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ORIGINAL ARTICLE

Black South Africans Who Migrate Away From Their Rural Homes and Their Chances of Having Abdominal Obesity

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Keywords: internal migration | longitudinal study | nutrition transition | obesity | South Africa | sub-Saharan Africa

ABSTRACT

Introduction: South Africa is experiencing a heterogeneous and rapid nutrition transition. Rural-origin Black South Africans frequently migrate to access employment opportunities in urbanized areas, which could place individuals at risk for obesity due to accompanying dietary and lifestyle changes.

Methods: We utilize longitudinal data—four waves from 2018 to 2022—with detailed internal migration and health information, and negligible participant attrition from the Migrant Health Follow-Up Study, with origin households located in rural northeast South Africa—Agincourt. We employ lagged-dependent variable regressions to test whether (1) the number of waves one is away from their rural home (0–4) and (2) residing in a densely populated urban area (Gauteng province) relative to other locations or remaining in Agincourt over the four waves, are differentially associated with having abdominal obesity, indicated by the preferable measure of the waist circumference-to-height ratio (WHtR), at Wave 4—after adjusting for Wave 1 obesity and other variables, including fast food consumption. WHtR is operationalized as a binary indicator of abdominal obesity as well as a standardized, continuous one. Our analytic sample includes women ($N = 895$) and men ($N = 1010$).

Results: Our results show that internal migrant women and men face higher chances of having abdominal obesity at Wave 4 than their nonmigrant counterparts. For men, both the number of waves as a migrant and ever migrating to Gauteng are consistently, strongly associated with the chances of having abdominal obesity—considerably more so than women.

Conclusion: As obesity rates rise throughout urbanizing low- and middle-income countries, this research emphasizes the importance of understanding the correlates of the risks of obesity that internal migrants will face.

1 | Introduction

The prevalence of obesity continues to rise and burden public health systems throughout sub-Saharan Africa (SSA; Melaku et al. 2019; NCD Risk Factor Collaboration (NCD-RisC) – Africa Working Group 2017). This is in large part due to nutritional transition—moving toward processed food and away from "traditional" locally produced nutrient and fiber rich

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foods—alongside other major social, financial, and health changes in recent decades (Kehoe et al. 2021; Popkin 1999; Popkin et al. 2012; Prentice 2018; Raschke and Cheema 2008).

Sub-Saharan Africans who migrate internationally to high-income countries (HICs) face increased risks of having obesity—and related comorbidities—due to changes in diet, the accessibility of fast food, processed food, and limited healthy food options (Agyemang et al. 2016, 2017; Boateng et al. 2017; Gele and Mbalilaki 2013; Saleh et al. 2002). These risks are not unexpected as a wealth of evidence shows that individuals from low- and middle-income countries (LMICs)—outside of Africa—who migrate to HICs experience the same health consequences of dietary acculturation (Gilbert and Khokhar 2008; Holmboe-Ottesen and Wandel 2012; Kaushal 2009; Lee et al. 2022; Roshania et al. 2008; Sanou et al. 2014). The WHO's *Global Report on Urban Health* documented the widespread increases in obesity and overweight in LMICs and linked this shift to urbanization (WHO 2016, 94). Research from LMICs beyond Africa has shown dietary and nutritional changes, and higher chances of having obesity—increasingly among lower-income urban residents (WHO 2016)—as well as among internal (within country) rural–urban migrants. In Peru, for example, rural–urban migrants and long-term urban dwellers have far higher chances of having obesity than rural dwellers, likely also due to higher energy diets (Carrillo-Larco et al. 2016). Yet, the urban environment is not necessarily, nor uniformly, detrimental to one's diet. In Indian cities, a variety of fruits and vegetables are readily accessible, but this access to healthy dietary components is offset by higher saturated fat, carbohydrate, and protein intake among rural–urban migrants (Bowen et al. 2011). There is also evidence of hybrid food environments, such as in Myanmar, whereby the strong cultural diet containing fish—stemming from rural origins—persists and adapts benignly to city life. In this circumstance, food consumption is not "simply [to] be reduced to the bodily assimilation of nutrients that predictably varies from rural to urban space, nor...boiled down to an expression of Westernised consumerism" (Tezzo et al. 2021, 43). Limited cross-sectional analyses from Kenya reveal similar dietary patterns and obesity risks; rural–urban migrant women—especially those who had resided in urban areas longer—were at greater risk of having obesity than other groups (Peters et al. 2019). Current scholarship from South Africa and Senegal has, nevertheless, identified that those who migrate from rural to urban areas are more likely to have related noncommunicable disease indicators such as high blood pressure and hypertension (Duboz et al. 2012; Motlhale and Ncayiyana 2019; Pheiffer 2021; Pheiffer et al. 2019). To our knowledge, though, virtually no scholarship has identified, longitudinally, the chances of obesity among sub-Saharan Africans who migrate within their own countries—the predominant form of migration (Akeju 2013; Collinson et al. 2006; Garcia et al. 2015; Mberu et al. 2017).

South Africa offers a compelling research setting because it is experiencing a heterogeneous and rapid nutrition transition (Ronquest-Ross et al. 2015; Shisana et al. 2015), even compared to LMICs and elsewhere in SSA. The proliferation of supermarket chains in urban and suburban areas (like Spar, Shoprite, and Pick N Pay) and fast food chains (like McDonald's, Kentucky Fried Chicken, Steers, and Wimpy) has contributed to this transition (Igumbor et al. 2012; Nkosi et al. 2020; Otterbach et al. 2021; Van Zyl et al. 2010). Local shops and street food vendors are also meeting growing demand for fast food in townships, informal settlements, and, increasingly, in rural areas (Feeley et al. 2009, 2011; Steyn et al. 2011), including stalls in front of primary and secondary schools. Understanding the social determinants of obesity in South Africa, amid the country's complex demographic, economic, and epidemiologic transitions (Houle et al. 2022) has never been more important.

Rural–urban migration is a prevalent livelihood strategy for individuals throughout LMICs, and most often for economic reasons (Abubakar et al. 2018; Collinson et al. 2014; White and Lindstrom 2005, 2019). Internal migration flows also increase as LMICs urbanize and ascend in global economic development, too (Bell et al. 2015; Darlington et al. 2016; UN Department of Economic and Social Affairs 2013). As found in other LMICs, rural-origin Black South Africans frequently migrate to access employment opportunities in urban areas to financially support their rural households and extended families (Ginsburg et al. 2021; Vearey et al. 2018). The shift to urban settlement continues to proceed more rapidly and is more widespread in LMICs. Recent UN-Habitat estimates indicate that the urban *share* of the population in UN-classified "Less Developed Regions" is estimated to grow from 40% to 57% between 2000 and 2030, with the urbanward shift (31%–47%) equally pronounced in SSA alone (UN-Habitat 2024). But unlike in other LMICs—which all have their own specific historical drivers of rural–urban migration, South Africa's rural–urban migration patterns are a direct legacy of apartheid (Collinson et al. 2006; Collinson 2010; Fourie 2022; Posel and Casale 2003; Reed 2013) that has created, entrenched, and sustained, inequalities in health and socioeconomic outcomes.

Since the end of apartheid in the early 1990s, rural–urban migration has become increasingly feminized; it is more common now for women to move for work in order to give themselves and their families a better chance of upward economic mobility (Camlin et al. 2010, 2014; Dworkin et al. 2012; Mbiyozo 2018; Morrell 2002; Posel and Casale 2003; Tienda and Booth 1991; von Fintel and Moses 2017). Still, male and female migrants' experiences differ in important ways. Urban migrant women often take on informal employment out of necessity, which can present physical danger in addition to low pay (Collinson 2010; Collinson et al. 2006; Ginsburg et al. 2021; Posel and Casale 2003; Vearey et al. 2017). Rural–urban migrant mothers also often decide to leave some of their children at "home" in the village, under the care of extended family members (Madhavan et al. 2012; Townsend et al. 2002), though this can lead to role strain for the mothers and a push to raise more of their children in their urban destinations (Madhavan et al. 2023).

On top of this, African women—across countries—continue to face substantially higher chances of having overweight or obesity than men, as nations urbanize (Steyn and Mchiza 2014; WHO 2016), even though the evidence from SSA and across LMICs shows virtually no gendered differences in diet (Darling et al. 2020; Letamo et al. 2022; Miller et al. 2022; Ratsavong et al. 2020). This is, in part, due to biological differences in the usage and storage of fat between women and men, including the slow or negligible loss of gestational weight gain after childbirth (Cintron et al. 2025; Kossou et al. 2023; Meyer et al. 2024;

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Senbanjo et al. 2021). For women, gestation and fat are closely tied—with higher fat associated (spread throughout the body) with greater chances of fertility; men tend to store fat more so in their abdomen (for broad reviews, see O'Sullivan 2009; Power and Schulkin 2008; Santosa and Jensen 2008). Yet variation in household composition, who is cooking food, and who eats the most food when resources are scarce may also be gendered. Conceivably, gendered migration experiences would strongly factor into differences in the chances of having obesity between men and women in South Africa—as has been found in other health domains—but this is unknown and without clear expectations for who is more at risk of having obesity.

By analyzing longitudinal data with detailed internal migration and health information, and negligible participant attrition, we test whether lengthy absence from one's rural home or residing in a densely populated urban area is differentially associated with having abdominal obesity by gender. These data and our empirical strategy are rare in LMIC studies of obesity, offering the rigor needed to advance the scientific understanding of internal migration and the chances of having obesity. We expect that living away from rural areas for longer periods, and migrating to Gauteng province—South Africa's urbanized hub, where two of the largest cities, Johannesburg and Pretoria, are located—will be most strongly associated with higher chances of having abdominal obesity.

2 | Methods

The Migrant Health Follow-up Study (MHFUS) in South Africa offers ideal longitudinal data to identify heterogeneous influences on having obesity among Black rural residents, and those who migrate within the borders of South Africa (Ginsburg et al. 2024). In MHFUS, internal migration episodes include those across the country as well as those moving considerably shorter distances. Migrant destinations are heterogeneous in terms of distance from the origin and socioeconomic environment, but most moves are urbanward. In our MHFUS sample, approximately half of migrants (those residing outside of the Agincourt district rural communities) at Wave 1 resided in Gauteng. Other migrants typically settle in medium-sized towns and small cities that have a diverse range of economic activities, such as eMalahleni and Middleburg, but also in more distant and remote industrial areas and game farms. MHFUS is nested within the Agincourt Health and socio-Demographic Surveillance System (HDSS)—a rural, longitudinal, population surveillance platform located in the Bushbuckridge district in Mpumalanga province. The Agincourt HDSS is located about 270 miles (400 km) northeast of Johannesburg (Kahn et al. 2012). At present, the Agincourt HDSS contains about 21000 households across 31 villages. The Agincourt HDSS study population includes long-term residents and those who reside outside the Agincourt study area but remain attached to their origin households in Agincourt.

The MHFUS data originate from a simple random sample of 3800 individuals, drawn in 2017, from all people aged 18–40 years in the Agincourt HDSS ($n = 48\,170$) resulting in the enrolment of 3092 eligible participants in Wave 1. MHFUS respondents were interviewed in 2018 (Wave 1) and then followed to Wave 2 (2019), Wave 3 (2020), and Wave 4 (2022) regardless of their ongoing connection to their original HDSS household. Wave 1 data collection was mostly conducted in-person (79.5%), with the remainder conducted over the phone (20.5%; those for whom fieldworkers were unable to meet in-person); in-person data collection also included anthropometric measures (following consent for such), key to measuring abdominal obesity in our study. Waves 2 and 3 were conducted overwhelmingly via phone (97.1% and 98.2%, respectively) and did not include anthropometric measures. Except for five cases, all of the Wave 4 data collection was conducted in person and included anthropometric measures. Notably, after the study initially enrolled 3092 individuals in Wave 1 (2018), only 4.6% of the cohort was lost to follow-up by Wave 4 (more details on this minimal attrition can be found in Ginsburg et al. 2024).

Ethical approval for MHFUS data collection was received from the University of the Witwatersrand Human Research Ethics Committee (Medical) (clearance certificate numbers M170277 and M220160) and the Mpumalanga Province Department of Health Research and Ethics Committee. Informed consent was provided by participants.

For this paper, we include individuals who participated in both Waves 1 and 4 *and* whose waist circumference and height were measured in both waves (some participants were interviewed by phone in Wave 1 but kept in the sample and measured in Wave 4 only). Thus, only those who participated in person were eligible to have their waist circumference and height measured (their differences, relative to those who completed Wave 1 over the phone, are noted in Tables A1 and A2). The survey design intended to exclude pregnant women from these anthropometric measurements too, but some pregnant women's measurements were erroneously taken in Wave 1, which we have retroactively excluded ($N = 54$, 5.2% among the analytic female sample). Women who had given birth in the year prior to their Wave 4 interview date ($N = 95$, plus 3 with missing data) were also excluded from the analyses due to bias in estimating obesity due to gestational weight gain and its rate of loss in that period, as well as nutrition changes and breastfeeding (Baker et al. 2008; Huseinovic et al. 2016; López-Olmedo et al. 2016; Nehring et al. 2011). In the end, our analytic sample consists of 1905 individuals (women = 895; men = 1010).

We examine participants' waist circumference-to-height ratios (WHtR; in metric units) to approximate abdominal obesity. Waist circumference was measured once at Waves 1 and 4, using a flexible plastic tape, at the umbilicus level. Height was measured once at Waves 1 and 4 and was taken with a portable stadiometer (for more details, see p. 5, tab. 2 of Ginsburg et al. 2024). Several studies have found that WHtR is a better measure of cardiometabolic risk than body mass index (BMI; kg/m^2) in several populations of different ancestries, including among sub-Saharan African populations (Ashwell et al. 2012; Jayawardana et al. 2013; Lear et al. 2007, 2010; Ware et al. 2014). We employ WHtR as a dichotomous indicator using the SSA recommended cutoffs of not having abdominal obesity ($0 \leq 0.5$) or having abdominal obesity ($1 > 0.5$) (Ware et al. 2014), as well as a continuous indicator (standardized with a mean of zero and standard deviations for each unit). Both the dichotomous *and* continuous WHtR measures at Wave 4 are used, separately, as the outcome

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variables. In our analyses, we employ Wave 1 height as the respondents' height for both Waves 1 and 4. Height measurements in both waves are not identical but *should* be fixed given that nearly all participants would have finished growing (any meaningful amount) at Wave 1 measurement; the differences in Waves 1 and 4 were not due to changes in measurement protocol and not directly attributable to fieldworker skill (participant assignment to fieldworkers was not random—sensitivity analyses on these issues are noted later in this manuscript).

Our key predictors measure internal migration episodes to see how they are associated with abdominal obesity at Wave 4 among Black South African women and men who originated in the Agincourt HDSS study area. We draw upon all four waves to identify an internal migration profile for participants. MHFUS defines internal migration as a current usual residence (where the respondent spends four or more nights per week) outside of the Agincourt HDSS study area. We operationalize it in two ways: (a) the *number of waves* a participant was an internal migrant (categorized by count 0–4); and (b) *Waves 1–4 migrant location*, operationalized as a trichotomy (Remained in Agincourt W1–4 = 0 (a nonmigrant); Migrant elsewhere in South Africa except Gauteng at least once W1–4 = 1; Migrant in Gauteng at least once W1–4 = 2). In this migration categorization, we capture any exposure to urban Gauteng (2), or to other locations beyond the Agincourt study area (1). That is, individuals who resided in Gauteng, or elsewhere, may have spent the duration of the four waves in that location or only part of that duration in that place, with the remainder spent in their Agincourt rural residence.

We test the robustness of the relationship between internal migration and abdominal obesity by employing a series of nested regression models. Control variables are progressively added into models and include conventional demographic characteristics, employment, self-reported comorbidities linked to obesity, and fast food consumption. These variables are operationalized as: *age at the study's initial household visit* prior to Wave 1 (a series of dummy indicators 18–24 [ref.]; 25–29; 30–34; and 35–39); if a respondent has *other people regularly living at their place of residence* in Wave 4 (no [ref.]; 1 other; 2 others; 3 others; and 4+ others); *employment status* in Wave 4 (unemployed [ref.]; employed-formal sector; and employed informal sector); self-reports of *HIV status* (HIV-negative [ref.]; and HIV-positive) and *diabetes/hypertension* in Wave 4 (neither condition present [ref.]; either condition or both conditions present); and whether participants eat any fast food meals or not (ref.) in an "average" (typical) week in Wave 4. This final variable, pertaining to fast food consumption, is included as a standalone key mediating variable in our models given the linkages between processed food and obesity. Analyses are stratified by sex given known gendered differences in internal migration patterns and potential obesity risks.

First, lagged-dependent variable (Allison 2009; W. R. Reed and Zhu 2017) logistic regressions are employed to estimate the log odds of having abdominal obesity in Wave 4 while controlling for Wave 1 abdominal obesity (binary cutoff of WHtR, described above). In separate sets of models, the two migration predictors (number of waves as an internal migrant and Waves 1–4 migrant location) are included. The control variables are progressively added to the models. Second, this entire lagged-dependent variable estimation procedure is conducted again but using OLS regression to predict standard deviation increases in Wave 4 WHtR while controlling for Wave 1 WHtR (continuous, standardized measures). All of these analyses are stratified by sex. Because the timing of the status of our Wave 4 controls preceded the fieldwork anthropometric measurements (and hence WHtR), our lagged-dependent variable regression choice allows us to affirm a temporal *order* of events within the conceptual framework that migration leads to having obesity, even if we refrain from insisting on causal inference. Our approach recognizes that, even after accounting for key observed characteristics, unobserved selectivity and time-varying characteristics not captured in survey data can induce error in such estimates; this problem is not unique to lagged-dependent variable regressions though (Anglewicz et al. 2017; Borjas et al. 1992; Fernández-Huertas Moraga 2013; Tong and Piotrowski 2012).

3 | Results

3.1 | Descriptive Statistics

Full descriptive statistics, stratified by sex, can be found in Table 1. A markedly higher percentage of women had abdominal obesity compared to men in both Wave 1 (women = 64.5%; men = 28.4%) and Wave 4 (women = 72.7%; men = 27.2%). Between Waves 1 and 4, 17.6% of women and 12.4% of men crossed above the 0.5 threshold (and were identified as having developed abdominal obesity). Approximately 9% of women and 14% of men did the opposite, having reduced their waist circumference enough to not have abdominal obesity at Wave 4. The mean WHtR scores (not transformed through standardization) for women in Waves 1 and 4 were 0.54 and 0.55, respectively, whereas the mean for men—in both waves—was 0.47. Figure 1 illuminates the within-wave and between-wave variation of these continuous WHtR distributions. For additional descriptive context only—and not included in inferences, below—we have included waist circumference and height, separately, as well as BMI categorizations for Waves 1 and 4.

Slightly over half of women (53.3%) were identified as internal migrants (residing away from Agincourt) at least once between Waves 1 and 4 compared to nearly two-thirds of men (65.6%); 19.9% of women and 31.8% of men were identified as internal migrants in all four waves of MHFUS. At the same time, about 23.5% of all women and 32.0% of all men resided in Gauteng at some point during Waves 1–4 (or possibly all four waves), emphasizing the strong draw to the economic hub of the country.

There is a large difference in the self-report of HIV infection between men (6.7%) and women (23.8%) which is both a reflection of what has been found in this age group previously in Agincourt and in Kwa-Zulu Natal (Gómez-Olivé et al. 2013; Houle et al. 2018), and the fact that women are more aware of their HIV condition due to more frequent use of the primary health care facilities. Additionally, most women (64.2%) and men (71.9%) indicated that they ate a fast food meal at least once in the "average" week.

Sex-stratified bivariate descriptive statistics, in Tables 2 and 3, depict meaningful longitudinal increases in abdominal obesity

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TABLE 1 | Descriptive statistics, stratified by sex.

	Women (N_{max} = 895)	Men (N_{max} = 1010)
Abdominal obesity		
Wave 1: Waist circumference (cm)	$\bar{x}$ = 87.4 (SD = 14.6)	$\bar{x}$ = 81.9 (SD = 13.1)
Wave 1: Height (cm)	$\bar{x}$ = 161.7 (SD = 6.3)	$\bar{x}$ = 173.2 (SD = 6.8)
Wave 1: WHtR > 0.5 (has abdominal obesity)	64.5% (*N* = 572)	28.4% (*N* = 285)
Wave 1: WHtR (continuous, not standardized)	$\bar{x}$ = 0.54 (SD = 0.09)	$\bar{x}$ = 0.47 (SD = 0.07)
Wave 4: Waist circumference (cm)	$\bar{x}$ = 89.0 (SD = 14.1)	$\bar{x}$ = 81.8 (SD = 11.2)
Wave 4: Height (cm); Wave 1 used for WHtR	N/A	N/A
Wave 4: WHtR > 0.5 (has abdominal obesity)	72.7% (*N* = 651)	27.2% (*N* = 275)
Wave 4: WHtR (continuous, not standardized)	$\bar{x}$ = 0.55 (SD = 0.09)	$\bar{x}$ = 0.47 (SD = 0.06)
Wave 1 to Wave 4: WHtR changes		
From ≤ 0.5 to > 0.5 (increase)	17.6% (*N* = 156)	12.4% (*N* = 125)
From > 0.5 to ≤ 0.5 (decrease)	9.1% (*N* = 83)	13.7% (*N* = 138)
Generalized obesity		
Wave 1: Body mass index (kg/m^2)[a]		
Underweight (≤ 18.5)	2.6% (*N* = 23)	7.2% (*N* = 73)
Normal range (> 18.5 to ≤ 25)	34.5% (*N* = 309)	63.5% (*N* = 641)
Overweight (> 25 to ≤ 30)	30.4% (*N* = 272)	22.2% (*N* = 224)
Obese (> 30)	32.5% (*N* = 291)	7.1% (*N* = 72)
Wave 4: Body mass index (kg/m^2)[a]		
Underweight (≤ 18.5)	1.5% (*N* = 13)	3.6% (*N* = 36)
Normal range (> 18.5 to ≤ 25)	27.2% (*N* = 243)	64.8% (*N* = 654)
Overweight (> 25 to ≤ 30)	42.7% (*N* = 382)	26.1% (*N* = 264)
Obese (> 30)	28.7% (*N* = 257)	5.5% (*N* = 56)
Internal migration		
Waves 1–4: Number of waves as migrant		
0	46.7% (*N* = 418)	34.4% (*N* = 347)
1	13.6% (*N* = 122)	12.4% (*N* = 125)
2	6.6% (*N* = 59)	6.8% (*N* = 69)
3	13.2% (*N* = 118)	14.7% (*N* = 148)
4	19.9% (*N* = 178)	31.8% (*N* = 321)
Waves 1–4: Migration location		
Remained in Agincourt W1-4	46.7% (*N* = 418)	34.4% (*N* = 347)
Migrant elsewhere in SA except Gauteng	29.8% (*N* = 267)	33.7% (*N* = 340)
Migrant in Gauteng	23.5% (*N* = 210)	32.0% (*N* = 323)
Controls		
Age at Study Initial Household Visit		
18–24	37.4% (*N* = 335)	39.3% (*N* = 397)
25–29	23.2% (*N* = 208)	26.9% (*N* = 272)

(Continues)

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TABLE 1 | (Continued)

	Women ($N_{max}=895$)	Men ($N_{max}=1010$)
30–34	23.9% ($N=214$)	21.3% ($N=215$)
35–39	15.4% ($N=138$)	12.5% ($N=126$)
Other household residents		
0	33.4% ($N=299$)	55.8% ($N=564$)
1	7.7% ($N=69$)	9.2% ($N=93$)
2	12.6% ($N=113$)	9.7% ($N=98$)
3	14.5% ($N=130$)	9.1% ($N=92$)
4+	31.7% ($N=284$)	16.1% ($N=163$)
Wave 4: Employment status		
Unemployed	52.9% ($N=473$)	36.9% ($N=373$)
Employed-informal sector	39.0% ($N=349$)	52.5% ($N=530$)
Employed-formal sector	8.2% ($N=73$)	10.6% ($N=107$)
Wave 4: Self-reported HIV+ status	23.8% ($N=213$)	6.7% ($N=68$)
Wave 4: Self-reported diabetes and/or hypertension	5.4% ($N=48$)	1.8% ($N=18$)
Wave 4: Eats any fast food meals in an average week	64.2% ($N=573$)	71.9% ($N=726$)

Note: Due to rounding, percentages might not add up to 100.
Abbreviations: SA = South Africa.
[a]For descriptive context only, not employed in inferences.

and differences in fast food meal consumption as they relate to internal migration. Among women (Table 2), a higher percentage of migrant women in general, and those who resided in Gauteng at some point during Waves 1–4 (including by location), crossed the WHtR threshold between Waves 1 and 4 from ≤ 0.5 to >0.5 (and were identified as having incident abdominal obesity), compared to nonmigrant women and migrants who were elsewhere in South Africa besides Gauteng (χ^2 test, $p<0.001$).

Large differences in fast food meal consumption by migrant status exist, at least at the bivariate level. Internal migrant women reported remarkably higher consumption of any fast food in an average week than those who did not migrate ($p<0.001$). A larger proportion of women who resided in Gauteng between Waves 1 and 4 reported eating a fast food meal in an average week than women who did not migrate to Gauteng ($p<0.01$). These same bivariate relationships hold for men (Table 3).

3.2 | Regression Results-Women

The logistic regressions in Table 4 show the positive associations between the two different measures of internal migration among women and the log odds of having abdominal obesity. After accounting for prior (Wave 1) abdominal obesity and additional, nested controls in Models 1–4, there are consistent, strong associations for women between being an internal migrant—away from the Agincourt study area—for all four waves of MHFUS and the log odds of having abdominal obesity, relative to staying in the Agincourt study area the entire time. However, the inclusion of whether female participants eat any fast food meals in an average week—relative to never doing so—in Model 4 noticeably reduces the magnitude of that migration coefficient (from 0.90 in Model 3 to 0.84 in Model 4, $p<0.01$).

Models 5–8 focus on migratory destination. Migrant women who resided in Gauteng province at least once during Waves 1–4 experienced higher log odds of having abdominal obesity, relative to those who never migrated (remained in the Agincourt study area) during that time *as well as* migrant women in another location in South Africa outside of Gauteng (identified in post-regression testing), in Models 5–8. The inclusion of whether female participants eat any fast food meals in an average week—relative to never doing so—in Model 8 also diminishes the association between migration and the log odds of having abdominal obesity.

The OLS regressions in Table 5 show the positive associations between the two different measures of internal migration among women and the standard deviation changes in the continuous WHtR outcome (Wave 4). As in Table 4 after controlling for Wave 1 abdominal obesity and additional, nested controls in Models 1–2, there are consistent associations for women in Table 5 between being an internal migrant—away from the Agincourt study area—for all four waves of MHFUS and increases in WHtR scores, relative to staying in the Agincourt study area the entire time between Waves 1 and 4; these associations drop out of conventional statistical significance indicators in Models 3 ($p=0.102$) and 4 ($p=0.173$). Even so, as found in the logistic regression models, the inclusion of whether female participants eat any fast food meals in an average week—relative to never doing so—in Model 4 of these OLS models still reduces the magnitude of that migration coefficient (from 0.15 in Model 3 to 0.13 in Model 4). Unlike the direction of effects found

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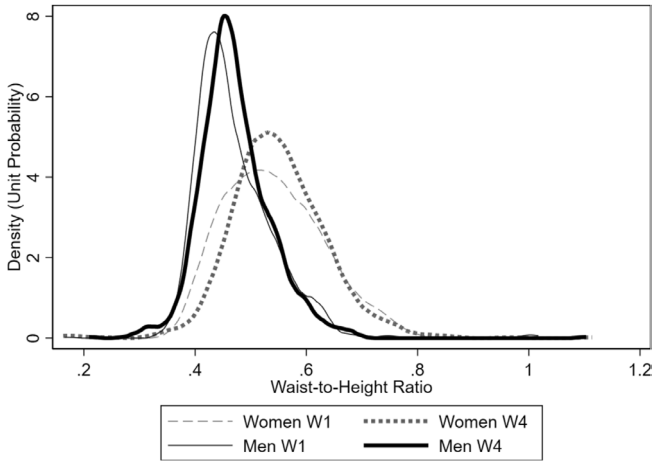


FIGURE 1 | Kernel density plots depicting waist-to-height ratio distributions by sex and wave.

in Table 4, in Table 5, migrant women who resided in Gauteng province at least once, or elsewhere (except for Gauteng) during Waves 1–4 did not have higher WHtR scores (at conventional statistical significance indicators), relative to those who never migrated to Gauteng during that time, in Models 5–8. The addition of controlling for fast food consumption appears to continue to attenuate the magnitude of the internal migration coefficients in Model 8.

3.3 | Regression Results-Men

The logistic regressions in Table 6 show the positive associations between the two different measures of internal migration among men and the log odds of having abdominal obesity, in the same manner as the regressions in the female stratified analyses above. Upon controlling for Wave 1 abdominal obesity and additional, nested controls in Models 1–3, there are consistent, strong associations for men between being an internal migrant—away from the Agincourt study area—for all four waves of MHFUS and the log odds of having abdominal obesity, relative to staying in Agincourt the entire time. Further, these positive internal migration associations with having abdominal obesity extend to men who were migrants for three waves as well (Models 2–3). Once again, the inclusion of whether participants eat any fast food meals in an average week—relative to never doing so—in Model 4 noticeably reduces the magnitude of the migration coefficients by waves as an internal migrant (0.96 in Model 3 to 0.88 in Model 4).

Men who were identified as migrants in Gauteng province at least once during Waves 1–4 experienced higher log odds of having abdominal obesity, relative to those who never migrated to Gauteng during that time *as well as* those who migrated to another location in South Africa outside of Gauteng (identified in post-regression testing), in Models 5–8. The inclusion of fast food meals as a mediator in Model 8 also diminishes the association between migration and the log odds of having abdominal obesity.

As with women in Table 5, the OLS regressions in Table 7 also show the positive associations between the two different

TABLE 2 | Bivariate descriptives between migration, abdominal obesity, and fast food meals, female participants ($N = 895$).

	Nonmigrant during Waves 1–4	Migrant during Waves 1–4	χ^2 test result	Remained in Agincourt Waves 1–4	Migrant elsewhere in SA except Gauteng Waves 1–4	Migrant in Gauteng Waves 1–4	χ^2 test result
Wave 1–4: Increase in WHtR from ≤0.5 to >0.5	12.4% ($N = 52$)	21.8% ($N = 104$)	$p < 0.001$	12.4% ($N = 52$)	19.1% ($N = 51$)	25.2% ($N = 53$)	$p < 0.001$
Wave 4: Eats any fast food meals in an average week	47.4% ($N = 197$)	78.8% ($N = 376$)	$p < 0.001$	47.4% ($N = 197$)	77.2% ($N = 206$)	81.0% ($N = 170$)	$p < 0.001$

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TABLE 3 | Bivariate descriptives between migration, obesity, and fast food meals, male participants.

	Nonmigrant during Waves 1–4	Migrant during Waves 1–4	χ^2 test result	Remained in Agincourt Waves 1–4	Migrant elsewhere in SA except Gauteng Waves 1–4	Migrant in Gauteng Waves 1–4	χ^2 test result
Wave 1–4: increase in WHtR from ≤0.5 to >0.5	5.5% ($N=19$)	16.0% ($N=106$)	$p<0.001$	5.5% ($N=19$)	12.4% ($N=42$)	19.8% ($N=64$)	$p<0.001$
Wave 4: Eats any fast food meals in an average week	49.3% ($N=171$)	83.7% ($N=555$)	$p<0.001$	49.3% ($N=171$)	77.9% ($N=265$)	89.8% ($N=290$)	$p<0.001$

measures of internal migration among men and the standard deviation changes in the continuous WHtR outcome (Wave 4). In Table 7, after including nested controls in Models 1–4, there are consistent, strong associations between internal migration (three or four waves) and increases in WHtR scores, relative to remaining in the Agincourt study area the entire time between Waves 1 and 4. Unlike the associations found in the OLS models for women (Table 5), men who were migrants in Gauteng province at least once during Waves 1–4 had conventionally statistically significant higher WHtR scores, relative to those who never migrated to Gauteng during that time *and* those who migrated to another location in South Africa outside of Gauteng (identified in post-regression testing), in Models 5–8.

In Tables 6 and 7, there is also evidence that fast food meals are weakly positively associated with having abdominal obesity among men (above all other observed factors).

4 | Discussion

The longitudinal MHFUS data provide insight into the increasingly relevant link between internal migration and obesity in South Africa, in a time of continued urbanization. A fundamental flaw of much previous LMIC research is that scholars have been limited in comparing urban-born residents to those moving into urban areas, and often with no indication of development over time. Our study and the MHFUS data allow us to compare rural nonmigrants with outmigrants from the same home locale (the Agincourt HDSS study area)—including migrants to the most densely populated urban area in South Africa (Gauteng province) *and* accounting for potential location changes over four survey waves. The fact that we collected longitudinal data from a rural origin migrant population also helps us uncover the consequences of urbanization over time within the broader nutrition transition scholarship in LMICs.

For women, being away from one's rural home as a migrant for longer periods—wherever that new location may be—is most consistently linked to higher chances of having abdominal obesity, even after accounting for fast food meal consumption. This relationship is not quite as strong for those who have moved to the highly urbanized province of Gauteng (based on the magnitude and statistical significance of coefficients), even before accounting for fast food meal consumption. For women, many non-Gauteng migration spells could be short distance, rural–rural or rural–small town migrations within Mpumalanga province for marriage, which could exert different influences on the chances of having abdominal obesity compared to a more substantial life change move to Gauteng; this is an area for future exploration within South Africa. However, for men, both measures of internal migration (number of waves as a migrant and ever migrating to Gauteng) are consistently, similarly strongly (and robustly) associated with the chances of having abdominal obesity—considerably more so than women—even though fast food consumption appears to attenuate the influence of being a migrant on the log odds of having abdominal obesity. Future work will focus on performing path analyses to test the direct and indirect effects

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TABLE 4 | Lagged-dependent variable logistic regressions predicting the log odds of women's ($N = 885$) Wave 4 abdominal obesity (binary WHtR indicator).

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wave 1: WHtR > 0.5 (Ref. ≤ 0.5)	1.89***	1.78***	1.78***	1.78***	1.90***	1.77***	1.77***	1.77***
Waves 1–4: Number of waves as migrant (Ref. 0)								
1	0.32	0.26	0.25	0.21				
2	0.32	0.36	0.35	0.36				
3	0.18	0.14	0.13	0.11				
4	1.10***	0.91**	0.90**	0.84**				
Waves 1–4: Migration location (Ref. Remained in Agincourt W1–4)								
Migrant elsewhere in SA except Gauteng					0.34#	0.17	0.17	0.14
Migrant in Gauteng					0.81***	0.69**	0.68*	0.64*
Age at study initial household visit (Ref. 18–24)								
25–29		0.46*	0.48*	0.49*		0.53*	0.55*	0.55*
30–34		0.70**	0.76**	0.76**		0.75**	0.81**	0.81***
35–39		0.67*	0.76*	0.78*		0.72*	0.80**	0.82**
Other household residents (Ref. 0)								
1		0.41	0.40	0.40		0.30	0.29	0.30
2		−0.17	−0.17	−0.14		−0.26	−0.26	−0.21
3		−0.37	−0.36	−0.31		−0.48	−0.47	−0.40
4+		−0.22	−0.22	−0.18		−0.32	−0.31	−0.25
Wave 4: Employment status (Ref. Unemployed)								
Employed-formal sector		0.08	0.07	0.04		0.13	0.11	0.08
Employed-informal sector		−0.09	−0.09	−0.09		−0.09	−0.09	−0.10
Wave 4: Self-reported HIV+ status (Ref. not HIV+)			−0.21	−0.17			−0.20	−0.16
Wave 4: Self-reported diabetes and/or hypertension (Ref. Not reported)			−0.10	−0.10			−0.09	−0.09
Wave 4: Eats any fast food meals in an average week (Ref. Never)				0.23				0.27
Constant	−0.33*	−0.47	−0.43	−0.59#	−0.33*	−0.41	−0.38	−0.58#
Observations	885	885	885	885	885	885	885	885
Pseudo R^2	0.147	0.164	0.165	0.166	0.140	0.161	0.162	0.164

Note: Unstandardized coefficients are presented. ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; #$p < 0.10$.
Abbreviations: SA = South Africa

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TABLE 5 | Lagged-dependent variable OLS regressions predicting women's ($N = 885$) Wave 4 abdominal obesity (continuous, standardized).

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wave 1: WHtR (continuous, standardized)	0.60***	0.59***	0.58***	0.58***	0.60***	0.59***	0.58***	0.58***
Waves 1–4: Number of waves as migrant (Ref. 0)								
1	0.01	0.02	0.02	0.00				
2	0.08	0.08	0.09	0.09				
3	0.01	0.02	0.02	0.01				
4	0.16*	0.16#	0.15	0.13				
Waves 1–4: Migration location (Ref. Remained in Agincourt W1–4)								
Migrant elsewhere in SA except Gauteng					0.06	0.06	0.06	0.05
Migrant in Gauteng					0.10	0.09	0.09	0.07
Age at study initial household visit (Ref. 18–24)								
25–29		0.17*	0.18*	0.18*		0.18*	0.19*	0.19*
30–34		0.02	0.04	0.04		0.04	0.05	0.05
35–39		0.08	0.10	0.11		0.09	0.11	0.12
Other household residents (Ref. 0)								
1		0.01	0.01	0.01		0.01	0.01	0.01
2		−0.13	−0.13	−0.11		−0.14	−0.13	−0.12
3		−0.04	−0.04	−0.02		−0.05	−0.05	−0.03
4+		−0.01	−0.01	0.01		−0.02	−0.02	0.01
Wave 4: Employment status (Ref. Unemployed)								
Employed-formal sector		−0.08	−0.08	−0.09		−0.07	−0.07	−0.09
Employed-informal sector		−0.03	−0.02	−0.02		−0.02	−0.02	−0.02
Wave 4: Self-reported HIV+ status (Ref. not HIV+)			−0.07	−0.06			−0.07	−0.06
Wave 4: Self-reported diabetes and/or hypertension (Ref. Not reported)			0.09	0.10			0.10	0.10
Wave 4: Eats any fast food meals in an average week (Ref. Never)				0.10				0.10
Constant	0.20***	0.20*	0.21*	0.14	0.20***	0.20*	0.21*	0.13
Observations	885	885	885	885	885	885	885	885
R^2	0.350	0.357	0.358	0.360	0.348	0.355	0.356	0.358

Note: Unstandardized coefficients presented (except Wave 1 WHtR). ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; #$p < 0.10$.
Abbreviations: SA = South Africa.

in the context of the temporal relationships. This stronger association between internal migration and abdominal obesity in men, coupled with their lower overall likelihood of having clinical and public health encounters, aside from emergencies, indicates real concern about their cardiometabolic sequelae as abdominal obesity increases in South Africa.

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TABLE 6 | Lagged-dependent variable logistic regressions predicting the log odds of men's ($N = 1005$) Wave 4 abdominal obesity (binary WHtR indicator).

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wave 1: WHtR > 0.5 (Ref. ≤ 0.5)	1.55***	1.46***	1.47***	1.45***	1.63***	1.49***	1.50***	1.47***
Waves 1–4: Number of waves as migrant (Ref. 0)								
1	0.23	0.38	0.39	0.36				
2	−0.16	−0.04	−0.04	−0.07				
3	0.38	0.48#	0.49#	0.42				
4	0.88***	0.95***	0.96***	0.88***				
Waves 1–4: Migration location (Ref. Remained in Agincourt W1–4)								
Migrant elsewhere in SA except Gauteng					0.26	0.29	0.29	0.24
Migrant in Gauteng					0.87***	0.90***	0.92***	0.84***
Age at study initial household visit (Ref. 18–24)								
25–29		0.09	0.08	0.10		0.21	0.20	0.22
30–34		0.59**	0.59**	0.61**		0.73***	0.72***	0.74***
35–39		0.11	0.09	0.12		0.27	0.25	0.27
Other household residents (Ref. 0)								
1		0.13	0.12	0.11		0.12	0.11	0.10
2		−0.13	−0.12	−0.09		−0.16	−0.16	−0.13
3		0.21	0.22	0.23		0.14	0.15	0.16
4+		0.22	0.22	0.24		0.12	0.12	0.14
Wave 4: Employment status (Ref. Unemployed)								
Employed-formal sector		0.04	0.04	0.01		0.13	0.13	0.09
Employed-informal sector		0.01	0.00	−0.02		−0.00	−0.01	−0.03
Wave 4: Self-reported HIV+ status (Ref. not HIV+)			0.13	0.13			0.13	0.13
Wave 4: Self-reported diabetes and/or hypertension (Ref. Not reported)			−0.19	−0.22			−0.15	−0.17
Wave 4: Eats any fast food meals in an average week (Ref. Never)				0.25				0.25
Constant	−1.92***	−2.21***	−2.22***	−2.36***	−1.96***	−2.29***	−2.30***	−2.43***
Observations	1005	1005	1005	1005	1005	1005	1005	1005
Pseudo R^2	0.120	0.129	0.129	0.130	0.117	0.129	0.129	0.130

Note: Unstandardized coefficients are presented. ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; #$p < 0.10$.
Abbreviations: SA = South Africa.

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TABLE 7 | Lagged-dependent variable OLS regressions predicting men's ($N = 1005$) Wave 4 abdominal obesity (continuous, standardized).

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wave 1: WHtR (continuous, standardized)	0.34***	0.32***	0.32***	0.32***	0.36***	0.32***	0.32***	0.32***
Waves 1–4: Number of waves as migrant (Ref. 0)								
1	0.04	0.09	0.08	0.07				
2	−0.02	0.02	0.02	0.01				
3	0.16*	0.19*	0.19*	0.17*				
4	0.29***	0.30***	0.29***	0.27***				
Waves 1–4: Migration location (Ref. Remained in Agincourt W1–4)								
Migrant elsewhere in SA except Gauteng					0.09#	0.10	0.10	0.08
Migrant in Gauteng					0.27***	0.27***	0.27***	0.24***
Age at study initial household visit (Ref. 18–24)								
25–29		−0.02	−0.02	−0.01		0.01	0.01	0.02
30–34		0.09	0.09	0.09		0.13*	0.12*	0.13*
35–39		0.14#	0.14#	0.15*		0.19**	0.19*	0.19**
Other household residents (Ref. 0)								
1		0.04	0.04	0.04		0.04	0.04	0.03
2		0.04	0.03	0.04		0.02	0.02	0.03
3		0.08	0.08	0.08		0.06	0.06	0.06
4+		0.08	0.07	0.08		0.05	0.04	0.05
Wave 4: Employment status (Ref. Unemployed)								
Employed-formal sector		0.10#	0.10#	0.08		0.12*	0.12*	0.10*
Employed-informal sector		0.09	0.09	0.09		0.08	0.09	0.08
Wave 4: Self-reported HIV+ status (Ref. not HIV+)			−0.02	−0.02			−0.02	−0.02
Wave 4: Self-reported diabetes and/or hypertension (Ref. Not reported)			0.22	0.22			0.23	0.23

(Continues)

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TABLE 7 | (Continued)

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wave 4: Eats any fast food meals in an average week (Ref. Never)				0.08				0.09#
Constant	−0.44***	−0.58***	−0.58***	−0.62***	−0.43***	−0.59***	−0.59***	−0.64***
Observations	1005	1005	1005	1005	1005	1005	1005	1005
R^2	0.190	0.200	0.201	0.203	0.183	0.198	0.199	0.202

Note: Unstandardized coefficients are presented (except Wave 1 WHtR). ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; #$p < 0.10$.
Abbreviations: SA = South Africa

Thus, for women, living away from one's rural home in Agincourt for an extended period—four MHFUS waves—matters more than greater urban exposure to fast food, per se, as is the case in Gauteng; being an internal migrant for longer rather than where appears to be a slightly more important determinant for having abdominal obesity among women. In short, there are likely different conditions leading to having abdominal obesity for female internal migrants than for their male counterparts; the generally weaker magnitude migration coefficients compared to men support this.

A greater understanding of the stressors (including crime-related stressors, specifically in Gauteng too), caregiving and domestic help available, work–life balance, and more detailed migration patterns for female migrants is necessary to unpack differences in obesity and health, generally. The timing of childbirth, movement in and out of the workforce, the reasons for food choices, and time use pertaining to cooking healthier food vs. serving processed foods (Jaacks et al. 2017) are worth exploring in the context of obesity risks as well. Though not exclusive to women, nutrition scholars have long pointed to the complex relationship between changing beauty standards, obesity, and nutrition transitions in SSA (Bosire et al. 2020; Mchiza and Parker 2020; Puoane et al. 2005; Renzaho 2004). Demographers and public health scholars have—to our knowledge—never longitudinally measured self-perceived body image, nutrition, and migration in SSA, let alone South Africa; if done carefully and correctly, this could help explain additional, currently unobserved, heterogeneity in gendered distinctions linking migration, urban residence, and obesity. This line of inquiry would benefit from formal mediation models about how these factors directly and/or indirectly influence abdominal obesity along with individuals living away from their rural origins.

The nature of migration for Black men—which has long been associated with mining and commercial agricultural labor, as well as low-wage, long-hour, blue-collar urban jobs—may be conducive to fast food consumption patterns linked to abdominal obesity. There is also the possibility that, because the levels of abdominal obesity among men are much lower at Wave 1, men have more "room" in the univariate frequency distribution of WHtR for the modeled influences to affect changes in abdominal obesity. With almost two-thirds of women already having abdominal obesity, the sample may have reached a plateau level of abdominal obesity, making it harder, with fewer incident cases, to detect the change in status over time; this is also problematic for South Africa's population health.

Our analyses are not without limitations. First, we only have anthropometric indicators at Waves 1 and 4, per the MHFUS study design; Waves 2 and 3 interviews were largely conducted over the phone, and physical measurements were not part of the study protocol for these telephone waves (Ginsburg et al. 2024). Therefore, the two-wave (2019 and 2020) gap excludes the potential for capturing additional fluctuation in abdominal obesity not reflected in Waves 1 (2018) and 4 (2022). Second, while we have participants' locations recorded for each wave, the moment-to-moment geographical location of our sample members is beyond what could be captured in MHFUS; nevertheless, the MHFUS panel structure of residence histories and minimal sample attrition are the leading standard for this type of data in SSA. Third, we estimate abdominal obesity via the WHtR but do not include inferences of generalized obesity through BMI. They are positively associated, but BMI is less indicative of abdominal obesity and future cardiometabolic disease risks that we focus on in a society undergoing a nutritional transition. Nonetheless, comparing WHtR and BMI within the MHFUS sample would be a valuable pursuit in future research. Fourth, the nature of our data is observational, and we cannot assert causal inferences for migrant status and abdominal obesity; migration experiences cannot be randomly assigned, as an experimental design would warrant. Fifth, though outside the scope of this paper, we could exploit mediation analyses to link one's diet and food environment to abdominal obesity among internal migrants in future work.

We also acknowledge that the longitudinal capture of waist circumference and height, and in wave intervals years apart, could lead to measurement error. Given that the MHFUS sample of 18–40 year-olds at the initial household visit was effectively at their full height, they should not have increased or decreased in height a few years later. In sensitivity analyses (not presented), we identified discrepancies in within-individual height measurement between Waves 1 and 4. When comparing our analyses presented in this manuscript (with Wave 1 as the "correct" height) to Wave 4, or both Waves 1 and 4 being employed as the "correct" height, some differences in coefficient size and some p values in regression models arise; the main results did not substantively change (please see Tables S1–S6 for estimates with Wave 1 height used for Wave 1 WHtR and Wave 4 height used for Wave 4 WHtR, where appropriate). Moreover, fieldwork managers were unable to attribute any potential differences in measurement to any

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systematic reasons, such as equipment, slouching, and hairstyles (among many other possibilities). Because MHFUS fieldworkers were not randomly assigned participants, it is impossible to assess—with certainty—whether fieldworkers themselves induced any error into anthropometric measurement. Nevertheless, when utilizing Wave 1 height as the "correct" height—as we present in this manuscript—and adding Wave 1 fieldworker fixed effects to our models, the Wave 1 fieldworker fixed effects collectively explain very little or effectively nothing based on post-regression tests (and they are excluded from our presented regression models, in part, because of this). Wave 4 fieldworker effects were somewhat more influential when employed in alternative models, reflecting greater variation in height measurements in Wave 4 and our decision to employ Wave 1 height when calculating WHtR at Waves 1 *and* 4 (as noted in Section 2).

5 | Conclusion

As the burden of disease shifts toward chronic, noncommunicable diseases, especially cardiometabolic diseases, in South Africa, this research reiterates that gender matters—likely for very different reasons—in efforts to prevent obesity or reverse trends among Black South African migrants and rural dwellers in efforts to inform evidence-based policy. Our research from the longitudinal MHFUS data shows the importance of having even more precise health data linking anthropometric indicators, biomarkers, and self-reported health to related obesity comorbidities. Such measures can provide more informative estimates of the prevalence of obesity and the trajectory of individuals' weight—offering context relevant to clinicians as well as public health scholars. Future research in SSA—and LMICs—should incorporate geographic location, residential change, and analyses of the determinants of metabolic syndrome and/or other widely recognized indicators of obesity too.

People are moving toward urban areas, *within their own countries*, in an increasingly urbanized world, and one in which processed food is becoming more readily available. Within the larger global picture of rising obesity rates (Murray 2024), the growing importance of understanding internal migration and health outcomes—including obesity (Abubakar et al. 2018)—needs to be at the forefront of public health research.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request. The data are not publicly available due to privacy or ethical restrictions. Please contact the corresponding author for further information.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

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Appendix A

TABLE A1 | Differences between female participants who completed all four waves, but by different Wave 1 modality ($N = 1121$).

	Analytic sample: In-person Wave 1	Excluded sample: Phone in Wave 1	χ^2 test result
Internal migration			
Waves 1–4: Number of waves as migrant			$p < 0.001$
0	46.7%	8.9%	
1	13.6%	8.4%	
2	6.6%	4.9%	
3	13.2%	14.6%	
4	19.9%	63.3%	
Waves 1–4: Migration location			
Remained in Agincourt W1–4	46.7%	8.9%	$p < 0.001$
Migrant elsewhere in SA except Gauteng	29.8%	55.3%	
Migrant in Gauteng	23.5%	35.8%	
Controls			
Age at study initial household visit			$p < 0.01$
18–24	37.4%	29.2%	
25–29	23.2%	34.1%	
30–34	23.9%	18.6%	
35–39	15.4%	18.1%	
Other household residents			$p < 0.001$
0	33.4%	56.2%	
1	7.7%	9.3%	
2	12.6%	9.3%	
3	14.5%	11.1%	
4+	31.7%	14.2%	
Wave 4: Employment status			$p < 0.01$
Unemployed	52.9%	41.2%	
Employed-informal sector	39.0%	51.3%	
Employed-formal sector	8.2%	7.5%	
Wave 4: Self-reported HIV+ status	23.8%	14.6%	$p < 0.01$
Wave 4: Self-reported diabetes and/or hypertension	5.4%	4.4%	$p = 0.57$
Wave 4: Eats any fast food meals in an average week	64.2%	78.8%	$p < 0.001$
Observations	895	226	

Note: Due to rounding, percentages might not add up to 100. Abdominal obesity measures excluded for comparison because Wave 1 phone participants did not have anthropometrics collected.
Abbreviations: SA = South Africa.

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TABLE A2 | Differences between male participants who completed all four waves, but by different Wave 1 modality ($N = 1356$).

	Analytic sample: In-person Wave 1	Excluded sample: Phone in Wave 1	χ^2 test result
Internal migration			
Waves 1–4: Number of waves as migrant			$p < 0.001$
0	34.4%	6.7%	
1	12.4%	4.9%	
2	6.8%	4.1%	
3	14.7%	12.1%	
4	31.8%	72.3%	
Waves 1–4: Migration location			
Remained in Agincourt W1–4	34.4%	6.7%	$p < 0.001$
Migrant elsewhere in SA except Gauteng	33.7%	59.8%	
Migrant in Gauteng	32.0%	33.5%	
Controls			
Age at study initial household visit			$p < 0.01$
18–24	39.3%	28.3%	
25–29	26.9%	31.8%	
30–34	21.3%	23.4%	
35–39	12.5%	16.5%	
Other household residents			$p < 0.001$
0	55.8%	73.7%	
1	9.2%	9.0%	
2	9.7%	6.7%	
3	9.1%	4.3%	
4+	16.1%	6.4%	
Wave 4: Employment status			$p < 0.01$
Unemployed	36.9%	26.3%	
Employed-informal sector	52.5%	64.5%	
Employed-formal sector	10.6%	9.3%	
Wave 4: Self-reported HIV+ status	6.7%	2.3%	$p < 0.01$
Wave 4: Self-reported diabetes and/or hypertension	1.8%	0.9%	$p = 0.23$
Wave 4: Eats any fast food meals in an average week	71.9%	78.8%	$p < 0.001$
Observations	1010	346	

Note: Due to rounding, percentages might not add up to 100. Abdominal obesity measures excluded for comparison because Wave 1 phone participants did not have anthropometrics collected.

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