He also noticed that oatmeal, which is usually considered good for blood glucose control, actually increased his levels. On the other hand, after dinner, his blood glucose remained stable, which made him feel relieved and happy. This experience helped him gain confidence in managing his blood glucose.

d: workday (usually) The self-initiated data provider spent most of the day sitting at work. Despite this, he was able to keep his blood glucose within the target range using only dietary therapy and oral medication. This success boosted his confidence in self-management. He also found that Shochu (a type of alcohol) helped lower his blood glucose. This discovery made him happy, as he realized he could still enjoy alcohol if he chose the right type.
e: workday (usually) On another workday, the self-initiated data provider noticed his blood glucose increased after lunch. To keep it within the target range, he did squat at work. This exercise successfully lowered his blood glucose. He learned that squat was an effective way to reduce post-meal spikes and that his blood glucose tended to rise more after lunch than other meals.

By observing these blood glucose changes, the self-initiated data provider gained a better understanding of how diet and exercise affected his body. Through repeated trial and error, the self-initiated data provider developed an optimized diet and exercise routine tailored to his lifestyle (Table 2).

Table 2 Adjustments to suit the self-initiated data provider's lifestyle

Category	Key Insights
Diet	- Split meals into two parts: consume protein food first, take medication, then eat the second portion. Prevents sudden spikes in blood glucose levels. - During the day, blood glucose levels rise most dramatically after lunch and remain relatively stable after dinner. - To reduce the consumption of staple foods (such as rice, bread, or noodles). - Shochu does not raise blood glucose. - Oatmeal, despite its reputation, raises blood glucose for this self-initiated data provider.
Exercise	[Workdays] - Walk quickly between home and the station, use stairs when changing trains (~1 hour total). - Squat at work to lower blood glucose. Number of times: 60 reps × 3 sets [Weekends] - Exercise bike effectively lowers blood glucose. Model used: ALINCO ALFITS, AFBX462 Load strength: 8 (maximum) Time: 1 cycle (approximately 1.5 to 2 minutes) × 5
Others	- Blood glucose rises in the morning even before eating, and medication alone does not lower it. Best to eat breakfast only after observing a natural glucose decline. -Blood glucose spikes post-bath but decreases as body temperature normalizes.

Visualization of daily blood glucose fluctuations clarified specific lifestyle prescriptions, including dietary patterns and types of physical activity.

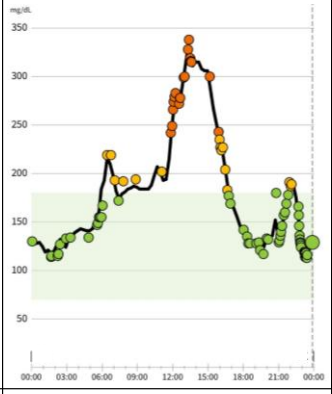
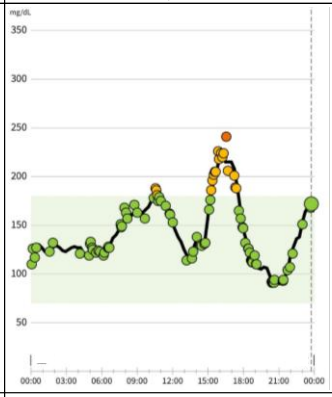
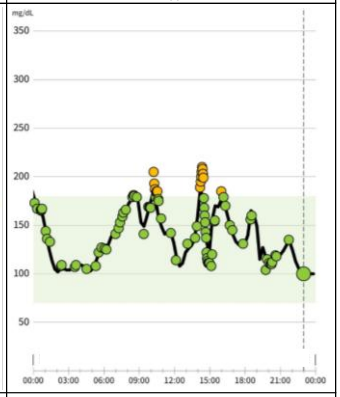
Psychological Changes Before and After Using Libre Table 3 shows how the self-initiated data provider's attitude toward DM management changed. Before Libre, he could only check HbA1c levels during medical checkups, making it difficult to understand the reasons behind fluctuations. As his HbA1c kept rising, he became more anxious about complications. However, with Libre, he could monitor his blood glucose at any time, gaining clarity on how his lifestyle affected his levels. He began to explore the relationship between lifestyle and blood glucose fluctuations. This led to increased motivation, confidence, and a willingness to actively manage his blood glucose levels.

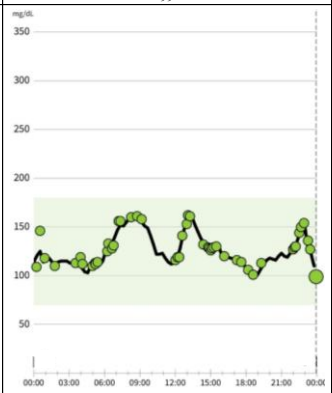
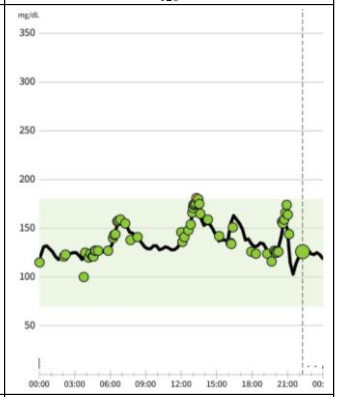
Table 3 Psychological Changes Before and After Using Libre

Before Using Libre	After Using Libre
- Struggled to fully recognize his DM. - Felt strong anxiety about complications. - Thought self-management of blood glucose was impossible. - Had no idea what affected his blood glucose levels. - Lost confidence due to poor blood glucose control.	- Accepted his DM and committed to managing it. - Developed a more positive attitude toward living with DM. - Gained confidence in self-management of blood glucose. - Became motivated to actively control his blood glucose. - Developed curiosity about how lifestyle impact glucose fluctuations. - Felt encouraged by praise from his physician.

A shift from negative to positive thinking was observed before and after the use of Libre.

Figure3　Key Observations from Libre Data (Five days between March and May 2024)

		a. Mid-March 2024（workday : business event）	b. Mid-April 2024（hospital checkup day）	c. Early May 2024（weekend :at home）
MBG (mg/dL)		129	172	100
diurnal variation graph (day)				
Meal details	Breakfast	Yogurt, Salad chicken, Miso soup (onion), Vegetables (tomato/cucumber/cabbage), Sausage 【Take medication】	After the test: Chicken bar 【Take medication】	5:18 Boiled egg, Cheese 【Take medication】 7:15 Lettuce, Pickled bean sprouts, Salad chicken, Vegetable juice, Oatmeal, Yogurt
	Lunch	Lunch for a business meeting (bento) Traditional Japanese sweets	13:30 Beef stew, Coleslaw salad, Danish pastry, Black coffee	13:00 Lettuce, Pickled bean sprouts, Half a pizza
	Dinner	No special notes 【Take medication】	No special notes 【Take medication】	17:49 Boiled egg, Cheese 【Take medication】 18:30 Shochu, Stir-fried mushrooms, Pickled bean sprouts, Tosa-zukuri bonito, Avocado, Cucumber, Tomato, Herring roe
Exercise therapy		None (could not)	None (could not)	Rapid increase after lunch → Exercise bike
Things to notice		White rice and traditional Japanese sweets (which contain sugar) cause blood glucose levels to rise rapidly.	Blood glucose level may rise even without eating. Eating after fasting may increase blood glucose levels more than usual.	Oatmeal may raise blood glucose levels. Exercise bike is beneficial for blood glucose control. Blood glucose levels do not rise much after dinner.

		d. Mid-May 2024（workday :usually）	e. Late May 2024（workday :usually）
MBG (mg/dL)		99	126
diurnal variation graph (day)			
Meal details	Breakfast	5:00 Boiled egg, Cheese 【Take medication】 6:45 Stir-fried mushrooms, Pickled bean sprouts, Boiled cabbage, Pickled plum	5:00 Boiled egg, Cheese 【Take medication】 6:13 Pickled cabbage, Stir-fried mushrooms, Sausage, Yogurt, Natto, Mozuku seaweed
	Lunch	11:59 Boiled egg, Cucumber, Tomato, Pickled plum, Stir-fried mushrooms, Salad chicken, Boiled freeze-dried tofu	12:36 Konjac somen noodles, Cucumber, Seaweed, Salad chicken
	Dinner	21:59 Boiled egg, Cheese 【Take medication】 22:10 Shochu, Stir-fried mushrooms, Grilled duck, Half a block of tofu (topped with salted fish)	18:19 Boiled egg, Cheese 【Take medication】 18:30 Stir-fried mushrooms, Grilled duck, Half a block of tofu (topped with salted fish), Pickled cabbage
Exercise therapy		None	Rapid increase after lunch → Squat
Things to notice		Shochu may lower blood glucose levels.	Squat is beneficial for blood glucose control. Blood glucose levels tend to rise after lunch.

Five days exhibiting characteristic changes in blood glucose levels during the Libre use period are presented.
a: workday (business event)　Due to work-related constraints, dietary choices were limited and blood glucose levels rose rapidly; however, appropriate management was achieved.
b: hospital checkup day (no work)　A greater increase in blood glucose levels was observed after food intake following a fasting state compared with usual conditions.
c: weekend (at home)　Reassurance and enjoyment regarding meal consumption were observed.
d: workday (usually)　Confidence was gained in the ability to manage blood glucose levels through diet and medication alone.
e: workday (usually)　Blood glucose levels were found to rise more easily after lunch compared with after breakfast and dinner.

DISCUSSION

Patients diagnosed with DM often experience shock and anxiety about possible complications. To prevent complications and manage DM effectively, it is essential to continuously monitor blood glucose levels and maintain good control. Therefore, newly diagnosed patients are usually highly motivated to follow recommended dietary and exercise habits strictly. However, integrating DM management into long-standing lifestyle habits without stress is not easy. In particular, working

individuals, like the self-initiated data provider in this study, tend to prioritize work over their health. Additionally, since early-stage DM often has no clear symptoms, patients may gradually lose their sense of urgency about complications, making it easier for them to develop poor blood glucose control.

The self-initiated data provider in this study had extensive knowledge of DM, which suggested that blood glucose self-management might be easier for him compared to the general patient population. However, his HbA1c levels continued to rise, and during routine hospital checkups, he could not determine how his diet, exercise, and other lifestyle habits influenced his blood glucose levels. As a result, he lost confidence in his ability to manage his DM and became increasingly anxious about complications, feeling that self-management was beyond his control.

During these times, he learned about Free Style Libre, a tool that enables real-time blood glucose monitoring. Libre is covered by insurance for type 1 DM patients who require insulin therapy. However, it is also available for purchase online, making it accessible to type 2 DM patients and those concerned about their blood glucose levels. Because of this, Libre is considered a useful tool for self-monitoring blood glucose. After reviewing various usage examples, the self-initiated data provider decided to use Libre for his self-management.

The self-initiated data provider started using Libre in January 2024. At first, he struggled to determine how to use it effectively for managing his lifestyle habits. As a results, his blood glucose and HbA1c levels showed no immediate improvement during routine hospital checkups. However, by continuously monitoring his blood glucose fluctuations and comparing them with activities such as waking up, going to bed, bathing, excretion, exercise, meals, and work attendance, he gradually identified patterns. After about three months, he could gradually see how his lifestyle affected his blood glucose. These findings, shown in Tables 2 and 3, were not obtained easily. Instead, they were the result of repeated testing and trial and error, as he actively experimented to determine what affected his blood glucose. The intake of staple foods—especially rice, bread, and noodles—was identified as a major factor influencing blood glucose variability, and rigorous management of their consumption was strictly implemented. As a result of these efforts, his blood glucose decreased from 181 mg/dL to 153 mg/dL, and his HbA1c dropped from 8.5% to 6.7% between March and June 2024 (Figure 3). The fact that he was able to reduce his HbA1c by more than 1.5% in just three months is a significant achievement with academic importance for DM management.

Dietary therapy, which is essential for DM management, requires patients to carefully select ingredients and consider cooking methods for every meal. This places a major burden on them (12,13,14). Additionally, working individuals often have business meals and social events that take priority over their blood glucose management. Exercise therapy is also difficult to incorporate into daily routines due to time constraints (8). Despite these obstacles, the self-initiated data provider has established dietary and exercise therapy that fits into his lifestyle (Table 3). The real-time monitoring capability of Libre likely contributed to these discoveries by making it easier to identify the relationship between diet, exercise, and blood glucose fluctuations, which helped improve his lifestyle. Furthermore, the sensor can remain attached throughout daily life without removal. As it continuously monitors blood glucose levels while in place, there is no need for the user to remain consciously aware of the need to perform individual measurements. When confirmation of blood glucose levels is required, a simple scan of the sensor suffices. As such, even working individuals, regardless of the nature of their occupation, can monitor their glucose levels without being constrained by time, location, or environmental conditions. This ease of use provided by the Libre system is considered to have been a contributing factor in the marked reduction of HbA1c levels over a relatively short period.

Observing improvements in his blood glucose and HbA1c levels led to major changes in the self-initiated data provider's attitude toward DM and self-management. As summarized in Table 4, before using Libre, he struggled with self-management, feeling discouraged and pessimistic. However, after integrating Libre into his routine and seeing improvements in his HbA1c, combined with praise from his doctor, he gained confidence and motivation to continue self-management. His self-esteem improved, and he developed a positive mindset, fully accepting his condition. Notably, when he spoke about his DM, he appeared to be enjoying the process rather than feeling burdened by it. Confronting DM has been reported to serve as a foundation for learning and implementing self-management (5). For this self-initiated data provider, adhering to dietary and exercise therapy was not just about preventing complications—it also reinforced a sense of accomplishment: "I am improving my

lifestyle" and "I am successfully managing my blood glucose." This increased his confidence and helped him develop a more positive self-image.

To understand the factors contributing to such a dramatic improvement in HbA1c, it is useful to consider the concept of Project-Based Learning (PBL). PBL is a learning approach that focuses on solving problems, where the process of finding a solution is more important than the solution itself. The self-initiated data provider continuously worked to keep his blood glucose within the target range by identifying which lifestyle factors influenced his glucose levels. His curiosity about why and when his blood glucose spiked led him to explore different problem-solving approaches, which ultimately helped lower his HbA1c. The visualization of blood glucose levels on the smartphone display upon scanning the sensor, along with the use of color changes to indicate the magnitude of the values, is considered to have been a significant factor contributing to the improvement in HbA1c levels. It may be concluded that the outcomes achieved by the self-initiated data provider in this study were the result of an approach closely aligned with the principles of Project-Based Learning (PBL).

Similar to this study, previous research has also reported that approaches based on the learning theory of Project-Based Learning (PBL) are effective in supporting self-management of blood glucose levels. Anderson et al. have suggested that a problem-solving–based empowerment education program designed for African American patients with type 2 DM may contribute to improved DM management (15). Funnell et al. stated that a Diabetes Self-Management Support (DSMS) program grounded in empowerment is effective not only in enhancing patients' self-management abilities but also in improving long-term blood glucose control. They emphasized that the key to sustaining behavioral change lies in the process by which patients identify their own problems and goals and develop solutions accordingly (16). Minamimura indicated that a self-management intervention utilizing a problem-solving approach for patients with type 2 DM could be effective in improving blood glucose control (17).

A common feature among these studies, including the present one, is the process through which patients independently recognize, understand, and resolve their own challenges related to blood glucose control. Therefore, this study proposes the term "Problem-solving-based blood glucose self-management" to describe this shared process. This concept is defined as: "A patient-centered approach whereby individuals recognize, understand, and analyze specific blood glucose control challenges arising from their own lifestyle habits, and, through the application of problem-solving techniques, identify solutions to achieve sustainable and optimal blood glucose management." DM, as a chronic condition, requires that patients take an active role in improving their own lifestyle habits as part of treatment. By establishing the concept of "Problem-solving-based blood glucose self-management", we believe it may be possible to promote sustainable, patient-led behavioral change and contribute to more effective DM care.

This study reports on a single case. The outcomes may have been influenced by the participant's unique background, lifestyle, and motivational factors. Thus, the generalizability and reproducibility of the findings, including the proposed concept of "Problem-solving-based blood glucose self-management," remain uncertain. Further studies with additional cases and larger populations are needed to evaluate this concept more rigorously. Key factors such as age, medical history, treatment history, social background, and patients' understanding and attitudes toward DM may shape the process of behavior change. Clarifying these influences will help define the applicability and limits of the proposed approach. This study provides preliminary evidence in this direction. It shows, in an exploratory manner, how the use of Free Style Libre in routine practice may affect patients' cognition and behavior. Future research should test whether these findings can be replicated and whether similar effects occur in broader patient groups. Such evidence would offer practical implications for the design of DM education and self-management support programs.

In Southeast Asian countries, DM prevention and control have become an urgent public health priority. The Lancet Regional Health – Southeast Asia reviewed the current status and challenges of the DM epidemic across 11 Southeast Asian nations, highlighting the rising prevalence in rural areas, dietary transitions, limited health literacy, and difficulties in accessing medical care (18). Nguyen TPL et al. examined the cost-effectiveness of interventions for the prevention of non-communicable diseases, particularly DM, in Southeast Asia. They proposed strategies such as expanding screening programs centered on primary care, improving access to health services, and ensuring the availability

of low-cost medications (19). Lim PC et al. investigated the knowledge level of patients with DM in 11 Southeast Asian countries and found that knowledge was particularly low among older adults, those with lower educational attainment, and patients with poor blood glucose control. As a policy recommendation, they emphasized the importance of identifying knowledge gaps, developing individualized educational plans, and promoting patient-centered communication and education through structured self-management programs (20). Phoosuwan N et al. reported that many patients with type 2 DM in Thailand lack sufficient knowledge about insulin use and overall DM management. They recommended strengthening DM self-management education—particularly in relation to nutrition and diet—and expanding support through community health facilities and educational programs, with special attention to individuals from lower educational and socioeconomic backgrounds (21).

The wider adoption of the Free Style Libre system has the potential to greatly contribute to behavioral change and improved treatment outcomes among people with DM. However, in Southeast Asia, several barriers remain, including high cost, insufficient insurance coverage and policy support, limited knowledge and health literacy among both patients and healthcare providers, and disparities in infrastructure and technology. Addressing these challenges will require multifaceted approaches that combine price subsidies, educational support, and the implementation of enabling policies.

CONCLUSION

This study reports a case of a patient with type 2 DM who utilized the Free Style Libre, a glucose self-monitoring tool, to explore the relationship between lifestyle habits and blood glucose fluctuations. Through this process, the patient achieved behavioral change and a marked improvement in HbA1c within a relatively short period. From these findings, several implications can be drawn.

First, in addition to conventional methods of blood glucose control, the introduction of a real-time glucose monitoring system was shown to enhance patients' self-efficacy and motivation, thereby encouraging active engagement in lifestyle modification. Its practicality and sustainability, even among individuals in employment, highlight its usefulness as a flexible self-management approach.

Second, the visualization of blood glucose fluctuations enabled by the Libre allowed the patient to recognize associations between lifestyle factors—such as diet and physical activity—and changes in blood glucose. This led to the proposal of a new concept termed "Problem-solving-based blood glucose self-management," in which patients identify, understand, and address their own challenges. This concept holds potential for application in DM education and support programs, contributing to the development of sustainable, patient-centered approaches to blood glucose control.

Third**, t**he documentation and analysis of a successful outcome in a single case, as presented in this study, may serve not only as a foundation for future collective and empirical research but also as an important contribution from a public health perspective. DM is a chronic disease of global prevalence, associated with substantial social and economic burdens. The insights gained from this case suggest that flexible, patient-centered approaches to self-management, tailored to individual lifestyles and values, may also contribute to DM prevention and control at the community and population levels. Furthermore, the demonstrated effectiveness of technology-assisted self-management has implications for healthcare systems and policy, particularly in low- and middle-income countries where the prevalence of DM is rapidly increasing. Thus, this study extends beyond the scope of a single case and carries meaningful significance from public health, policy, and international perspectives.

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Original

Evaluating a School-Based Nutrition Education Program to Improve Breakfast Habits Among Sixth-Grade Students: Efforts Targeting the Transition Period Between Elementary to Junior High School in Osaka, Japan

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ABSTRACT *Background and purpose.* Breakfast consumption is crucial for children's health and academic performance. However, the tendency to skip breakfast increases during the transition from elementary to junior high school. Despite existing efforts to encourage breakfast consumption, few programs have successfully integrated nutritional education into the transition period. This study evaluated a school-based nutrition education program designed to improve breakfast habits among sixth-grade students. *Methods*. A pre–post intervention study was conducted with 119 students from two public elementary schools in Osaka, Japan. The program included three lessons on the importance of breakfast, balanced meal compositions, and strategies for maintaining healthy eating habits. Breakfast records and self-administered questionnaires were used to assess the changes in breakfast intake, composition, knowledge, self-efficacy, and attitude. *Result*. While breakfast-skipping rates showed no significant change, breakfast records indicated increased consumption of staple foods ($p = 0.041$) and side dishes ($p < 0.001$). Self-efficacy in preparing a balanced breakfast ($p = 0.045$) and willingness to improve breakfast habits ($p = 0.044$) also improved. The results of classroom evaluations demonstrated that the program was well understood and perceived as highly useful by the participants, supporting the effectiveness and practical relevance of the instructional approach. The program effectively improved the students' breakfast quality and self-efficacy, thus supporting school-based nutrition education as a strategy to promote healthier eating habits. However, long-term interventions and evaluations may be required for sustained behavioral changes.
Keywords: nutrition education, breakfast habits, school-based intervention, self-efficacy, dietary behavior

INTRODUCTION

Breakfast consumption is a fundamental lifestyle behavior that supports children's daily energy requirements and contributes to a well-balanced nutrient intake essential for growth and development (1,2). Numerous studies have demonstrated that children who regularly consume breakfast have improved physical, cognitive, and psychosocial aspects (3-7). For example, breakfast consumption has been reported to positively influence academic performance, attention, problem-solving ability, and memory (3,4). On the other hand, skipping breakfast has been associated with obesity, an increased risk of lifestyle-related diseases, and a decline in self-efficacy (5-7).

In Japan, skipping breakfast is recognized as a critical issue in children's health. The Ministry of Agriculture, Forestry and Fisheries, in its "Fourth Basic Plan for the Promotion of Shokuiku," has set a national goal of reducing the breakfast-skipping rate among children from 4.6% in 2019 to 0% by 2025 (8). Moreover, the rate of skipping breakfast among those aged 15–19 years was 21.5% in 2020, with the aim of lowering it to less than 15% by 2025 (8).

A survey of Japanese elementary and junior high school students found a significant increase in breakfast-skipping with age (9). While the rates among 5th and 6th graders were 7.6% for boys and 8.9% for girls, these figures increased to 16.8% and 17.1% respectively, among junior high school students. This trend may be attributed to multiple factors, including lifestyle changes during adolescence, family environment, and differences in self-care capabilities (10,11).

In Japan's elementary school curriculum, students in the 4th grade learn about the relationship between food and health, and those in the 6th grade study the importance of breakfast (12). However, no corresponding curriculum exists for junior high schools. This discontinuity in educational content may hinder the continuation of dietary education. Given that the rate of breakfast-skipping increases during the transition from elementary to junior high school, the importance of interventions during this period has been suggested (13,14).

Previous studies have reported the effectiveness of interventions that promote breakfast consumption.

School-based programs, family involvement, and the incorporation of self-monitoring have been identified as key factors in enhancing the program impact (15). Individuals with high self-efficacy, as proposed by Bandura (1997) (16), are less likely to skip breakfast (17). According to the PRECEDE-PROCEED model developed by Green et al., to improve breakfast consumption behavior, programs should incorporate self-checking and self-monitoring strategies that foster self-efficacy, which is closely related to motivation for behavioral changes (18). In addition, these programs should aim to enhance children's decision-making and goal-setting skills.

A nutrition education program for upper-grade elementary school students was developed based on the PROCEED-PRECEED MODEL (19). The program aims to foster life skills, which are psychosocial abilities that enable individuals to cope effectively and constructively with the demands and challenges of everyday life, as defined by the World Health Organization (20). They argued that improving self-efficacy contributes to the enhancement of life skills such as decision-making and goal setting, which in turn can lead to increased self-esteem and improvements in both the frequency and quality of breakfast consumption (19,21).

This study aimed to evaluate the effectiveness of the elementary school component of a school-based breakfast nutrition education program that was collaboratively developed and implemented by elementary and junior high schools within the same administrative district. This empirical study focused on changes in breakfast intake, breakfast composition, and self-efficacy among elementary school students. Sixth-grade students were selected as the target group because the prevalence of breakfast skipping tends to increase upon transition to junior high school.

MATERIALS AND METHODS

Study Design

A before-and-after comparative design was implemented among 119 sixth-grade students from two public elementary schools in Osaka City, Japan, between June and December 2022. The intervention was designed as a nutrition education program for sixth-grade elementary school students. The intervention was conducted in two elementary schools within the same administrative district of Osaka City that provided consent to participate. Anonymous self-administered questionnaires were administered to the participants before and after the intervention in the classroom and were collected by the researchers after completion. Additionally, the students recorded their breakfast intake and composition for five days before and after the intervention.

Instrument

The original questionnaire developed for this study included three main sections: habits related to breakfast intake and actual breakfast composition; knowledge, self-efficacy, and attitudes related to breakfast intake and composition; and classroom process evaluation (post-intervention only).

Breakfast composition was defined as the presence of staple food, main dish, and side dish. The habits related to breakfast intake and composition section covered the frequency of breakfast preparation per week, morning appetite, and the percentage of intake of staple foods, main dishes, and side dishes. To assess the percentage of intake, the participants were asked whether they habitually consumed staple foods, main dishes, or side dishes during breakfast. Breakfast records were used to calculate the average consumption of these components based on five-day records maintained by the students.

For breakfast scores, one point was assigned for the consumption of each component (staple food, main dish, and side dish), resulting in a total score ranging from 0 to 3 for each questionnaire and recording. The knowledge, self-efficacy, and attitudes related to breakfast intake and the composition section assessed multiple aspects, including knowledge of the benefits of breakfast, perceived importance of daily breakfast consumption, and various dimensions of self-efficacy (e.g., eating breakfast daily, independently preparing breakfast, planning a nutritionally balanced menu, and prepar-ing a balanced meal, including staple foods, main dishes, and side dishes). Additionally, the willingness to improve breakfast habits was evaluated. The test scores for the five macronutrients measured the students' knowledge of their functions and nutritional content.

The classroom process evaluation section included items on the overall comprehension of the lessons, clarity of instructional materials, perceived usefulness of the three lessons in daily life, and the application of learned concepts and was conducted incorporating the concept of life skills (19). The questionnaire was reviewed in collaboration with schoolteachers and revised to ensure clarity and appropriateness for student comprehension. Homeroom teachers distributed the questionnaires and supervised questionnaire completion in classrooms, with an estimated completion time of approximately 20 mins.

Intervention

The program content was developed in collaboration with nutrition teachers from the target elementary schools, based on the findings of the pre-survey. Three classes were conducted between July and November 2022. The schedules and content of these classes are listed in Table 1. The results of the questionnaire and breakfast records before and after the intervention were compared.

The classes comprised of three key components: discussing the importance of breakfast, reflecting on a

balanced breakfast, and exploring methods to maintain a balanced breakfast. The program was designed to enhance students' self-efficacy through a stepwise approach across three sessions, incorporating self-directed learning and worksheet-based activities. The specific class content and teaching materials used are listed in Table 1. Each 45-minute session was structured into two segments: the first focused on knowledge dissemination, and the second involved interactive and creative activities.

Ethical Considerations

This study was approved by the Ethics Committee of the Graduate School of Human Life Science, Osaka City University (Approval No. 22-18).

The importance of breakfast

In Japanese nutrition education, fourth-grade students learn about the significance of breakfast and its role in daily life. The intervention class (targeting sixth-grade students) aimed to review this knowledge and empower students to convey the importance of breakfast to their peers as senior students. Specifically, they participated in the creation of Karuta (a traditional Japanese card game), with each student responsible for two of the 50 hiragana characters. The completed works were compiled on decorative paper, displayed at school for all students to view, and showcased at a district health exhibition. Examples of the Karuta cards are presented in Figure 1, featuring messages such as "Morning has come, eat your breakfast, and feel full of energy!", "Go to bed early tonight, wake up early tomorrow, and have breakfast."Reflecting on a balanced breakfast

The students explored the concept of a nutritionally balanced breakfast, defined as a meal consisting of staple foods, main dishes, and side dishes. Working in groups of four or five, participants brainstormed various examples of each meal component and recorded their ideas. Subsequently, they reviewed their breakfast records to identify any missing components necessary to achieve a balanced meal.

Methods to maintain a balanced breakfast

Students engaged in a brainstorming session to discuss strategies for consistently consuming a well-balanced breakfast and incorporating staple foods, main dishes, and side dishes as group work activities. At the conclusion of the session, participants established personal goals to enhance their breakfast habits and sustain a nutritious dietary routine.

Statistics Analysis

Descriptive statistics were calculated for each item using Wilcoxon's signed-rank test for ordinal data and McNemar's test for nominal data among the 77 participants who completed both pre- and post-surveys. Breakfast scores and recorded intakes of staple foods, main dishes, and side dishes were analyzed to compare participants' consumption percentages per day before and after the intervention using paired t-tests.

Classroom process evaluations were conducted with the 97 students who participated in the post-survey. As no significant sex differences were observed, all analyses were performed using a combined sample. Statistical analyses were conducted using SPSS Statistics 27.0 (IBM), with the significance level set at 5%.

RESULTS

Questionnaire Collection Rate

There were 107 (89.9%) valid questionnaire responses in the pre-survey period and 104 (87.4%) in the post-survey period. The number of valid responses and collection rates for breakfast records were 113 (95.0%) in the pre-test survey and 105 (88.2%) in the post-test survey. The pre- and post-surveys were compared using data from the 77 participants (64.7%) who provided complete responses to the questionnaire and breakfast records

Habits Related to Breakfast Intake

As shown in Table 2, a difference was observed in the percentage of participants who skipped breakfast before (18.2%) and after (15.6%) the intervention. However, this difference was not statistically significant ($p = 0.625$). No significant changes were observed in the frequency of breakfast preparation per week before or after the intervention ($p = 0.687$). Similarly, there was no significant difference in participants' morning appetite before and after the intervention ($p = 0.518$).

The analysis of breakfast records revealed significant improvements after the intervention. The percentage of students consuming staple foods increased from 80.4% to 88.4% ($p = 0.041$), and side dish consumption increased from 22.1% to 36.3% ($p < 0.001$). Although no significant change was observed in main dish consumption ($p = 0.739$), the overall breakfast scores based on the records increased significantly from 1.36 to 1.69 ($p < 0.001$). By contrast, the questionnaire results indicated no significant changes in the intake of staple foods ($p = 0.500$), main dishes ($p = 0.383$), or side dishes ($p = 0.248$). Similarly, questionnaire-based breakfast scores showed a non-significant increase from 2.13 to 2.31 ($p = 0.099$).

Table 1. Flow and contents of the intervention

Intervention lesson details	Month	Theme	Topics	Tools
Pre-intervention	June			Questionnaire (Pre) Breakfast records for five days.
First lesson (45 minutes)	July	The importance of breakfast	Functions of breakfast, setting lifestyle goals (to have breakfast every day), creation of Japanese Karuta to emphasize the importance of breakfast intake.	PowerPoint materials, handouts, Japanese card game (*Karuta*).
Second lesson (45 minutes)	September –October	Reflecting on a balanced breakfast	Review staple foods, main dishes, and side dishes; brainstorm and write down examples of staples, main dishes, and side dishes; check their own breakfast records and think about personal barriers to a balanced breakfast.	PowerPoint materials, handouts, food models, brainstorming and poster preparation.
Third lesson (45 minutes)	November	Methods to maintain a balanced breakfast	Reviewing the results of the pre-survey questionnaire (percentage of staple foods, main dishes, and side dishes); ideas to include staples, main dishes, and side dishes for breakfast; setting personal lifestyle goals to improve breakfast habits.	PowerPoint materials, handouts, food models.
Post-intervention	December			Questionnaire (Post) Breakfast records for five days

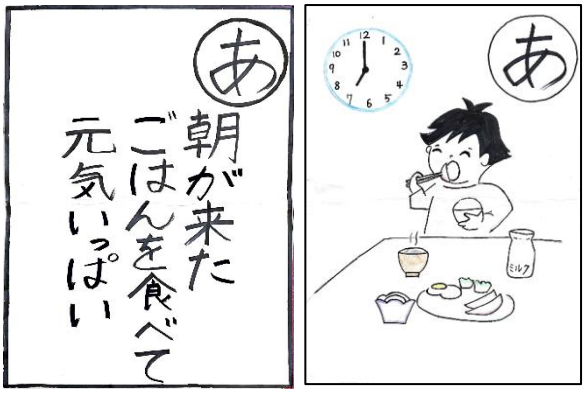

Figure 1. Example of *Karuta*

(Left: Reading card, right: Picture card for “Morning has come, eat your breakfast, and feel full of energy!")

Knowledge, Self-Efficacy, and Attitudes Related to Breakfast Intake

Significant improvements were observed after the intervention with regards to knowledge of the benefits of breakfast ($p < 0.001$), self-efficacy in preparing breakfast with staple, main, and side dishes ($p = 0.045$), and willingness to improve breakfast habits ($p = 0.044$). However, no significant differences were found in the other items (Table 3).

Classroom Process Evaluation

Regarding the overall understanding of the class, 98.9% of the respondents indicated that they understood the class "very much" or "to some extent." Similarly, for ease of understanding the class handouts, 98.9% of the students responded that they found the materials "very easy" or "somewhat easy" to understand. Concerning the perceived usefulness of the lessons, 94.8% answered "very much" or "to some extent" to the statement "The three intervention topics will be useful in life." Additionally, 88.7% of students reported that they reviewed the content learned in class (Table 4).

Table 2. Habits related to breakfast intake (n=77)

Question items and options	Pre-intervention		Post-intervention		*p*-value
How often do you eat breakfast?*					
Everyday	63	(81.8)	65	(84.4)	0.625
Sometimes	14	(18.2)	12	(15.6)	
How often do you prepare breakfast in a week?†					
Everyday	5	(6.5)	6	(7.8)	0.687
4~6 days/week	4	(5.2)	8	(10.4)	
2~3 days/week	20	(26.0)	12	(15.6)	
< 2 days/week	48	(62.3)	51	(66.2)	
Appetite in the morning†					
Very much	22	(28.6)	16	(20.8)	0.518
A little	31	(40.3)	37	(48.1)	
Not much	18	(23.4)	20	(26.0)	
Not at all	6	(7.8)	4	(5.2)	
Percentage of intake of staple foods, main dishes, and side dishes					
Questionnaire*					
Staple foods	74	(96.1)	76	(98.7)	0.500
Main dishes	51	(66.2)	56	(72.7)	0.383
Side dishes	39	(50.6)	46	(59.7)	0.248
Dietary record (percentage of students consuming per day)‡					
Staple foods	62	(80.3)	68	(88.4)	0.041
Main dishes	34	(44.5)	34	(44.5)	0.739
Side dishes	17	(22.1)	28	(36.3)	< 0.001
Breakfast scores‡					
Questionnaire	2.13	(0.864)	2.31	(0.847)	0.099
Dietary record	1.36	(0.655)	1.69	(0.722)	< 0.001

*McNemar's test

†Wilcoxon signed-rank test

‡*t*-test with correspondence (average [standard deviation])

Table 3. Knowledge, self-efficacy, and attitudes toward breakfast intake (n=77)

Question items and options	Pre		Post		*p*-value
Test scores on the five macronutrients*	5.9	(2.5)	6.2	(2.5)	0.171
Knowledge of breakfast benefits†					
Know a lot	27	(35.1)	42	(54.5)	< 0.001
Know a little	36	(46.8)	31	(40.3)	
Don't know much	11	(14.3)	4	(5.2)	
Don't know at all	3	(3.9)	0	(0)	
Perceived importance of eating breakfast every day†					
Very much	51	(66.2)	58	(75.3)	0.217
A little	21	(27.3)	14	(18.2)	
Not much	5	(6.5)	5	(6.5)	
Not at all	0	(0)	0	(0)	
Self-efficacy in eating breakfast every day†					
Very much	57	(74.0)	58	(75.3)	0.415
A little	9	(11.7)	11	(14.3)	
Not much	10	(13.0)	7	(9.1)	
Not at all	1	(1.3)	1	(1.3)	
Self-efficacy in preparing breakfast independently every day†					
Very much	13	(16.9)	14	(18.2)	0.567
A little	35	(45.5)	38	(49.4)	
Not much	22	(28.6)	17	(22.1)	
Not at all	7	(9.1)	8	(10.4)	
Self-efficacy in planning a menu with staple, main, and side dishes†					
Very much	7	(9.1)	7	(9.1)	0.061
A little	25	(32.5)	34	(44.2)	
Not much	31	(40.3)	29	(37.7)	
Not at all	14	(18.2)	7	(9.1)	
Self-efficacy in preparing one's own breakfast with staple, main, and side dishes†					
Very much	4	(5.2)	5	(6.5)	0.045
A little	26	(33.8)	29	(37.7)	
Not much	29	(37.7)	34	(44.2)	
Not at all	18	(23.4)	9	(11.7)	
Willingness to improve breakfast habits†					
Very much	24	(31.2)	31	(40.3)	0.044
A little	31	(40.3)	32	(41.6)	
Not much	20	(26.0)	13	(16.9)	
Not at all	2	(2.6)	1	(1.3)	

**t*-test with correspondence (average [standard deviation])

†Wilcoxon signed-rank test

Table 4. Intervention process evaluation (n=72)

Question items and options	*n*	%
Overall understanding of the intervention program		
Very much	55	76.4
A little	17	23.6
Not much	0	-
Not at all	0	-
Ease of understanding the handouts		
Very much	56	77.8
A little	15	20.8
Not much	1	1.4
Not at all	0	-
The three intervention topics will be useful in life		
Very much	55	76.4
A little	13	18.1
Not much	3	4.2
Not at all	1	1.4
Will you practice what you have learned?		
Yes	64	88.9
No	8	11.1

DISCUSSION

This study suggests that the breakfast improvement program implemented in collaboration between elementary and junior high schools contributed to the improvements in breakfast composition among sixth-grade students through increased knowledge and self-efficacy related to breakfast consumption. Analysis of students' breakfast intake habits revealed that the program had a positive impact, particularly in improving breakfast composition through enhanced self-efficacy. Notably, there was a significant increase in the actual intake of staple foods and side dishes, as confirmed by the one-week breakfast records. This suggests that the instructional sessions contributed to better breakfast composition. Furthermore, classroom process evaluations indicated that the lesson content and materials were well-suited for sixth-grade students. These findings provide preliminary evidence that the program may promote positive dietary behaviors. A strength of this study is that, despite common recruitment barriers in pragmatic intervention research, it implemented a breakfast-improvement program across two schools within one district and grade level. While the absence of a control group presents a methodological limitation, it is nevertheless significant that the implementation of nutrition education in Japanese schools demonstrated potential to improve children's dietary behaviors.

In terms of predisposing and enabling factors, there was an improvement in "Knowledge of breakfast benefits," indicating increased awareness of the importance of breakfast. Additionally, there was an upward trend in "Self-efficacy in planning a menu with staple, main, and side dishes," and a notable improvement in "Self-efficacy in preparing one's own breakfast with staple, main, and side dishes." These results imply that the program successfully enhanced the students' confidence in designing and preparing a well-balanced breakfast. There was also an increase in "Willingness to improve breakfast habits," suggesting that the program helped reduce the perception of breakfast as a burden. These results suggest that the program successfully enhanced the students' confidence in designing and preparing a well-balanced breakfast. This aligns with the concept of self-efficacy, which plays a crucial role in behavior change (16). However, the questionnaire results indicated no significant changes in the frequency of breakfast consumption, breakfast preparation, or morning appetite over a week. Given that the questionnaire assessed habitual behaviors, these results imply that the improvements observed in breakfast composition did not translate into sustained habitual changes. The relatively short intervention period of

approximately three months and the limited number of instructional sessions may not have been sufficient to induce long-term behavioral changes, as supported by previous studies indicating that short-term interventions often fail to produce substantial modifications (21,22). In contrast, programs implemented multiple times per year yielded more significant improvements (23,24).

Although no statistically significant changes were observed in breakfast consumption frequency, the percentage of students eating breakfast daily increased from 81.8% before the intervention to 84.4% after the intervention. This compares favorably with the national average of 81.4% (25). The high baseline adherence to breakfast consumption in the target group may have contributed to the lack of significant changes. Nevertheless, as the primary objective of this program was to prevent an increase in breakfast-skipping rates as students transitioned to the next grade level, the absence of significant deterioration suggests that this goal was achieved.

A previous study using self-administered questionnaires targeting sixth-grade students reported intake rates of 91.7%, 53.1%, and 44.8% of staple foods, main dishes, and side dishes, respectively (26). Participants in the present study exhibited similar or relatively high intake frequencies of these food groups before the intervention. Regarding breakfast balance, the questionnaire results indicated no significant changes in the intake of these components. However, breakfast records over a one-week period demonstrated significant increases in the intake of staple foods and side dishes, highlighting the short-term effectiveness of the instructional sessions (27,28). While the questionnaire captured habitual dietary behavior, the records reflected actual consumption, suggesting that although breakfast composition improved temporarily, these changes had not yet become habitual (29).

Similarly, regarding breakfast scores, no significant changes were found in the questionnaire responses. However, significant improvements were observed in the scores based on breakfast records. This pattern, which is consistent with the results for breakfast balance, suggests that the instructional sessions led to temporary improvements in breakfast composition. However, these did not develop into long-term habitual modifications. This again implies that, although students improved their breakfast composition immediately following the instructional sessions, these changes did not lead to sustained behavioral modifications (30,31).

Regarding the evaluation of the instructional process, classroom observations and student feedback indicated that the clarity of the lessons and materials was appropriate for sixth-grade students. However, some students reported that they found the lessons to have limited applicability to their daily lives or that they had not reviewed the materials after class (32,33). These responses suggest the need for more relatable and engaging content to enhance the program's impact.

Future interventions should consider increasing the frequency of sessions and integrating practical components to enhance the perceived relevance and sustainability of breakfast-related behavior changes (34). Implementing such programs in a coordinated manner across elementary and junior high schools may further enhance their impact. Employing a controlled study design will also be important to more accurately evaluate the effectiveness of the program. Sustained or repeated exposure to such programs within the same community is expected to promote healthy breakfast habits in children.

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CONFLICT OF INTEREST

The authors no conflict of interest to disclose.

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Original

Development and intervention of a nutrition education program for promoting health literacy among high school students

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ABSTRACT *Background and purpose.* This study aimed to develop a nutrition education program for high school students and evaluate whether its implementation in regular classes improves health literacy (hereafter referred to as HL), health/eating knowledge, attitudes, and behaviors. *Methods*. A non-randomized controlled trial was conducted with 98 high school students, divided into an intervention group (57 students) and a control group (41 students) at the class level. The primary endpoints were changes in HL and eating behaviors, while the secondary endpoints were changes in health awareness, attitudes, and knowledge. The intervention group participated in a total of four lessons using the nutrition education program composed of a card game, videos, three-color food cards, and cooking practice, while the control group received only a single lesson on health promotion. A pre- and post-intervention questionnaire surveys were conducted, along with a process evaluation based on feedback from both students and teachers. *Results*. We conducted a per-protocol analysis on 47 students (83.9%) in the intervention group and 26 students (63.4%) in the control group who completed the follow-up. No significant changes in HL were observed during the intervention period in either group, and no significant differences were found between the groups. The significant improvements in the intervention group compared to the control group were observed only in the items related to health knowledge: the term BMI and its appropriate range, and lean body mass. In the process evaluation, high school students showed interest in the nutrition education program, and teachers expressed a desire to continue incorporating it into their classes. *Conclusions.* No significant intervention effects were observed in HL, eating behaviors, or health awareness and attitudes. However, the process evaluation revealed positive feedback from students or teachers, indicating that the nutrition education program could be accepted and feasible in the school setting.
Keywords: high school students, health literacy, nutrition education program

INTRODUCTION

In recent years, health literacy (hereafter referred to as HL) has gained attention as a concept that enables individuals to obtain, understand, evaluate, and utilize health information (1), allowing them to maintain and promote their health throughout their lives (2). Developing HL through health education is not merely about understanding knowledge but is emphasized as a practical ability to recognize issues, make decisions, and take action using communication and social skills to maintain and improve health (3). On the other hand, during childhood and adolescence in which health risks have not still become apparent, it is presumed that active efforts to enhance HL are necessary from the perspective of acquiring healthy lifestyle habits. Research on HL has indicated a correlation between adolescent nutrition, physical activity, and HL, and intervention programs have been recommended to enhance HL (4). However, studies on HL (5,6) and observational research on HL among high school students (7,8) remain limited in Japan.

The high school curriculum guidelines (9) emphasize "thinking and decision-making skills" and state that students should "gather necessary information, acquire knowledge, and make judgments and decisions." Furthermore, they highlight the need for appropriate decision-making, behavioral choices, and the creation of environments that support health. High school represents the final stage in which school-based interventions can be implemented, while also being a period of increasing lifestyle diversity and prominent nutritional challenges. Therefore, the development of a nutrition education program (hereafter referred to as the program) and intervention research are necessary.

Accordingly, this study reports on the development process and evaluation of the program aimed at improving HL, which can be incorporated into formal high school classes in Japan.

MATERIALS AND METHODS

Setting, Participants, and Ethical Considerations

A non-randomized controlled trial was conducted at two high schools, with 57 students assigned to the intervention group and 41 students to the control group at the class level.

We requested cooperation to the target schools, and after discussions and coordination with the school principals and teachers in charge, written explanations were provided to the students and their guardians to obtain informed consent. Participation was voluntary, and it was explained that responses would not affect grades or result in any disadvantages. Since the study was conducted during regular classes, to ensure anonymity during the consent process, documents were distributed and collected in sealed envelopes individually.

The study was reviewed and approved by the Research Ethics Committee of Aomori University of Health and Welfare (Approval No. 22059).

Study Procedure (Fig. 1)

The intervention and data collection period lasted four months, from November 2022 to March 2023. Pre- and post-intervention surveys were conducted to assess changes in HL, eating behaviors, health awareness and attitudes, and health knowledge.

The baseline survey was conducted for both groups before the first lesson, and the post-intervention survey was conducted at the end of the four-month program for the intervention group and at the same time for the control group. The primary endpoints were changes in HL and eating behaviors, while the secondary endpoints were changes in health awareness, attitudes, and knowledge. The intervention group participated in four lessons using the program, while the control group received a single lesson on health promotion. Additionally, a process evaluation was conducted based on feedback from students and teachers.

Date	Frequency	Time	Intervention †	Control ‡
2022 /11	1	50min	★Pre-survey Health promotion for adolescents(1) Card games(1) Videos	★Pre-survey Health promotion for adolescents
	2	50min	Health promotion for adolescents(2) Card games(2) Three-color food cards	
2023 /3	3	50min	Cooking practice	
	4	50min	Tasting and reflection ★Post-survey	★Post-survey

† The intervention group incorporated puberty health promotion, card games, videos, three-color food cards, and cooking practical sessions.
The lessons were structured as four 50-minute sessions, all conducted in person.
‡ The control group participated in one session of health promotion education for adolescence and completed a self-administered questionnaire survey with identification.

Fig 1. Research flow

Structure and Materials of the Nutrition Education Program (Fig. 2)

The program incorporated games, videos, three-color food cards, and cooking practice with the aim of fostering the ability to obtain, understand, evaluate, and utilize health information. To design the intervention content, we conducted a needs assessment and survey among high school students (10). The survey (10) indicated that more than 50% of students were unaware of the "appropriate BMI range," yet many reported being "dissatisfied with their current weight." Furthermore, students identified "weighing themselves" and "cooking" as burdensome activities. In response, the lectures provided detailed explanations on appropriate BMI ranges and lean body mass, and students were guided through BMI calculations.

Based on the results, we developed the program. To maintain engagement, the program was not limited to lectures but also incorporated interactive elements such as games, videos, three-color food cards, and cooking practice to create a dynamic learning experience.

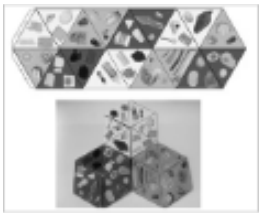
	Card games	Videos	Three-color food cards
Contents · Composition	Learn through games (health edition, knowledge edition, symptoms edition), become aware of your own and others' thoughts, physical discomfort, and bodily changes, and promote interactive communication.	University students created materials on the theme of "women's thinness," allowing high school students to deepen their understanding of the current state of thinness among Japanese women, the reasons for the increasing desire to be thin, DOHaD, and more, leading to greater awareness.	Understand food balance, learn its connection to cooking practice, and decide on ingredients for the cooking session. Create and use folded cards.
			

Fig 2. Content and structure of the nutrition education program

1) Card game

Since positive feedback was received regarding the use of games in class, we determined that including the game in the program would not pose significant issues. The game's concept was to "imagine the feelings of others experiencing physical discomfort and communicate with them to foster mutual understanding."

High school students rarely have opportunities to discuss topics related to health or disease prevention. As a result, they struggle to verbalize symptoms of physical discomfort and remain dissatisfied with their weight despite lacking knowledge of appropriate BMI range. The game was designed to help students learn about "health" "knowledge " and "symptoms " . Through this interactive experience, students could recognize their own and others' perspectives, symptoms of discomfort, and bodily changes, while also improving their ability to communicate their symptoms to others (10).

2) Video

A lack of adequate health education has been identified as a factor contributing to underweight issues and insufficient energy intake among females (11). To address this, we requested university students to collaborate for creating a video on the theme of "female thinness." The video aimed to enhance understanding of the current state of underweight women in Japan and the reasons behind the growing desire to be thin, making the content easier to comprehend.

Many of the university students involved had previously experienced weight-related concerns and dieting during their high school years, recognizing the importance of effective initiatives to improve high school students' HL. Therefore, we incorporated a peer education approach, allowing university students to share important health-related information and promote a healthy body image among high school students. The goal was to create an engaging and informative learning experience.

The video consisted of two sections: a lecture and a cooking demonstration. Narration was provided by university students. The featured dish was "Komatsuna Fried Rice," which could be easily prepared using a single frying pan. The ingredients consisting of rice, komatsuna (Japanese mustard spinach), eggs, dried whitebait, green onions, and sesame seeds, were selected to address deficiencies in energy, iron, and calcium intake.

3) Three-Color Food Cards

The three-color food card system which divides food into red, yellow, and green groups based on their functions is commonly used in school meal programs in primary and secondary schools. Therefore, we adopted it as a reference material because high school students are thought to be familiar with it.

In addition to learning about food balance, students were encouraged to apply this knowledge to cooking practice. The program was designed to help students understand food selection and meal planning, addressing difficulties they had previously identified, such as "cooking," "considering nutritional balance," and "planning meal combinations" (10).

The author proposed multiple (three to five) menu options, and students engaged in discussions to select a menu. They then determined the ingredients and portion sizes for their chosen meal.

4) Cooking Practice

The "Food and Nutrition" component of the home economics curriculum (12) emphasizes efficient cooking

methods and their application to meal planning and menu creation. During discussions on the nutrition education program, teachers highlighted that students' dietary intake was often inadequate and that they had limited opportunities to cook. Based on this finding, we incorporated a cooking practice session where students selected their own menu.

The selected dish was "Onigirazu"—a sandwich-like rice ball that does not require shaping by hand. Using the knowledge gained from the three-color food card activity, students planned the ingredients and portions based on the following categories:

1. Yellow: Energy-providing foods
    - Rice, oil, mayonnaise
2. Red: Body-building foods (supporting blood, muscles, bones, and teeth)
    - Eggs, tuna, ham, seaweed, edamame
3. Green: Body-regulating foods (supporting skin, mucous membranes, and various body functions)
    - Spinach, tomatoes, cucumbers, carrots

For the cooking session, students were divided into groups of three per cooking station, with ingredients and utensils pre-prepared. The cooking process involved spreading half of the rice onto a sheet of seaweed, layering the chosen ingredients, adding the remaining rice, and folding the seaweed from all four corners. After explaining safety precautions, a demonstration was conducted, followed by hands-on cooking. Each student prepared their dish creatively and took photos of their completed meal.

Evaluation composition

1) Questionnaire Composition

Basic information being collected only in the pre-intervention survey included grade level, age, gender, height, weight, and club activity participation. The pre- and post-intervention surveys assessed HL, eating behaviors, health awareness and attitudes, health knowledge, daily routines, exercise frequency, and menstrual records. HL was measured using the Communicative and Critical Health Literacy (CCHL) scale (13).

2) Data Collection and Analysis

The questionnaire was administered twice before and after the intervention in a self-reported format. Survey forms were distributed and collected in sealed envelopes to ensure confidentiality. Participants who were absent, left questions blank, or failed to provide their names were excluded from the analysis. A per-protocol analysis was conducted for the remaining participants.

Intra-group comparisons and inter-group comparisons were analyzed for HL, eating behaviors, health awareness and attitudes, health knowledge, daily routines, exercise frequency, and menstrual records.

Statistical power was set at 80%, with a 5% alpha error. A medium effect size ($d = 0.50$) was used to calculate a required sample size of 26 participants per group using G*Power 3.1.9.7.

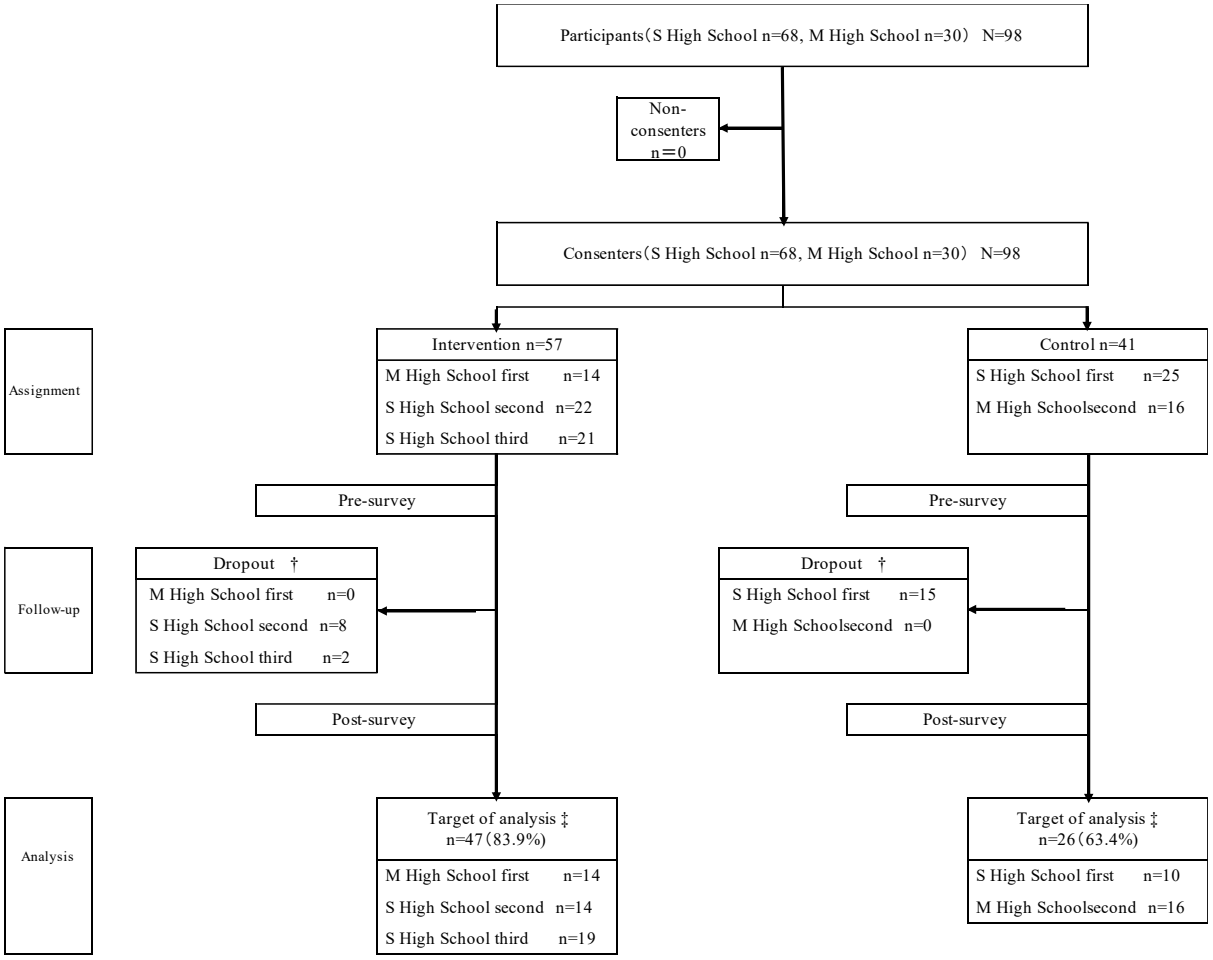
For group comparisons of HL scores and baseline characteristics, t-tests were conducted. Pre- and post-intervention comparisons within groups were analyzed using the Wilcoxon signed-rank test for ordinal variables and McNemar's test for nominal variables. Mann-Whitney U tests were used for inter-group comparisons of changes. Missing data were treated as missing values. Statistical analyses were performed using IBM SPSS Statistics Ver. 29® (IBM Japan), with a significance level of <5% (two-tailed).

3) Process Evaluation

Process evaluation was conducted based on program implementation status, student feedback, and teacher comments. Free-response feedback from students was categorized into themes related to games, lessons, and cooking practice. Teacher feedback was classified into observations of student engagement and opinions on the program.

RESULTS

The number of participants included in the analysis was 47 (83.9%) in the intervention group and 26 (63.4%) in the control group (Fig. 3).



It was targeted at first, second, and third-year students from five classes at S High School and M High School.
Consent was obtained from all participants, and the allocation was done by high school and grade (by class)
The dropout rate was 28% in the intervention group and 60% in the control group at S High School, while at M High School, the dropout rate was 0% in both the intervention and control groups.
† Dropout refers to those who were absent from the classes, attended but did not fill out the questionnaire items, or filled out the questionnaire but did not provide their name, making it impossible to conduct pre- and post-comparisons.
‡ Analysis subjects refer to those who are identified by name and have no missing responses.

Fig 3. Comparison test flow chart

Primary Endpoint

1) HL Score

The mean HL score before the intervention was 3.85 (SD 0.86) in the intervention group and 4.01 (SD 0.47) in the control group, with no significant differences between the groups at baseline.

After the intervention, the mean HL score was 3.94 (SD 0.62) in the intervention group and 3.90 (SD 0.58) in the control groups.

There were no significant changes in the mean HL scores before and after the intervention within each group, nor were there significant differences between the intervention and control groups.

A comparison of pre-intervention HL score averages by grade level showed that first-year students had a mean of 3.91 (SD 0.62) and second-year students had a mean of 3.79 (SD 0.68), with no significant differences between them.

Table 3. Comparison of mean health literacy scores

	n=47	SD	n=26	SD
Age	16.6	0.79	16.4	0.80
Height（cm）	163.5	9.16	160.0	8.07
Weight（kg）	57.0	12.66	54.3	13.99
Body Mass Index（kg/m²）	21.3	4.12	21.0	3.76
Gende Boys	20人(43%)		5人(24%)	
Girls	27人(57%)		21人(76%)	
Sports Club	21人(45%)		11人(42%)	
Non-Sports Club	26人(55%)		15人(58%)	

N=73

Age, height, weight, and BMI are presented as the mean and standard deviation.

Gender and club activity are presented as the number of participants (%).

2) Eating Behavior, Daily Routine, Exercise Frequency, and Menstrual Records (Table 4)

There were no significant changes before and after the intervention within either the intervention or control groups, and no significant differences were observed between the groups.

Secondary Endpoint

1) Health Awareness and Attitudes (Table 5)

No significant changes were observed before and after the intervention within either the intervention or control groups, nor were there any significant differences between the groups.

2) Health Knowledge (Table 6)

In the intervention group, significant changes were observed before and after the intervention regarding knowledge of "the term BMI," "the appropriate BMI range," "lean body mass," and "one's own physical condition."

When comparing between groups, significant differences were found in "The term BMI", "The appropriate BMI range", and "Lean body mass".

Process Evaluation

1) Students' Free Responses

The following comments were extracted as free responses.

(1) Card Game
- There were many words I didn't know.
- Using the symptom cards in the game helped me realize what symptoms I might have.
- If I know, I can approach things confidently and positively.
- I learned not to be swayed by incorrect information and to gather reliable information.

(2) Lessons
- I didn't know the BMI criteria before.
- If you focus too much on weight, it can lead to amenorrhea or osteoporosis.
- There is a lot of information, and I need to decide whether it's true or false.

(3) Cooking Class
- I feel like I could make this at home.
- I used to skip breakfast, but I realized that eating breakfast makes my day more enjoyable.
- I found cooking fun.
- Since I love eating, I felt very happy during the cooking class.
- I will try to eat more and increase my portion sizes.
- I plan to cook at home, even if it's just a little.

- I will start by being more conscious of eating breakfast and small things.
- I think I will try cooking at home.

2) Teacher Feedback

The following comments were extracted as free responses.

(1) Student Behavior

- In cooking classes, students showed creativity and initiative, and they became more interested in food.
- After the cooking class, some students brought their own lunch or snacks, saying, “I can make this with what I have at home.”
- Students felt a sense of familiarity with the video created by college students and showed interest in the simple recipes.

(2) Nutrition Education Program

- The program catered to students who had difficulty engaging or had varying interests, and continued participation led to knowledge retention. I want to incorporate it into future lessons.
- Before participating in the program, students only used the height and weight scales in the hallway of the health room. After the program, they were seen calculating their BMI after measuring their height and weight.

Table 4. Food behavior, lifestyle, exercise frequency, and menstrual records

		Intervention (n=43)			Control (n=26)			Intervention vs Control	
		Pre	Post		Pre	Post		Pre	Post
		n %	n %	*P*†	n %	n %	*P*†	*P*‡	*P*‡
Breakfast	Eat almost every day	34 (72.4)	33 (70.3)	0.317	23 (88.5)	21 (80.8)	0.48	0.118	0.293
	Eat 2-3 times a week	9 (19.1)	9 (19.1)		2 (7.7)	4 (15.4)			
	Hardly eat	4 (8.5)	5 (10.6)		1 (3.8)	1 (3.8)			
Lunch	Eat almost every day	42 (89.3)	42 (89.3)	0.317	25 (96.2)	26 (100.0)	0.317	0.298	0.087
	Eat 2-3 times a week	2 (4.3)	3 (6.4)		1 (3.8)	0 (0.0)			
	Hardly eat	3 (6.4)	2 (4.3)		0 (0.0)	0 (0.0)			
Dinner	Eat almost every day	45 (95.7)	46 (97.9)	0.564	25 (96.2)	23 (88.5)	0.157	0.933	0.093
	Eat 2-3 times a week	2 (4.3)	1 (2.1)		1 (3.8)	3 (11.5)			
	Hardly eat	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)			
Cooking	Almost every day	5 (10.6)	7 (14.9)	1	4 (15.4)	2 (7.7)	0.014	0.723	0.361
	Make it 2-3 times a week	23 (48.9)	19 (40.4)		12 (46.2)	10 (38.5)			
	Hardly cook	19 (40.5)	21 (44.7)		10 (38.5)	14 (53.8)			
Bedtime (weekdays)	Before 10p.m	4 (8.5)	3 (6.4)	0.74	5 (19.2)	2 (7.7)	0.059	0.245	0.518
	10 to 11p.m	6 (12.8)	8 (17.0)		4 (15.4)	6 (23.1)			
	11p.m to midnight	21 (44.7)	19 (40.4)		10 (38.5)	10 (38.4)			
	After midnight	16 (34.0)	17 (36.2)		7 (26.9)	8 (30.8)			
Bedtime (holidays)	Before 10p.m	3 (6.4)	3 (6.4)	1	3 (11.5)	3 (11.5)	0.705	0.604	0.697
	10 to 11p.m	4 (8.5)	4 (8.5)		3 (11.5)	2 (7.7)			
	11pm - midnight	17 (36.2)	17 (36.2)		8 (30.8)	9 (34.6)			
	After midnight	23 (48.9)	23 (48.9)		12 (46.2)	12 (46.2)			
Wake-up time (weekdays	Before 6 o'clock	19 (40.4)	15 (31.9)	0.034	8 (30.8)	10 (38.5)	0.705	0.849	0.519
	From 6 to 7	20 (42.6)	24 (51.0)		16 (61.5)	13 (50.0)			
	From 7 to 8	8 (17.0)	6 (12.8)		2 (7.7)	1 (3.8)			
	After 8 o'clock	0 (0.0)	2 (4.3)		0 (0.0)	2 (7.7)			
Wake-up time (holidays)	Before 6 o'clock	2 (4.3)	1 (2.1)	0.331	3 (11.5)	3 (11.5)	0.763	0.922	0.877
	From 6 to 7	10 (21.3)	8 (17.0)		2 (7.7)	3 (11.5)			
	From 7 to 8	15 (31.9)	18 (38.3)		10 (38.5)	7 (26.9)			
	After 8 o'clock	20 (42.5)	20 (42.6)		11 (42.3)	13 (50.1)			
Sleep time (weekdays)	Less than 6 hours	19 (40.4)	21 (44.7)	0.763	9 (34.7)	7 (26.9)	0.763	0.115	0.043
	6 to 7 hours	21 (44.7)	18 (38.3)		7 (26.9)	10 (38.5)			
	7 to 8 hours	6 (12.8)	7 (14.9)		5 (19.2)	4 (15.4)			
	Over 8 hours	1 (2.1)	1 (2.1)		5 (19.2)	5 (19.2)			
Sleep time (holidays)	Less than 6 hours	3 (6.4)	4 (8.5)	0.334	1 (3.8)	2 (7.7)	0.386	0.232	0.323
	6 to 7 hours	13 (27.7)	16 (34.1)		5 (19.2)	5 (19.2)			
	7 to 8 hours	17 (36.1)	12 (25.5)		9 (34.6)	9 (34.6)			
	Over 8 hours	14 (29.8)	15 (31.9)		11 (42.4)	10 (38.5)			
Exercises other than physical education	Hardly ever	16 (34.0)	17 (36.2)	0.763	4 (15.4)	4 (15.4)	0.655	0.065	0.035
	2-3 days a week	16 (34.0)	15 (31.9)		9 (34.6)	8 (30.8)			
	Every day	15 (32.0)	15 (31.9)		13 (50.0)	14 (53.8)			
Menstruation	Recording, aware of the cycle	12 (44.4)	9 (33.3)	0.681	8 (38.1)	9 (42.9)	0.705	0.894	0.467
	Recording, but not aware of the cycle	2 (7.4)	4 (14.8)		4 (19.0)	4 (19.0)			
	Not recording, aware of the cycle	10 (37.0)	12 (44.5)		8 (38.1)	6 (28.6)			
	Not recording, and not aware of the cycle	3 (11.1)	2 (7.4)		1 (4.8)	2 (9.5)			

N=73

Menstrual record =48

†: A comparison of pre- and post-intervention within the group was conducted using the Wilcoxon signed-rank test.

‡: A comparison of pre- and post-intervention between groups was conducted using the Mann-Whitney U test.

Table 5. Health awareness

		Intervention (n=47)			Control (n=26)			Intervention vs Control	
		Pre	Post		Pre	Post		Pre	Post
		n %	n %	$P^{\dagger}$	n %	n %	$P^{\dagger}$	$P^{\ddagger}$	$P^{\ddagger}$
My weight	Not satisfied	34 (72.3)	30 (63.8)	0.102	19 (73.1)	16 (61.5)	0.083	0.947	0.847
	satisfied	13 (27.7)	17 (36.2)		7 (26.9)	10 (38.5)			
My condition	Not satisfied	26 (55.3)	16 (34.0)	0.008	10 (38.5)	7 (26.9)	0.102	0.29	0.533
	satisfied	21 (44.7)	31 (66.0)		16 (61.5)	19 (73.1)			

N=73

†: A comparison within the group was conducted using the McNemar test.

‡: A comparison between groups was conducted using the chi-square test.

Table 6. Health Knowledge

		Intervention (n=47)			Control (n=26)			Intervention vs Control	
		Pre	Post		Pre	Post		Pre	Post
		n %	n %	$P^{\dagger}$	n %	n %	$P^{\dagger}$	$P^{\ddagger}$	$P^{\ddagger}$
The term BMI	Don't know	14 (29.8)	3 (6.4)	<0.001	8 (30.8)	8 (30.8)	1	0.931	0.006
	Iknow	33 (70.2)	44 (93.6)		18 (69.2)	18 (69.2)			
Normal BMI range	Don't know	34 (72.3)	13 (27.7)	<.001	20 (76.9)	17 (65.4)	0.083	0.671	0.002
	know	13 (27.7)	34 (72.3)		6 (23.1)	9 (34.6)			
Lean body mass	Don't know	40 (85.1)	23 (48.9)	<.001	24 (92.3)	19 (73.1)	0.025	0.373	0.047
	know	7 (14.9)	24 (51.1)		2 (7.7)	7 (26.9)			

N=73

†: A comparison within the group was conducted using the McNemar test.

‡: A comparison between groups was conducted using the chi-square test.

DISCUSSION

Health Literacy (HL)

1) Comparison with Previous Research Using the Measurement Scale

In this study, the pre-intervention mean HL score for the intervention group was 3.85 (SD 0.86), and for the control group, it was 4.01 (SD 0.47). This is comparable to the study by Kasahara et al. (8), which reported average HL scores of 3.66 (SD 0.81) for males and 3.71 (SD 0.68) for females. There was no significant difference when comparing the results of this study with those of Kasahara et al.

2) Within-group and Between-group Comparisons

For each item, there were no changes observed within the intervention group or the control group when comparing pre- and post-intervention surveys. Additionally, no significant differences were found when comparing the pre- and post-intervention surveys between the intervention and control groups. Regarding the interactive HL measurement scale, 34.0% of respondents agreed somewhat, and 55.3% strongly agreed with the information gathering items. However, there was significant variability in responses for information extraction, communication, critical HL, reliability judgment, and decision-making.

It has been reported that previous school health education primarily focused on the transmission of basic health knowledge, without providing skills to engage in community activities (14). The program developed in this study aimed to go beyond knowledge transmission, incorporating activities designed to foster active engagement and dialogue, allowing students to participate interactively.

Despite the positive intent and structured design of the program, the absence of significant changes in HL, eating behavior, and attitudes towards health suggests the need for further exploration and refinement of such programs. The lack of significant effects may be related to factors such as the duration of the intervention, the specific content delivered, or the engagement level of students with the materials and activities provided.

Eating Behavior and Eating Habits

1) Teacher Feedback

Teachers reported positive outcomes, such as students becoming more interested in cooking and bringing breakfast or lunch from home. In particular, students showed creativity during cooking classes, taking an active interest in food preparation. Feedback highlighted that the program helped students gain interest in meal planning and cooking, making it an important foundation for maintaining healthy eating habits.

2) Cooking Frequency and Future Implications

Around half of the students responded that they cooked "2-3 times a week," which may be influenced by the busy schedules of high school students with academics and extracurricular activities. However, it is expected that after graduation, when students often live independently, the frequency of cooking will increase. The hands-on cooking experiences and food-related activities in the program help reduce the burden and anxiety around cooking, encouraging students to enjoy the process. Feedback included comments like "cooking is fun" and "it's delicious when you eat together," which suggests that the program fostered a positive attitude toward cooking and shared meals.

Health Awareness and Attitudes

1) Pre- and Post-Intervention Health Awareness

Around 90% of students in both the intervention and control groups indicated that aspects such as "sleep" and "balanced body composition" were important both before and after the intervention. This suggests that a baseline awareness already existed among students. The program's interactive nature, which encouraged listening to others' opinions and engaging in two-way communication, was thought to reinforce these attitudes and maintained health awareness.

2) Body Weight and Satisfaction

Following the intervention, more students expressed satisfaction with their body weight, and learning how to calculate BMI and understand the criteria helped correct misconceptions about body image and weight. Additionally, increased satisfaction with their physical condition was observed, as students were able to reflect on and understand their symptoms and health status through discussions with peers.

Health Knowledge

1) Knowledge Acquisition and Behavior Change

A positive change in health knowledge was observed in the intervention group, especially concerning decision-making processes related to health. This suggests a direct effect of the program on students' knowledge. Acquiring knowledge about health is crucial for the prevention of lifestyle diseases. The process of actively engaging in discussions and learning from each other is expected to strengthen problem-solving abilities, and repeated learning is essential for effective retention.

2) Comparison with Other Studies

The LifeLab program based at Southampton University Hospital has reported lasting changes in HL and critical judgment related to personal behaviors (16). This program, combined with other studies, has led to an increase in awareness and positive changes in attitudes regarding adolescent health. Although HL improved, knowledge alone did not result in behavioral changes, suggesting that sustainable behavior change requires further research. Teachers also need training in supporting students to make healthier choices.

3) Further Considerations

While knowledge about health improved through the program, there were no substantial behavioral changes or lasting transformation in health habits. This underscores the challenge of achieving long-term behavior change. For sustainable change, students need to develop the ability to identify challenges in their own lifestyles and to select and apply accurate health information. It is also important to consider integrating family support and feedback into the program. Health education that focuses on information collection, discussion, critical thinking, and decision-making can play a significant role in fostering long-term health literacy.

Process Evaluation

In this study, no negative feedback was received about the program. On the contrary, the majority of the participants found the program to be enjoyable and engaging, providing a fun and interactive learning experience. Instead of passively acquiring knowledge, the students were able to engage in active and dialogic learning, creating a relaxed atmosphere where they could freely discuss health issues and physical conditions. This type of two-way communication was useful in drawing out the students' interest and attention.

1) Students' Free Descriptions

(1) Card Game

Students reported that the card game helped them recognize their own symptoms and approach health issues with a positive attitude. The game made them aware that symptoms can vary from person to person, which led to an appreciation for different perspectives. The card game allowed students to gain a deeper understanding of their symptoms, and they recognized the importance of gathering accurate information for health improvement.

(2) Class

During the lessons, students were able to select actions and plans to improve their health based on the information provided, which helped them critically evaluate and choose reliable information. The use of active learning in high school classes is expected to led students to think more comprehensively, expand their ideas, and

deepen their understanding. Dialogic learning seemed particularly effective, and students were able to acquire information, evaluate it, make decisions, and apply critical thinking.

(3) Cooking Classes

In cooking classes, even students who usually participated less in regular lessons became more active and engaged. The cooking activities allowed students to set realistic and achievable health goals. Moreover, they learned the joy of cooking and the importance of eating meals. Recent trends, such as the rising popularity of "Onigirazu" (rice ball wraps), which is easy to prepare and eat, fit well into the curriculum and helped reduce skipping meals and provide a convenient snack option. These cooking lessons seemed as valuable in promoting health.

2) Teacher Feedback

Teachers noted that students' interest and engagement in the program increased as they learned about their own bodies. Given that high school graduation marks a time when students' lifestyle habits change significantly, introducing such programs is expected to enhance students' motivation for health improvement. Teachers expressed positive feedback, and some mentioned they desire to keep using the program in the future. They also felt that the program could be easily implemented in high school classes.

Limitations of the Study

To assess the true effects of the intervention, a randomized controlled trial would be ideal. However, conducting such an experimental design in real-world school settings is often challenging. Therefore, this study adopted a quasi-experimental design with a non-randomized control group, conducting the intervention in two high schools with practical field constraints. The participants in this study may have had a high level of interest or concern about food and nutrition, which could have influenced the outcomes. While the program was designed to encourage active participation and knowledge transfer, there was insufficient consideration of activities to foster critical thinking during the application of this knowledge. Further research could improve these aspects to strengthen the program's effectiveness.

CONCLUSION

This study developed a nutrition education program aimed at improving health literacy (HL) among high school students and implemented it through an intervention trial in classrooms. However, it was not possible to demonstrate whether the program led to healthier eating habits. On the other hand, students were able to actively and dialogically engage in learning, gain a better understanding of their own health, and develop an interest in the nutrition education program. Teachers expressed interest in continuously incorporating the program into their lessons, and the feasibility of implementation in schools was favorable.

For high school students, it was crucial to cultivate the ability to obtain, understand, evaluate, and apply health information, as well as to develop the process of critical thinking to address health issues related to their lifestyles. Introducing health education in the classroom and allowing students to acquire knowledge was effective and highly satisfactory. It is believed that this would lead to improved HL and support long-term, healthy behaviors and appropriate decision-making in the future.

In light of this, to enhance the feasibility of introducing the developed nutrition education program in classrooms, standardization of the program's procedures and content is necessary. The program will be refined to improve HL from the perspective of developing problem-solving skills for health issues. A more sophisticated research design will be used to conduct a follow-up intervention study.

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CONFLICT OF INTEREST

The authors no conflict of interest to disclose.

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Original

Associations of appetite with anthropometric measurements, mental health, dietary and nutritional status: a cross-sectional study in elderly Japanese people attending a day-care facility

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ABSTRACT Our study investigated the prevalence of poor appetite (PA) and its associations with anthropometric measurements, mental health, dietary and nutritional status in the elderly. We analyzed 71 participants (26 men, 45 women) at a day-care facility in City N and surveyed their basic characteristics (age, sex, support/care level, and living status), anthropometric measurements (including height, weight, calf circumference), mental health status (Geriatric Depression Scale-15 [GDS-15], Philadelphia Geriatric Center Morale Scale [PGC-MS]), appetite (Japanese version of the Council on Nutrition Appetite Questionnaire), and nutritional status (Mini Nutritional Assessment, food frequency questionnaire). The participants were divided into a PA group and a good appetite (GA) group. Between-group differences were examined using the Mann-Whitney U test or chi-square test. Binary logistic regression analysis was conducted assigning 0 to PA and 1 to GA as dependent variables and using the relevant factors as independent variables. The prevalence of PA was 38% overall. Significant between-group differences were noted for living status, calf circumference, GDS-15 score, and PGC-MS. Intakes of energy, protein, other nutrients and various food groups in the PA group were significantly lower than those in the GA group. The proportion of individuals with insufficient/inadequate intake of energy was greater in the PA group than in the GA group. Regression analysis demonstrated significant relationships of appetite with living status (odds ratio 3.838, 95% confidence interval 1.136–12.969) and protein consumption/standard body weight (9.449, 1.285–69.487). Assessment of appetite in elderly persons needing nursing support/care seems important for the prevention of undernutrition or malnutrition.
Keywords: appetite, assessment, elderly, nutrient consumption, undernutrition

INTRODUCTION

Undernutrition or malnutrition constitutes a major health problem in the elderly, causing sarcopenia and frailty, increasing the need for nursing support/care, and acting as a trigger for higher morbidity and mortality (1-3). Screening with the Mini Nutritional Assessment (MNA®) tool found that approximately 50% of community-dwelling elderly persons attending day-care facilities or receiving home care were at risk of malnutrition and 10%–20% were malnourished (4-6); these figures were 40%–60% and 15%–30%, respectively, for elderly persons residing in nursing homes (7-9). Thus, the risk of malnutrition can be as high as 50% in elderly persons, whether they live in the community or in nursing homes.

Poor appetite (PA) appears to precede weight loss and undernutrition by causing lowered and/or imbalanced intake of energy and nutrients. Appetite is affected by various factors in the elderly, including age-related frailty and chronic diseases, socioeconomic factors including financial difficulty, residential and living status, and psychological stress (10,11). To the best of our knowledge, there have been few surveys of the associations of appetite with these factors, dietary and nutritional status in elderly persons attending day-care facilities in Japan. In this study, we investigated the prevalence of PA and associations of appetite with anthropometric measurements,

mental health, dietary and nutritional status in an elderly Japanese population for early intervention to prevent undernutrition or malnutrition.

MATERIALS AND METHODS

Study population. Eighty-three elderly individuals attending a day-care facility in City N, Aichi Prefecture, Japan, were initially eligible for an interview-based survey conducted between February and March 2015. After excluding 12 individuals due to incomplete information, data from the remaining 71 participants (26 men, 45 women) were available for analysis. The study protocol was approved by the Ethics Committee of Nagoya University of Arts and Sciences (approval number 94), and all participants provided written informed consent.

Basic characteristics. We obtained information on age, sex, care needs level (Support level 1 or 2, Care level 1–4) as defined by the Long-term Care Insurance System (12), number of medicines (categorized as 0 for fewer than 4 prescribed agents, and 1 for 4 or more agents), and living status (living alone or with others).

Anthropometric measurements. Height was measured using a digital height measurement device (YG-200DN; Yagami KK, Osaka, Japan). Body weight and body composition were determined using a portable device (In Body 430; Takumi KK, Tokyo, Japan). BMI was calculated as weight (kg)/height (m)2. Grip strength was measured twice in the left hand and right hand each using a digital grip dynamometer (T.K.K. 5401; Takei Instrument Industry KK, Niigata, Japan), and the average values were recorded. Arm and calf circumferences were measured, and the average values were calculated for both sides.

Mental health. Depression was assessed using the Geriatric Depression Scale (GDS-15) (13,14). A negative answer was scored as 1 and a positive answer as 0, with a maximum total score of 15. A total score of 0–4 indicates no depression, a total score of 5–10 a tendency for depression, and a total score of ≥11 depression. In this study, participants with a GDS-15 score of <5 were considered to be non-depressed, while those with a score of ≥5 to be depressed.

The Philadelphia Geriatric Center Morale Scale (PGC-MS) was used to measure subjective psychosocial well-being (15). An affirmative answer was scored as 1 and a negative answer as 0, with a maximum total score of 17. According to the instrument guidelines, scores of 13–17 were considered high, scores of 10–12 within the mid-range, and scores <9 at the low end of the scale.

Appetite. Appetite was assessed using the Japanese version of the Council on Nutrition Appetite Questionnaire (CNAQ-J) (16). The original version was developed by Wilson et al. (17). This questionnaire comprises 8 items with a maximum of 5 points each, for a total of 40 points. Individuals with a score of 8–16 may be at risk of anorexia and need nutritional counseling, those with a score of 17–28 may need frequent re-evaluation, and a score ≤28 may predict at risk of 5% weight loss within 6 months. In our study, individuals with a CNAQ-J score of ≤28 were allocated to a PA group and those with a score of ≥29 to a good appetite (GA) group.

Dietary and nutritional status. Dietary and nutritional status was evaluated using the MNA® (18), which consists of 6 screening items (maximum 14 points) including changes in food intake and body weight, and 12 assessment items (maximum 16 points) such as living environment and prescribed medication status. Scores were summed (maximum 30 points), and nutritional status was defined as malnutrition <17 points, at risk of malnutrition 17–23.5 points, or normal nutrition ≥24 points.

Participants were also assessed using a food frequency questionnaire with confirmed validity and reproducibility (version 3.5, based on the Standard Tables of Food Composition in Japan) (19), which asks about the frequency of intake of 29 food items with 10 cooking methods. Intakes were estimated for energy, 4 macronutrients (protein, lipids, carbohydrates, and dietary fibers), 8 minerals and vitamins (calcium, iron, zinc, vitamins A, B1, B2, C, and D) and were calculated for 13 food groups (cereals, potatoes, legumes, green and yellow vegetables, other vegetables, seaweeds, fish and shellfish, meat, eggs, milk and dairy products, fruits, confectionery, oils and fats).

Intakes of energy and protein per standard body weight (kg) (22.0 [BMI] × height [m]2) were also calculated in addition to crude values and per body weight values (kg). BMI <21.5 was considered to reflect insufficient consumption of energy according to the 2020 Dietary Reference Intakes for Japanese (20).

Statistical analysis. Median differences in participant's characteristics, anthropometric measurements, mental health, and nutritional status were compared between the PA and GA groups using the Mann-Whitney U test, a 2×2 table examined by the chi-square test or Fisher's direct method, or a 2×3 table examined by the chi-square test. Spearman's rank correlation coefficients were calculated between CNAQ-J and relevant parameters. Using the forced entry method, binary logistic regression analysis was performed assigning 0 to PA and 1 to GA as the dependent variables, with relevant factors as independent variables adjusted for age and sex. In view of the rather small sample size, the independent variables were narrowed down considering the correlation coefficients and collinearity of the variables in the categories of mental health and nutrient intake. All statistical analyses were conducted using SPSS version 22.0 (IBM Corp., Armonk, NY). A two-sided p-value of <0.05 was considered statistically significant.

RESULTS

Basic characteristics. The 71 participants (26 men [36.6%], 45 women [63.4%]) had a median age of 82 years (interquartile range [IQR] 76, 87) (Table 1). The prevalence of PA was 38.0% (n=27) and that of GA 62.0% (n=44). The CNAQ-J scores were 29 (IQR 27, 32) for all participants, 27 (IQR 20, 28) for the PA group, and 31 (IQR 30, 33) for the GA group.

Overall, 30 participants (42.3%) required Support level 1 or 2, 32 (45.1%) Care level 1 or 2, and 9 (12.7%) Care level 3 or 4. There was no significant difference in age, sex, Support/Care level, or number of prescribed agents between the PA and GA groups. The prevalence of living alone was significantly greater in the PA group than in the GA group (51.9% vs 27.3%, p=0.045).

Height could not be measured in 3 participants and body weight could not be measured in 10 because of difficulty in standing erect, having a rounded spine, or declining to participate in the examination. Therefore, the analyses of nutrient intake per standard body weight were based on data for 68 participants, while those involving body weight, BMI, and skeletal muscle mass were based on data for 61 participants. BMI was lower in the PA group than in the GA group (21.0 [IQR 19.5, 23.6] vs 22.8 [IQR 20.1, 25.7]); however, the difference was not statistically significant. Calf circumference was significantly smaller in the PA group (31.0 cm [IQR 29.0, 33.0] vs 33.0 cm (IQR 30.3, 35.0]; p=0.033). There was no significant between-group difference in skeletal muscle mass, arm circumference, or grip strength.

Mental health. The GDS-15 score was significantly higher in the PA group than in the GA group (5 [IQR 3, 8] vs 3 [IQR 1, 6]; p=0.005). The proportion of depression was greater in the PA group (55.6% vs 31.8%), but the difference was not statistically significant (p=0.081). The PGC-MS score was significantly lower in the PA group (10 [IQR 7, 12] vs 12 [IQR 9, 13]; p=0.040).

Table 1. Characteristics of the elderly participants, and comparison of anthropometric measurements and mental health by appetite status

	All participants		Poor appetite group		Good appetite group		*p*-value [b]
	n	Median [IQR [a]] or (%)	n	Median [IQR] or (%)	n	Median [IQR] or (%)	
CNAQ-J score [c]	71	29 [27, 32]	27	27 [20, 28]	44	31 [30, 33]	<0.001
Age (years)	71	82 [76, 87]	27	81 [74, 87]	44	82 [77, 80]	0.614
Sex (men/women)	26/45	(36.6)	10/17	(37.0)	16/28	(36.4)	0.999
LTCI care needs level [d]							
Support level 1 or 2	30	(42.3)	18	(40.7)	19	(43.2)	
Care level 1 or 2	32	(45.1)	14	(51.8)	18	(40.9)	0.927
Care level 3 or 4	9	(12.7)	2	(7.4)	7	(15.9)	
At least 4 prescribed medicines	45	(63.4)	18	(66.7)	27	(61.4)	0.801
Living alone	26	(36.6)	14	(51.9)	12	(27.3)	0.045
Anthropometric measurements							
Height (cm)	68	148.7 [142.9, 154.7]	27	149.3 [141.5, 156.2]	41	147.8 [143.0, 154.4]	0.764
Body weight (kg)	61	49.9 [42.9, 56.7]	24	46.9 [41.1, 55.5]	37	52.6 [43.5, 57.7]	0.238
BMI (kg/m^2)	61	22.1 [19.8, 25.3]	24	21.0 [19.5, 23.6]	37	22.8 [20.1, 25.7]	0.112
Skeletal muscle mass (kg)	61	17.4 [15.2, 20.8]	24	16.7 [15.4, 19.5]	37	17.6 [15.0, 21.0]	0.585
Arm circumference (cm)	71	26.0 [23.0, 28.0]	27	26.0 [22.0, 28.0]	44	27.0 [24.0, 28.0]	0.225
Calf circumference (cm)	71	32.0 [30.0, 34.0]	27	31.0 [29.0, 33.0]	44	33.0 [30.3, 35.0]	0.033
Grip strength (kg)	71	17.0 [12.9, 21.3]	27	16.6 [12.9, 19.2]	44	17.9 [12.9, 22.0]	0.485
Mental health							
GDS-15 score [e]	71	4 [2, 6]	27	5 [3, 8]	44	3 [1, 6]	0.005
Depression (GDS-15 score ≥ 5)	29/71	(40.8)	15/27	(55.6)	14/44	(31.8)	0.081
PGC Morale Scale score [f]	71	11 [8, 13]	27	10 [7, 12]	44	12 [9, 13]	0.040

[a] Interquartile range.

[b] Median values were examined by the Mann-Whitney *U* test, and proportions by the chi-square test or Fisher's direct test.

[c] Council on Nutrition Appetite Questionnaire for Japanese.

[d] Long-Term Care Insurance System.

[e] Geriatric Depression Scale-15.

[f] Philadelphia Geriatric Center Morale Scale.

Dietary and nutritional status. The MNA® score was 24 (IQR 22, 26) and the proportion with malnutrition or at risk of malnutrition was 49.2% overall with no significant difference between the GA and PA groups (Table 2).

Overall, dietary intakes were as follows: energy 1,473 kcal (IQR 1,228, 1,703), protein 52.8 g (IQR 43.5, 65.5), lipids 42.5 g (IQR 33.0, 55.2), carbohydrates 212.6 g (IQR 180.1, 236.1), and zinc, a crucial mineral for taste that influences appetite, 6.6 mg (IQR 5.4, 7.6). Intakes of nutrients (energy, protein, lipids, carbohydrates, dietary fibers, iron, zinc, vitamins B_1, B_2, C, and D) were significantly lower in the PA group than in the GA group ($p<0.05$).

Table 2. Comparison of nutritional status, and intakes of nutrients and food groups according to appetite status

	All participants		Poor appetite group		Good appetite group		*p*-value [b]
	n	Median [IQR [a]] or (%)	n	Median [IQR] or (%)	n	Median [IQR] or (%)	
Nutritional status							
MNA® score [c]	61	24 [22, 26]	24	24 [20, 26]	37	25 [22, 26]	0.103
Malnutrition or at risk of malnutrition (MNA® score ≤23.5)	30	(49.2)	13/24	(54.2)	17/37	(45.9)	0.605
Consumption of energy and nutrients							
Energy (kcal)	71	1,473 [1,228 1,703]	27	1,330 [1,107, 1,578]	44	1,605 [1,334, 1,745]	0.006
Energy (kcal)/body weight (kg)	61	30 [25, 35]	24	29 [23, 35]	37	31 [26, 36]	0.281
Energy (kcal)/standard body weight (kg) [d]	68	30 [25, 35]	27	27 [21, 35]	41	33 [28, 36]	0.008
Insufficient energy intake (BMI<21.5)	27/61	(44.3)	15/24	(62.5)	12/37	(32.4)	0.034
Protein (g)	71	52.8 [43.5, 65.5]	27	45.8 [33.6, 56.0]	44	55.8 [49.6, 71.3]	0.003
Protein (g)/body weight (kg)	61	1.08 [0.85, 1.32]	24	0.98 [0.75, 1.23]	37	1.18 [0.92, 1.33]	0.057
Protein (g)/standard body weight (kg)	68	1.03 [0.84, 1.37]	27	0.97 [0.73, 1.20]	41	1.19 [0.99, 1.46]	0.003
Lipids (g)	71	42.5 [33.0, 55.2]	27	38.6 [26.1, 46.4]	44	46.4 [34.7, 60.3]	0.015
Carbohydrates (g)	71	212.6 [180.1, 236.1]	27	198.1 [149.4, 226.2]	44	217.0 [195.0, 245.1]	0.040
Dietary fibers (g)	71	11.6 [8.8, 13.7]	27	9.6 [7.1, 12.2]	44	12.6 [9.4, 14.9]	0.004
Calcium (mg)	71	477 [331, 554]	27	426 [282, 525]	44	488 [412, 597]	0.061
Iron (mg)	71	5.9 [4.5, 7.3]	27	5.6 [3.9, 6.3]	44	6.0 [4.8, 7.9]	0.017
Zinc (mg)	71	6.6 [5.4, 7.6]	27	5.8 [4.1, 6.9]	44	7.0 [5.9, 8.4]	0.002
Vitamin A (μg RAE) [e]	71	493 [330 , 629]	27	438 [322, 523]	44	540 [351, 663]	0.079
Vitamin B_1 (mg)	71	0.73 [0.56, 0.88]	27	0.66 [0.53, 0.78]	44	0.79 [0.58, 1.00]	0.025
Vitamin B_2 (mg)	71	0.84 [0.66, 1.04]	27	0.73 [0.61, 0.89]	44	0.93 [0.71, 1.12]	0.025
Vitamin C (mg)	71	96 [64, 116]	27	71 [44, 99]	44	103 [71, 124]	0.003
Vitamin D (μg)	71	6.4 [3.6, 8.1]	27	4.2 [2.9, 7.0]	44	6.7 [4.7, 8.9]	0.010
Consumption of food groups							
Cereals (g)	71	336 [270, 398]	27	330 [222, 384]	44	345 [314, 405]	0.135
Potatoes (g)	71	21 [7, 43]	27	14 [7, 29]	44	21 [7, 50]	0.144
Green and yellow vegetables (g)	71	75 [50, 111]	27	71 [50, 100]	44	86 [50, 123]	0.149
Other vegetables (g)	71	129 [95, 193]	27	109 [91, 160]	44	167 [104, 210]	0.023
Seaweeds (g)	71	3 [1, 5]	27	2 [1, 4]	44	5 [2, 7]	0.003
Legumes (g)	71	35 [20, 55]	27	20 [10, 40]	44	40 [30, 69]	0.002
Fish and shellfish (g)	71	54 [31, 79]	27	41 [23, 70]	44	68 [45, 91]	0.006
Meat (g)	71	51 [29, 80]	27	49 [20, 63]	44	69 [34, 91]	0.060
Eggs (g)	71	14 [7, 29]	27	14 [7, 25]	44	21 [14, 36]	0.142
Milk and dairy products (g)	71	92 [33, 190]	27	109 [8, 186]	44	87 [50, 195]	0.648
Fruits (g)	71	86 [43, 150]	27	75 [32, 107]	44	150 [64, 150]	0.021
Confectionery (g)	71	27 [10, 52]	27	43 [11, 65]	44	23 [9, 47]	0.213
Fats and oils (g)	71	6 [3, 11]	27	5 [2, 9]	44	8 [4, 13]	0.021

[a] Interquartile range.

[b] Median values were examined using the Mann-Whitney *U* test, and proportions by the chi-square test.

[c] Mini Nutritional Assessment.

[d] Standard body weight: [22 × height(m)^2] kg.

[e] Retinol activity equivalents (μg).

No significant difference was noted in energy consumption per body weight between the two groups; however, energy consumption per standard body weight was significantly lower in the PA group than in the GA

group (27 kcal/kg [IQR 21, 35] vs 33 kcal/kg [IQR 28, 36]; p=0.008). The proportion of individuals with insufficient energy consumption (BMI<21.5kg/m^2) was greater in the PA group (62.5% vs 32.4%; p=0.034).

No significant difference was noted in protein consumption per body weight between the two groups, either; however, the value per standard body weight was significantly lower in the PA group than in the GA group (0.97 g/kg [IQR 0.73, 1.20] vs 1.19 g/kg [IQR 0.99, 1.46]; p=0.003).

In terms of protein sources, intakes of legumes, fish and shellfish were significantly lower in the PA group than in the GA group (legumes: 20 g [IQR 10, 40] vs 40 g [IQR 30, 69]; fish and shellfish: 41 g [IQR 23, 70] vs 68 g [IQR 45, 91]; both p<0.01). Consumption of meat tended to be lower in the PA group (p=0.06). The intakes of other vegetables, seaweeds, fruits, fats and oils were significantly lower in the PA group than in the GA group (p<0.05).

Table 3. Correlations between CNAQ-J[a] score and anthropometric measurements, mental health status and dietary consumption

	n	r [b]	p -value
Age (years)	71	0.033	0.783
BMI	61	0.230	0.074
Calf circumference (cm)	71	0.313	0.008
GDS-15 score [c]	71	-0.313	0.008
PGC-MS [d]	71	0.313	0.008
MNA® score [e]	61	0.231	0.073
Energy (kcal)	71	0.345	0.003
Energy (kcal)/body weight (kg)	61	0.229	0.076
Energy (kcal)/standard body weight (kg) [f]	68	0.375	0.002
Protein (g)	71	0.370	0.001
Protein (g)/body weight (kg)	61	0.299	0.019
Protein (g)/standard body weight (kg)	68	0.405	0.001
Lipids (g)	71	0.288	0.015
Carbohydrates (g)	71	0.276	0.020
Dietary fibers (g)	71	0.329	0.005
Calcium (mg)	71	0.265	0.025
Iron (mg)	71	0.281	0.018
Zinc (mg)	71	0.395	0.001
Vitamin A (μg RAE) [g]	71	0.231	0.052
Vitamin B_1 (mg)	71	0.277	0.019
Vitamin B_2 (mg)	71	0.308	0.009
Vitamin C (mg)	71	0.348	0.003
Vitamin D (μg)	71	0.272	0.022
Cereals (g)	71	0.200	0.094
Potatoes (g)	71	0.144	0.232
Green and yellow vegetables (g)	71	0.167	0.163
Other vegetables (g)	71	0.260	0.029
Seaweeds (g)	71	0.372	0.001
Legumes (g)	71	0.332	0.005
Fish and shellfish (g)	71	0.309	0.009
Meat (g)	71	0.187	0.121
Eggs (g)	71	0.233	0.050
Milk and dairy products (g)	71	0.144	0.231
Fruits (g)	71	0.300	0.011
Confectionery (g)	71	-0.130	0.280
Fats and oils (g)	71	0.270	0.023

[a] Council on Nutrition Appetite Questionnaire for Japanese.

[b] Spearman's rank correlation coefficient.

[c] Geriatric Depression Scale-15.

[d] Philadelphia Geriatric Center Morale Scale.

[e] Mini Nutritional Assessment.

[f] Standard body weight: [22 × height (m)^2] kg.

[g] Retinol activity equivalents (μg).

Correlations between CNAQ-J score and relevant factors. The Spearman's rank correlation coefficient between the CNAQ-J score and calf circumference was statistically significant (r=0.313, p=0.008), as was the PGC-MS score (r=0.313, p=0.008). (Table 3). The GDS-15 score was negatively associated with CNAQ-J score (r=

-0.313, p=0.008). The correlation coefficients between the CNAQ-J score and age, BMI, and MNA® were not statistically significant.

Intakes of energy (r=0.345, p=0.003), protein (r=0.370, p=0.001), dietary fibers (r=0.329, p=0.005), zinc (r=0.395, p=0.001), and other 8 nutrients were significantly associated with CNAQ-J score. Intakes of legumes (r=0.332, p=0.005), fish and shellfish (r=0.309, p=0.009), and other 4 food items were also significantly associated with CNAQ-J score.

Binary logistic regression analysis. The GDS-15 score was negatively associated with the PGC-MS score (r= -0.623), and protein consumption was strongly correlated with intakes of energy (r=0.907) and zinc (r=0.962). Calf circumference, living status, GDS-15 score (as a mental health status marker), and protein consumption (as a marker of energy and nutrient intake) were used as independent variables. Analyses were performed using two models (model 1, crude protein consumption; model 2, protein consumption per standard body weight). Factors associated with appetite were living status (odds ratio [OR] 4.237, 95% confidence interval [CI] 1.246–14.408) and crude protein consumption (OR 1.050, 95% CI 1.007–1.095) according to model 1, while living status (OR 3.838, 95% CI 1.136–12.969) and protein consumption per standard body weight (OR 9.449, 95% CI 1.285–69.487) according to model 2 (Table 4).

Table 4. Final results of binary logistic regression analysis according to the forced entry method

	Model 1[a]				Model 2[b]			
	OR[c]	95% CI[d]		*p* -value	OR	95% CI		*p* -value
Calf circumference (cm)	1.116	0.911	1.367	0.291	1.095	0.893	1.344	0.381
Living status[e]	4.237	1.246	14.408	0.021	3.838	1.136	12.969	0.030
GDS-15 (score)[f]	0.850	0.710	1.017	0.076	0.853	0.711	1.024	0.089
Crude protein consumption (g)	1.050	1.007	1.095	0.023	–	–	–	–
Protein consumption (g)/standard body weight (kg)[g]	–	–	–	–	9.449	1.285	69.487	0.027

[a] Model 1: calf circumference, living status, GDS-15, and crude protein consumption.

[b] Model 2: calf circumference, living status, GDS-15, and protein consumption/standard body weight.

[c] Odds ratio: adjusted for sex and age.

[d] 95% confidence interval.

[e] 0, living alone; 1, living with other(s).

[f] Geriatric Depression Scale-15.

[g] Standard body weight: [22 × height $(m)^2$] kg.

DISCUSSION

Prevalence of PA. In previous studies, the proportion of community-dwelling elderly with PA was 10%–25% when evaluated using the CNAQ or the Simplified Nutritional Appetite Questionnaire (SNAQ), while that of individuals in need of nursing support/care, outpatients, or hospitalized patients was 20%–45% (21-24). The prevalence of PA was 38.0% in this population. These figures suggest that elderly people who need nursing support and/or medical care are at higher risk of PA.

Anthropometric characteristics. Some studies have demonstrated associations of appetite with age and several anthropometric parameters, including BMI, skeletal muscle mass, calf circumference, and grip strength, in the elderly (25-27); however, the observed associations were not universal or consistent. In this study, we found a significant association of appetite with only calf circumference. These inconsistencies may be due in part to the different backgrounds of the study populations and the fact that physical changes occur as a result of persistent loss of appetite.

Living status. Similar to the present study, there have been some studies examining associations between eating alone and/or living alone and decreased appetite (27,28). Other studies have demonstrated that living alone and/or eating alone was associated with reduced consumption of energy, nutrients and certain food items and with malnutrition (29-31). Thus, living alone and/or eating alone can be considered a risk factor for PA or malnutrition in the elderly. The prevalence of living alone (36.6%) was greater in our participants than in the general population. Approximately 6.24 million people (26.3%) aged 65 years or over were living alone in Japan in 2015 (32). Given that elderly persons living alone have been increasing both in number and in proportion, careful attention should be paid to their appetite.

Mental health. The prevalence of depression of approximately 41% in the present study was greater than the range of 10%–30% previously reported for the elderly without functional impairment (21,33,34) but similar to the range of 30%–65% reported in the elderly living in nursing homes (7,21,35), suggesting that elderly people who

need nursing support/care are at higher risk of depression. Relevant studies have found that depression was significantly related to PA/anorexia and malnutrition in the elderly living in the community and in nursing homes (7,21,34), as seen in the present study.

Although some studies have demonstrated an association of PA/anorexia with QOL in patients with cancer (36-38), there is limited information on this relationship in the community-dwelling elderly or those who need nursing support/care. Acar Tek *et al*. reported that appetite was associated with mental and physical components of health-related QOL (39). There were no published observations on the relationship between the PGC-MS score and appetite in the elderly who need nursing support/care, whereas we noted that PGC-MS score was lower in the PA group than in the GA group. Therefore, it seems worthwhile to further investigate associations between PA/anorexia and QOL.

Dietary and nutritional status. Using the SNAQ and a 24-hour dietary recall survey, Hara *et al.* demonstrated significantly lower intakes of energy, protein, lipids, carbohydrates, dietary fibers, iron, and zinc, but not of calcium or sodium, in elderly outpatients with PA/anorexia compared with their counterparts without PA/anorexia in Brazil (24). van der Meij *et al*. administered a food frequency questionnaire to a group of community-dwelling elderly in the Netherlands and found lower intakes of protein and dietary fibers in individuals with PA than in those with GA/very GA (40). Payette *et al*. also reported associations of appetite with intakes of energy and protein in an elderly Canadian population receiving publicly funded home care packages (41).

Hara *et al.* reported that outpatients with anorexia had inadequate intakes of 87.7% for energy and 71.5% for protein: that is, they were below 30 kcal/kg (body weight) for energy and below 1 g/kg for protein according to the values recommended in the European Society for Clinical Nutrition and Metabolism guideline (24,42). Payette *et al.* found that 78% of elderly men and 70% of women had insufficient energy intakes, and 57% of elderly men and 80% of women did not meet the recommended protein consumption per day (0.8 g/kg) according to the advised nutrient intake for Canadians (41,43). In the present study, 62.5% of the PA group had insufficient energy consumption as defined by the Dietary Reference Intakes for Japanese. Median values for protein consumption per body weight and standard body weight in the PA group were under 1 g/kg, while those in the GA groups were over 1 g/kg, suggesting more than half of the PA group had insufficient protein intake. Given that the participants in the above-mentioned studies (24,40,41) had varied background characteristics and different criteria were used to determine insufficient dietary intake, a direct inter-comparison could not be made; however, it seemed obvious that participants with PA had lower/inadequate consumption of energy and protein than those with GA.

In Italy, Donini *et al*. reported that elderly participants with anorexia (in community-dwelling individuals aged ≥65 years, nursing home residents, patients in rehabilitation and emergency wards) had reduced intake in certain food groups including meat, eggs, fish, fruits and vegetables (44). van der Meij *et al*. also reported that their participants with PA had significantly decreased consumption of solid food, protein-rich food, whole grains, fruits and vegetables, but increased consumption of dairy food, oils and fats, sweets, and sodas when compared with those with GA (40). Our study also noted that PA was associated with lower or inadequate intake of various food items and nutrients in elderly population attending a day-care facility. All the aforementioned studies demonstrated that PA was strongly related to reduced intakes of crucial nutrients (including energy and protein) and relevant food items. In other words, it appeared that elderly people with PA were at risk of undernutrition or malnutrition.

Binary logistic regression. A multivariate binary logistic regression noted that PA was associated with reduced consumption of protein and living alone in the present study. We also detected a strong correlation between intakes of energy and protein (r=0.907). These results were compatible with the findings by Payette *et al.* (41), showing an association between decreased energy consumption and PA. Accordingly, consumption of nutrients (energy and protein, in particular) and living status seemed important factors of PA in elderly people.

Limitations. The main limitation of this study was its lack of statistical power because of a small study population. It had a cross-sectional design, which precluded investigation of cause-and-effect relationships and the risk of PA. Furthermore, because this study was conducted in a day-care facility, it appears unclear whether the findings could be generalized to other elderly populations.

Conclusions. We identified 38% prevalence of PA at a day-care facility in Japan. PA in this population was significantly associated with living alone and reduced protein intake and tended to be associated with depression. Given that nutritional intervention would generally be implemented after the onset of weight loss or undernutrition, assessment of appetite and related factors in the elderly should be of high priority to prevent undernutrition or malnutrition.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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Original

Hidden Risk in Normal BMI: Body Composition and Dietary Patterns of Middle-Aged and Older Japanese Women with Normal Weight Obesity

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ABSTRACT *Background and Purpose.* The "Specific Health Checkup" program, launched in Japan in 2008, aims to prevent cardiovascular disease by targeting visceral fat accumulation. However, normal weight obesity (NWO), a condition marked by a normal body mass index (BMI) but excess body fat, often fails to be detected by existing screening criteria, even though it affects approximately 50% of women at risk for future cardiovascular events. To develop more effective prevention strategies, a deeper understanding of the physical and dietary characteristics of women with NWO is needed. *Methods.* This cross-sectional study analyzed 202 women (age range, 40–74 years) who underwent a Specific Health Checkup in 2023. Participants with a BMI of 18.5–24.9 kg/m^2 were assessed for body fat using bioelectrical impedance analysis and categorized as either standard (<30% body fat) or NWO (≥30%). Anthropometric, metabolic, and dietary differences were then compared between groups. *Results.* A total of 114 participants (56.4%) were classified as having NWO. The NWO group exhibited significantly higher body fat percentage and waist circumference, and significantly lower skeletal muscle mass, particularly in the lower limbs. Compared with the standard group, the NWO group had significantly higher levels of triglycerides and low-density lipoprotein cholesterol and significantly lower levels of high-density lipoprotein cholesterol. Dietary analysis revealed significantly higher intakes of bread, noodles, pickled vegetables, dairy products, and sugar-sweetened beverages, and a significantly lower intake of rice. *Conclusions.* In the present study, women with NWO demonstrated a distinct fat accumulation, muscle loss, and dietary pattern profile associated with increased metabolic risk. Therefore, screening and interventions should move beyond BMI to include body composition and dietary quality, with a focus on lower-limb muscle preservation and balanced nutrition.
Keywords: Normal weight obesity, Middle-aged and older women, Body fat percentage, Dietary habits

INTRODUCTION

In recent years in Japan, the number of obese individuals has been increasing as a result of changes in the social environment surrounding dietary habits, such as the Westernization of the diet and lack of exercise[1)]. According to the Ministry of Health, Labour and Welfare and the Japan Society for the Study of Obesity, obesity is defined as a body mass index (BMI) of 25 kg/m^2 or higher. However, an accurate diagnosis of obesity requires the precise assessment of fat accumulation in adipose tissue. When obesity is accompanied by obesity-related health disorders, it is referred to as obesity disease[2)].

BMI is a convenient index calculated from height and weight, and an increase in BMI is strongly correlated with diseases associated with obesity, such as coronary artery disease and cerebrovascular disorders. Therefore, BMI is used as a diagnostic tool for obesity. However, the measurement of body fat percentage is not obligatory, and BMI alone is insufficient for assessing the detailed composition of body weight[3)]. That is, even if a person falls within the standard weight range, muscle mass tends to decrease and body fat percentage tends to increase with age. Therefore, individuals may have a normal BMI but a higher proportion of fat than muscle, a condition known as normal weight obesity (NWO). Particularly, the proportion of individuals with NWO is higher among middle-aged and older women than among men across all age groups[4)].

Approximately 20% of deaths in Japan are due to cardiovascular diseases such as cerebrovascular disease and myocardial infarction[1]. Since 2008, with the aim of facilitating early intervention for individuals with risk factors such as hyperglycemia, lipid metabolism disorders, and hypertension—which are indicators of metabolic syndrome (MetS)—Japan has mandated "Specific Health Checkups" for public health insurance enrollees aged 40–74 years. These health checkups include screening of individuals with a BMI ≥25 kg/m^2 in addition to waist circumference (WC), a traditional MetS diagnostic criterion. The checkups include a questionnaire on medical history, a physical examination, height, weight, systolic blood pressure (SBP), diastolic blood pressure (DBP), liver function tests (aspartate aminotransferase [AST], alanine aminotransferase [ALT], gamma-glutamyltranspeptidase [γ-GTP]), blood lipid levels (triglycerides [TG], high-density lipoprotein cholesterol [HDL-C], low-density lipoprotein cholesterol [LDL-C]), fasting blood glucose (FBG), and urinalysis (sugar, protein).

According to the 2022 National Health and Nutrition Survey[5], the proportion of women who met the criteria for MetS or were considered at risk was 5.8%, which was significantly lower than that for men (22.0%). This is likely due to the fact that the average WC (about 80 cm) and BMI (about 22 kg/m^2) of middle-aged Japanese women do not meet the current MetS criteria[1].

However, women aged 40–64 years with even one risk factor have an increased risk of cardiovascular disease[6]. Therefore, the current WC criteria may miss up to 50% of women at risk of cardiovascular disease[7]. It has also been reported that even nonobese individuals can have substantial visceral fat accumulation[8]. Moreover, individuals with NWO are at higher risk of having multiple MetS components[7] and may miss receiving proper guidance, increasing their health risks.

Research on NWO has mainly focused on young women[9,10] and working men[3,11], with fewer reports on middle-aged and older women. Previous studies have found that, among working men, fast eating and high protein/carbohydrate intake[11] were characteristics of NWO, while among female college students, deficiencies in vitamin K, dietary fiber, and beans[10] were observed.

NWO has been associated with an 8.2-fold higher risk of developing MetS[12], as well as an increased risk of sarcopenic obesity in older age[13,14].

However, the current Japanese Specific Health Checkup screening criteria (WC and BMI) are not sufficient to identify many middle-aged women with NWO. Given this background, the present study aimed to clarify the physical condition, body composition, and dietary intake of middle-aged women with NWO to provide foundational data for more appropriate health guidance.

MATERIALS AND METHODS

A cross-sectional study was conducted on women who received a Specific Health Checkup.

Participants

From March 2023 to March 2024, of the 670 women who received a Specific Health Checkup at the Yamashita Hospital Health Checkup Center, 202 women who were aged 40–65 years, had a BMI of 18.5 to <25 kg/m^2, and for whom complete data on body composition, blood biochemistry, and responses to a Food Frequency Questionnaire based on food groups (FFQg) were available, were included in the analysis. Individuals taking medication for hypertension, dyslipidemia, or diabetes were excluded.

Body Composition Measurements

Height (cm) and weight (kg) were measured to calculate BMI (kg/m^2), and WC (cm) was measured. Body composition was assessed using the bioelectrical impedance method (InBody470; InBody Japan, Tokyo, Japan), which measures muscle mass (kg), skeletal muscle mass (kg), fat-free mass (kg), trunk muscle mass (kg), limb skeletal muscle mass (kg), body fat mass (kg), body fat percentage (%), trunk and limb fat mass (kg), and the waist–hip ratio.

Blood Pressure and Blood Biochemistry

After 10 minutes of rest, SBP and DBP (mmHg) were measured using a pulse wave monitor (Heart Station S MPV-5500; Nihon Kohden, Tokyo, Japan). Blood samples were collected in a fasting state to measure FBG (mg/dL), HbA1c (%), HDL-C (mg/dL), LDL-C (mg/dL), TG (mg/dL), AST (IU/L), ALT (IU/L), γ-GTP (IU/L), and the LDL/HDL ratio.

Food Frequency Questionnaire

Dietary intake was assessed using the FFQg (Ver. 6). Participants who consented to participate in the study were asked to complete the questionnaire after the health checkup. The responses were collected and checked by a registered dietitian.

Statistical Analysis

Based on prior studies[5], the participants were classified into two groups: a standard group (BMI: 18.5 to <25 kg/m^2 and body fat percentage <30%) and an NWO group (BMI: 18.5 to <25 kg/m^2 and body fat percentage ≥30%). Statistical analysis was performed using EZR ver.1.65. Normality of data was checked. Student's *t*-test (for normal data) and the Mann–Whitney *U* test (for non-normal data) were used, with adjustments for age. FFQg data were converted per 1,000 kcal and analyzed using the Mann–Whitney *U* test. All tests were two-sided, with the level of significance set at $p<0.05$.

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki, with full consideration for the rights and welfare of the participants. Informed consent was obtained in writing after explaining the study purpose, methods, and ethical considerations. This study was approved by the Ethics Committee of Yamashita Hospital (approval No. 2023-01).

RESULTS

Of the 202 women with a BMI between 18.5 and 25 kg/m^2, 88 were classified into the standard group and 114 (56.4%) into the NWO group based on body fat percentage.

Body Composition (Table 1)

Table1. Body Composition Results of the Participants(n=202)

	Standard group n＝88	NOW n＝114	p-Value
Age (years)	49.8 (±6.0)	52.9 (±6.3)	0.001
Height (cm)	159.1 (±5.2)	158.1 (±5.3)	0.658
Weight (kg)	52.2 (±4.9)	55.1 (±5.6)	<0.001
Waist circumference (cm)	73.4 (±4.1)	79.2 (±4.4)	<0.001
BMI (kg/m²)	20.4 (19.5 - 21.5)	22.3 (21.1 - 23.4)	<0.001
Body fat mass (kg)	13.5 (±2.2)	18.7 (±2.8)	<0.001
Muscle mass (kg)	36.5 (±3.4)	34.2 (±3.4)	<0.001
Fat-free mass (kg)	38.7 (±3.7)	36.4 (±3.6)	<0.001
Skeletal muscle mass (kg)	20.9 (±2.2)	19.4 (±2.2)	<0.001
Body fat percentage (%)	26.3 (24.4 - 27.9)	33.7 (32.3 - 35.9)	<0.001
Right upper limb muscle mass (kg)	1.8 (±0.3)	1.7 (±0.2)	0.089
Left upper limb muscle mass (kg)	1.8 (±0.3)	1.7 (±0.2)	0.167
Trunk muscle mass (kg)	16.8 (±1.6)	16.4 (±1.6)	0.392
Right lower limb muscle mass (kg)	6.0 (±0.7)	5.7 (±0.8)	0.048
Left lower limb muscle mass (kg)	6.0 (±0.7)	5.7 (±0.8)	0.053
Right upper limb fat mass (kg)	0.9 (0.7 - 1.0)	1.3 (1.1 - 1.4)	<0.001
Left upper limb fat mass (kg)	0.9 (0.8 -1.0)	1.3 (1.2 - 1.5)	<0.001
Trunk fat mass (kg)	6.3 (±1.3)	9.2 (±1.5)	<0.001
Right lower limb fat mass (kg)	2.2 (±0.3)	3.0 (±0.4)	<0.001
Left lower limb fat mass (kg)	2.2 (±0.3)	3.0 (±0.4)	<0.001
Waist-to-hip ratio	0.8 (±0.03)	0.9 (±0.03)	<0.001
SMI (kg/(m)²)	6.1 (±0.5)	5.9 (±0.5)	<0.05
ASM (kg)	15.60 (±1.8)	14.73 (±1.9)	0.054
ASM ratio (kg/body weight kg)	0.30 (0.29 - 0.31)	0.27 (0.26 - 0.28)	<0.001
ASM/BMI	0.76 (±0.08)	0.67 (±0.07)	<0.001

Normal data were analyzed with a Student's t-test (mean ± SD), and non-normal data with the Mann-Whitney U test (median, IQR). For comparisons other than age, ANCOVA was used for normally distributed data, and multiple regression analysis for non-normally distributed data, with age-adjusted p-values presented.

After adjusting for age, the NWO group had significantly higher values for body weight, WC, BMI,

fat mass, body fat percentage, limb fat mass, and waist–hip ratio compared with the standard group. By contrast, the NWO group had significantly lower muscle mass, skeletal muscle mass, fat-free mass, and lower-limb muscle mass. No significant differences were observed in height, upper limb muscle mass, or trunk muscle mass.

Blood Biochemistry (Table 2)

Compared with the standard group, the NWO group had significantly higher TG, LDL-C, and LDL/HDL ratio values, and significantly lower HDL-C values. No significant differences in SBP,DBP, FBG, HbA1c, AST, ALT, or γ-GTP were observed.

Table2 blood pressure and blood biochemistry tests

	Standard group n＝88	NOW n＝114	p-Value
Systolic blood pressure (mmHg)	112.5 (103.8 - 124.0)	116.0 (112.0 - 141.0)	0.201
Diastolic blood pressure (mmHg)	70.8 (±10.5)	73.6 (±12.0)	0.191
Fasting Blood glucose (mg/dL)	93.0 (89.0 - 98.3)	96.0 (91.0 - 100.0)	0.767
HbA1c (%)	5.8 (5.0 - 6.9)	5.7 (5.2 - 7.4)	0.855
AST (IU/L)	19.5 (16.0 - 22.0)	19.0 (16.0 - 21.0)	0.126
ALT (IU/L)	15.0 (12.0 - 18.0)	15.0 (12.0 - 18.0)	0.701
γ-GTP (IU/L)	16.0 (13.0 - 23.0)	16.0 (13.0 - 24.0)	0.659
Triglycerides (mg/dL)	65.0 (51.0 - 84.0)	79.0 (61.0 - 112.0)	0.006
HDL cholesterol (mg/dL)	78.6 (±16.1)	73.7 (±18.1)	0.023
LDL cholesterol (mg/dL)	113.0 (97.8 - 129.3)	132.0 (112.0 -148.0)	0.002
LDL/HDL ratio	1.4 (1.2 - 1.8)	1.9 (1.5 - 2.4)	<0.001
Age at menopause (years)	49.7 (±3.5)	49.8 (±4.8)	0.617

Normal data were analyzed with a Student's t-test (mean ± SD), and non-normal data with the Mann-Whitney U test (median, IQR). For comparisons other than age, ANCOVA was used for normally distributed data, and multiple regression analysis for non-normally distributed data, with age-adjusted p-values presented.

FFQg Results (Tables 3 and 4)

No significant difference in total daily energy intake was seen between groups. However, when adjusted per 1,000 kcal, the NWO group had significantly higher bread/noodle, pickle, dairy product, and sweetened beverage (including fruit juice) intake, and significantly lower rice intake.

Nutritionally, the NWO group had significantly higher sodium, salt equivalent, and calcium intake, and significantly lower vitamin B_{12} intake per 1,000 kcal. No other significant differences were found.

Table3 Comparison of Food Intake Frequency Using the Density Method

	Standard group n=88	NOW n=114	p-Value
Grains (g/1000 kcal)	275.6 (207.9 - 354.2)	276.1 (206.3 - 328.8)	0.739
Rice (g/1000 kcal)	195.1 (138.6 - 273.1)	171.8 (110.7 - 230.3)	0.048
Bread and noodles (g/1000 kcal)	55.8 (33.1 - 87.3)	72.3 (49.1- 111.7)	0.009
Beans (g/1000 kcal)	40.0 (16.9 - 82.0)	40.4 (19.4 - 80.9)	0.869
Vegetables (g/1000 kcal)	71.4 (42.4 - 99.12)	73.7 (46.8 - 116.8)	0.354
Dark green and yellow vegetables (g/1000 kcal)	38.0 (20.4 - 57.4)	34.9 (20.6 - 57.1)	0.917
Light-colored vegetables (g/1000 kcal)	31.6 (16.4 - 44.01)	34.0 (19.0 - 54.4)	0.090
Pickled vegetables (g/1000 kcal)	1.0 (0.0 - 3.3)	2.4 (0.0 - 7.2)	0.013
Fruits (g/1000 kcal)	20.7 (8.1 - 52.7)	28.1 (7.8 - 60.4)	0.421
Mushrooms (g/1000 kcal)	2.3 (1.1 - 5.1)	2.5 (0.7 - 5.9)	0.594
Seaweed (g/1000 kcal)	4.2 (1.9 - 7.2)	3.6 (1.8 - 7.2)	0.496
Fish and shellfish (g/1000 kcal)	20.7 (13.6 - 35.8)	19.2 (7.5 - 32.9)	0.209
Meat (g/1000 kcal)	42.4 (27.1 - 61.4)	44.5 (27.9 - 68.1)	0.677
Eggs (g/1000 kcal)	28.6 (15.8 - 42.8)	27.3 (13.7 - 43.5)	0.634
Milk (g/1000 kcal)	25.8 (0.0 - 136.9)	87.5 (3.7 - 182.8)	0.042
Fats and oils (g/1000 kcal)	5.3 (4.0 - 6.9)	5.6 (4.1 - 7.0)	0.515
Sweets (g/1000 kcal)	3.8 （0.0 - 5.7)	3.4 （0.0 - 6.9)	0.590
alcohol (g/1000 kcal)	9.1 (0.0 - 123.0)	0.0 (0.0 - 50.6)	0.150
Sugar-sweetened beverages and fruit juice (g/1000 kcal)	288.7 (134.2 - 440.1)	318.7 (157.8 - 497.6)	0.054

All values were rounded to the second decimal place and expressed as median (interquartile range)

P-values were obtained using the Mann-Whitney U test and expressed to three decimal places.

Table4　Comparison of Energy Intake and Nutrient Intake (Comparison Using the Density Method)

	Standard group n＝88	NOW n＝114	p-Value
Energy (kcal/day)	1143.1 (951.9 - 1444.9)	1132.1 (903.1 - 1439.4)	0.900
Protein (g/1000 kcal)	40.2 (34.8 - 44.9)	40.4 (36.7 - 45.4)	0.653
Fat (g/1000 kcal)	33.1 (27.2 - 41.3)	35.3 (27.4 - 42.9)	0.550
Carbohydrates (g/1000 kcal)	128.5 (109.5 - 145.3)	128.3 (113.5 - 151.0)	0.678
Saturated fatty acids (g/1000 kcal)	10.2 (7.9 - 12.9)	10.8 (8.6 - 13.78)	0.177
Monounsaturated fatty acids (g/1000 kcal)	12.8 (10.6 - 15.3)	13.2 (9.9 - 16.5)	0.595
Polyunsaturated fatty acids (g/1000 kcal)	6.6 (5.4 - 8.0)	6.3 (5.2 - 8.1)	0.432
n-3 Polyunsaturated fatty acids (g/1000 kcal)	1.1 (0.8 - 1.5)	1.0 (0.7 - 1.4)	0.212
n-6 Polyunsaturated fatty acids (g/1000 kcal)	5.4 (4.7 - 6.5)	5.3 (4.4 - 6.7)	0.732
Cholesterol (mg/1000 kcal)	164.1 (133.0 - 226.6)	178.8 (117.2 - 228.2)	0.894
Sodium equivalent (g/1000 kcal)	3.8 (3.1 - 4.8)	4.2 (3.5 - 5.2)	0.029
Total dietary fiber (g/1000 kcal)	6.0 (4.2 - 7.2)	5.9 (4.8 - 7.5)	0.167
Soluble dietary fiber (g/1000 kcal)	1.1 (0.7 - 1.8)	1.2 (0.9 - 1.8)	0.229
Insoluble dietary fiber (g/1000 kcal)	4.2 (3.3 - 5.2)	4.4 (3.6 - 5.7)	0.126
Vitamin A (μg RAE/1000 kcal)	353.0 (254.1 - 533.4)	319.0 (224.2 - 434.4)	0.156
Vitamin D (μg/1000 kcal)	4.5 (3.1 - 6.3)	4.4 (2.6 - 6.5)	0.255
α-Tocopherol (mg/1000 kcal)	3.3 (2.7 - 4.5)	3.2 (2.5 - 4.2)	0.226
Vitamin K (μg/1000 kcal)	117.9 (63.3 - 217.4)	110.7 (64.7 - 179.7)	0.536
Vitamin B_1 (mg/1000 kcal)	0.7 (0.6 - 1.0)	0.8 (0.6 - 1.1)	0.130
Vitamin B_2 (mg/1000 kcal)	0.6 (0.5 - 0.7)	0.6 (0.5 - 0.7)	0.345
Niacin (mg NE/1000 kcal)	11.2 (9.0 - 14.4)	11.0 (8.8 - 13.5)	0.522
Vitamin B_6 (mg/1000 kcal)	0.8 (0.7 - 0.9)	0.8 (0.7 - 0.9)	0.780
Vitamin B_{12} (μg/1000 kcal)	3.7 (2.4 - 5.0)	3.0 (1.9 - 4.3)	0.034
Folate (μg/1000 kcal)	177.6 (131.7 - 226.6)	174.3 (139.0 - 228.2)	0.950
Vitamin C (mg/1000 kcal)	33.1 (20.7 - 56.4)	36.6 (25.1 - 56.5)	0.224
Phosphorus (mg/1000 kcal)	566.4 (469.0 - 645.2)	593.2 (515.6 - 691.2)	0.179
Potassium (mg/1000 kcal)	1411.0 (1088.3 - 1682.8)	1440.8 (1177.6 - 1766.5)	0.486
Calcium (mg/1000 kcal)	212.3 (140.4 - 294.0)	267.0 (162.6 - 368.4)	0.030
Sodium (mg/1000 kcal)	1484.5 (1220.9 - 1899.1)	1658.0 (1380.3 - 2040.1)	0.029
Iron (mg/1000 kcal)	4.7 (3.9 - 6.1)	4.7 (3.9 - 5.7)	0.531
Zinc (mg/1000 kcal)	4.7 (4.1 - 5.2)	4.6 (4.1 - 5.1)	0.660
Copper (mg/1000 kcal)	0.6 (0.5 - 0.7)	0.6 (0.5 - 0.7)	0.523
Iodine (mg/1000 kcal)	112.4 (35.1 - 167.4)	134.8 (42.1 - 209.9)	0.302
Magnesium (mg/1000 kcal)	164.3 (137.4 - 192.7)	165.6 (143.6 - 193.6)	0.655
Chromium (mg/1000 kcal)	3.2 (2.4 - 3.9)	3.5 (2.5 - 4.6)	0.079
Manganese (mg/1000 kcal)	1.8 (1.4 - 2.2)	2.0 (1.4 - 2.5)	0.153
Molybdenum (mg/1000 kcal)	134.8 (91.5 - 175.8)	124.4 (97.8 - 154.3)	0.456

All values were rounded to the second decimal place and expressed as median (interquartile range)

P-values were obtained using the Mann-Whitney U test and expressed to three decimal places.

DISCUSSION

This study focused on individuals with a high body fat percentage despite having a BMI and WC within standard ranges—so-called NWO. We aimed to investigate their physical characteristics, clinical indicators, and dietary habits as a basis for future guidance. Although the NWO group had significantly higher body fat percentage and lower lower-limb muscle mass compared with the standard group, they were not identified as candidates for lifestyle intervention under the current MetS screening criteria.

To our knowledge, there have been only a few reports on middle-aged Japanese women with NWO. Naito et al.[6] reported NOW prevalence rates of 12.7% in the 40s, 21.3% in the 50s, and 29.0% in the 60s, totaling 63% for those aged 40–60 years. In the present study, the prevalence was 54.1%, likely because we excluded individuals with a BMI <18.5 kg/m^2 and those over 65 years of age.

The NWO group exhibited significantly higher body weight, BMI, and WC compared with the standard group. Additionally, they had significantly lower skeletal muscle mass, fat-free mass, and lower-limb muscle mass, as well as a lower skeletal muscle index, appendicular skeletal muscle mass (ASM), ASM/BW, and ASM/BMI, and a higher waist-to-hip ratio (WHR). The age-related decrease in hormone levels in women increases visceral fat and bone loss and the risk of cardiovascular events. In women, muscle mass is stable until about age 50 years, after which it decreases, particularly in the lower limbs[16]. This was confirmed by adjusting for age. As a result of the age adjustment, a significant decrease in lower-limb muscle mass, as well as fat accumulation in the upper limbs, abdomen, and lower limbs, was observed; however, no changes were noted in trunk or upper limb muscle mass.

Decreased lower-limb muscle mass is increasingly recognized as a feature of NWO, especially in relation to metabolic disorders[17]. Recent studies have emphasized maintaining leg muscle mass to reduce the risk of developing MetS and insulin resistance[18]. Skeletal muscle mass plays a central role in basal metabolism, particularly large muscle groups in the legs (quadriceps femoris, hamstrings), which are critical for daily activities and energy expenditure[19]. A decline in this area reduces energy use and is considered to explain, at least in part, the mechanism by which body fat percentage increases even when body weight is within the normal range. Such a decline is caused by not only aging, but also a lack of exercise and protein intake, highlighting the importance of muscle maintenance in preventing NWO[20].

The mean WHR of the NWO group was 0.87, which meets the MetS threshold for women (0.85; WHO[21]). A higher WHR indicates upper body/abdominal fat accumulation and a greater risk of complications and death[22]. The WHR is associated with mortality more consistently than BMI and should be considered alongside fat distribution[22].

Bin et al.[23] studied oxidative stress, adipocytokines, and inflammation markers in middle-aged women, and reported that lower body fat mass was correlated with these factors more than BMI, WC, or trunk fat. In women, regional fat distribution beyond abdominal fat deserves attention. These findings suggest that NWO is associated with an increased visceral fat area, decreased lower-limb muscle mass, increased lower-limb fat accumulation, and related metabolic abnormalities, highlighting the need for accurate diagnosis from the perspective of sarcopenia prevention.

In blood biochemical tests, the NWO group had significantly higher levels of TG, LDL-C, and the LDL/HDL ratio compared with the standard group, whereas HDL-C levels were significantly lower. However, the median values of the blood biochemical test items were all below the threshold for health guidance interventions, suggesting that the group as a whole was not immediately subject to medical guidance. Nevertheless, In the NWO group, the 75th percentile value of SBP was 141 mmHg, which falls into the high blood pressure category. LDL-C levels of 148.0 mg/dL were observed, and 25% of the group fell within the diagnostic criteria for hyper-LDL cholesterolemia established by the Japan Atherosclerosis Society. These results support previous findings that individuals with a high body fat percentage, despite having a BMI <25 kg/m^2, exhibit elevated blood pressure and serum lipid levels, indicating a higher risk for lifestyle-related diseases[24,25].

To assess the dietary characteristics of the NWO group, we evaluated their diets using the FFQg. Although the FFQg has been used in many studies and its validity has been confirmed[26], recent developments in dietary survey methods, such as smartphone applications, have noted underreporting associated with the FFQg[27]. Therefore, instead of aiming for an exact measurement of intake, we used intake per 1,000 kcal to capture dietary characteristics. As a result, the NWO group had significantly higher intakes of bread and noodles, pickled vegetables, dairy products, and sugar-sweetened beverages such as fruit juices compared with the standard group, whereas their intake of rice was significantly lower. The

Framingham Heart Study[28] reported a direct correlation between the increased intake of high-calorie beverages and visceral fat accumulation. Sun et al.[29] reported that excessive sucrose intake disrupts the circadian rhythm of lipid metabolism in the small intestine and liver, promoting fatty liver and leading to TG accumulation, thereby contributing to the development of lean MetS.

Furthermore, the NWO group showed a tendency toward lower rice intake and higher consumption of bread and noodles, suggesting a dietary pattern characterized by the excessive intake of refined carbohydrates. This also raises concerns about the overconsumption of ultra-processed foods, which has been increasing in recent years[30]. In particular, it has been reported that individuals who frequently consume commercially available breads and sweet breads often eat them with dairy products and tend to have fewer main and side dishes[31]. On the other hand, rice eaters have a greater intake of main and side dishes, showing a better nutritional balance. The study also indicated that bread-based meals often emphasize convenience, leading to the lower intake of animal-based foods. Vitamin B_{12} is mainly found in animal-based foods such as meat, seafood, and eggs; thus, a diet centered on bread may likely result in insufficient intake. Especially at breakfast, carbohydrate-dominant foods such as breads and sweet breads are often selected, limiting opportunities to consume vitamin B_{12}-rich foods and contributing to its deficiency.

In terms of nutrients, the intake of sodium and salt equivalents was significantly higher in the NWO than in the standard group. Validity studies comparing estimated intakes from the FFQg and weighed dietary records suggest that sodium and potassium intake can be screened with comparable accuracy, indicating the potential utility of the FFQg for screening purposes[32]. Therefore, it is possible that sodium content from processed carbohydrates such as bread and noodles, rather than traditional Japanese seasonings like miso and soy sauce, significantly contributed to the increased salt intake. The higher dairy product intake in the NWO group supports previous findings[31]. While dairy products, which are rich in calcium and protein, can contribute to bone and muscle health when consumed appropriately[33], their high energy density means that excessive consumption could promote fat accumulation. Therefore, promoting appropriate choices, such as switching to low-fat dairy products or soy dairy products and encouraging moderate intake, is important. Furthermore, depending on the type of daily products consumed—such as sweetened yogurts and flavored dairy beverages—excessive intake could promote fat accumulation and induce lipid metabolism abnormalities[34]. Particularly among health-conscious individuals, the possibility that excessive intake in an attempt to prevent osteoporosis could lead to unintended adverse effects cannot be denied.

This study has several limitations. First, as a cross-sectional study conducted in a single facility, the findings cannot be generalized. The dietary survey assessed the participants' intake over a specific period, and seasonal variations were not reflected; underreporting and overreporting are also possible. Furthermore, because participation was voluntary, it is possible that the participants had higher health consciousness than the general population. Nevertheless, the findings of this study provide valuable evidence that can be utilized in future nutritional and exercise guidance for individuals with NWO. The findings suggest that the dietary habits of NWO individuals could have cumulative adverse effects on body composition, such as increased body fat and decreased muscle mass. Future dietary guidance should emphasize the impact of staple food selection on body composition and nutritional status, advocating for maintaining rice-centered dietary habits and appropriately incorporating animal-based foods. This study highlighted the importance of promoting balanced eating habits and expanding nutritional literacy.

CONCLUSION

Women with NWO face an elevated risk of cardiometabolic disorders because of high body fat, reduced skeletal muscle mass, and inappropriate dietary patterns. However, the existing screening criteria, which are based solely on BMI and WC, may miss this at-risk group. Therefore, preventive strategies should include comprehensive body composition analysis and targeted lifestyle guidance to emphasize lower-limb muscle preservation and a return to balanced, minimally processed, rice-centered dietary patterns.

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Original

Effectiveness of Fish protein on Vietnamese Malnourished Type 2 Diabetes Mellitus Patients

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ABSTRACT *Background and purpose* The research was conducted to evaluate the effectiveness of the capsules made from fish protein on malnourished type 2 Diabetes Mellitus (DM) patients in Vietnam. *Methods.* A clinical controlled trial was conducted in 2 groups. Subjects in the intervention group were continuously supplemented with fish protein capsules for 12 weeks, at 9 capsules/day, while those in the control group were not. General information interview, nutritional risk assessment using the Nutritional Risk Screening (NRS) questionnaire, and nutritional status assessment using anthropometric indexes, were assessed at baseline and after 12 weeks of intervention. Serum Albumin and glucose level, as well as lipid profile conditions, and liver and kidney function were further measured before and after intervention. *Results.* 30 subjects per group met the criteria to analyze data. After 12 weeks of using fish protein capsules, the weight and nutritional status of malnourished type 2 DM patients were improved, while tests indicated the liver and kidney function were not significantly changed. *Conclusion.* The fish protein capsules improves the malnourished type 2 DM patient's nutritional status without causing side effects on liver and kidney function and is safe for human use.

Keywords: amino acids, non-toxic pufferfish, type 2 Diabetes Mellitus, malnutrition, patients, Vietnamese.

INTRODUCTION

Malnutrition (chronic energy deficiency) in adults reduces labor productivity. It increases the severity in patients with chronic diseases (cardiovascular disease, and hypertension...), increasing the rate of infectious complications leads to increased mortality (1–4). In Southeast Asia, malnutrition is estimated to account for 30-50% of adult patients in hospitals. In Vietnam, studies show that at least 1/3 of hospitalized patients are malnourished (5–7) and the rate of malnutrition in hospitalized patients is nearly 60% (8,9). Clinical characteristics of malnutrition in patients usually are unintended weight loss, decreased BMI, decreased muscle mass, and decreased fat mass. The consequences are increased risk of complications, increased severity of the disease, prolonged hospital stay, increased readmission rate, reduced quality of life, increased risk of death, and increased treatment costs (10). Therefore, planning nutritional care during hospitalization and long-term nutrition after discharge for patients is always a necessary issue (11). The Nutrition Risk Screening (NRS) nutritional risk assessment method as recommended by the European Society of Nutrition and Metabolic Diseases in 2002, is a valuable tool for evaluating the effectiveness of nutritional interventions for patients (12).

In the human body, amino acids (aa) play a prominent role, being the building blocks of proteins. Protein is an essential and vital material for the body. Protein is a component of digestive enzymes, hormones, antibodies, and serum. Therefore, when the body is not provided with enough amino acids and proteins, it will affect growth, lead to weight loss, poor digestion, and susceptibility to infections. Studies around the world have shown the effectiveness of amino acid supplementation in improving malnutrition and disease progression in patients (13–15).

Thus, it is important to find many protein and amino acid-rich sources that are available and convenient for the outpatients. Research by the Research Institute for Marine Fisheries (RIMF) have made LW-Protein Capsules from fish meat which are rich in aa and minerals. Duc Giang General Hospital belongs to Hanoi captial, Vietnam, with the number of outpatients is quite large. However, nutritional interventions at this hospital have not yet received much attention. According to Circulars of the Ministry of Health of Vietnam, patients who come for outpatient examination and treatment at the hospital also need to be screened and consulted/intervened nutrition. Therefore, to improve the nutritional status of patients and support effective disease treatment, the research team conducted a study to evaluate the effectiveness of the fish protein capsules on nutritional status and biochemical indicators in patients with chronic energy deficiency and at risk of malnutrition coming for examination at Duc Giang General Hospital.

MATERIALS AND METHODS

1. Location: Duc Giang General Hospital, Hanoi.

2. Time: from July to December 2020.

3. Design: A clinical controlled trial was conducted in 12 weeks in 2 groups as following:

- Intervention group include patients continuously supplemented with fish protein capsules;
- Control group include patients who were not provided the capsule.

Both groups kept the same diet, and physical activity and took medications as usual.

4. Subjects and sample size

Sample size:

The sample size for each group was calcultaed as 36 patients. Then, for 2 groups, the total estimated study sample size is 72 patients. Subjects in control group was matched with intervention group by age and duration of treatment at the hospital.

Selection criteria:

Patients with type 2 DM, aged from 40 years and above, undergoing inpatient or outpatient treatment at Duc Giang General Hospital, with duration < 5 years, and no complications; without lipid disorder, BMI from 17.5 - 18.5 or NRS score ≥ 3, volunteered to participate in the research.

Exclusion criteria:

People with gastrointestinal disease or gastrointestinal surgery, cancer, heart disease, liver disease, kidney disease, or acute illness at the time of screening. People who intend to use functional foods/formula milk rich in amino acids/vitamins and minerals during the study period.

5. Methods and techniques

5.1. Screening and selecting subjects

All subjects were screened and selected by interviewing General information, nutritional risk assessment using NRS questionnaire, nutritional status assessment using BMI index.

5.2. Baseline survey (T0) and signing informed consent with the subjects

Researchers explain and invite subjects to sign informed consent to participate in the study. Assessing the patient's dietary intake by the 24-hour recall method. Fasting venous blood was collected from the patients to determine serum Albumin, Glucose, lipid profiles, GOT, GPT, and Creatinine concentration.

5.3. Providing fish protein capsules to the subjects and monitoring

The product called LW-Protein Capsules contains fish protein powder > 65%, starch and protein content > 50%, including 16 types of aa. The essential aa composition is described in detail in Table 1.

Table 1. Composition of essential amino acids in LW-Protein Capsules.

Amino acids	In 1000 mg	In dose of 9 capsules
Isoleucine (mg)	24.98	112.41
Leucine (mg)	36.36	163.62
Lysine (mg)	44.28	199.26
Methionine (mg)	13.94	62.73
Phenylalanine (mg)	20.45	92.03
Threonine (mg)	15.19	68.36
Valine (mg)	30.82	138.67
Histidine (mg)	12.83	57.34

Patients in the intervention group received the dose of 9 capsules/day and used it throughout 12 weeks. Patients were guided to take 9 capsules in a day, devided into 3 times (at the time of taking breakfast, lunch and dinner). Patients also recorded their own process and illness situation in the daily report diary. After 1 week from the initial time, the researcher contacted the patient and asked about compliance and problems to provide timely instructions. Staffs from the NIN and doctors of Duc Giang General hospital were directly responsible for supervising the study during the 12-weeks of intervention period. Every month, supervisors contacted, met , and reviewed the log book to monitor capsule product intake, and adverse events.

6. Data analysis

Data of subjects met the following criteria were included into analysis:

• Subjects took ≥ 80% of the prescribed amount of capsules during the intervention period;

• Subjects fully participated in baseline survey and final assessments at the end of study.

All data analysis were done using Excel, STATA, and SPSS 16.0 software with statistical tests.

RESULTS

After 12 weeks of participating in the study, there were 3 subjects in intervention group and 5 subjects in control group have droped out of study. Therefore, the analysis was done in 30 pair of subjects who completed the study.

Table 2 is the characteristics of the subjects at the beginning of the study (T0).

Table 2. General characteristics of the subjects at baseline

Variables	Control group (n = 30)	Intervention group (n = 30)	p*
	mean ± SD		
Age	68.5 ± 6.1	68.3 ± 5.9	
Weight (kg)	45.3 ± 5.0	45.2 ± 6.58	
Height (cm)	152.8 ± 7.5	152.3 ± 6.9	
BMI (kg/m^2)	18.98 ± 2.2	18.95 ± 2.2	> 0.05
Waist circumference (cm)	73.9 ± 5.1	74.3 ± 6.3	
Hip circumference (cm)	87.6 ± 4.8	87.3 ± 4.4	
Body fat percentage (%)	22.5 ± 8.5	22.7 ± 8.3	

T-test or Man-Whitney test

The information shows no difference in age, height, weight, waist circumference, hip circumference, and body fat percentage between the two groups at the time before the study.

The results of Table 3 showed that, at baseline, there was no difference in the average concentration of biochemical indices: Albumin, Glucose; indices evaluating blood fat status including Cholesterol, Triglycerides, HDL-C, LDL-C; indices evaluating liver and kidney function: AST, ALT, Creatinine between two groups.

Table 3. Biochemical indices of the two groups at the beginning of the study

Variables	Control group (n = 30)	Intervention group (n = 30)	p*
	mean ± SD		
Albumin (g/L)	39.2 ± 2.6	39.5 ± 2.2	> 0,05
Glucose (mmol/L)	8.1 ± 3.2	9.7 ± 36	
Cholesterol (µg/L)	4.36 ± 1.24	4.44 ± 0.86	
Triglyceride (mmol/L)	1.96 ± 1.11	1.86 ± 1.22	
HDL-Cholesterol (mmol/L)	1.07 ± 0.34	1.18 ± 0.34	
LDL-Cholesterol (mmol/L)	2.55 ± 0.88	2.41 ± 0.76	
Creatinin (µmol/l)	89.7 ± 14.5	98.5 ± 11.5	
AST (U/L)	24.1 ± 11.4	28.9 ± 15.7	
ALT (U/L)	16.5 ± 15.1	17.1 ± 14.4	

T-test or Man-Whitney test

Table 4. Changes in anthropometric indexes after 12 weeks of intervention

Variables	Time	Control group (n = 30)	Intervention group (n = 30)	p*
		mean ± SD		
Waist circumference (cm)	T0	73.9 ± 5.1	74.3 ± 6.3	> 0.05
	T3	74.1 ± 5.3	74.1 ± 6.5	
	T3 – T0	0.1 ± 1.1	-0.3 ± 1.2	
Hip circumference (cm)	T0	87.6 ± 4.8	87.3 ± 4.8	> 0.05
	T3	86.9 ± 5.3	85.9 ± 3.9	
	T3 – T0	-0.8 ± 3.2	-1.1 ± 3.9	
Body fat percentage	T0	22.5 ± 8.5	22.7 ± 8.3	> 0.05
	T3	22.8 ± 8.6	23.8 ± 7.6	
	T3 – T0	0.3 ± 4.7	1.1 ± 6.3	
BMI (kg/m^2)	T0	19.0 ± 2.2	18.9 ± 2.2[a]	> 0.05
	T3	18.9 ± 2.4*	19.9 ± 2.2[a*]	< 0.05
	T3 – T0	-0.1 ± 0.2*	1.0 ± 0.6*	
Weight (kg)	T0	45.3 ± 5.0	45.2 ± 6.6[a]	> 0.05
	T3	45.2 ± 5.2*	46.4 ± 6.5[a*]	< 0.05
	T3 – T0	0.2 ± 0.4*	1.1 ± 1.6*	

[*]p < 0.05 comparison between 2 groups (Man-Whitney test)
[a]p < 0.05 compare before and after intervention in the same group (paired t-test).

The results showed that after 3 months of supplementing with LW-Protein Capsules, patients had an average weight increase to 46.4 ± 6.5 (kg) and BMI of 19.9 ± 2.2, statistically significant compared to the beginning (average weight is 45.2 ± 6.6 kg and BMI is 18.9 ± 2.2). The average weight of the intervention group increased by 1.1 ± 1.6 (kg). The intervention group's waist and hip circumference indexes mildly decreased, and body fat percentage increased compared to the baseline, but there was no statistical significance in these 3 indexes. For the control group, after 12 weeks, no changes in anthropometric indexes were seen.

Regarding the effects on biochemical indexes in patients participating in the study.

Table 5. Changes in albumin concentration after 12 weeks of intervention

Variables	Time	Control group (n = 30)	Intervention group (n = 30)	p*
		mean ± SD		
Albumin (g/L)	T0	39.2 ± 2.6	39.5 ± 2.2[a]	>0.05
	T3	40.1 ± 2.7	41.1 ± 2.5[a]	<0.05
	T3 – T0	0.4 ± 0.6	1.5 ± 0.4*	

**p < 0.05 compared to the control group (Man-Whitney test)*
[a]p < 0.05 compare before and after intervention in the same group (paired t-test).

The result demonstrated that the plasma albumin concentration of the intervention group (41.1 ± 2.5 g/L) was statistically significantly higher than the control group (39.5 ± 2.2 g/L) with p<0.05. The increase in average albumin concentration before and after 3 months in the intervention group was 1.5 ± 0.4 (g/L), which was higher than the corresponding difference in the control group (0.4 ± 0.6 g/L) with p < 0.05.

Changes in blood glucose, lipid concentrations, and liver and kidney function before and after the intervention of patients are presented in Table 6.

Table 6. Changes in biochemical indexes after 12 weeks of intervention.

Variables	Time	Control group (n = 30)	Intervention group (n = 30)
		mean ± SD	
Glucose (mmol/L)	T0	8.3 ± 3.2	8.7 ± 3.6
	T3	8.4 ± 3.5	8.8 ± 4.1
	T3 – T0	0.1 ± 2.6	0.2 ± 2.4
Cholesterol (mmol/L)	T0	4.36 ± 1.24	4.44 ± 0.86
	T3	4.51 ± 1.14	4.53 ± 0.84
	T3 – T0	0.15 ± 0.85	0.09 ± 0.76
Triglycerid (mmol/L)	T0	1.96 ± 1.11	1.86 ± 1.22
	T3	1.91 ± 1.01	1.69 ± 0.97
	T3 – T0	-0.07 ± 0.68	-0.18 ± 0.87
HDL-C (mmol/L)	T0	1.19 ± 0.34	1.18 ± 0.34[a]
	T3	1.31 ± 0.36	1.34 ± 0.41[a]
	T3 – T0	0.11 ± 0.41	0.16 ± 0.20
LDL-C (mmol/L)	T0	2.55 ± 0.88	2.41 ± 0.76
	T3	2.68 ± 0.69	2.57 ± 0.79
	T3 – T0	0.12 ± 0.84	0.15 ± 0.60
Creatine (µmol/L)	T0	78.0 ± 14.1	98.45 ± 9.15
	T3	78.8 ± 14.8	97.33 ± 9.56
	T3 – T0	0.9 ± 5.4	1.12 ± 6.5
GOT (U/L)	T0	24.1 ± 11.4	28.97 ± 8.53
	T3	25.9 ± 9.0	27.93 ± 10.4
	T3 – T0	1.8 ± 4.6	1.04 ± 5.2
GPT (U/L)	T0	17.2 ± 14.6	17.1 ± 9.49
	T3	18.8 ± 9.8 [a]	18.03 ± 17.84
	T3 – T0	1.6 ± 5.3	1.02 ± 4.9

[a]p < 0.05 compare before and after intervention in the same group (paired t-test).

In the intervention group, HDL-C concentration at the end was statistically significantly higher than before the intervention. The average HDL-C concentration in the intervention group increased by 0.16 ± 0.20 mmol/L after 12 weeks of taking LW-Protein Capsules.

There was no difference in the concentrations of Glucose, Cholesterol, Triglyceride, and LDL-C between the 2 study groups before and after intervention as well as no difference when comparing between 2 time points in the same group.

The concentrations of biochemical index assessing liver and body function in both the control group and the intervention group did not change with statistical significance, proving that the product is effective in protein metabolism and patient health without causing side effects on liver and kidney function.

Table 7. Dietary intake after 12 weeks of intervention

Variables	T0 (n=36)		T3 (n=30)	
	Control	Intervention	Control	Intervention
	Median (p25; p75)		Median (p25; p75)	
Energy (kcal)	1007 (873;1417)	1078 (826;1398)	1021 (827; 1234)	1188 (1036; 1398)*
Protein (g)	40.5 (38.2; 52.4)	42.4 (28.0; 61.2)	41.3 (32.4; 48.6)	48.3 (31.7; 60.2)*
Lipids (g)	18.2 (18.9; 351)	19.6 (28.4; 38.9)	20.3 (18.5; 33.4)	27.3 (25.1; 41.0)*
Glucid (g)	176.5 (119.8; 175.3)	178.2 (121.7; 181.2)	174.7 (145.7; 206.3)	193.1 (162.2; 215.5)*
Calcium (mg)	306 (216; 474)	311 (195; 468)	289 (221; 468)	367 (272; 497)*
Iron (mg)	9.2 (5.9; 10.1)	9.1 (6.3; 9.3)	9.2 (6.1; 11.3)	10.1 (6.2; 11.6)*
Zinc (mg)	5.4 (4.4; 8.6)	5.4 (3.9; 7.6)	5.5 (4.5; 9.0)	6.3 (4.2; 8.6)*
Vitamin A (mcg)	60.1 (8.7; 151.2)	53.9 (15.6; 161.2)	60.3 (19.0; 134.3)	64.2 (12.4; 175.2)*
Vitamin C (mg)	90.5 (37.2; 153.5)	89.9 (40.8; 186.3)	91.5 (35.8; 145.1)	189.6 (99.8; 324.6)*
Folate (mcg)	193.3 (128.2; 345.8)	196.2 (116.5; 375.2)	195.8 (125.6; 367.8)	223 (135.2; 338.6)*
Vitamin D (mcg)	0.04 (0.0; 2.24)	0.03 (0.0; 2.21)	0.03 (0.0; 2.16)	0.04 (0.0; 2.37)*

**p<0.01 using the Wilcoxon rank sum-test to compare between 2 groups*

Research results showed that, at the time before intervention, there was no difference in nutrient consumption between the 2 groups. However, after 12 weeks of conducting the study, the total energy consumption, protein, lipid, carbohydrate, and micronutrients are all significantly higher in intervention group compared to the control group. The results showed that supplementing with LW-Protein Capsules after 3 months stimulated the diet of the patients, effectively increasing food consumption.

DISCUSSION

Research using capsules rich in amino acids made from fish meat on malnourished patients has shown the effectiveness of the nutritional intervention for patients with malnutrition.

The study was designed as a controlled study, evaluating both comparison with control and before - and after-intervention. The study lasted 3 months (12 weeks) in accordance with the minimum recommended duration of use of functional foods. The initial comparison showed that there was no difference between the 2 groups in terms of basic information assessing nutritional status, biochemical indices assessing protein intake, blood sugar status, lipid profile, liver, and kidney function, showing that 2 groups and sample sizes were appropriate to conduct the study (Tables 1, 2, 3). The average BMI of all subjects was about 19.0, in the normal range (because the study used BMI criteria from 17.5 - 18.5 for people 40 - 70 years old, or BMI < 20 for people 71 - 80 years old) but is the lower limit of normal, indicating the patient's malnutrition. After 12 weeks of intervention research, the 2 groups had the above indicators measured again and compared. The results showed an increase in the patient's BMI and weight (Table 4), demonstrating an improvement in the patient's weight. In addition, albumin concentration, representing protein in the patient's body, also increased with statistical significance. Besides, to further understand the nutrient consumption of participants, diets were also analyzed,

before and after using the product (Table 7). The results showed that there was a significant improvement in the nutritional diet of patients using the product.

However, the improvement results are not too great, possibly because the time of using the product is not long, and the patient's psychological condition affects eating and absorption. The study also did not evaluate the effectiveness of the LW-Protein Capsules on the improvement of the disease progression. However, the research results have resolved some of the issues mentioned above, showing the safety of the product, and the role of nutritional intervention (essential amino acids) on humans (patients).

In conclusion, after 12 weeks of using LW-Protein Capsules, the weight and nutritional status of diabetic patients being treated at Duc Giang General Hospital were improved, while the liver and kidney function of the subjects were not increased, proving that the product is effective for the patient's nutritional health without causing side effects on liver and kidney function, and the product is safe for users.

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Original

Cooking-integrated Nutrition Education Program Affects Stages of Behavior Change among Fourth-Grade Students in Vegetable, Fruit and Sugar-Sweetened Beverage Consumption

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ABSTRACT *Background.* Studies have shown that integrating cooking activities with nutrition education can improve children's preferences for and intake of fruits and vegetables (FV). However, evidence regarding its impact on sugar-sweetened beverages (SSB) and stages of behavior change remains limited. This pilot study aimed to evaluate the effect of an experiential cooking and nutrition education intervention on stages of behavior change related to FV and SSB consumption among elementary school students. *Methods.* A total of 35 fourth-grade subjects were recruited through purposive sampling. Using crossover design, the effects of cooking integrated nutrition education curriculum on nutrition knowledge (NK), selecting attitude (AT), and consuming behavior (BE) towards FV and SSB, as well as stages of behavior change (SOC), were examined. Subjects were divided into Group A (n=16) and Group B (n=19), randomized to begin with either cooking or nutrition education curriculum, before switching to the alternate curriculum. The intervention comprised eight lessons over two 4-week periods, with five assessments conducted at pretest (W_0), midterm test (W_4), posttest (W_8), follow-up test (W_{10}) and a final test (W_{20}). *Results.* Results indicated significant improvements in NK and BE score ($p<.05$). The overall intervention facilitates subjects' behavior change to progress to a later stage by 20%, 25.7% and 37.1% towards vegetables, fruits and sugar sweetened beverages, respectively. *Discussion.* The intervention improved NK with retention and carryover effects. BE increased especially when nutrition education preceded cooking. Cooking was more effective for FV, while education reduced SSB. *Conclusion.* The integration of cooking activities with nutrition education effectively supported students' advancement through stages of behavior change and yielding stronger outcomes, particularly in reducing unhealthy SSB consumption. This approach shows promises for promoting healthy eating behaviors in elementary school settings.

Keywords: Cooking program, Knowledge Attitude Behavior (KAB), Stages of Change, Fruits and Vegetables, Sugar-sweetened Beverages

INTRODUCTION

The epidemic of childhood obesity has emerged as an important public health problem worldwide. In 2016, the prevalence of childhood obesity increased at an alarming rate. This is associated with various diseases such as type 2 diabetes mellitus, hypertension, nonalcoholic fatty liver disease, Obstructive sleep apnea, and dyslipidemia later in their adult age (1).

In Taiwan, the prevalence rate of overweight and obesity among elementary school children aged 6-12 years old was increasing substantially since year 2008 (25.0%) to 2013 (30.4%) but decreasing steadily to 27.6% in 2017 (2). Despite the decreasing trend being observed over the past five years, Taiwan Nutrition and Health Survey in Taiwan Elementary School Children (NAHSIT IV Children) in year 2012 reported that the highest prevalence rate of obesity was noticed among 4th grade male students (17.1%) and 5th grade female students (15.6%) (3).

Diet plays an important role in preventing overweight and obesity. Study reviewed that there was an inverse association between a prudent/healthy dietary pattern and overweight/obesity risk and a positive association between a western/unhealthy dietary pattern and overweight/ obesity risk (4). Fruits and vegetables (5), fiber (6), fat (7), fast food (8) and sugary drinks (9) are included but not limited to as important dietary determinants of obesity in childhood and adolescence. It is plausible that dietary pattern that are

energy- and fat- dense but low in fiber may be predictive of later overweight and obesity in children (10). By consuming recommended amounts of fruits, vegetables, and whole grains would result in a healthier dietary pattern. Unfortunately, children often have poor compliance with dietary guidelines for these foods (11). Furthermore, evidence that decreasing sugar- sweetened beverage (SSB) consumption will reduce the prevalence of obesity andobesity- related diseases is increasingly clear (9).

Health Promotion Administration, Ministry of Health and Welfare of Taiwan has implemented the daily dietary guidelines to combat the problem of imbalance diet among school-aged children. In term of consumption of fruits and vegetables, dietary patterns of students reflected that 72.9% of students do not fulfill the recommended intake which is five servings per day. Among all, only 12.3% of school-aged children fulfill the daily recommended intake of three servings of vegetables and two servings of fruits at the same time. Nutrition and Health Survey in Taiwan Elementary School Children (NAHSIT II Children) year 2001-2002 documented that energy intake from carbohydrate was inadequate. In addition, 7.2% of the carbohydrate source was from sugar sweetened beverages. This issue should be addressed wisely because the more sugar- sweetened beverage (SSB) consumed, both weight and body mass index (BMI) of children will increase (12,13).

Many studies focused on the evaluation of nutrition education intervention towards students' knowledge, attitude and behavior, most studies showed the same outcome that there was a significant increase in students' knowledge, attitude and behavior. The concept of experiential learning such as cooking, gardening and tasting has emerged and incorporating in nutrition education program which helps to improve the preference of students towards fruits and vegetables (14,15,16).

Unfortunately, there are lack of researches done in assessing stages of behavioral change after implementing cooking-integrated nutrition education intervention. It is utmost important as stage-tailored intervention concept is believed to increase the effectiveness of nutrition education program (17). Thus, this study aims to evaluate the effectiveness of experiential cooking program and nutrition education intervention through nutrition knowledge (NK), selecting attitude (AT) and consuming behavior (BE). Also, its effect towards stages of behavioral change (SOC) on consumption of fruits, vegetables and sugar sweetened beverages were evaluated as well.

MATERIALS AND METHODS

Study Design This was a 5-months evaluation of experiential cooking and nutrition education program. By adapting cross-over design concept in nutrition education intervention (18), the research design called for a random assignment of all 41 subjects to either Group A (n=20) or Group B (n=21). A total of 8 lessons of curriculum were delivered in two 4-week periods. Group A subjects were randomized to begin with cooking curriculum in first 4-weeks period, whereas Group B begin with nutrition education curriculum, and then both groups switch to the remaining curriculum in second 4-weeks period. Both programs had a similar delivery and length. Each subject completed a pretest (W_0), a midterm test (W_4), a posttest (W_8), a follow-up test (W_{10}) and a final test after semester break (W_{20}) as shown in Figure 1.

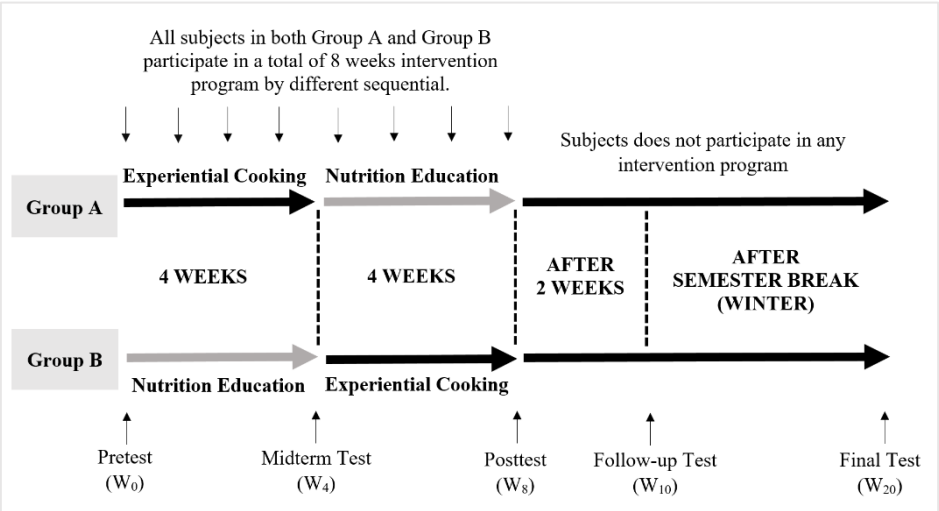

Figure 1 Study design

Participants and Recruitment The evaluation included 41 subjects selected through purposive sampling from an elementary school located in *Daliao* district, Kaohsiung. Application was opened for all Fourth-grade students one month prior to the intervention. Students applied to participate according to their own willingness. The inclusion criteria for the program were subjects without food allergy history especially milk, eggs and nuts. Subjects with asthma history were also excluded. Application packets, which contain informed consents for both parents and subjects were distributed to selected subjects.

Ethical Approval This research was reviewed and approved by the institutional review board in Antai Medical Care Corporation Antai Tian-Sheng Memorial Hospital. (Protocol No. 18-109-B)

Interventions Both experiential cooking and nutrition education curriculum were discussed and designed by nutrition teacher and third year nutrition students, incorporating the service- learning courses that is selective among undergraduate students. The experiential cooking curriculum was designed to focus primarily on simple hands on preparing hand- hold food rather than cooking skills. However, simple cutting and preparing skills were also imparted to subjects to ensure that they could experience food ingredients. The nutrition education curriculum was designed with aims of instilling nutrition knowledge towards subjects through different teaching methods including didactic instruction, drama in education, practice instruction and team-games-tournament. Both curriculums were reviewed by registered dietitian to ensure that recipes created were aligned with principles of good nutrition and the appropriateness of nutrition knowledge imparted. Lessons were led by nutrition students and they were required to went through food tasting and rehearsal training at least 2 times (1 hour per time) by nutrition teacher and registered dietitian. The whole program consisted of 8 30-minutes lessons taught during the self-study period in the morning. All lessons were taught in Mandarin and nutrition principles illustrated was aligned with new version of Dietary Guideline of Taiwan in 2018. Subjects were formed into teams of four to five, which were maintained throughout the course, to practice food preparing skills, and carry out team games throughout the lessons.

Instruments and Measures The evaluation of the intervention was assessed by self-developed survey questions. The survey was first developed by adapting questions from publicly available sources (19,20), then was reviewed by five experts in nutrition education and/or public health to ensure content validity and audience appropriateness. A total of 50-items including subject's demographic data (8 items), NK (15 items), AT (12 items), BE towards FV and SSB (12 items) and SOC (3 items) were collected through the written surveys. The survey was pilot tested among 65 subjects which were not participated in the study. Average item discrimination index (D) for nutrition knowledge-testing questions reported was 0.41, considered very usable (21). Internal consistency was assessed with Cronbach alpha coefficient; scale structure was analyzed using principle components extraction with varimax rotation. Cronbach alpha coefficient of 0.72 and 0.84 were achieved for both scale of selecting attitude and consuming behavior which were measured in five-point Likert scale. Due to the poor time frame estimation among elementary school students, excluding question regarding time frame in stage of behavior change was necessary. Thus, instead of five stages, three stages of behavior change were used including precontemplation (PC, do not know/plan to change), contemplation/preparation (C/P, plan to change) and action/maintenance (A/M, have changed unhealthy behavior) (3).

Survey Administration Surveys were administered for all subjects present on the day of administration. Teacher was present in the classroom but not directly involved in survey administration. Instructions for all parts of survey were read aloud by researchers in preferred language (Mandarin) with guidance to students to complete the rest of the page independently. Measuring instrument (10cm circumference bowl) was used to guide students on the portions of fruits and vegetables being consumed. Completion of survey took around 20 minutes. Upon collecting the survey form, researcher ensure that all parts were answered.

Data Analysis Subjects who missed out at least two lessons or surveys that contains one third uncomplete parts will be excluded for analysis. Statistical analysis was performed using IBM SPSS Statistics Version 22 (SPSS Inc., Chicago, IL, USA). For each scale except for the SOC, item responses were summed to create a scale score. Desired outcomes were noted by higher scores. Wilcoxon Signed Rank test was used to compare the median difference of NK, AT, and BE from pretest to final test within both Group A and B. Median difference between Group A and B were tested using Mann-Whitney U test. Subjects' behavioral stage distribution at each time point and the congruence of stages between pretest, midterm test and posttest were examined using frequency distribution and cross-tabulations. $P<.05$ were considered statistically significant.

RESULTS

Demographics Of all 41 applicants, 35 subjects remained and completed the whole program and surveys, survey response rate was 85.3%. Subjects were predominantly female (68.6%), with cooking experience (71.4%) and cooking interest (97.1%) (Table 1). Data between Group A and B showed no statistically different ($p>.05$), which are comparable. Subjects' stage of behavioral change for vegetables and fruits were predominantly at precontemplation stage whereas for sugar sweetened beverage was at action/maintenance stage during pretest. (Table 2).

Table 1 Demographic data of fourth-grade subjects, n(%)

	Total Subjects (n=35)	Group A (n=16)	Group B (n=19)
Gender			
Male	11(31.4)	4(25.0)	7(36.8)
Female	24(68.6)	12(75.0)	12(63.2)
Cooking Experience			
No	10(28.6)	3(18.8)	7(36.8)
Yes	25(71.4)	13(81.3)	12(63.2)
Cooking Interest			
No	1(2.9)	0(0.0)	1(5.3)
Yes	34(97.1)	16(47.1)	18(94.7)

Table 2 Subjects' stage of behavioral change during baseline (pretest), n (%)

	Total subjects (n=35)			Group A (n=16)			Group B (n=19)		
	PC	C/P	A/M	PC	C/P	A/M	PC	C/P	A/M
Vegetables	18(51.4)	9(25.7)	8(22.9)	6(37.5)	4(25.0)	6(37.5)	12(63.2)	5(26.3)	2(10.5)
Fruits	19(54.3)	6(17.1)	10(28.6)	6(37.5)	3(18.8)	7(43.8)	13(68.4)	3(15.8)	3(15.8)
Sugar Sweetened Beverages	11(31.4)	9(25.7)	15(42.9)	3(18.8)	5(31.3)	8(50.0)	8(42.1)	4(21.1)	7(36.8)

PC indicates precontemplation or do not plan to change; C/P indicates contemplation/preparation or plan to change; A/M indicates action/maintenance or have changed unhealthy behavior.

Nutrition Knowledge (NK) Subjects in Group A which attend cooking class first increased the median score for nutrition knowledge by 1.5 ($p<.05$) during midterm test whereas subjects in Group B which attend nutrition education class first showed and increased by 3.5 ($p<.05$). (Table 3). Both Group A and Group B showed significantly increase in median score during posttest compared to pretest. It was also noticed that median score for both Group A and B during final test, showed a significantly increase ($p<.05$) compared to pretest. Subjects in Group B who attend nutrition education curriculum first then experiential cooking showed a maintenance in median score at 10 since midterm test, however subjects in Group A who attend experiential cooking curriculum first then nutrition education showed a significant decreased of median score by 1 ($p<.05$) during the final test.

Selecting Attitude (AT) Attitude score for subjects in Group B showed a significantly higher than Group A by 2.5 ($p<.05$) during the final test (Table 3). After the whole program, both Groups showed a decrease in attitude score, but it did not show statistically significant. Median score for selecting attitude of subjects within both groups considered the same during pretest and final test.

Consuming Behavior (BE) The median of Group A subjects' behavior towards FV and SSB does not show significantly increase in neither midterm test nor posttest compared to pretest, yet it showed a significantly increased by 4.5 ($p<.05$) during follow-up test. However, median of Group B subjects showed a significant increased by 2 and 2.5 ($p<.05$) during midterm test and posttest respectively, but there was no statistically different between midterm test and posttest.

Table 3 Nutrition knowledge, selecting attitude and consuming behavior score of vegetables, fruits and sugar sweetened beverages during pretest, midterm test, posttest, follow-up test and final test, median (IQR)

	Group A (n=16)[1]					Group B (n=19)[1]				
	W_0 (Pretest) (Before intervention)	W_4 (Midterm Test) (After cooking)	W_8 (Posttest) (Cook-Education)	W_{10} (Follow-up Test (2 weeks after program)	W_{20} (Final Test) (After winter break)	W_0 (Pretest) (Before intervention)	W_4 (Midterm Test) (After Education)	W_8 (Posttest) (Education-Cook)	W_{10} (Follow-up Test (2 weeks after program)	W_{20} (Final Test) (After winter break)
Nutrition Knowledge [2]	6.5 (5-8)^a	8 (7-10.75)^b	10.5 (9-11)^{bc}	10 (9-11)^c	9 (8-10)^b	6.5 (5-8)^a	10 (8-11.25)^b	10 (9-12)^b	10 (9-12.25)^b	10 (9-11)^b
Selecting Attitude [2]	52 (49.25-54.75)	50.5 (48-54)	50.5 (46.25-56.5)	52 (43.25-55)	52* (43.25-55)	54.5 (49.5-57.25)	54 (49-56)	53 (46-56.25)	52 (47.75-55.25)	54.5* (49.25-57)
Consuming Behavior [2]	46.5^a (34.25-54.25)	49^a (33-54.75)	48 (37.5-56.75)	51^b (35.25-58.5)	48 (38.5-57.25)	43^a (33.75-53.5)	45^b (38.5-58.25)	45.5^b (41.25-56.25)	47 (40-53)	46.5 (38.75-58.25)

1. Median in the same row with * marks are significantly different ($p<.05$)
2. Median in the same row with different letters are significantly different ($p<.05$)

Score range: Nutrition Knowledge 0-15; Selecting Attitude 12-60; Consuming Behavior 12-60

Stages of Behavior Change Behavior change in this study indicated that subjects consumed two daily servings of vegetables, one daily serving of fruits and less than four times per week of sugar- sweetened beverages. Regress indicates backward movement to an earlier stage, stable indicates no change in stage, while progress indicates forward movement to a later stage. Data in Table 4 represents the percentages of subjects evidencing each pattern in experiential cooking curriculum, nutrition education curriculum and the overall intervention. In terms of vegetables and fruits, percentage of progress was more desirable in cooking curriculum than that of nutrition education curriculum which were 20.0% and 25.71% respectively. However, it shows a contrast in terms of sugar sweetened beverage. Percentage of progress was more favorable in nutrition education curriculum (25.71%). As an overall intervention which including both cooking and nutrition education intervention, all subjects either in Group A or Group B, showed a better outcome which progressed to a later stage by 20.0%, 25.71% and 37.14% for vegetables, fruits and sugar sweetened beverages respectively as shown in Table 4.

Table 4 Patterns of stability and change in stage after cooking curriculum, nutrition education curriculum and overall intervention, n (%)

	Cooking Curriculum (n=35) W_4-W_0(A)+W_8-W_4(B)			Nutrition Education Curriculum (n=35) W_8-W_4(A)+ W_4-W_0(B)			Overall Intervention (n=35) W_8-W_0(A)+W_8-W_0(B)		
	Regress	Stable	Progress	Regress	Stable	Progress	Regress	Stable	Progress
Vegetables	3 (8.57)	25 (71.43)	7 (20.0)	8 (22.86)	24 (68.57)	3 (8.57)	3 (8.57)	25 (71.43)	7 (20.0)
Fruits	1 (2.86)	25 (71.43)	9 (25.71)	4 (11.43)	29 (82.86)	2 (5.71)	1 (2.86)	25 (71.43)	9 (25.71)
Sugar-Sweetened Beverages	6 (17.14)	22 (62.86)	7 (20.0)	4 (11.43)	22 (62.86)	9 (25.71)	5 (14.29)	17 (48.57)	13 (37.14)

W_0, Pretest (before intervention); W_4, Midterm test (after first period/4 weeks of curriculum); W_8, Posttest (after second period/4 weeks of curriculum)

DISCUSSION

This study examined the effectiveness of experiential cooking and nutrition education intervention through NK, AT and BE towards FV and SSB. Besides, readiness of subjects to consume two daily servings of vegetables, one daily serving of fruits and less than four times per week of sugar sweetened beverages were assessed by stages of behavior change (SOC) among Fourth-grade elementary school students. Results showed a significant increase in both subjects' nutrition knowledge after cooking program in Group A and after experiential learning in Group B during the first 4-week curriculum. These results are consistent with a meta-analysis of a wide variety of school-based nutrition education programs found that experiential learning programs such as hands-on cooking or gardening can improve nutrition knowledge and vegetable consumption in elementary school children (22). Even though the knowledge score of both Group A and Group B subjects were not significantly improved after the second 4-week curriculum, but both groups of knowledge score during posttest was significantly higher than during pretest. This may be explained by the retention of knowledge gained during the first 4-weeks when Group B received nutrition education intervention before crossover took place, which in crossover design is referred to as a carryover effect (23). Carry-over effect in this situation explained that the subjects from both groups have obtained nutrition knowledge during the first 4-weeks of curriculum. Then, the knowledge obtained was carried forward to the second 4-weeks of curriculum. In addition, knowledge score was able to retain for two weeks and up to ten weeks in Group A and Group B subjects, respectively.

In terms of selecting attitude towards FV and SSB by subjects, no significant difference in attitude score was noticed by both groups after 8- weeks intervention. This might be due to the duration of both cooking and nutrition education programs that could influence children's food-related preferences (24). Median duration of most nutrition education intervention was found to be 10 sessions with duration of 90 minutes. Due to time constraint consideration, the duration in this study was only held for 4 weeks each with a duration of 30 minutes each week. It was relatively low compared to most studies. Subjects' diet -related behavior reported as significant higher immediately after 4-weeks of curriculum and after the whole intervention which was another 4- weeks after. This phenomenon was noticed in Group B subjects which started with nutrition education curriculum first and then cooking curriculum. Even though there was no instant significant increase in behavior score for Group A subjects, yet a significant higher in behavior score was noticed during follow-up test (2-weeks after the intervention) compared to pretest and midterm test. This might show that whenever there was experiential and contextual knowledge program, a lasting impact on diet-related behavior could be noticed (25).

Behavior change in consuming FV and SSB was assessed further through stages of change. No comparison of food consumption frequency between different stages of change was made. Subjects were compared individually beginning from pretest to posttest to obtain the pattern of stability and change in stage after different curriculum. Despite review demonstrated that stage-tailored intervention is preferable to increase the effectiveness and success of nutrition education intervention, nonetheless, this study reported that the whole program which included both cooking and nutrition education curriculum could facilitate subjects' behavior change to progress to a later stage rather than only one type of curriculum. The results also indicated that different curriculum might be suitable for different food items. For instance, the effect of cooking curriculum was found to be more suitable for vegetables and fruits while nutrition education curriculum which mainly carried out through lecturing, drama in education, and games were more effective for sugar sweetened beverages. Surprisingly, as the result suggested, a combination of both cooking and nutrition education curriculum would eventually provide a better outcome in terms of facilitating subjects to move forward to a later stage which lastly changed their unhealthy behavior especially for sugar sweetened beverages.

CONCLUSION

The findings of this study demonstrate that both the cooking curriculum and the nutrition education curriculum independently contributed to significant improvements in nutrition knowledge and dietary behaviors among elementary school children, particularly in relation to fruit and vegetable (FV) intake and reduced consumption of sugar-sweetened beverages (SSB). Importantly, the most compelling outcome emerged when both curricula were implemented together. The integration of practical cooking skills with structured nutrition education produced a synergistic effect, reinforcing knowledge while simultaneously enabling children to apply it in real-life contexts. This dual approach facilitated progression to more advanced stages of behavioral change, suggesting that children were not only learning but also internalizing and practicing healthier habits.

Such progression is critical, as it reflects the potential for sustained lifestyle modifications rather than short-term improvements. By combining experiential learning with theoretical understanding, the intervention empowers children to make informed food choices and actively engage in their own health management. This integrated model is particularly effective in the elementary school setting, where early interventions can establish foundational habits that persist into adolescence and adulthood.

In conclusion, the combined cooking and nutrition education curricula provide a comprehensive framework for promoting healthy eating concepts in schools. Beyond improving knowledge and immediate behaviors, this approach supports long-term behavioral change, offering valuable insights for educators, policymakers, and health professionals seeking to design impactful school-based interventions. The evidence underscores the importance of holistic strategies that address both knowledge and practice in fostering lifelong healthy eating behaviors.

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Original

Nutritional quality, perceptions, and sensory evaluation of plant-based meat alternatives

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Abstract. ***Background and purpose.*** Plant-based meat alternatives (PBMAs) have gained popularity as sustainable and health-conscious substitutes for conventional meat products. However, there is limited research on their nutritional quality, consumer perceptions, and sensory attributes compared to traditional meat and homemade meat products. The objective of the study is to assess the nutritional quality of plant-based meat alternatives (PBMAs), determine knowledge, attitudes, behaviour, and perception of PBMAs and evaluate their acceptability through sensory evaluation testing. ***Methods.*** Nutrition data of PBMAs and meat products were collected from packaging and assessed against recommended dietary allowances. Knowledge, attitude, behaviour (KAB), and perception of PBMAs were evaluated using questionnaires. Sensory evaluation was conducted using commercial meat products (CMP), homemade products (HMP) and plant-based meat alternatives (PBMA) (nuggets, fish fingers, minced meat, and beef patties). Twenty-six food products were evaluated for nutritional quality. Fifty-two participants completed the KAB questionnaire with twenty-one participants completing sensory evaluation. ***Results.*** PBMAs have higher fibre but lower protein content compared to HMP. PBMAs and CMP have higher saturated fat and sodium due to being ultra-processed. Key predictors of PBMA purchase intent included male gender (OR=4.25, P=0.015), obese BMI (OR=6.67, P=0.034), and positive attitudes towards healthy eating (OR=5.08, P=0.007). Sensory evaluation showed PBMAs are less preferred in taste (mean score: 2.43 for PBMA nuggets vs. 1.24 for CMP nuggets, P<0.001) and texture (mean score: 2.24 for PBMA nuggets vs. 1.52 for CMP nuggets, P=0.028). ***Conclusion.*** The study highlights the need to consider nutritional quality and consumer perceptions when evaluating PBMAs as meat substitutes. Addressing nutritional challenges and improving consumer education can enhance PBMAs' contribution to healthier, sustainable diets.

Keywords: Plant-based meat alternatives, meat analogs, nutritional quality, sensory evaluation

INTRODUCTION

In recent years, plant-based diets have gained mainstream traction as a promising dietary pattern for health. They have been associated with a reduced risk of cancer, cardiovascular disease, diabetes, and overall mortality 1,2. Characteristically, plant-based diets emphasize plant products, such as fruits and vegetables, wholegrains, legumes, nuts and seeds, while limiting or excluding animal-derived products 1 .

Plant-based meat alternatives (PBMAs) are food products made from a mix of legumes and cereals, using various food technologies, with or without added food additives. They are designed to closely resemble the organoleptic attributes (flavour, texture, and appearance) of meat products they are intended to replace 3. In recent years, PBMAs have seen a dramatic increase in production and availability worldwide. This growth is driven by factors such as sustainability concerns, animal welfare, rising population demands, and the perceived health benefits of these foods 4,5.

Research has shown that for PBMAs to effectively replace meat, they must replicate the taste, texture, visual appearance, and cooking methods of meat 6. However, concerns have been raised about the nutritional quality of these products. Studies frequently highlight potential health issues related to the additives used to mimic the sensory characteristics of meats 7. The nutritional composition of PBMAs can vary widely due to different ingredient combinations, making it challenging difficult for consumers to choose the most nutritionally beneficial option. The processing steps involved in producing many PBMAs can affect their macronutrient and micronutrient profiles 8. This is significant because many consumers believe that incorporating PBMAs into their diets will provide similar nutritional advantages to a plant-based diet that primarily consists of whole foods 6,9. Additionally, many processed PBMAs contain flavour enhancers to make them more palatable 8.

Several research groups have published comprehensive reviews on the nutrient content of a wide range of PBMAs 10–12. However, globally, dietary guidelines provide little guidance on the use of PBMAs 13. Therefore, the ramifications of reducing meat consumption on nutrient intake must be considered as meat contributes significantly to nutrient intake globally. In Singapore, the annual consumption of meat (including chicken, pork, beef, and mutton) is estimated to be 62kg per capita in 2021 14. With the "30 by 30" vision to sustainably produce 30% of Singaporean's nutritional needs locally by 2030 14, it is important to first understand the nutritional composition and quality

of meat substitutes available in the market. To our knowledge, there is currently no study evaluating the nutritional quality of PBMAs by comparing the nutrient content against local Recommended Dietary Allowances (RDAs).

Unlike PBMAs, which are considered processed foods, home-cooked meals are increasingly promoted to encourage healthier eating habits and improve overall dietary quality 15. Consumers' inclination to purchase processed PBMAs, conventional meat products, or homemade versions of meat largely depends on their perceived healthiness 11,16. Furthermore, studies have indicated that consumers are more accepting of PBMAs than other types of meat alternatives, although these studies have primarily been conducted in Western populations.

Despite technological advancements, producing PBMAs with sensory attributes similar to animal- based meat products, such as appearance, flavor, odour, and texture 17,18 remains a challenge. To our knowledge, there are few studies that specifically assess consumers' sensory perceptions of plant protein meat alternatives (PBMAs) specifically through taste testing sessions. Most studies analyzed consumer attitudes and intentions through questionnaires and surveys 19,20. Sensory studies evaluating consumer preferences for different meat alternatives are still limited 21.

With the burgeoning popularity and growth in PBMA innovation, little is known about the nutritional quality and consumption patterns of PBMAs in Singapore. Therefore, the aims of the study are to: (1) compile and compare the Nutrition Information Panel (NIP) of existing PBMAs sold in Singapore against the Singapore Recommended Dietary Allowances (RDAs), (2) investigate the knowledge, attitudes and behaviours of participants who consume PBMAs, and (3) evaluate the perceived acceptability and sensory distinctions between PBMAs, conventional meat products, and homecooked meat equivalents through sensory evaluation testing.

MATERIALS AND METHODS

Nutritional Quality Assessment of Plant-based Meat Alternatives (PBMAs)

The nutrition information panel of PBMAs and commercial meat counterparts across three major supermarkets in Singapore (NTUC FairPrice, Cold Storage, Sheng Siong) were collated from November 2022 to November 2023. These supermarket chains accounted for the majority of the Singaporean market shares and were chosen to reflect choices readily available to most Singaporean grocery shoppers. Additionally, four online grocery retailers (RedMart, Shopee, FairPrice Online, Cold Storage Online) were also included as they contributed a proportion of online grocery sales in Singapore 22.

The compilation comprised of commercial meat products, and food products made from plant-based proteins that aim to mimic the taste, texture, and overall consumer experience of meat. Products were further categorized into patties, sausages, and minced meat. Products that were excluded were non-beef patties (e.g. chicken and veggie patties), plant-based foods not meant to imitate meat products such as tofu, tempeh, and falafel, composite meals, and plant-based dairy products.

To ensure data on all relevant and available food products were captured, an additional internet search was carried out via the supermarket and respective manufacturers' websites. This involved using the keywords 'beef burger', 'patty', 'sausage', 'hot dog', 'mince', and 'grounded' for commercial meat products. Search terms for PBMAs included 'meat alternatives', 'meat substitutes', 'meat-free', 'meatless', 'plant-based', 'vegan', and 'vegetarian'.

Information collected from the nutrition information panels included energy, protein, total fat, saturated fat, carbohydrates, dietary fibre, and sodium, all recorded per 100g of each food product. For products without nutritional information per 100g, manual conversions were performed to standardize the data. This ensured consistent comparison of nutrient values across different food products. For homemade meats, the quantity of ingredients used was based on recipes sourced online. The nutritional information of these recipes was tabulated through Foodworks (Xyris, 2024). The nutritional composition of all food products was compared against the Recommended Dietary Allowances (RDAs) based on Singapore guidelines and reported in percentages.

Assessment Of The Perceived Acceptability Of PBMAs

Participants aged between 21 to 60 years old and residing in Singapore were recruited through convenience sampling, word of mouth and social media advertisements (Telegram and WhatsApp). The study recruited 52 participants, comparable with other pilot studies using KAB questionnaires 23,24. The self-administered online KAB survey consisted of 23 questions and was disseminated to recruited participants from April 2023 to August 2023.

Demographic information, including age, gender, height, weight, ethnicity, gross monthly income, tobacco use, weekly alcoholic intake, and dietary preferences were collected using close-ended multiple-choice questions. Additionally, data on health attitudes, perceptions, knowledge, and consumption patterns of PBMAs, as well as barriers and facilitators to PBMA consumption were gathered using 5-point Likert scales. Response options for agreement included 'Strongly agree', 'Agree', 'Neutral', 'Disagree', 'Strongly disagree', and 'Unsure'. The likelihood of purchasing PBMAs and replacing meat products with PBMAs was measured with options such as 'Not likely at all', 'Somewhat likely', 'Moderately likely', 'Very likely', 'Extremely likely', and 'Already doing it'.

Sensory Evaluation Testing

Only participants who had completed the KAB survey and were screened to have no gustatory and olfactory deficits, food intolerance, allergies, or dietary patterns were eligible for the sensory evaluation. A total of 21 participants were recruited to assess their acceptance and sensory differences between PBMAs, conventional meat products, and homemade meat equivalents. The sensory evaluation used a consumer hedonic method, with 10 close-ended survey questions where participants rated the products based on their attributes.

Six different food samples were prepared, consisting of two sets of food products: minced meat and patties. Each set included three different variations: the PBMA, the commercial meat product, and the homemade meat product. The samples were prepared in the sensory lab at the Singapore Institute of Technology (SIT). The selected PBMAs and meat samples were commercially available and purchased frozen from local supermarkets to maintain their sensory qualities during food preparation.

PBMAs and commercial meat products were prepared according to the cooking instructions on their packaging. Homemade meat products were prepared using online recipes. Samples were cooked, portioned into 20g servings, and kept warm during the sensory evaluation to maintain temperature and texture. To reduce potential position bias, the samples served were coded with randomized alphabets.

The sensory analysis took place in the sensory lab in SIT. Environmental settings like ambient light, positive pressure, and airflow were standardized throughout all sessions. Prior to the start of the sensory evaluation, participants were briefed on the food-tasting procedure and instructions.

During the food-tasting session, each set of samples was served one tray at a time, with cutlery provided. Plain water was provided as a palate cleanser before tasting each sample. After tasting, participants filled out an online evaluation form to rate attributes like taste, texture, colour preferences, saltiness and fat content based on the following: 1- most tasty/salty/fatty, 2 – moderately tasty/salty/fatty, 3 – least tasty/salty/fatty; 1- most appealing colour/texture, 2 – moderately appealing colour/texture, 3- least appealing colour/texture. According to current literature, these sensory traits significantly influence food acceptance 6,25. Each sensory evaluation session lasted approximately 45 minutes to 1 hour.

Statistical Analyses

All data analyses were performed using IBM SPSS Statistics Version 29.0. No missing data was reported.

Nutritional Quality

Descriptive statistics were performed to determine the overall nutritional quality of PBMAs, commercial meat products, and homemade meat products.

KAB Survey

Demographic information was analyzed using descriptive statistics, presented in the form of frequency counts and percentages. Multinomial logistic regression was performed to assess the predictors of PBMAs' purchase and replacement intent from the KAB data. Results were reported in odds ratios (ORs) and 95% confidence intervals (CIs). Significance levels were set at $\alpha < 0.05$.

Sensory Evaluation

Median ratings of taste, texture, colour, saltiness, and fat content of plant-based, commercial, and homemade minced meat and patties were compared by non-parametric Friedman's two-way analysis of variance by ranks to determine whether there were significant differences between sensory perceptions across all three meat/meat alternative per food product. When significant differences were observed ($p<0.05$), Wilcoxon signed-rank tests on different pairs of minced meat and patties were carried out to determine their differences. The *p*-value threshold was set at $\alpha < 0.05$.

Ethical Approval

Ethical approval for the involvement of human subjects in this study was granted by SIT Institutional Review Board, reference number 2023059, 28 March 2023. All participants gave informed consent.

RESULTS

Participant Characteristics

Table 1 shows the demographic characteristics of the participants (N=52). Majority of the participants were aged 21 to 30 years old (51.9%) with an equal proportion of males and females (50.0%). Most of the respondents were Chinese (82.7%), within the normal BMI range (46.2%) with a monthly income of less than S$1000 (34.6%). Most of them have never smoked (88.5%) and take alcohol less than once a week (67.3%). Participants were mostly omnivores (86.5%), with few identifying as flexitarian (9.5%), vegetarian (1.9%) and pescetarian (1.9%).

Table 1. Demographic characteristics (N=52)

	n	%
Demographics		
Age (Years)		
21 - 30	27	51.9
31 - 40	8	15.4
41 - 50	8	15.4
51 - 60	9	17.3
Gender		
Female	26	50.0
Male	26	50.0
Body Mass Index (BMI)		
Underweight (< 18.5)	5	9.6
Normal (18.5 - 22.9)	24	46.2
Overweight (23.0 - 24.9)	13	25.0
Obese (≥ 25)	10	19.2
Ethnicity		
Chinese	43	82.7
Non-Chinese1	9	17.3
Monthly income (Singapore dollars)		
Low ($0 - $2000)	21	40.4
Middle ($2001 - $5000)	16	30.8
High (>$5000)	15	28.8
Dietary Habits		
Diet Type		
Omnivore	45	86.5
Others2	7	13.5
Tobacco Use		
Never	46	88.5
Ever3	6	11.5
Alcohol Intake		
Non-drinker	35	67.3
Drinkers4	17	32.7

1 Non-Chinese includes Malay, Indians, and Others.

2 Others includes vegetarian, pescatarian, and flexitarian.

3 Ever includes active smokers and ex-smokers.

4 Drinkers include occasional drinkers.

Nutritional Quality Assessment

A total of 41 food products were evaluated for nutritional quality (Appendix 1). These food products were classified as plant-based meat alternatives (PBMA) or commercial meat-based products (CMP). Homemade meat products were used as a reference. Figure 1-5 compares the composition of macronutrients (protein, carbohydrates, total fat) composition, dietary fibre and sodium content of PBMA and CMP with the Recommended Daily Allowances (RDA) for each macronutrient, expressed as a percentage of RDA per 100g of each product.

Figure 1. Comparison of protein content (per 100g) of food products against the RDA (%)

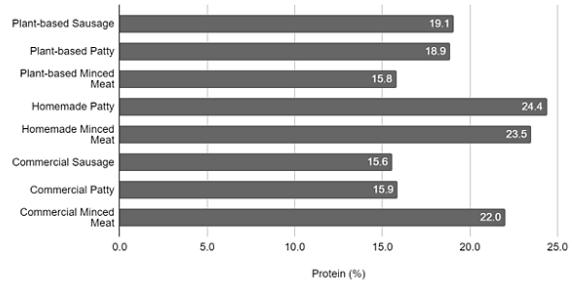


Figure 2. Comparison of carbohydrates content (per 100g) of food products against the RDA (%)

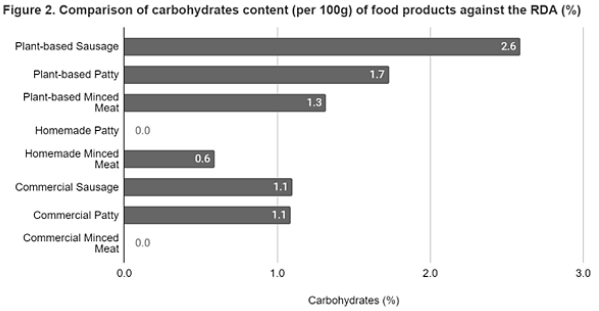


Figure 5. Comparison of sodium content (per 100g) of food products against RDA (%)

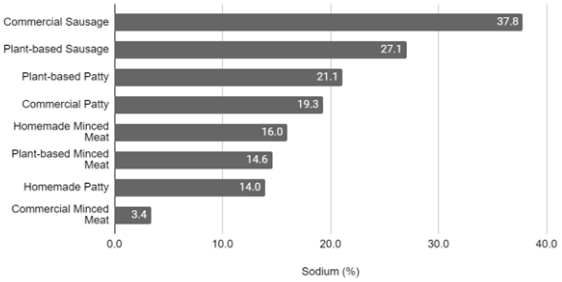


Figure 3. Comparison of fat content (per 100g) of food products against the RDA (%)

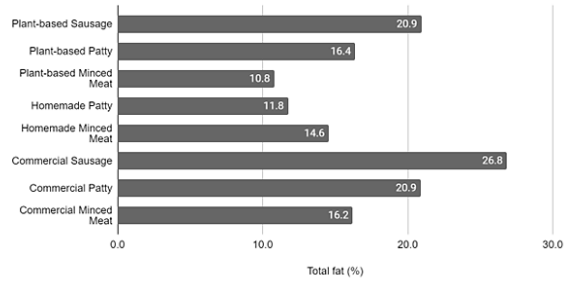
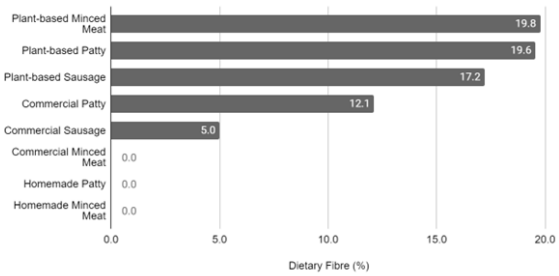


Figure 4. Comparison of dietary fibre content (per 100g) of food products against RDA (%)



The top three products with the highest protein content were home-made patty (24.4% of RDA), home-made minced meat (23.5% of RDA), and commercial minced meat (22.0% of RDA). Plant-based sausages contained the most carbohydrates (2.6% of RDA) while homemade meat patty did not. Total fat content was the highest among commercial sausages (26.8% of RDA), commercial patty (20.9% of RDA) and plant-based sausages (20.9% of RDA). The saturated fat content also follows the same trend; commercial sausage (30.3% of RDA), commercial patties (27.9% of RDA), and PBMA sausages (22.8% of RDA) (data not shown). Dietary fibre was not found in homemade or commercial minced meat products, but in all PBMAs. For sodium, products with the highest sodium levels were commercial sausages (37.8% RDA), PBMA sausages (27.1% RDA), and PBMA patties (21.1% RDA).

Table 2. Perceived Acceptability of PBMAs

Participants' Perception of PBMAs (n=52)	n	%
I think it is important to eat healthily		
Strongly agree / Agree	52	100.0
PBMAs are healthier than meat products		
Strongly agree / Agree	10	19.2
Neutral	19	36.5
Strongly disagree / Disagree	17	34.6
Unsure	6	11.5
PBMAs are high in proteins		
Strongly agree / Agree	9	17.3
Neutral	24	46.2
Strongly disagree / Disagree	13	25.0
Unsure	6	11.5
PBMAs have equivalent amounts of salt as meat and meat products	21	40.4
Strongly agree / Agree	19	36.5
Neutral	6	11.5
Strongly disagree / Disagree	6	11.5
Unsure		
PBMAs are high in dietary fibre		
Strongly agree / Agree	5	9.6
Neutral	20	38.5
Strongly disagree / Disagree	21	40.4
Unsure	6	11.5
The production of PBMAs emits lesser greenhouse gases compared to meat and meat products		
Strongly agree / Agree	5	9.6
Neutral	13	25.0
Strongly disagree / Disagree	24	46.2
Unsure	10	19.2
PBMAs are ultra-processed foods		
Strongly agree / Agree	2	3.8
Neutral	11	21.2
Strongly disagree / Disagree	33	63.5
Unsure	6	11.5
Do you eat PBMAs?		
Yes, on a regular basis	3	5.8
I have tried plant-based meat alternatives, but do not eat them on a regular basis	41	78.8
No	8	15.4
If you eat PBMAs regularly, what are the reasons for eating them? [Multi-select] (n = 3)		
Environment reasons		
Animal welfare	1	1.0
Health reasons	3	3.0
I like the taste	2	2.0
Accessible	2	2.0

Participants' Perception of PBMAs (n=52)	n	%
It tastes authentic to real meat	1	1.0
	1	1.0
If you do not eat PBMAs regularly, what is the likelihood of you trying them? (n = 49)		
Not likely at all	6	12.2
Somewhat likely	16	32.7
Moderately likely	17	34.7
Very likely	9	18.4
Extremely likely	1	2.0
If you do not eat PBMAs regularly, what are the reasons for not eating them regularly? [Multi-select] (n = 49)		
Unhealthy	4	4.6
Too processed	15	17.2
I do not like the taste of meat alternatives	18	20.7
I do not like to try new foods	1	1.1
Meat alternatives are for vegans and vegetarians only	1	1.1
Too expensive	25	28.7
Inaccessible	18	20.7
Others	5	5.7
What is the likelihood of you purchasing PBMAs regularly?		
Not likely at all	25	48.1
Somewhat likely	13	25.0
Moderately likely	11	21.2
Very likely	1	1.9
Extremely likely	0	0.0
Already purchasing	2	3.8
What is the likelihood of you replacing conventional meat with PBMAs?		
Not likely at all	28	53.8
Somewhat likely	13	25.0
Moderately likely	7	13.5
Very likely	2	3.8
Extremely likely	0	0.0
Already replacing	2	3.8

Perceived Acceptability of PBMAs

Table 2 illustrates the perceived acceptability of PBMAs. All 52 respondents agreed that healthy eating is important. Respondents were mostly ambivalent towards the notion that PBMAs are healthier than meat products (36.5%) and are high in proteins (46.2%). The largest proportion of respondents perceived PBMAs to have the same amount of salt as meat and meat products (40.4%), disagree that PBMAs are high in dietary fibre (40.4%), and emit less greenhouse gases during its production (46.2%). Interestingly, almost two-thirds of the respondents did not view PBMAs as ultra-processed foods (63.5%).

Amongst all respondents, only three respondents consumed PBMAs regularly (5.8%), with their top motivating factors including animal welfare, health reasons, and liking the taste of PBMAs. For the remaining 49 respondents who do not regularly eat PBMAs, their main barriers included PBMAs being too expensive (28.7%), disliking the taste of PBMAs (20.7%), and inaccessibility (20.7%). Most respondents were unlikely to purchase PBMAs regularly (48.1%) or replace conventional meat with PBMAs in their diets (53.8%).

Table 3. Regression analysis to investigate demographic and dietary habits associated with intent of purchase and replacement of PBMA. (N=52)

	Likelihood of Purchase		Likelihood of Replacement	
	OR	*P-value*	OR	*P-value*
Demographics				
Age (years)				
21 - 30	*Reference*	*NA*	*Reference*	*NA*
31 - 40	8.75	*0.056*	14.00	*0.021*
41 - 50	0.75	*0.728*	1.20	*0.827*
51 - 60	1.56	*0.565*	2.50	*0.243*
Gender				
Female	*Reference*	*NA*	*Reference*	*NA*
Male	4.25	*0.015*	3.60	*0.029*
BMI				
Normal	*Reference*	*NA*	*Reference*	*NA*
Underweight	0.42	*0.464*	0.50	*0.563*
Overweight	3.75	*0.072*	3.20	*0.104*
Obese	6.67	*0.034*	4.67	*0.059*
Ethnicity				
Chinese	*Reference*	*NA*	*Reference*	*NA*
Non-Chinese1	2.10	*0.337*	0.52	*0.401*
Income				
Low	*Reference*	*NA*	*Reference*	*NA*
Middle	0.86	*0.815*	0.61	*0.472*
High	2.20	*0.260*	2.69	*0.163*
Diet Type				
Omnivore	*Reference*	*NA*	*Reference*	*NA*
Others2	2.61	*0.279*	3.42	*0.167*
Perception				
I think it is important to eat healthy	5.08	*0.007*	3.24	*0.046*
PBMAs are healthier than meat products	2.65	*0.018*	2.49	*0.022*
PBMAs are high in proteins	0.76	*0.469*	0.84	*0.655*
PBMAs have equal salt as meat and meat products	0.42	*0.025*	0.57	*0.110*
PBMAs are high in dietary fibre	0.81	*0.571*	1.01	*0.988*
PBMA production emits lesser greenhouse gasses	0.84	*0.559*	0.95	*0.845*
PBMA are ultra-processed foods	1.13	*0.737*	1.17	*0.666*

1 Non-Chinese includes Malay, Indians and Eurasians

2 Others is defined as vegetarian, pescatarian, flexitarian.

Statistical differences under a logistic regression model, where *P<0.05* are indicated in bold.

Table 4. Mean participant sensory perceptions between commercial meat products (CMP), homemade (HMP), and plant-based meat alternative (PMBA) food products (N=21)

Food Products	Nugget				Fish finger				Minced meat				Beef patty			
	CMP	HMP	PBMA	P-valued	CMP	HMP	PBMA	P-valued	CMP	HMP	PBMA	P-valued	CMP	HMP	PBMA	P-valued
Taste	1.24a,b	2.33a	2.43a	*<0.001*	2.00	2.19	1.81	*0.467*	2.14	2.14	1.71	*0.276*	1.57a	2.24a	2.19	*0.055*
Texture	1.52a,b	2.24a	2.24a	*0.028*	1.76	2.24	2.00	*0.304*	1.86	2.10	2.05	*0.717*	2.10	1.86	2.05	*0.717*
Colour	1.91	2.52a	1.57b	*<0.001*	1.43b	2.24a	2.33a	*0.006*	2.24	2.10	1.67	*0.156*	2.00	2.00	2.00	*1.00*
Saltiness	1.38b	2.67a	1.95c	*<0.001*	1.81a	2.62b	1.57a	*0.002*	2.10a	2.62a	1.29b	*<0.001*	1.57a	2.52b	1.91a	*0.007*
Fat	1.57a	2.52b	1.91a	*0.007*	1.33b	2.71a	1.95b	*<0.001*	2.24	2.05	1.71	*0.229*	2.00	1.95	2.05	*0.953*

Abbreviations: CMP = Commercial Meat Products, HMP = Homemade Meat Products, PBMA = Plant-based Meat Alternatives.

Mean values within a column with unlike superscript letters were significantly different (P<0.05)

d Friedman's Two-way ANOVA were used.

(1- Most tasty/salty/fatty, 2 – moderately tasty/salty/fatty, 3 – least tasty/salty/fatty; 1- most appealing colour/texture, 2 – moderately appealing colour/texture, 3- least appealing colour/texture

Predictors Of PBMAs Purchase And Replacement Intent

From Table 3, male gender (OR 4.25, P=0.015), obese BMI classification (OR 6.67, P=0.034), a positive perception towards healthy eating (OR 5.08, P=0.007) and the perception that PBMAs are healthier than meat products (OR 2.65, P=0.018) are significant predictors of the likelihood to purchase PBMAs. The likelihood to replace existing meat consumption with PBMAs are significantly determined by age range of 31-40 years (OR 14.0, P=0.021), male gender (OR 3.60, P=0.029), a positive perception towards healthy eating (OR 3.24, P=0.046) and the perception that PBMAs are healthier than meat products (OR 2.49, P=0.022).

ensory Evaluation

Table 4 shows the participants' sensory perceptions between plant-based meat alternatives (PBMA), commercial meat products (CBP) and homemade meat products (HMP). For nuggets, significant differences were observed across all sensory attributes (P<0.05). PBMA nuggets were the least preferred in terms of taste compared to CMP and HMP nuggets (P<0.001). Texture preferences for PBMA and HMP nuggets were similar, but both were found to be less appealing than CMP nuggets (P=0.028). In terms of colour, HMP nuggets have the most appealing colour, followed by CMP and PBMA nuggets (P<0.001). Significant differences in saltiness were noted, with HMP nugget perceived as the least salty compared to the CMP and PBMA nuggets (P<0.001). CMP nuggets were considered the fattiest, followed by PBMA and HMP nuggets (P=0.007).

For fish fingers, no significant differences were found in perceived taste and texture. However, significant differences were noted for colour (P=0.006), saltiness (P=0.002) and fat content (P<0.001). PBMA fingers were rated the lowest for colour, homemade fish fingers rated the lowest for saltiness and fattiness. In the minced meat category, PBMA was perceived as the saltiest compared to CMP and HMP (P<0.001). For beef patty, CMP and PBMA were perceived as saltier than HMP (P=0.007).

DISCUSSION

The findings of this study provide valuable insights into the nutritional quality, perceptions, and sensory evaluation of plant-based meat alternatives (PBMAs) compared to conventional meat products and homemade meat equivalents. Our results indicate that while PBMAs offer a viable alternative to meat products, there are significant differences in their nutritional profiles and sensory attributes that warrant consideration.

Our study revealed that while PBMAs contained the highest fibre content, they had lower protein content compared to homemade meat products. Additionally, the highest levels of saturated fat and sodium were found in plant-based sausages and commercial meat products such as sausages and patties. These findings are consistent with existing literature. Firstly, PBMAs have been reported to have higher fibre and sodium content compared to meat products 26. Secondly, both PBMAs and commercial meat products are generally associated with higher saturated fat and sodium content due to their ultra-processed nature 11,27. Lastly, in line with our study, PBMAs have generally been shown to have a lower protein content 28. In contrast, homemade meat products contained the highest protein levels but the lowest sodium and saturated fat content.

Nutritionally, reducing the consumption of red and processed meat and partially replacing it with PBMAs has been shown to improve the intake of unsaturated fatty acids and dietary fibre 29,30. Generally, PBMA products contain fewer calories, less total and saturated fat, and more dietary fibre than their meat counterparts 16. However, the production PBMAs often results in products with high levels of sodium, sugar, saturated fat, and added flavourings and additives 11. Additionally, PBMAs may lack essential micronutrients like iron, zinc, and vitamin B_{12}12. PBMA products with low nutritional quality and elevated sodium levels poses health risks such as chronic kidney disease 31.

Iron, zinc, and vitamin B_{12} are challenging to obtain in a meat-free diet, and their bioavailability in meat substitutes can be limited by factors like phytate content 32. Vitamin B_{12}, which is absent in plants, presents an additional challenge, potentially causing deficiencies, especially among vegetarians, vegans, pregnant women, or females in their reproductive years 33. Reducing sodium content through natural seasonings, improved processing techniques, fortifying PBMAs, and advocating for nutrient-rich plant foods can mitigate these challenges 28,34. Therefore, there is a critical need for education and guidelines centred on plant-based nutrition and fortification strategies to enhance the nutritional profile of PBMAs, positioning them as part of a healthy and sustainable diet.

The knowledge, attitudes, and behaviours (KAB) survey indicated that while there is a growing interest in PBMAs, several misconceptions persist among consumers. A significant proportion of respondents did not consider PBMAs to be ultra-processed and were ambivalent about the health benefits of PBMAs. These findings could be attributed to the lack of familiarity and knowledge deficit regarding PBMAs and highlight the need for better consumer education on the nutritional quality of PBMAs. Our study identified several demographic and attitudinal factors that significantly predict the likelihood of purchasing PBMAs and replacing meat products with them. The key predictors of PBMA purchase included male gender, an obese body mass index, positive attitudes towards healthy eating, and regular PBMA consumption. Interestingly, previous studies have reported a higher propensity for females to buy PBMAs, with some even identifying no significant gender differences 23,35,36. Although the relationship between males and the increased likelihood of purchasing PBMAs is not well-explored in previous research, several suggested reasons for this finding could be attributed to the rise in number of males expressing personal health and environmental goals - goals that could potentially be attained by decreasing red meat consumption or increasing PBMAs intake 37. Our findings showed that an obese BMI classification is a predictor of PBMAs' purchase intent. This aligns with a recent study, which found that a higher BMI status was associated with a higher purchase intent for beef patties 38. However, this correlation was not observed for plant-based patties. Moreover, the current literature is limited regarding the correlation between BMI classifications and the purchase intent of PBMAs, indicating a need for further studies to better establish this relationship.

Our findings also suggest that positive attitudes towards healthy eating influence the decision to purchase PBMAs, likely due to the perceived health benefits of plant-based diets 39. However, positive attitudes toward healthy eating do not necessarily correlate with PBMA purchase intent, possibly due to the perceived overly-processed nature of PBMAs 40,41. Additionally, consumers have limited access to reliable scientific publications or the ability to evaluate robust scientific data 11. Knowledge of PBMAs depends on claims made by manufacturers and internet searches, which generally do not provide clear, validated evidence for specific features. Therefore, there is a need to inform consumers about the nutritional quality of PBMAs to enable them to make informed purchasing decisions.

The intent to replace meat consumption with PBMAs is primarily driven by individuals aged 31-40 years and those with a positive perception towards PBMAs. Studies on factors affecting PBMA replacement intent are rarely examined 42. Nonetheless, our results provide more insights into the habits of those replacing meat with PBMAs, thereby contributing to the current literature. Despite these predictors, consumers' food decisions are influenced by a multitude of other factors 11,43,44. Although our findings showed that only a small number of participants consume PBMAs regularly, this is consistent with other studies 45. The top facilitators for these individuals were animal welfare and health reasons. For the majority, costs, taste preferences, and the perception that PBMAs as overly processed were the key barriers to consumption. These results align with many existing studies, reiterating that animal welfare and health reasons are enablers to

purchasing and replacing meat with PBMAs, while price, taste, and perceived unnaturalness are common barriers 27,44,46. Additionally, individuals with strong attachments to meat and habitual meat intake are reported to be less likely to purchase and regularly replace meat with PBMAs 36,46.

The study found that plant-based meat alternatives (PBMAs) were generally less preferred compared to commercial meat products (CMP) and homemade meat products (HMP) across various sensory parameters. Specifically, PBMA nuggets were rated lower for taste and texture while PBMA fish fingers were less favoured in terms of colour. In the minced meat category, PBMAs were perceived as the saltiest. The overall appearance of a product is important for priming consumers and developing expectations prior to consumption 17. Disconfirmation of expectations occurs when the perceived liking after consumption is below the expected liking, which may happen when the visual cues misrepresent the taste, odour, and flavour of the product 17. One processing limitation of using plant proteins is that the colour of PBMAs may fade when exposed to light or oxygen, leading to an unappetizing product 47, as observed with nuggets and fish fingers in our study. Certain ingredients can affect the colour and appearance of PBMAs. For example, changing the ratio of chickpea flour to texturized vegetable protein in meatless nuggets improved colour and appearance scores 48. However, the presence of carotenoids in chickpea flour contributed to a yellow colour, which was unappealing to the participants. In our study, homemade nuggets had the most appealing colour, followed by commercial and PBMA nuggets. This suggests that the colour profile can be optimized in homemade nuggets, especially when using healthy ingredients (lean chicken, chopped vegetables) and healthy cooking methods (air-frying, grilling).

Saltiness is a marker of sodium content in the product. Our results showed that PBMA minced meat and beef patties were perceived as the saltiest compared to commercial and homemade meat products. This aligns with findings from a study comparing PBMA beef patties to their meat equivalent, which showed that maintaining a high sodium level in PBMAs is important for consumer acceptance in terms of flavour 49. In contrast, homemade nuggets were perceived as the least salty, indicating that commercial products are usually formulated with high sodium levels to enhance flavour, which in turn lowers the nutritional quality of the final product.

Another challenge for PBMAs is recreating the unique texture, mouthfeel, and juiciness of traditional meat products 50. In our study, the texture of commercial nuggets was more appealing than that of PBMA and homemade nuggets, suggesting consumer familiarity with the texture of commercial nuggets, which are high in saturated fat and sodium. These heterogenous findings highlight the sensory challenges PBMAs face in gaining consumer acceptance compared to traditional meat products. While PBMAs show potential, particularly in texture for certain products, they need improvement in taste, texture and colour profiles. Addressing these sensory attributes, in addition to the nutritional quality, could enhance the appeal of PBMAs and support their adoption as viable alternatives to conventional meat products.

The strength of our study lies in its comprehensive assessment of the nutritional quality of PBMAs in Singapore. Additionally, our findings provide valuable insights into consumers' perception of PBMAs, examining their knowledge, attitudes, & behaviours through sensory profiling. However, the demographics in this study was not representative of the Singapore population. Our participants were mostly of Chinese ethnicity and from a younger age group, which may have limited purchasing ability. Future studies should consider using a larger sample size, a wider age group and including other ethnicities to explore potential differences with respect to ethnicities, age groups and socio-economic stratifications.

CONCLUSIONS

The variety of novel protein alternatives on the market is increasing, with many new product innovations potentially prompting consumers to change their dietary habits. Plant-based meat alternatives (PBMAs) may replace and complement meat- and animal-derived products in the human diet, potentially reducing the environmental impact of food consumption.

Our results suggest differences in the nutritional quality of PBMAs compared to their meat counterparts. Homemade meats have better nutritional quality compared to PBMAs and commercial meat products. However, it is important to highlight that the nutritional quality of foods still depends on the ingredients used during the preparation and cooking. Additionally, the nutritional advantages of plant-based diets cannot be directly extrapolated to diets that include PBMA. Although completely substituting meat with PBMAs does not necessarily equate to an improved or healthier diet, partially replacing meat or including PBMAs in one's diet is unlikely to result in adverse nutritional status.

The increasing popularity of PBMAs presents both opportunities and challenges for public health nutrition and dietetics practice. The knowledge, attitudes, and behaviors (KAB) survey indicated that while there is a growing interest in PBMAs, several misconceptions persist among consumers. A significant proportion of respondents did not consider PBMAs to be ultra-processed and were ambivalent about the health benefits of PBMAs. These findings highlight the need for improved consumer education regarding the nutritional quality and health benefits of PBMAs. Dietitians and nutritionists can play a pivotal role in dispelling misconceptions and promoting informed food choices. As the PBMA market continues to grow and evolve, valuable insights from this study can be channeled towards nutrition education and the development of evidence-based guidelines for PBMAs to allow the public to make better-informed food choices.

In conclusion, our study highlights the importance of considering both nutritional quality and consumer perceptions when evaluating PBMAs as substitutes for meat. By addressing the identified nutritional challenges and improving consumer education, PBMAs have the potential to significantly contribute healthier and more sustainable dietary patterns.

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