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Dietary patterns and their socio-demographic correlates in the context of migration and urbanisation demonstrate nutrition transitions in South Africa

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ABSTRACT

This paper investigates the demographic and socio-economic correlates of dietary patterns in South Africa, drawing on a sample of young adults experiencing internal migration and urbanisation. We use data from the 2018 baseline survey of the Migrant Health Follow-Up Study, an original longitudinal cohort study consisting of 3,087 internal migrants and rural residents aged 18–40 nested within the Agincourt Health and socio-Demographic Surveillance System in rural northeast South Africa. We employ principal components analysis to identify dietary patterns from food frequency questionnaires and ordinary least squares regression to assess whether migration and other socio-economic characteristics correlate with specific dietary patterns at baseline. We observe five distinct dietary patterns characterised by frequent consumption of processed foods, red meat, fruits and vegetables, diverse foods, and high sugar/fat foods. We find migration to be significantly associated with more frequent consumption of both processed foods and fruits and vegetables; we also find the association between migration status and dietary patterns to be heterogenous depending on migrants' destinations. This paper extends current understanding of changing dietary patterns in the context of nutrition transitions with attention to dynamic migration processes rather than static rural-urban differences.

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Migration; urbanisation; nutrition transitions; dietary patterns; South Africa

Introduction

Urbanisation, migration, and economic development in low- and middle-income countries (LMICs) have produced changes in diet and physical activity resulting in increases in adiposity and chronic non-communicable diseases (Baker et al. 2020; Popkin, 2004; Popkin et al. 2020). These changes have been driven by complex social and economic processes related to changes in the types and quantities of available foods in both urban and rural places. Generally, rising urbanisation and industrialisation have led to a market reliance on starchy food purchases and the proliferation of

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energy dense 'industrial foods', i.e. foods that have high energy per weight, high sugar, high saturated fats, high sodium, and low micronutrient levels. The rapid rise of low cost – and heavily marketed – take-away foods, snack foods, and sugar-sweetened beverages has become a hallmark of this dietary shift (Willet et al., 2019). Much of the African region, and especially South Africa itself, has experienced these dietary changes and the consequent rise in overweight and obesity (Laar et al., 2022; Voster et al., 2011). Attention to the rise of obesity in the context of the nutrition transition has increased in particular as a result of the 'double burden' of undernutrition (stunting and wasting) and overnutrition (overweight and obesity) observed at both household and population levels in transitioning places (Conde & Monteiro, 2014; Kehoe et al., 2021; Prentice 2018).

There is not just one type or pace of nutrition transition across the world and in communities. At the country level, there is a spectrum of such transitions influenced by a variety of historical, political, economic, and regional factors (Raschke & Cheema, 2008). There is wide variation in the degree to which newly introduced foods are added to a local foods-based diet, likely with changes in the relative consumption of new and standard cuisine and their nutrients (Popkin 2004). Within nations, the pace and particulars of nutrition transitions depend on age, poverty, social class, education, wealth, income, social mobility, cultural cuisine patterns, nutritional health literacy, and health status. A number of large studies that include low- and middle-income samples have explored sex differences in adult diets and findings have been diverse, either showing no differences or pointing to slightly better diets among women compared to men (Mayén et al., 2014; Miller et al., 2016; Miller et al. 2022). Miller et al. (2022)'s recent cross-national study of dietary quality in 185 countries, for example, found that women on average scored higher than men on the Alternative Healthy Eating Index, but these sex-differences were not statistically significant in Sub-Saharan Africa. In addition, single-country cross-sectional studies in LMICs have found small or no differences in dietary intake between men and women (Letamo et al. 2022; Ratsavong et al. 2020). Further studies on gendered differences in dietary patterns over the life course, in specific geographic settings, and across the rural-urban continuum are needed.

Importantly, no nutrition transition occurs in isolation from other health and population processes. Nutrition transitions are best understood as occurring as part of the demographic and general health transitions (GBD, 2020). Further, urbanisation, as a constituent part of the demographic transition (Dyson, 2011), plays an important role in the evolution of nutrition transitions (Popkin, 1999). Research continues to document divergent diets in rural and urban populations, with urban dietary patterns generally shifting first toward processed, high-sugar, and high-value foods (vs. commodity crops) compared with rural residents who continue to consume more diversified or traditional diets (Auma et al., 2019). While such rural-urban differences continue to be documented, the literature on the nutrition transition has underappreciated that these geographic differences emerge in contexts of very dynamic internal migration processes. Rural and urban places are perpetually connected by people who move back and forth between them, which is especially true in LMICs where temporary and circular migration is pervasive, and where we expect rural-urban differences in diet to be greatest (Monteiro et al., 1995). Rather than consuming only 'rural diets' or 'urban diets', migrants' diets are shaped by both rural and urban food environments, behaviours, and cultural food practices in iterative and interactive ways.

South African food consumption and the changing food environment

South Africa has experienced significant changes in overall dietary patterns and in its food environment over the past decades (Ronquest-Ross et al., 2015). As in other LMICs, the proliferation of supermarkets, fast food chains, and the rise in average incomes has facilitated a shift toward greater consumption of convenient and high-value food items, including foods that are high in sugar, foods that are processed and packaged, foods that originate from animal sources, and foods that have added caloric sweeteners (Laurie et al., 2018; Ronquest-Ross et al., 2015). South Africans generally consume diets low in variety, especially with respect to fruits and vegetables (Labadarios et al., 2011;

Madlala et al., 2022; Shiana et al., 2014). Vegetable consumption is greatest in urban areas, which may reflect greater availability, and lower prices, of fresh produce there (Ronquest-Ross et al., 2015; Shiana et al., 2014). A large proportion of the South African population consumes fast food frequently. Fast food includes items such as burgers, pizza, fried chicken, and sugar-sweetened beverages (Feely et al., 2009; Van Zyl et al., 2010). Consumption of street food is also common, and includes prepared items such as fried potatoes, vetkoek (fried dough filled with meat, cheese, and sauces), and kotas (quarter loaf of bread filled with fried potato chips, meats, cheese, and sauces), but street foods also include low-cost fresh fruits and vegetables. Street foods are purchased almost exclusively by black South Africans, and fruit is the most-consumed street food item (Steyn et al., 2011). Steyn et al. (2011) found a strong correlation between socio-economic status and consumption patterns: fast foods are most frequently consumed by those in the high socio-economic group, and street foods are most frequently consumed by those in the medium socio-economic group. Overall, the South African food environment is characterised by increasingly frequent consumption of convenient, fast, and processed foods with diets generally low in diversity.

Historic and contemporary labour migration in South Africa

Substantial geographic mobility of population is a characteristic of nearly all societies experiencing economic development. In the case of South Africa, this is true as well, but the mobility pattern is accentuated by the country's history. The experience of apartheid, and within that policy the direct regulation of residence and movement, has made geographic redistribution an issue of key interest and policy concern since the end of the apartheid regime.

Much geographic mobility within South Africa (as elsewhere) has been labour mobility, spurred by the search for economic opportunity. From the 1990s's through mid-2000s employment-related reasons are cited overwhelmingly as the motivation for migration among adults (Posel, 2020). In the apartheid era in South Africa labour migration was strictly controlled through pass laws. With the end of the pass laws and then the end of apartheid itself in 1994, constraints on geographic mobility were reduced then removed (Reed, 2013). The apartheid-era restriction also gave rise to a pattern of temporary and circular migration (Posel, 2006), which has a legacy in the present day (Bank et al., 2020). The net result is that contemporary South Africa migration streams are generally urbanward, while retaining a substantial component of circulation. The Gauteng Province (Johannesburg-Tshwane region and hub of the economy) is a major magnet of movers from other provinces. Gauteng received 43 percent of all interprovincial migrants in the 2011–2016 period (StatsSA, 2021). This rural-urban migration along with the increased exposure to urbanity from both circular and permanent migration are seen to play a role in dietary patterns.

Migration, urbanization and changes in dietary patterns

Dietary changes associated with nutrition transitions have been associated with urbanisation in many LMICs, including large heterogeneous nations such as China (Mendez et al., 2005; Popkin et al., 2012), and Brazil (Conde & Monteiro, 2014; Monteiro et al., 1995) as well as several other nations in Latin America (Rivera et al., 2004), Asia, and Africa, which range widely across gross national income and level of urbanisation (Mustafa et al., 2021). Such changes have also been identified or implicated for South Africa (Laar et al., 2022; Vorster et al., 2011). Still, migration's influence on dietary changes has been studied most often using ecological designs comparing individuals from a low-income nation to migrants from those nations living in high-income countries or comparing rural and urban residents within the same nation (Misra & Ganda, 2007; Ngongalah et al., 2018). Very little research has been conducted on the role of internal migration and its complexities in initiating and contributing to dietary changes associated with nutrition transitions.

Only a handful of studies examine the association between migration and diet. One study of migrant women in Kenya using the 2014 Demographic and Health Survey found that rural-urban

migrant women were less likely to consume staples and nuts, and more likely to consume animal-source products and energy-dense foods compared with rural non-migrant women (Peters et al., 2019). Migrant women were also more likely to consume fruits and vegetables compared with non-migrant women. This finding of both positive and negative dietary changes among migrants is consistent with earlier work on migrants in India (Bowen et al., 2011). Notably, in Kenya, the association between migration and animal-source protein was explained entirely by differences in wealth between migrants and non-migrants so that any significant differences disappeared once household wealth was included in statistical models (Peters et al., 2019). The association between migration status and vegetable consumption remained statistically significant after controlling for wealth, however, which the authors interpret as reflecting greater availability of fruits and vegetables in urban places.

In this paper, we investigate demographic and socio-economic correlates associated with types of dietary patterns in the changing South African food environment. Rather than look for rural/urban differences as is common in the nutrition transition literature, we examine whether internal migrants exhibit dietary patterns that differ significantly from rural-resident non-migrants. This approach allows us a more dynamic lens through which to understand how urbanisation might be shaping dietary patterns and nutrition transitions in LMICs. Our approach is, first, to use principal components analysis (PCA) to identify distinct dietary patterns from food frequency data, and then to assess whether migration and other socio-economic characteristics correlate with specific dietary patterns. In our analysis, we use baseline data from the Migrant Health Follow-Up Study (MHFUS) to describe dietary patterns in a cohort of rural residents and internal migrants from northeast South Africa, a population that is characteristic of a typical rural South African context.

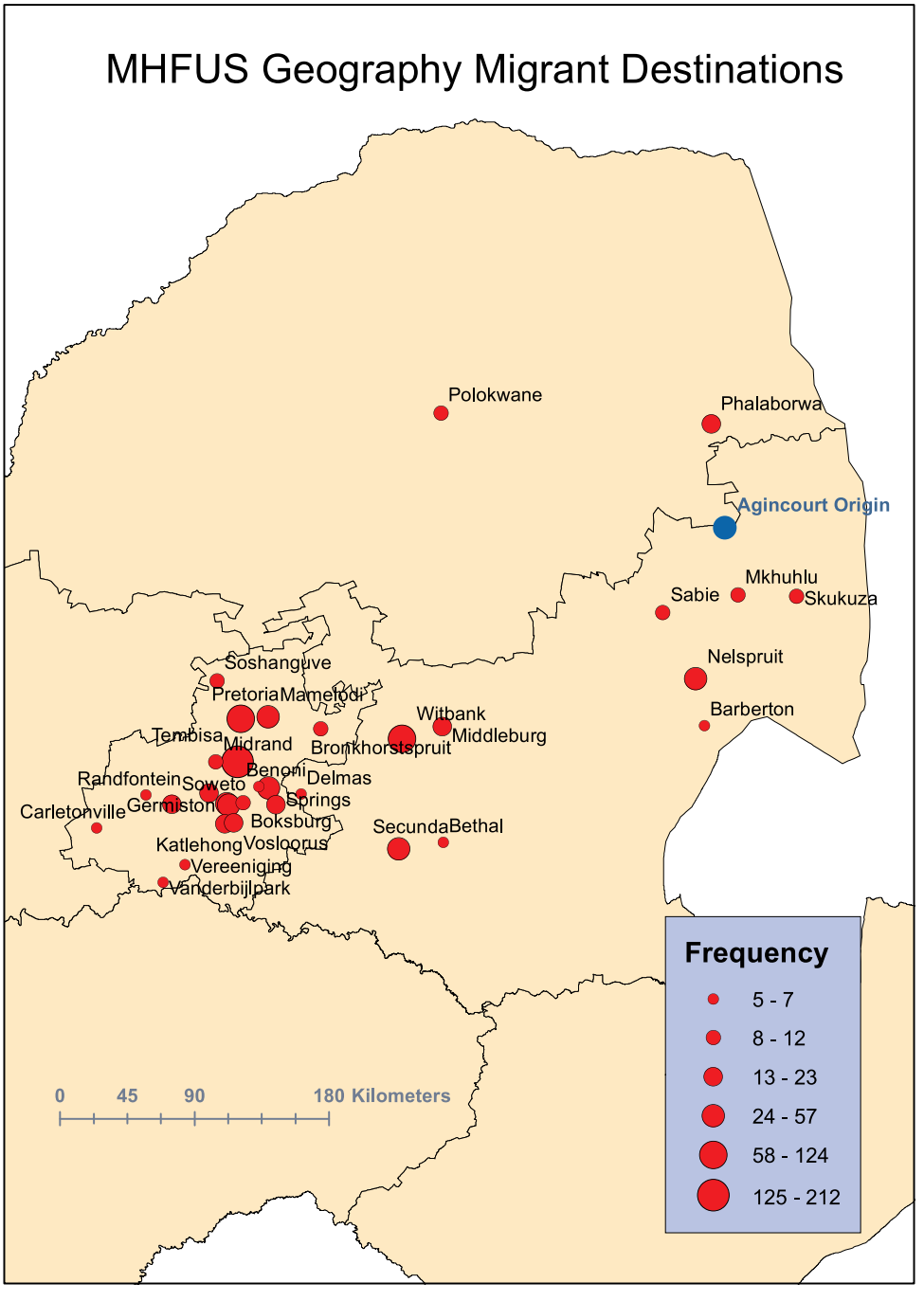
Methods

Study design

The MHFUS is an original longitudinal cohort study nested within in the Agincourt Health and socio-Demographic Surveillance System (AHDSS). The AHDSS is located in the Mpumalanga Province in northeast South Africa (see Map 1). In this study, virtually all participants, whether migrants or not, share the same origin district, which limits the amount of confounding that might arise from variation in origin geography or social setting. In 2017, MHFUS drew a simple random sample of 3,800 adults aged 18–40 from the previous years' AHDSS annual census. Initial household visits were conducted in 2017 to obtain contact information for the sampled AHDSS residents; we received consent to contact 3,491 sampled members from either the respondent themselves (if they were a current resident), or from their respective rural household (if they were currently a migrant living outside of the AHDSS). Of these, 3,092 respondents were successfully interviewed in 2018–2019. Our analytic sample consists of the 3,087 interviewed respondents for whom we have non-missing values on variables of interest.

Data

The MHFUS survey includes a 39-item food-frequency questionnaire (included in supplementary materials), which forms the basis of this analysis. The questionnaire collected information on the frequency with which each food item was consumed, but it did not estimate portion size or micronutrient intake for each food item in the survey. 'Alcoholic beverages' was excluded from the FFQ analysis since there were very large sex-differences in reported alcohol consumption (86.3% of women reported never consuming alcohol compared with 32.1% of men). Our analysis thus proceeds with 38 food items. At baseline, the FFQ was collected during an in-person interview for most participants, except for 634 respondents who were very difficult to reach physically and who we instead interviewed over the phone. The FFQ was administered near the middle of the interview, and generally caused few problems for data collection in the field. Occasionally



Map 1. MHFUS geography migrant destinations.

Note: Map 1 was originally published in Ginsburg et al. BMC Public Health (2021) 21:554. Reprinted with permission.

participants struggled to recall the frequency with which they consumed a particular food item, which required additional time and patience in data collection on the part of both fieldworkers and respondents. The FFQ was successfully completed in entirety by 99.1% ($N = 3{,}063$) of the total Wave 1 baseline sample. In addition to those who completed the full FFQ, our analytic sample also includes those who completed most, even if not all, of the FFQ; 0.6% ($N = 17$) of respondents

had one missing value on the 39 item FFQ, 0.2% ($N = 6$) were missing 2 values on the 39 item FFQ, and 0.3% ($N = 1$) of the sample was missing 3 values on the 39-item FFQ. Only 0.1% of the sample ($N = 4$) had missing values on all 39 items of the FFQ and were therefore excluded from the analysis.

Our analysis proceeds in three steps: 1. conversion and standardisation of the FFQ; 2. principal components analysis (PCA) analysis to identify dietary patterns from the FFQ; 3. regression analysis of the socio-demographic correlates of the dietary patterns.

Conversion and standardization of the FFQ

We standardised and converted the FFQ response categories (never, 1–3 times per week, 4–6 times per week, once a day, 2 times a day, 3 or more times a day) to number of times per day to make the frequency of consumption categories comparable (supplemental appendix, table 1). In a second standardisation step, we divided each item value by the person-specific mean across all items. In this way we adjusted for those who tend to report at the high or low end of the frequency scale (across all items), either because of total actual or perceived consumption.

Principal components analysis

We used PCA to analyze the FFQ to reduce the food items into dietary patterns that can be analyzed informatively, as is standard in analyses of FFQs (Willet, 2012). For each of the factor solutions, we implemented an orthogonal (varimax) rotation so that each factor has a mean of zero, standard deviation of one, and is uncorrelated with the other factors. We then compare the food items that have relatively large absolute values of factor loadings: positive loadings greater or equal to 0.3 or negative loadings below -0.3. This allows us to identify the smallest number of factors with the greatest amount of explained variance while also yielding interpretable food patterns. We then assign a more intuitive descriptive label to each factor, depending on the pattern of loadings, as is common with the use of PCA.

Regression analysis

We next use regression analysis to examine the socio-demographic correlates of each of the factors identified from the PCA analysis. For each of the dependent variables (factors) we perform an ordinary least squares (OLS) regression that includes age group, sex, high school completion, employment status, and number of children and adults in the household. In addition to these standard demographic and socio-economic variables, we include a measure of food insecurity in light of the burgeoning literature on the role of poverty in nutrition transitions, and both undernutrition and obesity. Food insecurity is measured as an indicator of a positive response to the question: 'Have there been any days in the last three months when your household experienced a shortage of food to eat because there was not enough money to buy food?'

Migration status, our primary independent variable of interest, is a 3-category variable that classifies respondents as 'non-migrants' (reference), 'Gauteng migrants', or 'Other migrants'. Non-migrants reside within the rural AHDSS (origin area) at the time of interview while Gauteng migrants reside in Gauteng province. Other migrants are respondents who are living outside of the AHDSS at the time of interview but not in Gauteng province – most often in areas around the AHDSS or smaller cities and towns between Gauteng and Agincourt (Map 1). We present regression results that are weighted for sample non-response.

Robustness checks

In the primary analyses we pool models for men and women together and include a control for sex. Given evidence of sex differences in the pooled models, we repeat the same regression analyses stratified by sex (supplemental appendix, tables 4 and 5). We prefer the pooled models for efficiency of

presentation, but we indicate key features of this alternative sex-stratified specification in the discussion section. We also examine an alternative regression model that includes a separate fast-food measure not included in the FFQ, and a measure of chronic illness since awareness of illness might change dietary behaviour (supplemental appendix, table 3). The results we present are overall consistent regardless of model specification, and the additional variables perform as we expect.

Results

Principal components analysis

The PCA yielded 12 factors with eigenvalues greater than 1 (supplemental appendix, table 2). We carefully compared both positive and negative loadings on the first eight factors based on the results from the scree plot (not shown), which is the point where the curve begins to flatten. We concluded that factors 6, 7, 8 did not clearly indicate discernible dietary patterns that allowed for meaningful interpretation (we could not successfully name these factors based on the loadings). We therefore proceeded with the first 5 factors which allowed us to identify the smallest number of factors that had the greatest amount of explained variance while also yielding interpretable food patterns that made sense from a substantive standpoint. Table 1 summarises these five factors and identifies the food items that load strongly both positively (at or above 0.3) and negatively (at or below −0.3) on each factor. The five factors that result represent five dietary patterns that are broadly classified by processed and high dairy foods (factor 1), red meat and energy drinks (factor 2), fruit and vegetables (factor 3), a diversified diet (factor 4), and high sugar and fat items (factor 5). These five factors explain a total of 30.4 percent of the variation in the 38-item FFQ.

Descriptive characteristics

Table 2 presents the descriptive characteristics of the MHFUS analytic sample by migration status. Migrants and non-migrants are similar in terms of their age – with migrants on average about one year older than non-migrants. The majority of migrants are male (58.4% and 57.9% among Gauteng and Other migrants respectively), whereas the majority of non-migrants are female (56%). A much greater percentage of Gauteng migrants (58.6%) and Other migrants (62.9%) are currently employed full time compared with non-migrants (24.7%). Gauteng migrants are the most educated group, with 77.2% having completed their high school education compared with 67.3% of Other migrants and 46.7% of non-migrants. Migrants live in households that are smaller than non-migrants both in terms of adult and child household members. Non-migrants live in households with 2.2 adult and 2.3 child household members, while both Gauteng and Other migrants live in households with less than one adult and child household member. Self-report of food insecurity in the last 3 months is much more prevalent among Gauteng Migrants (14.9%) compared with both non-migrants (7%) and Other Migrants (4.6%).

Descriptively, migrants and non-migrants differ in terms of their factor scores across the 5 factors. Migrants consume processed foods, fruits and vegetables, and high sugar/fat diets with greater frequency, as is evident of means greater than 0, compared with non-migrants who score below 0 on average across these factors. The opposite pattern is evident for factor 3 (diversified), where migrants score below 0 on average and non-migrants above 0, suggesting less frequent consumption of diversified diets among migrants compared with non-migrants. Across most factors, Gauteng and Other migrants have average scores in the same direction relative to non-migrants. Scores on factor 2 (red meat) diverge for Gauteng and Other migrants, with Gauteng migrants having average factor scores of −0.20 and Other migrants an average score of 0.32.

OLS regression

Table 3 presents results from weighted OLS regressions with selected socio-demographic correlates for each of the five dietary patterns (factors), and Figure 1 summarises these differences in terms of

Table 1. Summary of FFQ and factor loadings.

Food Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Cheese and cottage cheese	**0.5057**	0.1414	0.1065	−0.2376	0.0467
Processed meat	**0.4847**	0.0747	**−0.3499**	**−0.3444**	−0.1078
Yoghurt/maas	**0.3668**	0.1759	**0.3039**	−0.0562	0.0352
Non-dairy creamer/Cremora	**0.3309**	**−0.57**	−0.1272	−0.0427	−0.1009
Breakfast cereals	**0.3238**	0.1253	**0.3638**	−0.1219	0.1175
Eggs	**0.315**	0.0458	**−0.3717**	0.2659	−0.1234
Milk	**0.3145**	**−0.3214**	**0.4335**	−0.0566	0.0472
Puddings	0.2588	0.1348	0.0655	−0.1608	0.2573
Citrus fruit	0.2485	0.1983	0.2614	−0.1577	−0.1067
Sauces	0.245	0.2019	**−0.3347**	0.0859	0.0014
Red meat	0.2381	**0.3326**	−0.102	−0.2062	−0.0872
Rice and pasta	0.1755	0.1402	0.066	**0.4092**	0.0094
Offal and traditional meats	0.1127	0.1259	−0.1904	0.2853	−0.2441
Samp and mielie rice	0.1116	0.0447	0.214	0.2197	0.1626
Peanuts and nuts	0.1088	0.0909	0.082	**0.3911**	0.0288
Cakes and biscuits	0.1045	0.0921	0.0198	−0.1132	**0.4533**
Chicken	0.0835	0.1967	−0.1886	**0.4655**	0.0705
Margarine	0.082	−0.1917	**−0.4194**	−0.0301	−0.0549
Crisps (Potato chips)	0.0759	0.0268	−0.0196	0.1392	**0.6921**
Boiled potatoes	0.0755	0.0431	**0.4593**	0.2524	−0.1091
Salad vegetables	0.0728	0.2203	**0.5544**	−0.0878	0.0139
Roast potatoes and chips (French fries)	0.0475	0.2452	−0.2465	**0.3154**	0.1936
Other fruit	0.0446	0.1826	**0.3675**	−0.1723	−0.2684
Tea and coffee	0.0366	**−0.7677**	−0.1154	0.1011	0.0077
High-energy soft drinks	0.0305	**0.426**	−0.2139	0.0127	0.0368
White and traditional bread	0.0105	−0.0316	0.0872	−0.0205	0.104
Green vegetables	0.0065	0.0258	**0.3538**	0.1732	−0.2688
Other vegetables	−0.0328	0.0973	**0.3382**	−0.0162	**−0.4392**
Sweets and chocolate	−0.0524	0.0472	0.0621	−0.0178	**0.6696**
Fat cakes, samosas and pizza	−0.0527	0.1175	−0.0063	−0.0825	0.2558
Fruit juices	−0.1247	0.1692	−0.0969	**−0.5349**	−0.1138
Diet soft drinks	−0.1431	0.2905	−0.0983	−0.1538	0.2436
Added sugar	−0.1851	**−0.7273**	0.0209	−0.2191	−0.0267
Legumes	−0.1933	0.11	−0.1533	**0.4382**	−0.0841
Brown and wholemeal bread	−0.2223	−0.1508	−0.2006	0.0628	−0.208
Fish	−0.2766	0.0798	−0.1002	**0.401**	−0.1158
Cooking fats and salad oils	**−0.4783**	−0.1599	0.0449	**−0.4058**	−0.168
Cooked porridge	**−0.8048**	0.0793	−0.0553	−0.1334	−0.017

Note: bolded values identify the food items that load strongly both positively (at or above 0.3) and negatively (at or below −0.3) on each factor.

Table 2. Weighted descriptive characteristics of the migrant health follow-up analytic sample.

	Non-Migrant $N = 1739$	Other Migrant $N = 661$	Gauteng Migrant $N = 687$
	Mean (SD)/Percent	Mean (SD)/Percent	Mean (SD)/Percent
Age	27.8 (6.1)	29.4 (5.3)	28.8 (5.4)
Male	44	58.4	57.9
Female	56	42.6	42.1
Employed Full Time	24.7	62.9	58.6
Complete Highschool	46.7	67.3	77.2
Adult Household Members	2.2 (1.6)	0.66 (1.0)	0.85 (1.1)
Child Household Members	2.3 (1.7)	0.50 (1.1)	0.45 (1.0)
Food Insecure	7.0	4.6	14.9
Factor 1 score (Processed)	−0.079 (1.04)	0.078 (0.96)	0.12 (0.90)
Factor 2 score (Red Meat)	−0.043 (0.88)	0.32 (0.99)	−0.20 (1.2)
Factor 3 score (Fruit & Veg)	−0.30 (0.85)	0.094 (0.95)	0.69 (1.0)
Factor 4 score (Diversified)	0.18 (1.0)	−0.33 (0.86)	−0.14 (0.89)
Factor 5 score (High Sugar/Fat)	−0.052 (1.0)	0.12 (0.84)	0.009 (1.1)

predicted margins holding all other covariates at their means. We find notable differences in dietary patterns by migration status. Migration status, regardless of destination, is associated with more frequent consumption of diets characterised by highly processed foods compared with non-migrants

Table 3. Weighted Regressions of Dietary Patterns and their Socio-Demographic Correlates

	Processed		Red Meat		Fruits & Vegetables		Diversified		High Sugar/Fat	
	Scores for factor 1		Scores for factor 2		Scores for factor 3		Scores for factor 4		Scores for factor 5	
	COEF	SE	COEF	SE	COEF	SE	COEF	SE	COEF	SE
Migration Status (ref. non-migrant)										
Other Migrant	0.121*	0.0528	0.197***	0.0505	0.329***	0.0492	-0.342***	0.0494	0.133**	0.0492
Gauteng Migrant	0.141**	0.0513	−0.292***	0.0579	0.896***	0.0520	-0.190***	0.0515	-0.000506	0.0545
Age	−0.00194	0.00324	−0.00691*	0.00331	0.0130***	0.00312	0.00860**	0.00328	-0.0244***	0.00336
Male	−0.298***	0.0360	0.348***	0.0375	−0.108**	0.0352	0.110**	0.0364	-0.0678	0.0373
Employed Full Time	0.0168	0.0407	0.106*	0.0435	0.0363	0.0406	-0.279***	0.0400	-0.0363	0.0417
Completed High School	0.421***	0.0374	0.0459	0.0367	0.0755*	0.0351	-0.214***	0.0370	0.0326	0.0370
Adult household members	0.0360**	0.0131	−0.0225	0.0125	−0.0101	0.0115	0.0278*	0.0130	-0.0264*	0.0123
Child household members	−0.0218	0.0129	−0.0207	0.0116	−0.0161	0.0113	-0.00691	0.0136	-0.0338**	0.0126
Food Insecure	−0.289***	0.0657	−0.230**	0.0785	0.313***	0.0668	0.400***	0.0696	0.0684	0.0780
Constant	−0.107	0.105	0.0580	0.105	−0.628***	0.0988	-0.0151	0.108	0.777***	0.107
Observations	3087		3087		3087		3087		3087	
Adjusted R-squared	0.081		0.076		0.179		0.092		0.028	

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.



Figure 1. Predicted margins of factor scores by migration status.

($p < 0.05$), but migrants also consume diets higher in fruits and vegetables with greater frequency compared with non-migrants ($p < 0.001$). Migrants who move to Gauteng province consume red meat diets less frequently than non-migrants ($p < 0.001$), while migrants to other locations consume greater frequencies of both red meat ($p < 0.001$) and sugar ($p < 0.01$) compared with non-migrants.

We also find differences in dietary patterns by age, sex, and education. Increased age is associated with less frequent consumption of red meat ($p < 0.05$), and high sugar/fat diets ($p < 0.001$), and more frequent consumption of diversified ($p < 0.01$), and fruit/vegetable diets ($p < 0.001$). Men on average consume red meat ($p < 0.001$) and diversified ($p < 0.01$) diets more frequently than women, and diets characterised by processed foods ($p < 0.001$) and fruit/vegetable ($p < 0.01$) consumption less frequently compared with women. Full time employment is associated with more frequent consumption of red meat ($p < 0.01$), and less frequent consumption of the diversified dietary pattern ($p < 0.01$). High school completion is associated with more frequent consumption of processed diets ($p < 0.001$), and less frequent consumption of diversified diets ($p < 0.001$). Larger household size is correlated with more frequent consumption of processed foods ($p < 0.01$) and less frequent consumption of high-sugar diets ($p < 0.05$). Food insecurity in the past three months is associated with less frequent consumption of processed ($p < 0.001$) and red meat diets ($p < 0.01$) and more frequent consumption of fruit and vegetable ($p < 0.001$) and diversified dietary patterns ($p < 0.001$).

In terms of additional covariates examined in robustness checks, (supplemental appendix, table 3) chronic illness diagnosis is associated with less frequent consumption of processed foods and more frequent consumption of a diversified diet. Fast food consumption is associated with more frequent consumption of processed foods, red meat, and high sugar/fat diets, and associated with less frequent consumption of fruits and vegetables and diversified diets.

Discussion

This paper provides a rich baseline description of the dietary patterns evident in the MHFUS cohort in South Africa. Our analysis identifies five distinct dietary patterns characterised by consumption

of processed foods, red meat, fruit & vegetable, diversified, and high sugar/fat diets, which may represent the expected heterogeneity of dietary patterns in the context of nutrition transitions. Our findings indicate that migration is associated with greater consumption of processed, red meat, and high sugar/fat diets, and less frequent consumption of diversified diets. This may reflect greater availability of such food items in urban and peri-urban areas compared with rural areas. Equally important, our analysis shows the value of moving beyond simple dichotomous comparisons of place. We uncover notable divergences in the frequency of dietary pattern consumption by the destination location, pointing to potential differences in behaviours and food environments of Gauteng migrant and Other migrants. While migrants located outside of Gauteng province consume diets high in red meat and sugar compared with non-migrants, there is no evidence of parallel behaviour among Gauteng-based migrants. In fact, Gauteng-based migrants consume significantly less red meat than non-migrants and Other migrants.

Our findings are consistent with extant literature that has found evidence of patterns shifting toward greater consumption of high-sugar and convenience diets as a result of rising incomes in sub-Saharan African settings (Cockx et al., 2017). Our analysis supports that greater socio-economic status – especially as measured by education – is associated with more frequent consumption of red meat and processed foods.

At the same time, our findings amplify and sometimes adjust previous results and expectations based on our approach of replacing simple comparisons of place with more detailed information about individual geographic migration and residential environment. Higher socio-economic status is associated with less frequent consumption of diversified diets characterised by chicken, fish, traditional meats, legumes, nuts, roasted potatoes, and pasta/rice. While we cannot test directly for substitution, these parallel findings suggest that more disposable income may be associated with shifts away from diversified diets toward the consumption of highly processed and red meat diets, which is consistent with findings from Kenya presented by Peters et al. (2019).

The relationship between the food environment and food consumption is complex, however, especially in the context of high levels of poverty and inequality as is the case in South Africa. We find that Gauteng migrants are more likely to be food insecure compared with non-migrants, while Other migrants are less likely to be food insecure compared with non-migrants. There is evidence that poverty reduces the consumption of both obesogenic and protective foods in favour of energy dense staples in South Africa (Kroll et al., 2019). Our finding that food insecurity in the past 3 months is associated with less frequent consumption of processed and red-meat diets, and more frequent consumption of more diversified diets is consistent with this evidence. However, we also find food insecurity to be associated with more frequent consumption of fruits and vegetables. In South Africa, diets with healthier substitutions for typical less healthy choices generally cost 10% to 60% more (Temple et al., 2011; Temple & Steyn, 2009). One potential exception – and explanation for increased fruits and vegetable consumption in the face of food insecurity – could be increased consumption of affordable fruits and vegetables sold by informal street vendors especially in rural areas where food insecurity is greater. Rural households (especially ones headed by female household heads) may also engage in agricultural production to supplement household food availability, potentially increasing fruit and vegetable consumption under conditions of resource constraint (StatsSA, 2023). Importantly, in our study, while we do find significant associations between socio-economic characteristics and dietary patterns, and food insecurity and dietary patterns, these factors do not explain the significant association between migration and diet.

One potential explanation for differences in dietary patterns observed is that average income differs between migrants within – and outside of – Gauteng province given the larger more competitive labour market in Gauteng province. A sensitivity analysis that included a measure of income (not shown) rather than employment (the two measures are correlated at 0.85) showed consistent results with what we present with the education measure, suggesting that differences in income do not explain the divergence between Gauteng and Other migrants. Other explanations might lie in the relative cost of food availability in different geographic locations – which would

be an important next point of inquiry for this work. A recent analysis of the 2021 General Household Survey found that the City of Johannesburg was among the metros with the highest inadequacy in accessing food (StatsSA, 2023).

There is a growing literature on food environments in LMICs, but few studies have examined the relationship between food environments and dietary outcomes. As a result, we do not yet have a good understanding how personal and local food availability, accessibility, and affordability shape consumption access in transitioning contexts (Claasen et al., 2016). Nor do we fully understand how these may interact with demographic and socio-economic characteristics of individuals. Studies that have examined the relationship between the food environment and diet generally find significant associations, but the limited nature of these studies highlights the need for more such research (Turner et al. 2020). The extensive penetration of supermarkets into South Africa has been well documented, but the distribution of food availability and healthy food options provided by supermarkets is patterned by spatial inequality (Battersby & Peyton, 2016). In urban and peri-urban places in South Africa – including in townships (where many migrants live) – supermarkets tend to dominate as the source for most foods (Kroll et al., 2019). Supermarkets provide ready access to affordable ultra-processed foods but may not offer the same healthy food options in low-income areas as in high-income neighbourhoods (Laar et al., 2022; Peyton et al., 2015). The proliferation of informal and street food vendors also has a spatial logic that offers convenient food options to working people in urban areas (Claasen et al., 2016). Understanding spatial variation in access to supermarkets and the food they provide, as well as other formal and informal sources of foods is an important next step in understanding patterning in diets in transitioning contexts, and how exposure may change with migratory behaviour.

There are no studies of which we know that directly compare the availability and cost of a basket of goods in diversity of migrant sending and in migrant receiving areas, but limited national-level data suggest that rural-urban differences in food prices may vary notably by specific food items. A 2019 report by the National Agricultural Marketing Council (NAMC) comparing rural and urban food prices in South Africa found milk, margarine, rice, peanut butter, and sugar to be cheaper in urban areas compared with rural ones, whereas tea, oil, maize, and bread were less expensive in rural areas (NAMNC, 2019). Such differences, which likely also have local variation, call for more dynamic conceptualisation of differences in dietary patterns especially as highly mobile migrants may tailor their diets depending on cost, availability, satiety, and geography. In addition to supply-side factors of availability and cost, there are likely also demand-side factors at play that influence dietary choices. These may include a greater demand for prepared and convenient foods among migrants who live alone and work and therefore have temporal limits on food buying and preparation, and potential changes in tastes associated with greater exposure to processed and high-value food items with migration.

Finally, additional sex-stratified models (supplemental appendix, tables 4 and 5) point to the potentially important role of gender in understanding the relationship between migration, urbanisation, and nutrition transitions. While the sex-stratified results are overall consistent with the pooled results, they do suggest important differences. Migrants are more likely to be male, employed, educated, and to live in smaller households compared with non-migrants. The significant negative association between being a Gauteng migrant and red meat consumption in the pooled models (table 3) is driven by the strong negative association among men (supplemental appendix, table 4), whereas the positive association between being an Other migrant and sugar consumption in the pooled models (table 3) is driven by the positive association among women (supplemental appendix, table 5). These sex differences are difficult to parse conceptually without more knowledge about whether and how often men and women share meals, who prepares food, and how migrants make food purchase and consumption decisions, but the role of gender in the nutrition transition is an important future line of inquiry. A next step for this analysis is to understand how dietary patterns change over time, accounting for individuals' pre-migration dietary behaviours, which we will undertake with follow-up waves of the MHFUS data. Another important next question is whether and to what extent

dietary patterns – and changes in these patterns – affect health. The literature that aims to link dietary patterns to obesity risk factors has found mixed results (Kehoe et al., 2021; Turner et al., 2020; Wrottesley et al., 2017) in part because of the cross-sectional nature of much health data, the relative crudeness of adiposity measurements, as well as the potential for metabolic compensation (Halsey, 2021). Our future work aims to understand how changes in dietary patterns over time may be associated with changes in BMI, blood pressure, glycosylated haemoglobin (HbA1c) and the risk for developing hypertension and type 2 diabetes with consistent and longitudinal measures of biomarkers and anthropometrics at the individual level.

Limitations

The present analysis uses cross-sectional baseline survey data to describe dietary patterns and their socio-demographic correlates and therefore cannot account for selection processes or confounding due to unobserved heterogeneity. We did not independently validate the FFQ instrument used in the MHFUS, but the FFQ was adapted from the Transition and Health during Urbanisation of South Africans (THUSA) study's FFQ, which had been appropriately validated in a similar urbanising population (MacIntyre et al. 2000; Venter et al. 2000; Vorster et al. 2005). Further, preliminary analysis of the MHFUS Wave 2 FFQ data indicate that Wave 1 factor scores are positively associated with Wave 2 factor scores after controlling for basic demographic characteristics (age, sex, migration status), which we interpret as indicative of the reliability of the FFQ instrument used in MHFUS. We limited our analysis to the first five factors identified by the PCA analysis based on the scree plot and our ability meaningfully to interpret and name the dietary patterns; this analytical choice does leave unexplained variation in dietary patterns for which we do not account. Finally, our food inventory does not account for portion size or energy intake, so conclusions about the implications for nutritional adequacy or health risk factor associations are limited.

Conclusions

In this paper, we show that the changing food environment in LMICs like South Africa can be observed as several distinct dietary patterns. We find that migration is significantly associated with these dietary patterns, but also that the association between migration and diet is heterogenous. The population health perspective about the relationship between migratory behaviour and dietary patterns in the context of demographic and nutrition transitions reveals that migrants had significantly more frequent consumption of both processed foods and fruits and vegetables, and overall less diverse diets than rural non-migrants. The association between migration status and dietary patterns was heterogenous depending on migrants' destinations; urban metropolitan Gauteng migrants consumed red meat less frequently than non-migrants, while migrants to other regions consumed red meat and high sugar/fat foods more frequently than non-migrants. Among all participants, higher socio-economic status was associated with less diverse diets, and especially with more frequent red meat consumption. These findings provide new insight about the socio-demographic correlates of dietary patterns in the context of nutrition transitions in LMICs. Differences in diet in the context of where migrants resided suggests the need for further longitudinal research on accessibility and costs of foods, further investigation of heterogeneity in diets among migrants, and potential sex differences in dietary patterns among migrants and non-migrants.

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