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A COMPARATIVE ANALYSIS OF 24-HOUR DIETARY RECALLS AND FOOD FREQUENCY QUESTIONNAIRES ADMINISTERED SIMULTANEOUSLY IN THE KAZAKHSTANI POPULATION

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Introduction: Dietary habits and eating patterns of individuals have a significant impact on overall health. Proper nutrition is vital to preventing chronic diseases and improving physical and mental performance. Kazakhstan, a rapidly developing country in Central Asia, offers a unique opportunity to study the diverse dietary behavior of its population due to cultural, ethnic and geographic differences.

Purpose: to study dietary habits and nutritional status of persons aged 18 years and older in various regions of Kazakhstan.

Materials and methods: The study was conducted over a period of six months and covered urban and rural areas of various regions of Kazakhstan, including large cities such as Astana, Almaty and Aktobe, as well as their surrounding rural areas. A stratified sample of 370 participants was used and were randomly selected from each stratum to ensure representativeness. Statistical analyzes included determination of dietary patterns, assessment of agreement between food frequency questionnaires and 24-hour recalls, and correlation and visualization of agreement between these methods using Bland-Altman plots. To improve the accuracy of food intake estimates, Willett energy adjustment was applied using Python 3.9 and associated libraries (NumPy, SciPy, pandas, Scikit-learn).

Results: In this study, conducted in different regions of Kazakhstan, significant regional differences in food intake and nutritional status were observed among 370 participants. A comparative analysis of food frequency questionnaires (FFQ) and 24-hour recall showed that urban residents tend to have higher consumption of processed foods, whereas rural residents are more likely to consume traditional, minimally processed foods. This difference highlights the influence of geography, culture, and economic factors on eating habits. Urban and rural settings exhibited unique dietary patterns: urban areas experienced greater diversity in food consumption, but also a higher propensity for nutrient inequalities.

Conclusions: Combining multiple dietary assessment tools and using larger sample sizes may improve the accuracy and reliability of dietary data. Additionally, education and training of participants in portion size estimation and dietary reporting may help improve the quality of data collected using these methods. In conclusion, the study shows that the FFQ and 24-hour recall methods are reliable and correlate well in assessing intake of essential nutrients in Kazakhstan.

Keywords: *Nutritional status, dietary habits, urban-rural disparities, Kazakhstan, Food Frequency Questionnaire (FFQ), 24-hour recall, nutrient intake, dietary patterns.*

Резюме

СРАВНИТЕЛЬНЫЙ АНАЛИЗ АНКЕТЫ ПОТРЕБЛЕНИЯ ПИЩИ ЗА ПОСЛЕДНИЕ 24 ЧАСА И АНКЕТЫ О ЧАСТОТЕ ПОТРЕБЛЕНИЯ ПРОДУКТОВ, ПРОВОДИМЫЙ ОДНОВРЕМЕННО СРЕДИ НАСЕЛЕНИЯ КАЗАХСТАНА

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Введение: Диетические привычки и режим питания людей существенно влияют на общее состояние здоровья. Правильное питание имеет жизненно важное значение для предотвращения хронических заболеваний и повышения физической и умственной работоспособности. Казахстан, быстро развивающаяся страна в Центральной Азии, предлагает уникальную возможность изучить разнообразное пищевое поведение своего населения, обусловленное культурными, этническими и географическими различиями.

Цель: изучить особенности питания и статус питания у лиц в возрасте 18 лет и старше в различных регионах Казахстана.

Материалы и методы: Исследование проводилось в течение шести месяцев и охватывало городские и сельские районы различных регионов Казахстана, включая крупные города, такие как Астана, Алматы и Актобе, а также прилегающие к ним сельские районы. Была использована стратифицированная выборка из 370 участников, которые были случайным образом выбраны из каждой страты, чтобы обеспечить репрезентативность. Статистический анализ включал определение структуры пищевого рациона, оценку соответствия между анкетами по частоте приема пищи и 24-часовыми отзывами, а также корреляцию и визуализацию согласия между этими методами с использованием графиков Бланда-Альтмана. Для повышения точности оценок потребления пищи применялась энергетическая корректировка Уиллетта с использованием Python 3.9 и соответствующих библиотек (NumPy, SciPy, pandas, Scikit-learn).

Результаты: В этом исследовании, проведенном в различных регионах Казахстана, среди 370 участников наблюдались значительные региональные различия в потреблении пищи и статусе питания. Сравнительный анализ опросников частоты питания (FFQ) и 24-часовых воспоминаний показал, что жители городов имеют тенденцию к более высокому потреблению обработанных пищевых продуктов, тогда как жители сельской местности чаще потребляют традиционные, минимально обработанные продукты. Это различие подчеркивает влияние географии, культуры и экономических факторов на пищевые привычки. В городских и сельских условиях наблюдались уникальные модели питания: в городских районах наблюдалось большее разнообразие в потреблении продуктов питания, но также и более высокая склонность к неравенству в питательных веществах.

Выводы: Сочетание нескольких инструментов оценки питания и использование выборки большего размера может повысить точность и надежность данных о питании. Кроме того, обучение и подготовка участников по вопросам оценки размера порций и составления отчетов о диете могут помочь повысить качество данных, собираемых с помощью этих методов. В заключение исследование показывает, что методы FFQ и 24-часового отзыва надежны и хорошо коррелируют при оценке потребления основных питательных веществ в Казахстане.

Ключевые слова: *статус питания, пищевые привычки, различия между городом и деревней, Казахстан, опросник частоты приема пищи (FFQ), 24-часовой отзыв, потребление питательных веществ, модели питания.*

Түйіндеме

ҚАЗАҚСТАН ХАЛҚЫ АРАСЫНДА БІР МЕЗГІЛДЕ ЖҮРГІЗІЛГЕН ТАМАҚТАНУ САУАЛНАМАЛАРЫНЫҢ САЛЫСТЫРМАЛЫ ТАЛДАУЫ (СОҢҒЫ 24 САҒАТТАҒЫ ТАҒАМДЫ ТҰТЫНУ САУАЛНАМАСЫ ЖӘНЕ АЗЫҚ-ТҮЛІКТІ ТҰТЫНУ ЖИІЛІГІ САУАЛНАМАСЫ)

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Кіріспе: Жеке адамдардың тамақтану әдеттері мен тамақтану үлгілері жалпы денсаулыққа айтарлықтай әсер етеді. Созылмалы аурулардың алдын алу және физикалық және психикалық өнімділікті жақсарту үшін дұрыс тамақтану өте маңызды. Орталық Азиядағы қарқынды дамып келе жатқан Қазақстан мәдени, этникалық және географиялық ерекшеліктерге байланысты өз халқының әртүрлі диеталық тәртібін зерттеудің бірегей мүмкіндігін ұсынады.

Мақсаты: Қазақстанның әртүрлі аймақтарындағы 18 жастан асқан адамдардың тамақтану әдеттерін және тамақтану жағдайын зерттеу.

Материалдар мен әдістер: Зерттеу алты ай бойы жүргізілді және Қазақстанның әртүрлі аймақтарының қалалық және ауылдық жерлерін, соның ішінде Астана, Алматы және Ақтөбе сияқты ірі қалаларды, сондай-ақ олардың маңындағы ауылдық елді мекендерді қамтыды. 370 қатысушыдан тұратын стратификацияланған іріктеу пайдаланылды және репрезентативтілікті қамтамасыз ету үшін әр қабаттан кездейсоқ таңдалды. Статистикалық талдаулар диеталық үлгілерді анықтауды, тамақ жиілігі сауалнамасы мен 24 сағаттық еске түсіру арасындағы келісімді бағалауды, сондай-ақ Бланд-Алтман сюжеттерімен осы әдістер арасындағы сәйкестікті визуализациялауды қамтиды. Азық-түлікті тұтынуды бағалаудың дәлдігін жақсарту үшін Уиллетт энергиясын реттеу Python 3.9 және оған қатысты кітапханалар (NumPy, SciPy, pandas, Scikit-learn) арқылы қолданылды.

Нәтижелер: Қазақстанның әртүрлі аймақтарында жүргізілген бұл зерттеуде 370 қатысушының арасында азық-түлікті тұтыну мен тамақтану жағдайындағы елеулі аймақтық айырмашылықтар байқалды. Азық-түлік жиілігі сауалнамасын (FFQ) және 24 сағаттық еске түсіруді салыстырмалы талдау қала тұрғындарының өңделген тағамдарды көбірек тұтынатынын, ал ауыл тұрғындарының дәстүрлі, ең аз өңделген тағамдарды тұтынуы ықтимал екенін көрсетті. Бұл айырмашылық географияның, мәдениеттің және экономикалық факторлардың тамақтану әдеттеріне әсерін көрсетеді. Қалалық және ауылдық жерлер бірегей диета үлгілерін көрсетті: қалалық аудандар азық-түлікті тұтынуда үлкен әртүрлілікті бастан кешірді, сонымен бірге қоректік заттардың теңсіздігіне бейімділік жоғары болды.

Қорытынды: Диетаны бағалаудың бірнеше құралдарын біріктіру және іріктеудің үлкен өлшемдерін пайдалану диета деректерінің дәлдігі мен сенімділігін арттыруы мүмкін. Бұған қоса, қатысушыларды үлес мөлшерін бағалау және диета туралы есеп беру бойынша оқыту және оқыту осы әдістерді қолдану арқылы жиналған деректердің сапасын жақсартуға көмектесуі мүмкін. Қорытындылай келе, зерттеу FFQ және 24 сағаттық еске түсіру әдістері сенімді және Қазақстандағы маңызды қоректік заттардың тұтынуын бағалауда жақсы сәйкес келетінін көрсетеді.

Түйінді сөздер: *Тамақтану күйі, тамақтану әдеттері, қала мен ауыл арасындағы диспропорция, Қазақстан, Азық-түлік жиілігі сауалнамасы (FFQ), 24 сағаттық есте сақтау, қоректік заттарды қабылдау, диета үлгілері.*

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Introduction

The dietary habits and nutritional patterns of individuals play a pivotal role in maintaining overall health and well-being. Proper nutrition is crucial for preventing various chronic diseases and promoting optimal physical and mental performance. Understanding the dietary behaviors of diverse populations is essential for developing targeted interventions and policies aimed at improving public health outcomes. Due to the diverse cultural, ethnic, and geographic characteristics of Kazakhstan, a rapidly developing nation in Central Asia, the population exhibits unique dietary habits.

Despite the significance of dietary habits in influencing health, there is a lack of comprehensive research exploring

the dietary intake and nutritional status of individuals residing in different regions of Kazakhstan.

Considering this knowledge gap, the present study sought to investigate the dietary intake patterns and nutritional status of individuals aged 18 years and above from various regions of Kazakhstan. By comprehensively examining the dietary behaviors of the Kazakh population, this research aims to shed light on regional differences in nutritional practices and identify potential areas of concern or improvement in dietary choices. The findings from this study will not only provide valuable insights into the nutritional health of the population but also serve as a foundation for designing targeted health interventions and public health strategies to address any identified nutritional disparities.

Hypothesis: Based on the diverse geographic and cultural landscape of Kazakhstan, we hypothesize that there will be significant regional variations in dietary intake and nutritional status among individuals aged 18 years and above. Factors such as geographical location, cultural traditions, and economic conditions are expected to influence dietary patterns, leading to variations in the consumption of different food groups and nutrients across different regions. Additionally, we anticipate that urban centers may exhibit different dietary behaviors compared to rural areas, reflecting varying access to food sources and lifestyle choices.

To test our hypothesis, we have recruited participants from multiple regions of Kazakhstan, encompassing both urban and rural settings, to ensure a representative sample. Utilizing a combination of Food Frequency Questionnaires and 24-hour recalls, we will assess the participants' dietary habits and intake of essential nutrients. Furthermore, we will employ the Automated Self-Administered Dietary Assessment Tool (ASA24) and the FFQ EPIC Tool for Analysis (FETA) to comprehensively evaluate nutrient intake and dietary composition. Through this study, we aim to provide valuable insights into the dietary behaviors and nutritional status of the Kazakh population, enabling the development of targeted strategies to promote healthier eating habits and overall well-being in the country.

Aim To study dietary patterns and nutritional status of population aged 18 years and older in various regions of Kazakhstan.

Materials and Methods

Participant Recruitment: In this study, a total of 370 individuals, including both males and females, aged 18 years and above, were recruited from various regions in Kazakhstan. The only inclusion criterion for participants was their age, which had to be over 18 years. No exclusion criteria were applied.

Survey Administration: The geographical scope of the study covered both urban and rural areas of various regions, including large cities such as Astana, Almaty and Aktobe, as well as rural areas located near these urban centers.

Ethical Considerations: Prior to any data analysis, all participants provided their informed consent by signing the relevant consent documents. The study protocol and consent documents were reviewed and approved by the Ethic Committee of the Center for Life Sciences, National Laboratory Astana. The research was conducted with the approval number 02-2022 from 01.04.2022, IORG0006963.

Survey Administration: To collect data, a telegram bot was developed and utilized as a survey tool. The survey comprised Food Frequency Questionnaires and 24-hour recalls. Two questionnaires were adapted to suit an online format and were made available in two languages: Russian and Kazakh. Once the telegram bot was tested for functionality, it was distributed to all study participants.

Dietary Intake and Assessment: Out of the total number of participants, 231 individuals successfully completed both questionnaires, and their data were used for the study analysis. The information from these 231 questionnaires was inputted into the Automated Self-Administered Dietary Assessment Tool (ASA24), accessible at https://asa24.nci.nih.gov/. ASA24 is designed to collect detailed data on food consumption within a 24-hour period. Each participant was provided with login credentials for authorization on the ASA24 website. The questionnaire included nine categories of meals (e.g., breakfast, brunch, lunch) and recorded information on the time, location of food consumption, and media use (e.g., phone, TV, laptop) during eating. Participants were asked to provide specific details about the type of food, its preparation method, and the quantity consumed. Additionally, participants were required to report the time they woke up and went to bed, along with their morning well-being and sleep quality. ASA24 autonomously computed nutrient intake and energy value for each participant based on the provided data. A dietary analysis was performed using this information, considering the participants' well-being and sleep quality.

Food Frequency Questionnaire (FFQ): The Food Frequency Questionnaire used in this study consisted of 137 questions related to the frequency of consuming specific food items necessary for maintaining a healthy lifestyle. Participants were asked to indicate how often they consumed each food item, and the responses were recorded on a numerical scale as follows: 1 = never, 2 = 1-3 times per month, 3 = once a week, 4 = 2-4 times per week, 5 = 5-6 times per week, 6 = once per day, 7 = 2-3 times per day, 8 = 4-5 times per day, and 6 = 6 or more times per day. All responses were compiled for each participant and uploaded to the FFQ EPIC Tool for Analysis (FETA), available at https://www.epic-norfolk.org.uk/for-researchers/ffq/. FETA was utilized to calculate the intake of minerals, vitamins, proteins, carbohydrates, and other nutrients based on the participants' reported food frequency.

Statistical analysis: To adjust for measurement error and improve the accuracy of dietary intake estimates, we also applied the Willett energy adjustment (Willett *et al*, 1996). The aim of this adjustment is to improve the quality of the estimates by approximating a total energy intake based on the relevant demographic characteristics. The Willett energy adjustment was calculated using a linear regression model based on age, sex, weight, and height. This estimated energy intake was then used to adjust the reported nutrients (marked as “adjusted”). All outlier measurements lying outside of ±3 sd from the sample mean were removed before calculating the adjustment. As self-reported ASA27 demonstrated a negative correlation between weight and energy intake after correction (probably

due to misreporting), the final correction was based on the FFQ27 energy estimate for the same subjects, which exhibited positive correlation. All statistical calculations were done in Python 3.9, using NumPy 1.21.5, SciPy 1.7.0, pingouin 0.5.3, pandas 1.5.2 and Scikit-learn 1.2.2 libraries. Visualization was done using Matplotlib 3.7.1 and seaborn 0.11.2. To assess the agreement between ASA27 and FFQ27, we evaluated the correlation between estimated nutrient intakes by calculating Pearson's correlation coefficient and intraclass correlation coefficient (ICC). Additionally, we calculated classification error by comparing per-subject quintile rankings for each parameter and constructed bland-altman plots to assess the pairwise significance of differences between individual measurements and overall measurement biases (Figure 1).

Results

231 respondents took questionnaires; most of them were from Astana (Table 1).

To account for consistency in dietary habits, only respondents from Astana (n=104) were selected for comparison. Demographic characteristics of the selected sample are provided in Table 2.

Central statistics of vitamin, nutrient, macronutrient intakes estimated using ASA27 and FFQ27 in the studied sample are shown in Tables 3,4,5.

Table 1. **Respondents by city.**

City	n
Astana	104
Zhansary	47
Almaty	31
Aktobe	21
Semey	15
Ust-Kamenogorsk	10
Kyzylorda, Karaganda, Taraz, Pavlodar, Aktau, Uralsk, Abay, Samarskoe, Bishkek, Samarkand, Kokshetau	<=3

Table 2. **Demographic characteristics of the sample.**

Gender	Group	Frequency	
	Men	129	
	Women	102	
	Total	231	
Age	**Min**	**Max**	**Mean ± Sd**
	18	64	37.15 ± 12.57
Height	**Min**	**Max**	**Mean ± Sd**
	151	192	169.625 ± 7.99
Weight	**Min**	**Max**	**Mean ± Sd**
	37	115	70.46 ± 15.76

Table 3.

Central statistics of vitamins estimated using ASA27 and FFQ27 in the studied samples.

	WX-p	WX-st	ICC3	ICC3-p	ICC3-CI95%	pearson-r	spearman-r	pearson-p	spearman-p	classification-same-quintile%	diff-means	ASA27-sd	FFQ27-sd	ASA27-median	FFQ27-median	ASA27-mean	FFQ27-mean
Vitamin B12	0	106	0.17	0.13	[-0.13 0.44]	0.17	0.17	0.25	0.25	0.09	4.85	5.15	4.29	3.37	9.42	4.90	9.75
Vitamin E	0	108	0.16	0.13	[-0.13 0.44]	0.16	0.13	0.27	0.36	0.18	3.35	3.10	2.83	6.49	10.03	6.82	10.18
Vitamin D	0.16	375	0.16	0.14	[-0.14 0.44]	0.31	0.41	0.03	0	0.25	-0.02	3.52	0.99	2.26	2.95	3.11	3.08
D_TOTAL	0	199	0.12	0.21	[-0.18 0.4]	0.13	0.12	0.36	0.41	0.20	238.09	213.92	366.62	125.86	305.85	190.19	428.28
Folate	0	63	0.02	0.43	[-0.27 0.32]	0.02	0.05	0.86	0.70	0.11	-133.73	117.28	68.00	371.55	244.02	390.05	256.32
Niacin	0.69	461	0.02	0.44	[-0.27 0.31]	0.02	0	0.88	0.96	0.20	-1.19	12.92	9.25	22.79	22.65	26.52	25.33
Thiamin	0.14	369	0.02	0.44	[-0.27 0.31]	0.02	0.08	0.87	0.59	0.11	-0.18	0.58	0.37	1.52	1.43	1.65	1.46
Vitamin B6	0	189	0	0.48	[-0.29 0.3]	0	0.06	0.97	0.67	0.18	0.63	0.89	0.60	1.50	2.15	1.70	2.34
Riboflavin	0	148	0	0.49	[-0.29 0.3]	0	0.07	0.99	0.63	0.18	0.60	0.62	0.68	1.59	2.28	1.65	2.25
Retinol	0	1	-0.03	0.58	[-0.32 0.26]	-0.10	-0.13	0.51	0.39	0	1297.21	197.50	1225.63	226.08	1512.25	283.49	1580.70
Vitamin C	0.01	286	-0.05	0.64	[-0.34 0.24]	-0.05	0.06	0.71	0.68	0.18	18.89	38.04	32.50	34.64	58.85	44.21	63.11
Carotene, beta	0.98	493	-0.1	0.74	[-0.38 0.2]	-0.13	-0.19	0.37	0.21	0.11	-316.67	2906.86	1250.07	1274.12	1545.34	2421.32	2104.64
Vitamin A	0	133	-0.10	0.75	[-0.39 0.19]	-0.19	-0.15	0.21	0.32	0.11	644.90	344.23	1126.59	471.11	939.27	522.00	1166.91
Carotene, alpha	0.65	456	-0.11	0.76	[-0.39 0.19]	-0.18	-0.30	0.23	0.04	0.04	-354.68	1255.58	434.25	65.53	177.86	807.53	452.84

Table 4.

Central statistics of macroelements estimated using ASA27 and FFQ27 in the studied samples.

	WX-p	WX-st	ICC3	ICC3-p	ICC3-CI95%	pearson-r	spearman-r	pearson-p	spearman-p	classification-same-quintile%	diff-means	ASA27-sd	FFQ27-sd	ASA27-median	FFQ27-median	ASA27-mean	FFQ27-mean
Phosphorus	0	90	0.26	0.04	[-0.04 0.52]	0.26	0.37	0.08	0.01	0.11	473.49	375.10	348.50	1087.47	1674.95	1178.65	1652.15
Zinc	0	142	0.21	0.08	[-0.09 0.48]	0.21	0.30	0.16	0.04	0.13	4.04	5.04	5.05	9.24	14.36	10.80	14.85
Magnesium	0	206	0.11	0.22	[-0.19 0.39]	0.11	0.19	0.46	0.19	0.13	48.30	67.45	64.61	243.68	286.06	251.00	299.30
Calcium	0	161	0.08	0.29	[-0.22 0.37]	0.08	0.09	0.57	0.52	0.15	353.75	320.30	426.55	547.23	877.98	624.07	977.82
Iron	0.02	303	0	0.48	[-0.29 0.3]	0	0.12	0.96	0.42	0.15	-1.53	3.36	2.96	13.41	12.35	13.85	12.32
Sodium	0	349	-0.07	0.67	[-0.36 0.23]	-0.09	0	0.55	0.97	0.15	-541.78	1315.17	619.82	3252.15	3083.55	3657.93	3116.15
Selenium	0	123	-0.08	0.70	[-0.37 0.22]	-0.11	-0.06	0.45	0.68	0.09	-45.75	50.49	20.73	114.60	73.67	124.27	78.52
Potassium	0	60	-0.09	0.73	[-0.38 0.2]	-0.09	-0.01	0.51	0.93	0.06	1049.46	569.62	758.10	2204.05	3209.15	2248.01	3297.47

Table 5.

Central statistics of nutrients estimated using ASA27 and FFQ27 in the studied samples.

	WX-p	WX-st	ICC3	ICC3-p	ICC3-CI95%	pearson-r	spearman-r	pearson-p	spearman-p	classification-same-quintile%	diff-means	ASA27-sd	FFQ27-sd	ASA27-median	FFQ27-median	ASA27-mean	FFQ27-mean
Energy (kcal)	0	0	0.89	0	[0.82 0.94]	0.89	0.84	0	0	0	308.66	75.98	74.74	1993.03	2299.63	1974.28	2282.94
Carbohydrate	0.64	455	0.29	0.02	[-0. 0.54]	0.29	0.13	0.05	0.36	0.25	7.03	58.74	51.53	243.30	243.75	236.84	243.87
Protein	0	135	0.25	0.04	[-0.04 0.51]	0.25	0.25	0.09	0.09	0.15	30.84	34.48	31.34	72.85	103.57	81.86	112.70
Sugars	0	271	0.17	0.12	[-0.13 0.45]	0.18	0.17	0.22	0.25	0.11	23.50	48.50	34.16	79.29	115.74	90.54	114.04
Eggs	0	116	0.05	0.35	[-0.24 0.35]	0.05	-0.04	0.70	0.75	0.13	25.24	21.36	26.42	1.25	28.37	9.88	35.12
Cholesterol	0	116	0.04	0.38	[-0.25 0.34]	0.04	-0.08	0.75	0.57	0.04	222.74	208.63	157.41	196.55	467.64	270.43	493.17
Total_fat	0	158	0.02	0.42	[-0.27 0.32]	0.02	-0.05	0.85	0.72	0.22	19.26	18.17	20.70	79.06	98.15	76.56	95.82
Alcohol	0	21	0.02	0.44	[-0.27 0.31]	0.03	0.08	0.82	0.58	0	0.40	2.92	1.11	0	0	0.44	0.84
Fatty acids	0	149	0.01	0.45	[-0.28 0.31]	0.01	0.00	0.90	0.99	0.09	7.64	7.12	8.77	26.10	34.25	26.66	34.30
Vegetables	0	98	0	0.50	[-0.3 0.29]	0	-0.01	0.97	0.90	0.13	-268.4	296.62	64.89	359.68	117.54	398.08	129.66
Fruits	0.44	428	0	0.69	[-0.37 0.22]	-0.11	-0.22	0.47	0.14	0.09	-22.86	284.18	119.19	55.39	143.40	186.38	163.51
Nuts, seeds	0.02	273	-0.08	0.70	[-0.37 0.22]	-0.08	-0.05	0.56	0.70	0	0.51	18.38	12.92	0	3.18	6.65	7.17

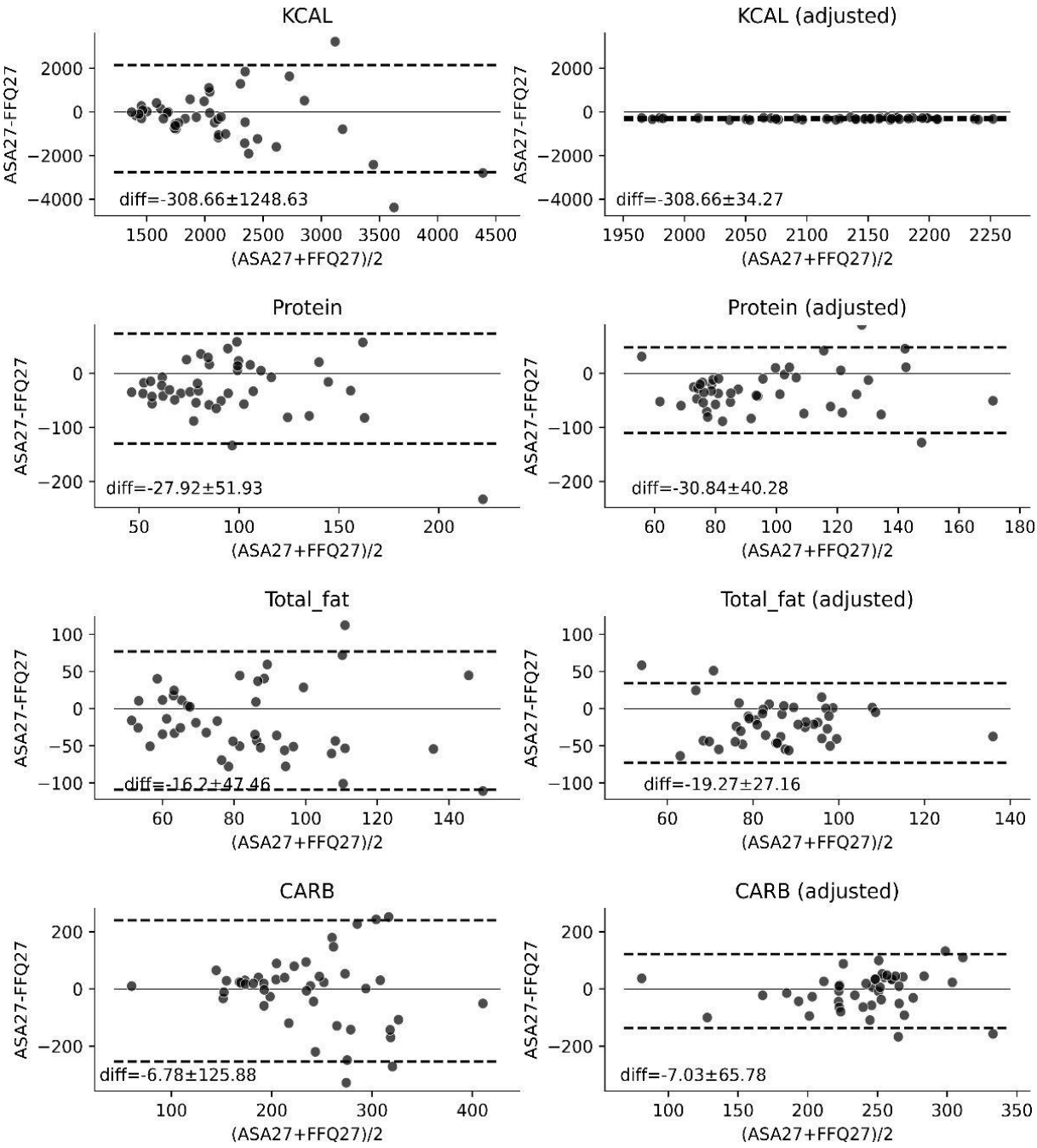

Figure 1. Bland-Altman plots of the differences between pairwise measurements.

Discussion

The study included a total of 231 respondents from various cities in Kazakhstan, with most participants recruited from Astana (n=104). Other cities represented in the study were Zhansary (n=47), Almaty (n=31), Aktobe (n=21), Semey (n=15), and Ust-Kamenogorsk (n=10). Additionally, participants from several other cities, including Kyzylorda, Karaganda, Taraz, Pavlodar, Aktau, Uralsk, Abay, Samarskoe, Bishkek, Samarkand, and Kokshetau, accounted for a total of 3 or fewer respondents each. Regarding the gender distribution, there were 129 male participants and 102 female participants, making up the total sample of 231 respondents.

The age of the respondents ranged from 18 to 64 years, with an average age of 37.15 years (± standard deviation 12.57). The participants' height ranged from 151 cm to 192 cm, with an average height of 169.625 cm (± standard deviation 7.99). Similarly, the weight of the respondents varied between 37 kg and 115 kg, with an average weight of 70.46 kg (± standard deviation 15.76). Overall, the study population consisted of a diverse group of participants in terms of age, gender, height, and weight, representing various regions and socio-demographic backgrounds in Kazakhstan.

The data presented in the table show the results of various statistical analyses conducted on dietary variables in the study population. The table includes different parameters, such as Pearson correlation coefficients (pearson-r), Spearman correlation coefficients (spearman-r), p-values for the correlation tests (pearson-p and

spearman-p), intraclass correlation coefficients (ICC3 and ICC3-p), and 95% confidence intervals for ICC3 (ICC3-CI95%).

The study shows a high level of reliability (ICC3 = 0.897) and a strong positive correlation (Pearson-r = 0.897, Spearman-r = 0.845) between the calorie intake reported using the FFQ and 24-hour recall methods. According to the standard indexes, the relevant correlation coefficients to demonstrate the feasibility of the data should vary from 0.5 to 0.7 *(Gilsing et al., 2018*). For our results, the coefficients appeared to be even higher, therefore, it can be inferred that they have a strong validity. This suggests that both methods are consistent in capturing calorie intake data, and individuals who report higher calorie intake using one method are likely to report higher intake using the other method as well. Aside from the calorie intake, positive correlations were also shown to be true for phosphorus, zinc, and vitamin D, the validity of which was evaluated by the spearman-r coefficient. The values of the latter appeared to be 0.372, 0.306, and 0.419 respectively, therefore, falling within the range of satisfactory validity which is approximately 0.4 (*Al-Shaar et al., 2021*).

Despite the high reliability and correlation, there is a significant difference in calorie intake reported between the two methods (p-values < 0.001). This indicates that the FFQ and 24-hour recall methods yield different results in terms of calorie intake reported by the participants. The reasons for this discrepancy could be due to differences in how participants recall their dietary habits and portion sizes between the two assessment methods. In addition to that, the differences in calorie consumption could be a result of systematic errors generated by the dietary intake assessment methods. ASA27 approach is known to bring out explicit and accurate records on nutrient uptake throughout the 24 hours, and, consequently, the probability of making a systematic error is much less than in FFQ, which inquires data over a longer period, leading to much higher chances of bias and systematic errors (*Castellanos-Gutierrez et al., 2021*). So, for several variables to acquire an absolute value, it might be better to rely on ASA27 if the purpose of the study is designed for a shorter period of evaluation.

The dietary variables analyzed include KCAL (calories), CARB (carbohydrates), PHOS (phosphorus), Protein, Zinc, SUGR (sugar), VB12 (vitamin B12), ATOC (alpha-tocopherol, a form of vitamin E), VITD (vitamin D), D_TOTAL (total vitamin D), Magnesium, CALC (calcium), Eggs, CHOLE (cholesterol), Total_fat, FOLA (folic acid), Alcohol, NIAC (niacin, a form of vitamin B3), VB1 (thiamin, a form of vitamin B1), MFAT (monounsaturated fats), IRON, VB6 (pyridoxine, a form of vitamin B6), VB2 (riboflavin, a form of vitamin B2), Vegetables, RET (retinol, a form of vitamin A), VC (vitamin C), Sodium, Fruits, Selenium, Nuts_seeds, Potassium, BCAR (beta-carotene, a form of vitamin A), VARA (variance of retinol), and ACAR (all-trans-retinoic acid, another form of vitamin A).

The statistical analyses reveal various associations between these dietary variables, and the p-values indicate the significance of these associations. Additionally, the intraclass correlation coefficients provide information about the reliability of the measurements. For instance, some variables show strong correlations, such as KCAL (calories) and ICC3 (intraclass correlation coefficient), suggesting that the measurement of calorie intake is highly reliable in the study population. Even though the calorie intake demonstrated the highest correlation scores among other dietary variables, the latter falls within the range of acceptable outcomes if they maintain their correlation coefficient in the span of 0.2 - 0.49 (*Lombard et al., 2015*). According to our data, most of the variables indeed represent the values within the above-mentioned range.

On the other hand, variables like ACAR (all-trans-retinoic acid) show weaker correlations and higher p-values, indicating less consistent measurements for this dietary component. These findings provide valuable insights into the dietary habits and nutritional status of the study population, allowing for a better understanding of their dietary patterns and potential areas for health interventions and improvements.

Based on the results provided in the table, we can draw the following conclusions about the difference between KCAL (calories) reported in the 24-hour recall (ASA27) and FFQ (FFQ27) questionnaire. The Intraclass Correlation Coefficient (ICC3) value of 0.897 indicates a high level of reliability between the measurements obtained from the 24-hour recall and FFQ questionnaire. This suggests that the two methods of dietary assessment are consistent and agree well with each other in capturing the calorie intake of the study participants. The Pearson correlation coefficient of 0.896 and Spearman correlation coefficient of 0.845 indicate a strong positive relationship between the calorie intake reported in the 24-hour recall and FFQ questionnaire. This indicates that participants who reported higher calorie intake in one method also tended to report higher calorie intake in the other method. The extremely low p-values (1.13687E-13 and 5.8204E-13) associated with the "WX-p" and "WX-st" columns, respectively, suggest that there is a significant difference between the calorie intake reported in the 24-hour recall and FFQ questionnaire. In other words, the two methods yield different results in terms of calorie intake reported by the participants. The "classification-same-quintile%" value of 0 indicates that there is no percentage of participants who maintain the same quintile ranking (e.g., top 20%, bottom 20%) for calorie intake between the two methods. This suggests that there might be substantial differences in how individuals are classified based on their calorie intake when using the two dietary assessment methods. The results indicate that while there is a strong positive correlation and no significant mean difference between the calorie intake reported in the 24-hour recall and FFQ questionnaire, there are significant differences between the two methods at the individual level. This could be due to various factors, such as recall bias, the ability of participants to accurately report their dietary intake and differences in the underlying assumptions and methodologies of the two dietary assessment tools.

One of the possible explanations for the discrepancies on the individual level could be a different scale of food processing. So far, there are four categories in compliance with which the product can be processed: ultra-processed food (UPF), processed food (PF), processed culinary ingredient (CPI), and minimally processed food (MPF) (*Smiljanec et al., 2020*). It was previously revealed that FFQ

is not a suitable diet assessment for PCI, since it seemed to depreciate the energy and nutrients obtained from this processing group, and, vice versa, it tends to overrate the nutritional value derived from PF (*Jung et al., 2022*). Thus, since CPI is usually consumed in combination with other products, participants may incorrectly provide information about intake of such products, for example, believing that they are already included in the dish, or, conversely, reporting them as a separate product (*Fangupo et al., 2019*). Therefore, it turns out that other categories of processing can also be interpreted with slight lapses, depending on what pattern of reporting the participants followed. Another example is the fact that ASA27 does not ask in the questionnaire whether the participant adds salt or not, in advance assuming the salt is put into the dish (*Moyen et al., 2022*). In ASA27 there are about 4800 types of food included, which gives a wide variety of choices and a greater likelihood of accurate recording *(Laramee et al., 2022*). Besides, one can add his recipe, thereby allowing including national food in the report, which cannot be done in FFQ. Such distinctions between the two methods may result in little discrepancy at the individual level of variables.

It should be kept in mind that validation methodologies rarely provide absolute measurements true for every variable. Therefore, to reduce the number of errors it can be helpful to unite the data of both methods and apply enhanced regression calibration which appeared to decrease the bias occasions in similar studies (*Looman et al., 2019*).

Conclusion

Combining multiple dietary assessment tools and using larger sample sizes can improve the accuracy and reliability of nutrition data. Additionally, education and training for participants on portion size estimation and dietary reporting can help enhance the quality of data collected through these methods. In conclusion, the study indicates that both FFQ and 24-hour recall methods are reliable and correlate well in assessing the main nutrient intake in Kazakhstan.

Authors' Contributions

All authors were equally involved in the research and writing of this article.

Conflicts of interest

There are no conflicts to declare.

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The results of this study have not been previously published in other journals and are not pending review by other publishers.

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