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Longitudinal analysis of lifestyle risk factors, nutrition status, and drivers of food choice among urban migrants in Ulaanbaatar, Mongolia and Almaty, Kazakhstan: a formative study

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Short title: Drivers of food choice in urban migrants

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Ethical standards disclosure: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Scientific Review Committees of the Mongolian National University of Medical Sciences and Kazakh Academy of Nutrition, and the Institutional Review Board of Harvard T.H. Chan School of Public Health (#IRB18-1276). Written informed consent was obtained from all subjects/patients.

Abstract

Objective: To quantify and compare concurrent within-person trends in lifestyle risks, nutrition status, and drivers of food choice among urban migrants in Central Asia.

Design: We collected panel data on household structure, drivers of food choice, nutrition knowledge, and diverse measures of nutrition status and lifestyle risk from urban migrants at 0, 3, 6, and 9 months using harmonized methodology in two cities. Trends were analyzed using mixed-effects models and qualitatively compared within and between cities.

Setting: Ulaanbaatar, Mongolia and Almaty, Kazakhstan.

Participants: 200 adults (22-55 years) who migrated to these cities within the past 2 years.

Results: Adjusting for age and sex, each month since migration was positively associated with fasting triglycerides in Almaty (0.55 mg/dL; 95%CI: 0.13-0.94) and BMI (0.04 kg/m^2; 95%CI: 0.01-0.07), body-fat (0.14%; 95%CI: 0.01-0.26), and fasting glucose (0.04 mmol/L; 95%CI: 0.02-0.05) and lipids in Ulaanbaatar ($p<0.05$). In Almaty, nutrition knowledge (measured using an objective 20-point scale) declined despite improvements in diet quality (measured by Prime Diet Quality Score). Influence of food availability, price, and taste on food choice increased in Almaty ($p<0.05$). Upon multivariable-adjustment, nutrition knowledge was positively associated with diet quality in Almaty and adherence to “Acculturated” diet patterns in both cities ($p<0.05$). Different trends in smoking, sleep quality, and generalized anxiety were observed between cities.

Conclusions: Findings indicate heterogenous shifts in nutrition, lifestyles, and drivers of food choice among urban migrants in Central Asia and provide an evidence base for focused research and advocacy to promote healthy diets and enable nutrition-sensitive food environments.

Key words: urban migration, urbanization, acculturation, food environment, drivers of food choice, lifestyle risk factors, nutrition transition, nutritional epidemiology, formative research, Central Asia.

Introduction

Migration is a major driver of change in food cultures and systems globally[1,2]. Migrants bring traditional tastes and recipes to their new homes where they assimilate new habits, and this intersection affects supply and demand for foods among migrant and host populations[3]. Migrants are exposed to new languages, food environments, and socioeconomic circumstances that influence their awareness of the culinary uses and nutritiousness of foods, ability to access or afford foods, responses to food marketing, and diets[4-7]. Shifts in migrants' diets affect their nutrition status, which is also affected by migration-induced shifts in time use including adoption of more or less sedentary lifestyles and changes in sleeping patterns[8,9].

Studies in diverse populations have documented changes in diets, lifestyles, and nutrition accompanying migration, particularly international migration, and have posited or adapted frameworks of food choice in the context of acculturation to explain these changes[10,11]. Little research has examined how drivers of food choice (DoFC) change following migration, how these changes relate to trends in nutrition status and risk factors for nutritional disease, and how these trends and relationships differ between contexts.

Understanding these trajectories, relationships, and contrasts is especially important with respect to internal urban migration. This category accounts for the largest fraction of migration globally, over half the world's population reside in cities, and a vast majority of urbanites reside in low- and middle-income countries (LMICs) which are experiencing the most uncontrolled urban growth and are home to 90% of the global slum-dwelling population[4,12]. Those dwelling in slums, other informal urban and peri-urban settlements, and the homeless disproportionately comprise voluntary urban migrants and refugees, and the destitution, infrastructural deficiencies, social exclusion, and digital divides associated with these living conditions, combined with migrants' unfamiliarity with local food and civic environments, render them less equipped to make healthy food choices[4,13,14].

This study tracked changes in nutrition status, lifestyle risk factors, and DoFC among migrants to two cities in Central Asia, and produced an evidence base for focused research and advocacy to support locally-tailored strategies for improving nutrition. The study was conducted jointly in Ulaanbaatar, the largest city in Mongolia (estimated population in 2023: 1.7 million) and Almaty, the largest city in Kazakhstan (2 million) in collaboration between the Mongolian Health Initiative and Kazakh Academy of Nutrition, using harmonized assessment methods to qualitatively compare findings across cities. These cities were considered useful comparators given a shared national heritage of nomadic pastoralism and comparable food cultures[15-17], parallel transitions toward market economies status as primary migration targets in each country[18-22], as well as dissimilar economic and migration trends in recent years. Since 2010, Mongolia has experienced extremely volatile economic growth, contributing to massive, sporadic influxes of internal migrants to Ulaanbaatar and major challenges for urban planning and infrastructure development40. By contrast, Almaty has seen comparatively sustainable urbanization due to Kazakhstan's relatively stable economic growth, accelerating economic diversification beyond natural resources, and more balanced influxes of skilled migrants.

Methods

Participants must have migrated to Ulaanbaatar or Almaty within 2 years, intended to remain there over follow-up, not previously resided in a city, and been 22-55 years old at baseline. Migrants to Ulaanbaatar were screened and randomly sampled using a database provided by the General Authority for State Registration while Almaty migrants were sampled from sectors of the city frequently employing migrants (including vendors and maintenance workers at 23 public markets and those employed in cleaning and repairing public streets), adapting respondent-driven sampling methodology used in prior studies in Almaty[23]. Individuals were contacted by phone to introduce the study and verify eligibility using a standard script, and invited to attend an informal information session led by the investigating team in each city. At each sessions, the team provided additional background on the study, summarized assessment procedures, addressed any questions, and obtained written informed consent. Required sample size was estimated as that necessary to detect within-person changes in BMI over four repeat assessments with 80% power at alpha=0.05, assuming baseline BMI of 25.8$\pm$4.0 kg/m^2, a moderate increase over follow-up[15], and a linear mixed model design; this parameterization indicated 83 participants needed per city (conservatively rounded to 100)[24].

A questionnaire was assembled to develop a formative understanding of how DoFC are contextualized by key domains of lifestyle risk during the process of urban migration. Assessed domains included demographics and migration history, DoFC, nutrition knowledge, dietary habits, International Physical Activity Questionnaire-Short Form (IPAQ-SF), Pittsburgh Sleep Quality Index (PSQI), Generalized Anxiety Disorder 7-Item (GAD-7) Scale, and Fagerström Test for Nicotine Dependence (**Methods S1**). Diet was measured in terms of frequency of consumption (<1/week, 1/week, 2-4/week, 5-7/week, >1/day) of 23 key nutritionally relevant food groups included in the Prime Diet Quality Score (PDQS), a holistic metric of diet quality designed for use in diverse populations and operationalized as a screening instrument by adapting published guidance (**Methods S2**). Reference periods over which different questions were asked varied from “prior to migration” to “currently” (or undefined), “past 2 weeks”, “past month”, or “past 3 months”; questions regarding dietary habits and nutrition knowledge were asked in reference to the past 3 months, such that the “combined” reference period for these questions across the four assessments ranged 12 months, i.e., from 3 months prior to migration to baseline (assessed at baseline) to 6-9 months post-migration (assessed at 9 months). Research teams at the Mongolian Health Initiative and Kazakh Academy of Nutrition evaluated the questionnaire for content validity, translated and back-translated it to and from Mongolian in Ulaanbaatar and Kazakh and Russian in Almaty, piloted it, and considered iterative adjustments in coordination between teams. The final version is provided in **Methods S3**.

The questionnaire was administered in a guided fashion by research assistants, ensuring that all participants could participate regardless of literacy level, at baseline, 3, 6, and 9 months. Study nurses took clinical measurements at baseline and 9 months. Height and weight were measured by portable stadiometer and scale, waist circumference (WC) by anthropometric tape, and blood pressure (BP) by automated sphygmomanometer. AccuCheck (Roche Diabetes Care, Inc.) and LipidPro (Infopia Co., Ltd.) point-of-care devices were used to measure fasting blood glucose (FBG) and lipids, respectively, and body composition was analyzed using TANITA SC-331S (Tanita Corporation) and Inbody 230 (InBody Co., Ltd.) instruments in Ulaanbaatar and Almaty, respectively. Assessments were conducted at the Songino-Khairkhan District Health Office in Ulaanbaatar and at participants' households in Almaty. Participants received a small monetary incentive for each assessment completed.

Physical activity categories and PSQI, GAD-7, and Fagerström scores were calculated following published guidance (**Methods S1**). Dietary habits were used to calculate the PDQS, a "PDQS-healthy" sub-metric, and a "PDQS-unhealthy" sub-metric (higher scores of which indicate higher overall diet quality, higher consumption of healthy foods, and lower consumption of unhealthy foods, respectively) (**Methods S4**). A nutrition knowledge score[25] (range: 0-20) was derived from responses to four questions asking whether a particular food group is generally more or less nutritious for healthy adults to consume habitually than another group, and six questions asking whether it is generally more or less nutritious to consume certain food groups at all; correct, unsure, and incorrect responses received two, one, and zero points, respectively.

BMI was categorized using WHO global cutoffs considering evidence suggesting WPRO cutoffs are less applicable to Mongolian and Kazakh populations[26,27]. Abdominal adiposity was defined as WC ≥102 cm (men), ≥88 cm (women); hypertension: systolic BP ≥130 mmHg, diastolic BP ≥85 mmHg, or current use of antihypertensives; raised triglycerides: ≥150 mg/dL; reduced HDL-C: <40 mg/dL (men), <50 mg/dL (women); raised LDL-C: ≥160 mg/dL; normal FBG: <6.1 mmol/l, impaired FBG: 6.1-7 mmol/l, diabetes: FBG >7 mmol/l; and metabolic syndrome (MetS) using Adult Treatment Panel (ATP III) criteria (≥3 of the following: abdominal obesity, raised triglycerides, reduced HDL-C, hypertension, raised FBG)[28].

Statistical analyses were conducted in R v.4.3.1 (see **Methods S5** for packages and functions). In each city, descriptive statistics were calculated to summarize assessed characteristics at baseline and 9 months. Exploratory diet patterns were derived in each city by applying principal component analysis to food group consumption frequencies across all four assessments and patterns were retained according to quantitative and qualitative criteria[15]. Mixed-effects regression models[29] including a random intercept for participant were used to estimate age- and sex-adjusted associations between time since migration on measures of nutrition status, lifestyle risk, and aspects of food choice and nutrition knowledge in each city. We also ran models to estimate multivariable-adjusted associations between nutrition knowledge, diet quality, and diet patterns, and separate models incorporating an interaction term between nutrition knowledge and migration time to evaluate whether associations changed over time. Concurrent trends in different assessed parameters were qualitatively compared within each city, and descriptive statistics, trends, and associations were qualitatively compared between cities.

Results

Two hundred participants (100 from each city) enrolled at baseline. Baseline assessments were conducted in Ulaanbaatar and Almaty in November 2019 and February 2020, respectively. Fifteen participants in Ulaanbaatar missed at least one follow-up assessment; five of these participants could be re-enrolled in subsequent assessments. Of an expected 400 person-assessments in Ulaanbaatar, 26 (6.5%) were missed. In Almaty, six participants were lost to follow-up (two at 6 months and four at 9 months); it was not possible to re-enroll these participants. They were instead replaced with new participants at the next assessment date, such that data from 100 participants contributed to the analysis at each assessment. Demographic characteristics were comparable between the six replacement participants and the original sample (not shown).

In Almaty and Ulaanbaatar, respectively, 50% and 61% of participants were women, mean age was 33.8 ± 9.8 and 36.6 ± 10.5 years, 90% were ethnic Kazakhs and Khalkha, 53% and 77% had at least high school education, and mean time since migration was 10.4 ± 6.0 and 13.0 ± 5.9 months (**Table 1, Figure 1**). All participants in Almaty and 52% in Ulaanbaatar reported their primary reason for migrating was to find work; 31% of those in Ulaanbaatar primarily migrated to join family. From prior to migration to baseline, mean household size decreased from 3.8 to 1.7 in Almaty and remained stable at 2.9 in Ulaanbaatar. In Ulaanbaatar, 46% of participants were nomadic herders prior to migration, 55% were unemployed at baseline, and all were employed by 9 months, while 22% of participants in Almaty were unemployed prior to migration, none were unemployed at baseline, and the distribution of occupations remained relatively stable from baseline to 9 months.

In Almaty, an "Acculturated" diet pattern accounted for 17.2% of variation in food group consumption and was marked by higher factor loadings for fruits, vegetables, fish, legumes, fried foods obtained outside home, whole grains, and nuts and seeds (**Table 2**). In Ulaanbaatar, Acculturated and "Acculturating" patterns accounted for 16.6% and 12.0% of variation, respectively, both were marked by higher loadings for refined grains, red meat, white tubers, and milk and dairy products, and the latter also had lower factor loadings for citrus and other fruits, dark green leafy vegetables, legumes, nuts and seeds, fish, poultry, fried foods from outside home, sugar-sweetened beverages, processed meat, and eggs. Migrants to Almaty increased consumption of eggs, whole grains, liquid oils ($p<0.05$), and milk and dairy ($p<0.1$) and decreased that of poultry, fried foods from outside home, white tubers, sweets, citrus fruits, legumes, other vegetables ($p<0.05$), and deep orange fruits

($p<0.1$), while migrants to Ulaanbaatar increased consumption of white tubers, deep orange fruits, legumes, and other vegetables ($p<0.05$), and decreased that of eggs, fried foods from outside home, sugar-sweetened beverages, citrus fruits ($p<0.05$), processed meat, and liquid oils ($p<0.05$) over follow-up (**Figure 2**).

At baseline, in Almaty and Ulaanbaatar, respectively, 43% and 47% of participants were abdominally obese, 6% and 22% were hypertensive, 3% and 18% were prediabetic or diabetic, 35% and 33% had reduced HDL-C, 3% and 1% had raised LDL-C, 5% and 42% had raised triglycerides, and 3% and 22% had MetS (**Table 3**). Each month since migration to Almaty was associated with increased fasting triglycerides (95%CI: 0.13, 0.94; $p=0.007$) while each month since migration to Ulaanbaatar was associated with increased BMI ($\beta=0.04$ kg/m^3; 95%CI: 0.01, 0.07; $p=0.023$), body fat percentage ($\beta=0.14\%$; 95%CI: 0.01, 0.26; $p=0.032$), FBG ($\beta=0.04$ mmol/L; 95%CI: 0.02, 0.05; $p<0.0001$), total cholesterol ($\beta=0.58$ mg/dL, 95%CI: 0.02, 1.12; $p=0.042$), LDL-C ($\beta=0.54$ mg/dL, 95%CI: 0.12, 0.95; $p=0.012$), and HDL-C ($\beta=0.26$ mg/dL; 95%CI: 0.03, 0.50; $p=0.026$). A marginally significant increase in WC was also observed with each month since migration to Ulaanbaatar ($\beta=0.09$ cm; 95%CI: -0.01, 0.19; $p=0.090$).

In Almaty and Ulaanbaatar, respectively, 31% and 38% of participants smoked and 23% and 63% of smokers were moderately nicotine dependent, 19% and 32% of participants had low physical activity, 27% and 68% had disturbed sleep, and 2% and 9% had at least moderate generalized anxiety at baseline (**Table 4**). Each month since migration to Almaty was associated with increased PDQS-unhealthy sub-metric scores ($\beta=0.05$; 95%CI: 0.00, 0.09; $p=0.032$) indicating lower consumption of unhealthy foods, PSQI scores ($\beta=0.02$; 95%CI: 0.00, 0.05; $p=0.042$) indicating declining sleep quality, and marginally significantly increased GAD-7 scores ($\beta=0.04$; 95%CI: -0.00, 0.09; $p=0.063$) indicating worsening anxiety. Among migrants to Ulaanbaatar, each month since migration was associated with decreased PSQI ($\beta=-0.09$; 95%CI: -0.13, -0.04; $p<0.001$) and GAD-7 scores ($\beta=-0.12$; 95%CI: -0.16, -0.06;

p<0.001), and increased odds of smoking (β=1.26; 95%CI: 1.01, 1.57; *p*=0.039) albeit decreased Fagerström scores (β=-0.04; 95%CI: -0.07, -0.01; *p*=0.008) indicating less physical addiction. Each month since migration to Ulaanbaatar was also marginally significantly associated with increased PDQS scores (β=0.07; 95%CI: -0.01, 0.16; *p*=0.096) and adherence to the Acculturating diet pattern (β=0.28; 95%CI: -0.03, 0.58; *p*=0.074).

Each month since migration to Almaty was associated with increased influence of local food availability (OR for one-unit change in ordered category=1.20; 95%CI: 1.12, 1.30; *p*<0.001), price (OR=1.19; 95%CI: 1.11, 1.27; *p*<0.001), and taste (OR=1.04; 95%CI: 1.03, 1.04; *p*<0.001) on food choices, and marginally significant increases in the influence of the time, effort, or skill required to cook foods (OR=1.07; 95%CI: 1.00, 1.15; *p*=0.055) and their nutritive quality (OR=1.01; 95%CI: 0.94 1.08; *p*=0.076) (**Table 5**). By contrast, each month since migration to Ulaanbaatar was associated only with a marginally significant decrease in the influence of local availability of foods (OR=0.96; 95%CI: 0.92, 1.00; *p*=0.068). With each month since migration, migrants were more likely to report that healthy foods were less available than healthy ones in Almaty (OR=0.97; 95%CI: 0.97, 0.97; *p*<0.001) and that healthy foods were easier to cook than unhealthy ones in Ulaanbaatar (OR=1.05; 95%CI: 1.00, 1.10; *p*=0.056). Nonsignificant trends (*p*>0.10) are presented in **Supplementary Results**.

Each month since migration was associated with decreased nutrition knowledge scores in Almaty (β=-0.15; 95%CI: -0.21, -0.08; *p*<0.001) but not Ulaanbaatar (**Table 4**). The proportion of correct responses to 8 of 10 nutrition knowledge questions among migrants to Almaty decreased significantly (*p*<0.05), while a marginally significant decrease (*p*<0.1) and significant increase (*p*<0.05) were observed for questions about salty foods and high vs. low fat dairy, respectively (**Figure 3**). By contrast, the proportion of correct responses among migrants to Ulaanbaatar increased for questions on high vs. low fat dairy, whole vs. refined grains, and salty foods ($p<0.05$); decreased for the question on fruits and vegetables ($p<0.05$); and were otherwise nonsignificant ($p>0.10$).

Adjusting for age, sex, migration time, education, ethnicity, physical activity, smoking, and household type (single- vs. multi-person), nutrition knowledge scores were positively associated with PDQS (β=0.37; 95%CI: 0.27, 0.47; $p<0.001$) and PDQS-unhealthy scores (β=0.11; 95%CI: 0.05, 0.17; $p<0.001$) among migrants to Almaty, and marginally associated with higher PDQS-healthy (β=0.21; 95%CI: -0.02, 0.46; $p=0.087$) and PDQS-unhealthy scores among migrants to Ulaanbaatar (β=0.05; 95%CI: -0.01, 0.10; $p=0.092$) (**Table 6**). Nutrition knowledge scores were also positively associated with adherence to Acculturated diet patterns in both Almaty (β=0.56; 95%CI: 0.12, 1.02; $p=0.016$) and Ulaanbaatar (β=1.43; 95%CI: 0.64, 2.23; $p<0.001$). Among migrants to Almaty, time since migration modified the association between nutrition knowledge and the PDQS-unhealthy sub-metric, such that for each month since migration, the strength of this association decreased by 0.01 points (95%CI: 0.00, 0.02; p-interaction=0.008).

Discussion

In analysis of panel data on first-time migrants to Ulaanbaatar and Almaty, migrants to Ulaanbaatar had a moderate prevalence of metabolic and lifestyle risk factors for chronic disease at baseline and incurred deteriorations in metabolic indicators over follow-up. These findings generally agree with studies across diverse LMICs that tend to observe cardiometabolically deleterious shifts following urban migration, including increasing gradients in weight-for-height across rural, urban migrant, and urban host populations[30,31] that we also found in prior investigations in Mongolia[15,16]. However, the relationship between migration and nutrition is heterogeneous (in the current study, metabolic and lifestyle health among migrants to Almaty were comparatively good at baseline and changed little over time), and despite risks, urban migration can improve access to fruits and vegetables[16,32,33] and be a potentially advantageous adaption strategy for household livelihoods[35,36].

Acculturating and Acculturated diet patterns among migrants to Ulaanbaatar share similarities in factor loadings with “Nomadic” and “Urban” patterns, respectively, that we previously identified in a nationwide survey of Mongolians[15]. In that survey, rural nomadic and urban host populations adhered more strongly to the Nomadic and Urban patterns, respectively, and adherence to the Urban (but not nomadic) pattern was associated with higher BMI after adjustment for total energy intake. Collectively, these findings suggest the process of assimilating urban food culture in Mongolia – marked by transitions from Nomadic to Acculturating, Acculturated, and Urban diet patterns – may have contributed to observed deteriorations in metabolic health among migrants to Ulaanbaatar. In our prior survey, we also found rural Mongolians adhered more to the Nomadic dietary pattern in summer than winter[15]. Seasonal changes in food availability may explain the marginally significant increase in adherence to the nomadic-like Acculturating diet pattern (but not the Acculturated one) observed among migrants to Ulaanbaatar over follow-up from November (start of winter in Mongolia) to August (end of summer). These findings, and the fact that all four patterns identified in the prior and current studies share positive factor loadings for two food groups comprising 60% of the national diet by mass (red meat and refined grains)[15], suggest nomadic transitions remain strongly influential on the diet of urban migrants throughout acculturation. Increased use of traditional foods by migrants during early acculturation may also reflect a greater degree of choice, nostalgia, or neophobia linked to acculturative stress following initial familiarization with new environments[37,38].

In comparison with migrants to Almaty, DoFC and related perceptions and behaviors were largely uninfluenced by migration to Ulaanbaatar. This may be explained by differences in household migration patterns between Mongolia and Kazakhstan. Internal migration in Mongolia is typified as a sequence of movements from the countryside to tertiary, district, and provincial centers, and finally Ulaanbaatar[19], during which households increasingly acculturate to urban lifestyles. As observed in studies of international migration, kinship is an important aspect of the migration process in Mongolia, families are a key source of information in migration decisions, and family members typically migrate together even if only one has secured employment at the destination[18,19], factors which buffer migration-related shocks. However, despite their relative assimilation of urban food culture, urban migrants in Mongolia usually reside in peri-urban slums[40] where deprivation of the food environment challenges migrants' access to healthy foods[4]. By contrast, while migrants to Kazakh cities usually find permanent housing there[41], internal migration in Kazakhstan is costly in comparison with other countries and finding employment is a major priority[21,22]. Resultingly, urban migrants in Kazakhstan frequently move individually and directly from the periphery instead of in a stepwise fashion, both characteristics which we observed in the current study. The comparatively abrupt and often solitary nature of internal migration in Kazakhstan may have a disruptive effect on intra- and intergenerational understanding of healthy foods and unhealthy foods, may render migrants more susceptible to internalizing persuasive marketing tactics and misleading information disseminated by fast and processed food corporations, and may have contributed to observed declines in nutrition knowledge[4-7,13,14].

A recent study among urban poor in Vietnam found an objective nutrition knowledge scale was associated with higher consumption of healthy dietary components and lower consumption of starchy staples and sodium[42], and studies in other countries have found education of household heads is positively correlated with diet quality[39]. Among migrants to Almaty we observed significant and positive, multivariable-adjusted associations between objective nutrition knowledge and diet quality. It is also possible that among environmental and infrastructural changes associated with urban migration to Almaty (including upgraded living standards), shifts in perceptions and behaviors related to food choice and at least somewhat unrelated to nutrition knowledge – e.g., influence of price, taste, and availability on food choice decisions, and cooking skills, use of food packaging, and perceived influence of diet on bodyweight – partially replaced nutrition knowledge as determinants of diet quality. This hypothesis is based on three circumstantial observations: Almaty migrants reported concurrent increases in all the aforementioned perceptions and behaviors (and others); unhealthy food consumption improved despite a concurrent decline in nutrition knowledge; and the multivariable-adjusted association between these improvements and nutrition knowledge attenuated with time since migration. Insofar as migration to Almaty is accompanied by improvements in affordability, desirability, or availability of *healthy* foods, these factors may have plausibly contributed to observed improvements in diet quality despite declines in nutrition knowledge.

To the extent that shifting DoFC collectively represent a measure of dietary acculturation, stable metabolic health observed among migrants to Almaty, but not Ulaanbaatar, may be partly explained not only by exposure to healthier food and civic environments but by active acculturation to healthier dietary habits therein. Factor loadings for Acculturated diet patterns in Almaty and Ulaanbaatar were negative for 7 and 1 unhealthy food group(s), respectively, and PDQS scores were higher among migrants to Almaty than Ulaanbaatar at all four assessments. Significant, positive, multivariable-adjusted associations between nutrition knowledge and adherence to Acculturated patterns were observed in both cities, and while the extent to which acculturation leads to healthier diets is context-specific, positive associations between nutrition knowledge and diet quality were also observed in both cities despite substantial differences in migration dynamics, food environments, and trends in nutrition knowledge and diet quality themselves. This may implicate objective nutrition knowledge as a partial proxy for acculturative stress and reinforces nutrition knowledge as a modifiable factor in enabling migrants to adopt healthy dietary habits while navigating urban food environments.

This study was strengthened by concurrent assessment of diverse domains of demographics, nutrition status, lifestyle risk factors, DoFC, and nutrition knowledge that provided nuanced perspectives on food choice decisions and their objective and subjective correlates. Use of harmonized assessment methods enabled direct comparisons between cities in different countries, and a panel design involving four repeated measures allowed precise estimation of within-person changes in assessed parameters. By restricting to recent, first-time migrants and using a mixed-effects modelling approach, we could ensure participants were relatively unacculturated at baseline and a broad distribution of times since migration could contribute to the analysis, respectively.

However, because follow-up began after participants had moved to each city, it was impossible to measure more momentous changes occurring during migration events per se. Partly for this reason, the sampling approach prioritized the number of repeated measurements over that of unique participants to provide adequate power for the primary aim of capturing within-person changes. This tradeoff decreased our power for exploring associations between concurrent trends within cities, precluded inclusion of non-migrant controls, and limited the extent to which our results are generalizable to two very large and heterogeneous target populations (which we were not positioned to compare statistically). Limited generalizability may be particularly true in the case of Almaty, where a sample frame was not defined and in which respondent-driven sampling could have also contributed to selection bias. Furthermore, diet was assessed using a food group-based screener that, while rapidly administered and readily analyzable for understanding diet quality, prevented analysis of nutrient intakes and reduced resolution with which dietary patterns and trends could be captured. Generally, because most assessments were subjective in nature, they were varyingly influenced by learning effects over repeat assessments, social desirability and other forms of participation bias. Finally, given the large number of statistical tests conducted, some were likely significant by chance. Overall, findings should be interpreted with caution, considering how trends track with one another within cities and qualitatively compare between cities, and with the understanding that hypotheses generated from this largely exploratory study are primarily intended to provide a foundation for guiding more focused evaluations going forward.

Implications

Findings from this study should guide focused efforts to map peri-urban food environments in Ulaanbaatar, drawing on a local history of spatial participatory and sustainability research[43-45], to advocate evidence-based strategies for empowering urban migrants to translate nutrition knowledge and dietary guidance toward healthier diets. Prior studies have identified non- and anti-obesogenic “Transitional”[15] and “Healthy”[46] Mongolian diet patterns, respectively, that prevail in urban host populations and provide entry points for designing and advocating food-based programs. Given the vastness of Ulaanbaatar’s peri-urban slum districts (where over one-third of Mongolia’s population lives), effective policies will primarily be implemented through long-term, muti-sectoral poverty reduction, urban planning, and community engagement programs[40,47-49], and research and advocacy should be framed in the context of development priorities to effectively complement these programs.

Given the observed association between nutrition knowledge and diet quality, circumstantial decline in nutrition knowledge, and otherwise dynamic DoFC among migrants to Almaty, findings from this study should be used to inform a focused evaluation to holistically understand these dynamics and distinguish the contributions of different aspects of food-related perceptions and behaviors on diet quality in Almaty migrants. This effort should be guided by contextual food systems research[50,51] and, in turn, guide health promotion and education interventions for disseminating nutrition information and enabling its uptake by urban migrants, ideally employing staged designs based on lengths of residence in the city[52]. Broadly, these programs should support underdeveloped national policy objectives for improving nutrition awareness, quality of the food supply, and dietary surveillance[17,53,54] to incentivize concerted, cost-effective noncommunicable disease strategy in Kazakhstan[55].

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Table 1: Demographic and migration characteristics assessed at baseline

Characteristic	**Almaty, mean ± SD or n (%)**	**Ulaanbaatar, mean ± SD or n (%)**
Age, years	33.8 ± 9.8	36.6 ± 10.5
<30	42 (42)	31 (31)
≥30 to <40	27 (27)	28 (28)
≥40 to <50	24 (24)	25 (25)
≥50	7 (7)	16 (16)
Women	50 (50)	61 (61)
Ethnicity		
Kazakh or Khalkha	90 (90)	90 (90)
Other	10 (10)	10 (10)
Education level		
None or primary school	0 (0)	7 (7)
Secondary school	47 (47)	16 (16)
High school	38 (38)	56 (56)
Vocational certificate	10 (10)	5 (5)
University	4 (4)	15 (15)
Graduate or postgraduate	1 (1)	1 (1)
Time since migration, mo.	10.4 ± 6.0	13 ± 5.9
<12	56 (56)	27 (27)
≥12 to <24	44 (44)	73 (73)
Migrated from		
Rural village or countryside	80 (80)	32 (32)
Rayon or *soum* center[1]	18 (18)	53 (54)
Oblast or *aimag* center[1]	2 (2)	14 (14)
Purpose of migration		
Employment	100 (100)	52 (52)
Live with family	0 (0)	31 (31)
Study	0 (0)	2 (2)
Receive medical care	0 (0)	2 (2)
Other	0 (0)	13 (13)
Household size prior to migration	3.8 ± 1.6	2.9 ± 1.6
Single person household	0 (0)	9 (9)
Household size at baseline	1.7 ± 1.5	2.9 ± 1.7
Single person household	21 (21)	9 (9)
Occupation or workplace prior to migration		
Clerk or other office job	2 (2)	2 (2)
Driver or courier	8 (8)	1 (1)
Herder or farmer	3 (3)	46 (46)

Hospital or laboratory personnel	5 (5)	0 (0)
Professional tradesperson	20 (20)	9 (9)
Restaurant or food service	2 (2)	4 (4)
Security guard	7 (7)	0 (0)
Self-employed or entrepreneur	5 (5)	5 (5)
Teacher or teaching assistant	11 (11)	6 (6)
Vendor at a shop or market	5 (5)	6 (6)
Other	11 (11)	2 (2)
Unemployed or homemaker	21 (21)	19 (19)
Occupation or workplace at baseline		
Clerk or other office job	13 (13)	2 (2)
Driver or courier	3 (3)	2 (2)
Herder or farmer	0 (0)	0 (0)
Hospital or laboratory personnel	15 (15)	0 (0)
Professional tradesperson	25 (25)	12 (13)
Restaurant or food service	6 (6)	6 (6)
Security guard	4 (4)	3 (3)
Self-employed or entrepreneur	2 (2)	4 (4)
Teacher or teaching assistant	12 (12)	1 (1)
Vendor at a shop or market	6 (6)	4 (4)
Other	14 (14)	5 (5)
Unemployed or homemaker	0 (0)	55 (59)

Footnote: Given an expected sample size of 100 participants in each city at each assessment, n is usually equal to % for categorical variables; both statistics are presented in this and subsequent tables for consistency and to prevent confusion. [1]*Rayon* (Kazakhstan) and *Soum* (Mongolia) are district-level administrative divisions and *Oblast* (Kazakhstan) and *Aimag* (Mongolia) are province-level divisions.

Table 2: Exploratory diet pattern factor loadings

Food group	**Almaty Acculturated Pattern**	**Ulaanbaatar Acculturated Pattern**	**Ulaanbaatar Acculturating Pattern**
Other fruits	0.71	0.23	-0.20
Citrus fruits	0.70	0.16	-0.59
Dark green leafy vegetables	0.62	0.07	-0.66
Fish	0.55	-0.04	-0.55
Legumes	0.55	0.01	-0.43
Fried foods from outside home	0.54	0.02	-0.49
Cruciferous vegetables	0.53	0.59	-0.11
Whole grains	0.49	0.11	-0.11
Nuts & seeds	0.39	0.06	-0.55
Deep orange fruits	0.30	0.55	0.29
Red meat	0.27	0.35	0.38
SSBs	0.10	0.21	-0.38
Processed meat	0.08	0.24	-0.53
Sweets	0.00	0.41	-0.15
Eggs	-0.04	0.23	-0.59
Other vegetables	-0.05	0.68	0.22
Poultry	-0.16	0.21	-0.61
Milk & dairy	-0.17	0.45	0.14
White tubers	-0.24	0.46	0.29
Refined grains	-0.31	0.51	0.24
Liquid oils	-0.51	0.36	0.15

Footnote: The Acculturated diet pattern accounted for 17.2% of variation in food group consumption in Almaty and the Acculturated and Acculturating patterns accounted for 16.6% and 12.0% of variation in Ulaanbaatar, respectively. Shading is proportional to the magnitude and direction of factor loadings (darkest green: 0.71, yellow: 0%, darkest red: -0.66).

Table 3: Trends in anthropometric and clinical measurements

Measurement	Almaty				Ulaanbaatar			
	Baseline, mean ± SD or n (%)	**9 months, mean ± SD or n (%)**	**β (95%CI)[1]**	***p*[1]**	**Baseline, mean ± SD or n (%)**	**9 months, mean ± SD or n (%)**	**β (95%CI)[1]**	***p*[1]**
BMI, kg/m^3	24.4 ± 4.6	24.5 ± 4.5	0.00 (-0.03, 0.02)	0.935	25.9 ± 4.7	26.5 ± 5.0	0.04 (0.01, 0.07)	0.023**
<18.5	7 (7)	5 (5)			2 (2)	1 (1)		
≥18 to <25	53 (53)	57 (57)			45 (45)	39 (43)		
≥25 to <30	27 (27)	26 (26)			36 (36)	31 (34)		
≥30	13 (13)	12 (12)			16 (16)	19 (21)		
Waist circumference, cm	83.3 ± 14.3	83.0 ± 13.6	-0.04 (-0.12, 0.04)	0.379	83.5 ± 10.7	84.1 ± 10.7	0.09 (-0.01, 0.19)	0.090*
Among men only	90.7 ± 12.2	89.6 ± 11.8			82.5 ± 10.4	83.8 ± 10.9		
Among women only	75.9 ± 12.3	76.3 ± 12.0			84.1 ± 10.9	84.3 ± 10.7		
Normal	57 (57)	59 (59)			53 (53)	45 (50)		
Abdominal obesity	43 (43)	41 (41)			47 (47)	45 (50)		
Body fat percentage	28.7 ± 14.6	28.7 ± 14.0	0.00 (-0.26, 0.26)	0.988	27.6 ± 10.7	29.3 ± 13.0	0.14 (0.01, 0.26)	0.032**
Among men only	24.8 ± 8.5	27.2 ± 17.9			19.3 ± 6.5	20.4 ± 7.8		
Among women only	32.5 ± 18.2	30.3 ± 8.2			33.0 ± 9.4	34.5 ± 12.7		

Systolic BP, mmHg	117.6 ± 14.0	118.2 ± 12.9	0.03 (-0.09, 0.14)	0.636	124.9 ± 22.2	122.6 ± 17.1	-0.17 (-0.44, 0.11)	0.215
Diastolic BP, mmHg	75.1 ± 8.5	74.8 ± 7.5	-0.05 (-0.13, 0.04)	0.293	82.5 ± 15.7	83.3 ± 12.9	0.02 (-0.17, 0.22)	0.815
Hypertension	6 (6)	9 (9)			22 (22)	17 (19)		
Blood glucose, mmol/L[2]	4.8 ± 0.7	4.7 ± 0.7	0.00 (-0.01, 0.01)	0.563	5.4 ± 0.9	5.9 ± 0.9	0.04 (0.02, 0.05)	<0.001**
Normal	97 (97)	97 (97)			80 (80)	53 (60)		
Impaired	0 (0)	1 (1)			12 (12)	22 (25)		
Diabetic	3 (3)	2 (2)			8 (8)	14 (16)		
Total cholesterol, mg/dL[2]	173.0 ± 31.3	171.3 ± 24.5	-0.15 (-0.52, 0.23)	0.443	160.1 ± 38.7	168.9 ± 39.5	0.58 (0.02, 1.12)	0.042**
LDL-cholesterol, mg/dL[2]	102.2 ± 33.0	95.7 ± 29.2	-0.29 (-0.71, 0.12)	0.166	78.2 ± 30.2	85.4 ± 30.2	0.54 (0.12, 0.95)	0.012**
Normal	97 (97)	98 (98)			95 (99)	79 (98)		
Raised	3 (3)	2 (2)			1 (1)	2 (2)		
HDL-cholesterol, mg/dL[2]	53.9 ± 14.1	56.8 ± 16.2	0.02 (-0.08, 0.12)	0.711	51.8 ± 13.9	54.9 ± 15.0	0.26 (0.03, 0.5)	0.026**
Among men only	50.9 ± 12.8	55.2 ± 17.0			48.1 ± 12.6	50.8 ± 13.3		
Among women only	57.0 ± 14.7	58.4 ± 15.3			54.0 ± 14.2	57.2 ± 14.5		
Normal	65 (65)	68 (68)			66 (66)	61 (61)		
Reduced	35 (35)	32 (32)			32 (32)	28 (28)		
Triglycerides,	84.3 ± 29.2	94.0 ± 25.8	0.55 (0.13,	0.00	142.6 ± 80.0	141.3 ± 86.6	-0.63 (-	0.322

mg/dL[2]			0.94)	7**			1.86, 0.62)	
Normal	95 (95)	97 (97)			57 (58)	59 (66)		
Raised	5 (5)	3 (3)			42 (42)	31 (34)		
MetS components, #	0.9 ± 0.9	0.9 ± 0.9	0.00 (-0.01, 0.01)	0.689	1.6 ± 1.2	1.8 ± 1.3	0.00 (-0.02, 0.02)	0.732
<3 (MetS absent)	97 (97)	94 (94)			76 (78)	64 (73)		
≥3 (MetS present)	3 (3)	6 (6)			22 (22)	24 (27)		

Footnote: BP, blood pressure; MetS, metabolic syndrome. [1]β (95%CI) and *p* statistics indicate the age- and sex-adjusted parameter estimate and *p* value for the association between a one-month increase in time since migration and each continuous outcome estimated using linear mixed models (these statistics are omitted for binary and ordered categorical outcomes). [2]Glucose and lipids were measured in fasting samples. **p*<0.05, ***p*<0.01.

Table 4: Trends in lifestyle risk factors for chronic disease

Risk factor	Almaty				Ulaanbaatar			
	Baseline, mean ± SD or n (%)	**9 months, mean ± SD or n (%)**	**β or OR (95%CI)[1]**	***p*[1]**	**Baseline, mean ± SD or n (%)**	**9 months, mean ± SD or n (%)**	**β or OR (95%CI)[1]**	***p*[1]**
PDQS score (range: 0-80)	31.1 ± 4.9	31.5 ± 5.3	0.04 (-0.03, 0.11)	0.263	27.7 ± 5.4	27.9 ± 5.6	0.07 (-0.01, 0.16)	0.096 *
PDQS-healthy score (range: 0-52)	16.0 ± 5.0	15.7 ± 4.7	0.00 (-0.07, 0.07)	0.910	13.1 ± 6.5	12.3 ± 5.8	0.03 (-0.06, 0.12)	0.541
PDQS-unhealthy score (range: 0-28)	15.1 ± 2.8	15.8 ± 2.7	0.05 (0.00, 0.09)	0.032 **	14.6 ± 4.0	15.6 ± 3.5	0.04 (-0.01, 0.10)	0.141
Acculturated diet pattern (scaled from 0-100)	37.6 ± 20.8	35.1 ± 20.5	-0.16 (-0.47, 0.15)	0.302	47.2 ± 20.9	45.3 ± 19.0	0.12 (-0.18, 0.43)	0.430
Acculturating diet pattern (scaled from 0-100)	NA	NA	NA	NA	66.2 ± 21.4	72.4 ± 18.9	0.28 (-0.03, 0.58)	0.074 *
Self-described diet quality			0.02 (-0.06, 0.10)	0.615			-0.01 (-0.06, 0.04)	0.800
Very healthy	1 (1)	2 (2)			10 (10)	7 (8)		
Healthy	35 (35)	29 (29)			32 (33)	25 (28)		
Average	58 (58)	58 (58)			49 (50)	53 (59)		

Unhealthy	5 (5)	10 (10)			7 (7)	4 (4)		
Very unhealthy	1 (1)	1 (1)			0 (0)	1 (1)		
Nutrition knowledge score (range: 0-20)	13.0 + 4.2	11.1 + 4.7	-0.15 (-0.21, -0.08)	<0.001**	12.7 + 2.7	12.9 + 2.8	0.02 (-0.02, 0.06)	0.256
IPAQ physical activity category			-0.04 (-0.12, 0.04)	0.296			0.00 (-0.05, 0.05)	0.943
High	59 (59)	44 (44)			54 (54)	49 (54)		
Medium	22 (22)	33 (33)			14 (14)	12 (13)		
Low	19 (19)	23 (23)			32 (32)	29 (32)		
Self-described physical activity			0.04 (-0.05, 0.14)	0.378			0.04 (-0.01, 0.09)	0.107
High	5 (5)	12 (12)			25 (28)	19 (21)		
Moderate	84 (84)	71 (71)			51 (57)	45 (50)		
Low	11 (11)	17 (17)			23 (26)	26 (29)		
Sedentary time, hr/d	3.8 + 3.2	3.8 + 1.9	-0.04 (-0.12, 0.03)	0.294	3.6 + 3.0	3.4 + 2.8	0.00 (-0.05, 0.04)	0.867
PSQI score (range: 0-21)	3.7 + 1.7	4.0 + 1.4	0.02 (0.00, 0.05)	0.042**	6.1 + 3.1	5.0 + 3.2	-0.09 (-0.13, -0.04)	<0.001**
Normal sleep quality	73 (73)	57 (57)			32 (32)	52 (52)		
Disturbed sleep	27 (27)	43 (43)			68 (68)	48 (48)		
Self-described sleep quality			0.04 (-0.01,	0.126			-0.08 (-	0.003

			0.1)				0.13, -0.03)	**
Very good	36 (36)	24 (24)			15 (15)	23 (26)		
Fairly good	59 (59)	73 (73)			60 (60)	45 (50)		
Fairly poor	5 (5)	3 (3)			21 (21)	20 (22)		
Very poor	0 (0)	0 (0)			4 (4)	2 (2)		
Current smoker	31 (31)	31 (31)	0.03 (-0.23, 0.3)	0.831	38 (38)	39 (39)	0.23 (0.01, 0.45)	0.039 **
Fagerström score (range: 0-10)	3.0 ± 1.8	3.0 ± 1.8	-0.01 (-0.02, 0.00)	0.214	4.7 ± 1.0	3.6 ± 1.5	-0.04 (-0.07, -0.01)	0.008 **
Low nicotine dependence	15 (48)	15 (48)			1 (3)	10 (26)		
Low to moderate nicotine dependence	9 (29)	10 (32)			13 (42)	19 (49)		
Moderate nicotine dependence	7 (23)	6 (19)			24 (77)	10 (26)		
High nicotine dependence	0 (0)	0 (0)			0 (0)	0 (0)		
GAD-7 score (range: 0-21)	2.0 ± 2.3	2.8 ± 2.3	0.04 (0.00, 0.09)	0.063 *	4.9 ± 3.8	2.3 ± 4.0	-0.11 (-0.16, -0.06)	<0.001**
Minimal generalized anxiety	94 (94)	79 (79)			47 (47)	57 (63)		
Mild generalized anxiety	4 (4)	20 (20)			43 (43)	25 (28)		
Moderate generalized	2 (2)	1 (1)			7 (7)	7 (8)		

anxiety								
Severe generalized anxiety	0 (0)	0 (0)			2 (2)	1 (1)		
Self-described bodyweight			0.15 (0.01, 0.29)	0.042 **			0.08 (-0.06, 0.25)	0.283
Overweight	20 (20)	28 (28)			37 (41)	36 (40)		
Normal	79 (79)	65 (65)			53 (59)	47 (52)		
Underweight	1 (1)	7 (7)			9 (10)	7 (8)		

Footnote: PDQS, Prime Diet Quality Score; IPAQ, International Physical Activity Questionnaire; PSQI, Pittsburgh Sleep Quality Index; GAD, Generalized Anxiety Disorder; NA, not applicable. [1]β or OR (95%CI) and *p* statistics indicate the age- and sex-adjusted parameter estimate (for continuous outcomes) or odds ratio (for binary and ordered categorical outcomes) and *p* value for the association between a one-month increase in time since migration and each outcome, estimated using linear mixed models for continuous outcomes, generalized linear mixed models for one binary outcome (PSQI category), and cumulative link mixed models for ordered categorical outcomes (OR for binary and ordered categorical outcomes is that associated with a one-row descent in ordered category presented in the table, e.g., the OR for "IPAQ physical activity category" is that associated with being in either the "Moderate" vs. "High" category or "Low" vs. "Moderate" category). *$p<0.05$, **$p<0.01$.

Table 5: Statistically significant (*p*<0.05) trends in drivers of food choice and related perceptions and behaviors

		Almaty				Ulaanbaatar			
Question	**Response**	**Baseline, n (%)**	**9 months, n (%)**	**OR (95%CI)[1]**	***p*[1]**	**Baseline, n (%)**	**9 months, n (%)**	**OR (95%CI)[1]**	***p*[1]**
Influence of the availability of food where you live on your food choice	None	0 (0)	0 (0)	1.20 (1.12, 1.30)	<0.001**	21 (21)	18 (20)	0.96 (0.92, 1.00)	0.068*
	Weak	22 (22)	7 (7)			22 (22)	19 (21)		
	Moderate	47 (47)	26 (26)			22 (22)	30 (33)		
	Strong	31 (31)	62 (62)			22 (22)	15 (17)		
	Very strong	0 (0)	5 (5)			13 (13)	8 (9)		
Influence of the price of food on your food choices	None	15 (15)	3 (3)	1.19 (1.11, 1.27)	<0.001**	17 (17)	12 (13)	1.01 (0.96, 1.06)	0.658
	Weak	0 (0)	0 (0)			18 (18)	16 (18)		
	Moderate	51 (51)	28 (28)			31 (31)	24 (27)		
	Strong	31 (31)	63 (63)			22 (22)	26 (29)		
	Very strong	3 (3)	6 (6)			12 (12)	12 (13)		
Influence of the taste of food on your food choice	None	0 (0)	0 (0)	1.04 (1.03, 1.04)	<0.001**	17 (17)	17 (19)	0.98 (0.94, 1.03)	0.484
	Weak	18 (18)	4 (4)			18 (18)	13 (14)		
	Moderate	29 (29)	46 (46)			24 (24)	31 (34)		
	Strong	53 (53)	49 (49)			28 (28)	24 (27)		
	Very strong	0 (0)	1 (1)			13 (13)	5 (6)		
Influence of the nutritive quality of food on your food choice	None	12 (12)	7 (7)	1.01 (0.94, 1.08)	0.076*	8 (8)	11 (12)	0.99 (0.95, 1.04)	0.692
	Weak	15 (15)	14 (14)			17 (17)	10 (11)		
	Moderate	58 (58)	61 (61)			33 (33)	34 (38)		
	Strong	15 (15)	18 (18)			30 (30)	26 (29)		
	Very strong	0 (0)	0 (0)			12 (12)	9 (10)		
Influence of the	None	12 (12)	7 (7)	1.07 (1,	0.055	24 (24)	26 (29)	1.00 (0.95,	0.87

time, effort, or skill required to cook food on your food choice				1.15)	*			1.04)	5
	Weak	6 (6)	6 (6)			20 (20)	13 (14)		
	Moderate	64 (64)	54 (54)			23 (23)	25 (28)		
	Strong	16 (16)	32 (32)			19 (19)	13 (14)		
	Very strong	2 (2)	1 (1)			14 (14)	13 (14)		
Compared with unhealthy foods, healthy foods are generally…	Much less available	7 (7)	14 (14)	0.97 (0.97, 0.97)	<0.001**	5 (5)	3 (3)	1.02 (0.97, 1.08)	0.355
	Less available	21 (21)	14 (14)			22 (22)	15 (17)		
	Equally available	66 (66)	67 (67)			34 (34)	39 (43)		
	More available	6 (6)	5 (5)			36 (36)	27 (30)		
	Much more available	0 (0)	0 (0)			3 (3)	6 (7)		
Compared with unhealthy foods, healthy foods are generally…	Much harder to cook	2 (2)	2 (2)	1.01 (0.95, 1.09)	0.691	4 (4)	1 (1)	1.05 (1.00, 1.10)	0.056*
	Harder to cook	17 (17)	16 (16)			10 (10)	6 (7)		
	Same difficulty	40 (40)	33 (33)			45 (45)	43 (48)		
	Easier to cook	30 (30)	40 (40)			38 (38)	37 (41)		
	Much easier to cook	11 (11)	9 (9)			2 (2)	3 (3)		
"My diet influences my bodyweight."	Strongly disagree	1 (1)	0 (0)	1.03 (1.02, 1.03)	<0.001**	8 (8)	7 (8)	0.98 (0.93, 1.03)	0.504
	Disagree	9 (9)	6 (6)			9 (9)	8 (9)		
	Neutral	21 (21)	27 (27)			16 (16)	15 (17)		
	Agree	61 (61)	47 (47)			44 (44)	44 (49)		
	Strongly agree	8 (8)	20 (20)			23 (23)	16 (18)		
"I pay attention to nutrition information on food packaging."	Strongly disagree	9 (9)	2 (2)	1.04 (1.04, 1.04)	<0.001**	6 (6)	4 (4)	1.01 (0.96, 1.06)	0.752
	Disagree	19 (19)	16 (16)			11 (11)	8 (9)		
	Neutral	25 (25)	30 (30)			12 (12)	17 (19)		
	Agree	42 (42)	44 (44)			49 (49)	40 (44)		

	Strongly agree	5 (5)	8 (8)			22 (22)	21 (23)		
"I eat worse when I am stressed, depressed, or tired."	Strongly disagree	24 (24)	15 (15)	1.08 (1.02, 1.14)	0.004 **	19 (19)	10 (11)	0.99 (0.94, 1.04)	0.696
	Disagree	15 (15)	11 (11)			21 (21)	26 (29)		
	Neutral	33 (33)	28 (28)			16 (16)	14 (16)		
	Agree	24 (24)	35 (35)			34 (34)	29 (32)		
	Strongly agree	4 (4)	11 (11)			10 (10)	11 (12)		
How would you characterize your own cooking skills?	Very skilled	5 (5)	5 (5)	1.07 (1.07, 1.07)	<0.001**	10 (10)	7 (8)	1.02 (0.96, 1.08)	0.552
	Skilled	30 (30)	24 (24)			44 (44)	40 (44)		
	Average	53 (53)	55 (55)			45 (45)	41 (46)		
	Poor	10 (10)	15 (15)			0 (0)	2 (2)		
	Very poor	2 (2)	1 (1)			0 (0)	0 (0)		
How frequently has your household cooked its meals?	All meals	11 (11)	23 (23)	0.88 (0.81, 0.95)	0.002 **	65 (66)	52 (58)	1.02 (0.95, 1.08)	0.635
	Most meals	52 (52)	44 (44)			33 (33)	33 (37)		
	Some meals	35 (35)	28 (28)			0 (0)	1 (1)		
	Few meals	1 (1)	3 (3)			1 (1)	3 (3)		
	No meals	1 (1)	2 (2)			0 (0)	1 (1)		
How often has your household eaten together? (multi-person households only)	All meals	36 (36)	44 (44)	0.89 (0.82, 0.98)	0.016 **	60 (67)	50 (60)	1.05 (0.99, 1.11)	0.143
	Most meals	35 (35)	25 (25)			19 (21)	22 (27)		
	Some meals	5 (5)	9 (9)			8 (9)	10 (12)		
	Few meals	3 (3)	0 (0)			1 (1)	1 (1)		
	No meals	0 (0)	1 (1)			2 (2)	0 (0)		

Footnote: [1]OR (95%CI) and *p* statistics indicate the age- and sex-adjusted odds ratio and *p* value for the association between a one-month increase in time since migration and each outcome, estimated using cumulative link mixed models (OR is that associated with a one-row descent in ordered category presented in the table, e.g., the OR for "Influence of the price of food on your food choices" is that associated with being in either the "Weak" vs. "None" category, "Moderate" vs. "Weak" category, "Strong" vs. "Moderate" category, or "Very strong" vs. "Strong" category). $^*p<0.05$, $^{**}p<0.01$.

Table 6: Associations between nutrition knowledge, diet quality, and diet patterns

	Almaty				Ulaanbaatar			
	Main Effect[1]		Interaction Term[2]		Main Effect[1]		Interaction Term[2]	
Outcome	**β (95%CI)**	***p***	**β (95%CI)**	***p***	**β (95%CI)**	***p***	**β (95%CI)**	***p***
PDQS score (range: 0-80)	0.37 (0.27, 0.47)	<0.001**	-0.01 (-0.02, 0.00)	0.171	-0.08 (-0.31, 0.15)	0.497	0.00 (-0.02, 0.03)	0.747
PDQS-healthy score (range: 0-52)	0.03 (0.15, 0.35)	0.365	0.00 (-0.01, 0.01)	0.706	0.21 (-0.02, 0.46)	0.087*	-0.01 (-0.04, 0.02)	0.696
PDQS-unhealthy score (range: 0-28)	0.11 (0.05, 0.17)	<0.001**	-0.01 (-0.02, 0.00)	0.008**	0.05 (-0.01, 0.10)	0.092*	0.01 (-0.01, 0.03)	0.284
Acculturated diet pattern (scaled from 0-100)	0.56 (0.12, 1.02)	0.016**	0.04 (-0.01, 0.09)	0.121	1.43 (0.64, 2.23)	0.001**	-0.09 (-0.19, 0.02)	0.109
Acculturating diet pattern (scaled from 0-100)	NA	NA	NA	NA	-0.12 (-0.94, 0.69)	0.780	-0.10 (-0.20, 0.00)	0.057*

Footnote: PDQS, Prime Diet Quality Score; NA, not applicable. [1]β (95%CI) and *p* statistics for main effects indicate the age- and sex-adjusted parameter estimate and *p* value for the association between a one-unit increase in nutrition knowledge score (range: 0-20) and each outcome. [2]β (95%CI) and *p* statistics for interaction terms are estimated using a separate set of models incorporating an interaction term between nutrition knowledge score and time since migration (in months). Models are estimated using linear mixed-effects models adjusted for age, sex, time since migration, education level, ethnicity, physical activity category, smoking, and household type (single vs. multi-person). *$p<0.05$, **$p<0.01$.

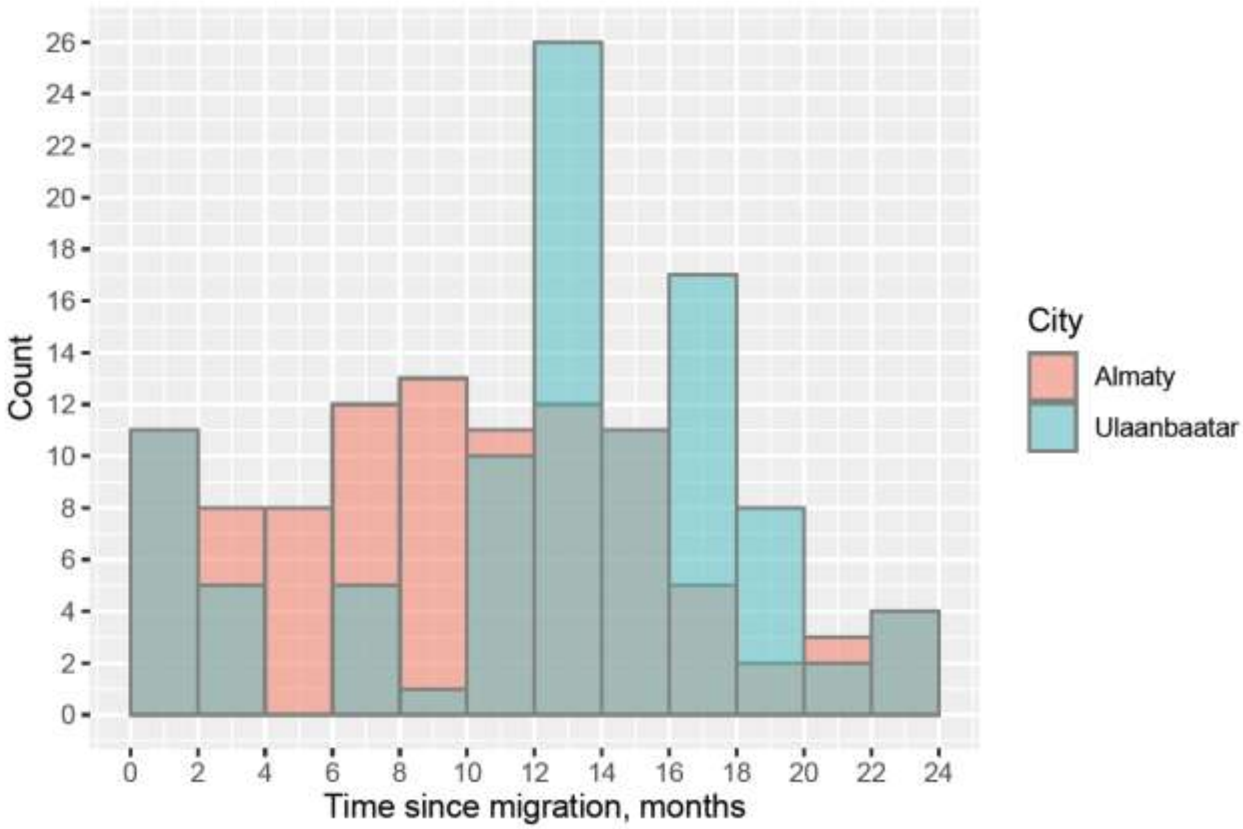

Figure 1 Title: Distribution of time since migration at baseline

Figure 1 Legend: [none]

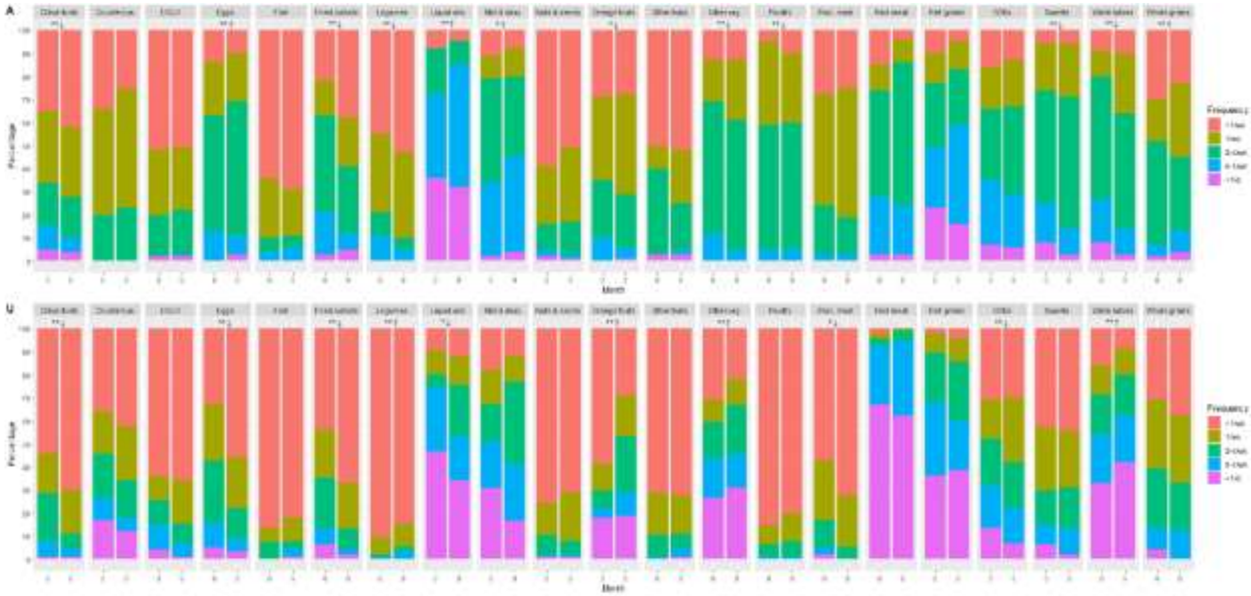

Figure 2 Title: Trends in food group consumption frequencies

Figure 2 Legend: Panel A: Almaty; Panel U: Ulaanbaatar. Cruciferous, cruciferous vegetables; DGLV, dark green leafy vegetables; Fried outside, fried foods obtained outside the home; Orange fruits, deep orange fruits; Proc. meat, processed meat; SSBs, sugar-sweetened beverages Significance and direction of age- and sex-adjusted trends from baseline to 9 months are estimated using cumulative link mixed models and are indicated as follows: **↑, significant increase (p<0.05); *↑, marginally significant increase (p<0.1); **↓, significant decrease (p<0.05); *↓, marginally significant decrease (p<0.1); no symbols, NS (p>0.10).

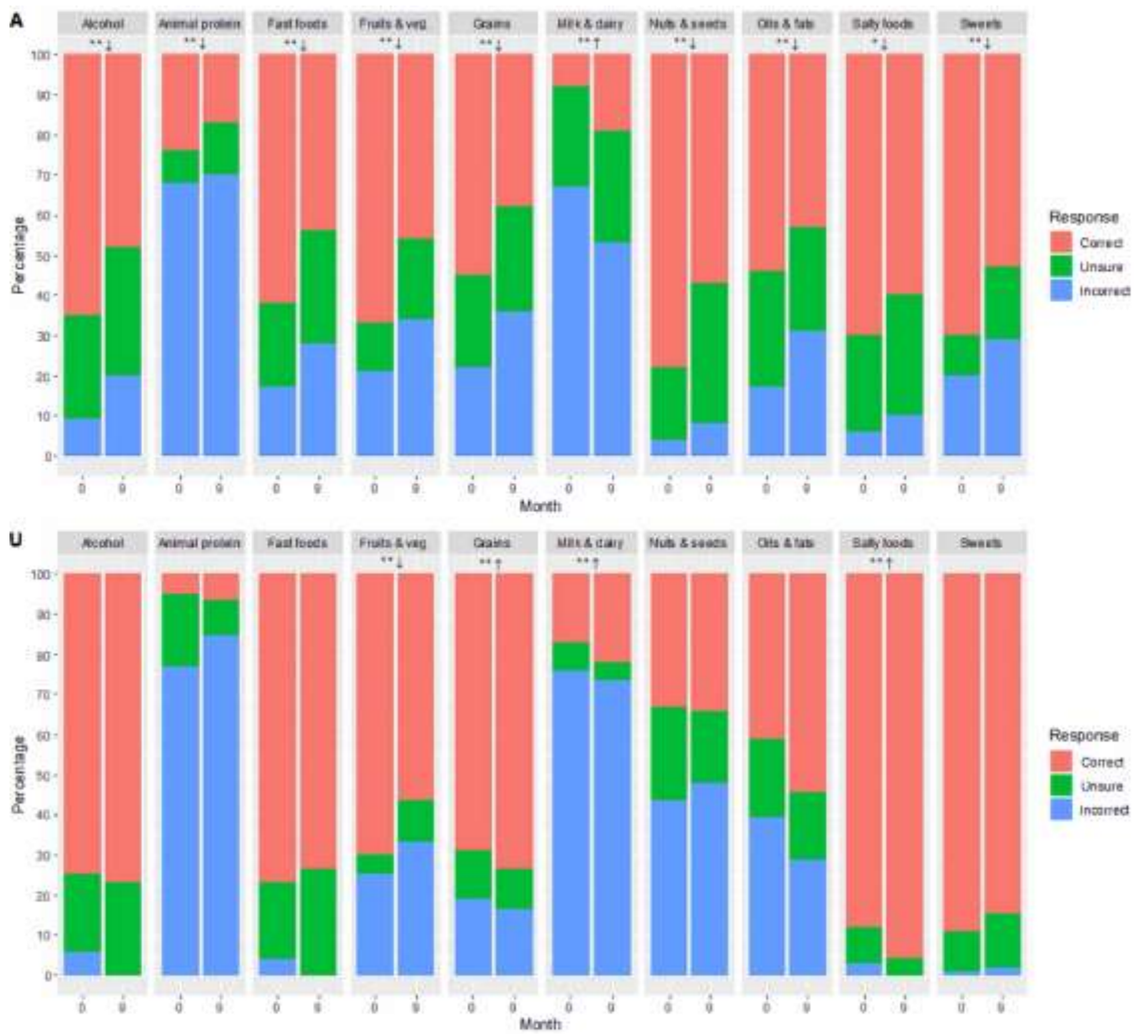

Figure 3 Title: Trends in nutrition knowledge components

Figure 3 Legend: Panel A: Almaty; Panel U: Ulaanbaatar. Bar heights indicate the proportion of correct, unsure, and incorrect responses to four questions asking whether it is generally more nutritious for healthy adults to habitually consume either (1) “red meat vs. lean meat (e.g., chicken, fish)” (abbreviated as “Animal protein” in the Figure), (2) “whole fat vs. reduced fat milk and dairy products” (“Milk & dairy”), (3) :liquid oils vs. animal fats: (“Oils & fats”), and (4) “whole vs. refined grains and grain products” (“Grains”), and 6 questions asking whether it is generally more nutritious for healthy adults to habitually consume more or less of (5) “salt and salty foods” (“Salty foods”), (6) “sugar and sugary foods and drinks” (“Sweets”), (7) “fruits and vegetables” (“Fruits & veg.”), (8) “nuts and seeds” (“Nuts & seeds”), (9) “processed and fast foods” (“Fast foods”), and (10) “alcoholic drinks” (“Alcohol”). Significance and direction of age- and sex-adjusted trends from baseline to 9 months are estimated using cumulative link mixed models and are indicated as follows: **↑, significant increase (p<0.05); **↓, significant decrease (p<0.05); *↓, marginally significant decrease (p<0.1); no symbols, NS (p>0.10).