ORIGINAL ARTICLE

Socioeconomic gradients in chronic disease risk behaviors in a population-based study of older adults in rural South Africa

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Abstract

Objectives To investigate the associations between household wealth, household consumption, and chronic disease risk behaviors among older adults in rural South Africa.

Methods Data were from baseline assessments of 5059 adults aged ≥ 40 in the population-based "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" in 2015. Confounder-adjusted prevalence ratios were estimated for the associations between each of household wealth and household consumption quintiles with low moderate-to-vigorous physical activity (MVPA), current smoking, frequent alcohol intake, and overweight/obese body mass index (BMI).

Results Low MVPA and overweight/obese BMI were common (57% and 58%, respectively), and linearly increased in prevalence across household wealth quintiles. Low MVPA decreased and overweight/obese BMI increased in prevalence across household consumption quintiles. Smoking and frequent alcohol intake were rare (9% and 6%, respectively); they decreased in prevalence across wealth quintiles, but did not vary by consumption quintile.

Conclusions Chronic disease risk behaviors are socioeconomically graded among older, rural South African adults. The high prevalence of overweight and obesity in rural South Africa is a public health concern requiring urgent attention.

Keywords South Africa · Aging · Rural · Physical activity · Smoking · Alcohol · Body mass index · Socioeconomic inequalities

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Introduction

The population of South Africa is rapidly aging. Life expectancy at birth in 2015 was 59.0 years for men and 66.0 years for women, an increase of more than 10 years for both genders since the peak of the HIV/AIDS epidemic in 2005 (World Health Organization 2017a). Correspondingly, the burdens of aging-related chronic diseases such as Alzheimer's disease and related dementias, cardiovascular disease, and cancers are rising dramatically (Kabudula et al. 2017; Prince et al. 2015). A substantial proportion of these chronic diseases can be prevented through modifiable risk-related behaviors such as physical activity, diet, smoking, and alcohol consumption (American Cancer Society 2017; Wiseman 2008; McCullough et al. 2011). The investigation and reduction of socioeconomic gradients in these behaviors among aging populations is essential for future prevention efforts to be as equitable and effective as possible.

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Although a small body of evidence from a range of countries shows socioeconomic gradients in health-related behaviors (Caldwell et al. 2008; Tehranifar et al. 2009; Akinyemiju et al. 2017; National Department of Health 2017), the socioeconomic drivers of chronic disease risk behaviors in South Africa's older rural population are unknown. An important consideration when measuring socioeconomic status among older, low-income populations, such as in rural South Africa, is selection of the appropriate socioeconomic measures (Howe et al. 2012; Grundy and Holt 2011). Many older adults in rural South Africa do not work, and for those who do, income and employment can be sporadic, informal, and difficult to report in a simple manner (Grundy and Holt 2011; Statistics South Africa 2014). Measures of household wealth, as indexed by housing conditions and assets rather than financial wealth, as well as household consumption have therefore been advocated for in this context, rather than measures of income or occupation (Headey 2008). As household consumption directly reflects daily expenditures, food production, and assistance from government support programs, it is considered to be more accurate measure of daily household welfare than income (Howe et al. 2012). The relationships between household wealth, consumption, and chronic disease risk behaviors in the older population of rural South Africa are unknown.

We therefore aimed to estimate the independent associations between each of household wealth and consumption quintiles and four chronic disease risk behaviors (moderate-to-vigorous intensity physical activity, overweight/obese body mass index, smoking, and frequent alcohol intake) in a population-based study of older adults in rural South Africa.

Methods

Study Population

Data were from baseline assessments collected in 2015 in "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" (HAALSI), a population-based study of 5059 men and women aged ≥ 40 years in the Agincourt Health and Socio-Demographic Surveillance System (HDSS) area covering approximately 116,000 people residing in 31 villages in Mpumalanga province, South Africa (response rate = 85.9%) (Gómez-Olivé et al. 2018). HAALSI is harmonized with the US Health and Retirement Study and other international cohort studies of aging (see: https://g2aging.org/). The demographic profile of the Agincourt region population is typical of rural South Africa (Gómez-Olivé et al. 2018). Although the social and economic situation of

the region has improved since the end of Apartheid in 1994, the region has a history of systematic racism, poor infrastructure development, and low access to education, employment, and other economic opportunities (United Nations 1963; Christie and Collins 1982).

Data collection

In-person interviews were conducted with trained, local fieldworkers in the participants' homes in the local Shangaan language using computer-assisted personal interviews (CAPI). All interview measures were translated from English and back-translated to ensure reliability. The interview covered broad topics including socio-demographic factors, health status, social networks, health risk behaviors, and living conditions (Gómez-Olivé et al. 2018).

Measures

Household wealth and consumption

Household wealth and consumption were assessed using validated measures from the Demographic and Health Surveys (DHS) and the Longitudinal Aging Study in India (LASI) (Rutstein and Johnson 2004; Arokiasamy et al. 2012). Using the DHS methodology, we constructed a wealth index from interview data on housing, durable and non-durable assets, land ownership, and livestock (Rutstein and Johnson 2004; Arokiasamy et al. 2012). After identifying variables with variation across households, we used principal components analysis (PCA) to create the wealth index and group households into quintiles of household wealth (Riumallo-Herl et al. 2017). Household consumption was calculated by aggregating data on regular and non-regular expenditures of different food products, goods, and services as well as home-based food production. Consumption is a more appropriate measure of living standards in developing countries when compared to income, as it captures what is consumed by the household, whether it is produced or purchased (Deaton and Grosh 2000). We scaled the level of consumption according to the number of people living in the household size (Hentschel and Lanjouw 1996). For the analyses of smoking and drinking behaviors, we excluded expenditures on tobacco and alcohol from the household consumption index. As with the wealth index, households were then categorized into quintiles of household consumption.

Chronic disease risk behaviors

Moderate-to-vigorous intensity physical activity, smoking, alcohol consumption, and body mass index were selected as the outcome variables of interest due to their strong and

consistently observed associations with risks of several chronic diseases and all-cause mortality (Ford et al. 2011; Khaw et al. 2008; Kvaavik et al. 2011). All were assessed during the in-person interview. We were interested in identifying the proportions of the HAALSI study population who met evidence-based public health guidelines for these behaviors and body mass index, overall and according to socioeconomic position. We therefore coded the chronic disease risk behaviors and body mass index as binary outcome variables according to evidence-based South African national public health guidelines and internationally recognized recommendations for chronic disease risk reduction (Wiseman 2008; American Cancer Society 2017; World Health Organization 2010, 2017b, 2018). The variable measurements and coding are described below:

Moderate-to-vigorous physical activity (MVPA)

Physical activity was measured using the WHO's Global Physical Activity Questionnaire (GPAQ), which has been validated for use in low-income settings (Bull et al. 2009). Participants reported the number of hours and minutes in the average week that they spent walking or bicycling and in moderate or vigorous intensity activity for work and for recreation (Bull et al. 2009). Minutes per week of total moderate-to-vigorous intensity physical activity (MVPA) was calculated from these responses, including walking and bicycling. The binary outcome variable indicated the harmful and protective MVPA categories, respectively: < 210 versus ≥ 210 min per week of MVPA (equivalent to 30 min per day), based on the South African Department of Health recommendation and the World Cancer Research Fund recommendation for cancer prevention (Wiseman 2008).

Smoking

Participants were classified as current smokers versus former/never smokers, based on their answer to the question "Do you currently use tobacco products?", reflecting the harmful versus protective categories of smoking.

Alcohol consumption

Participants were asked about the frequency with which they consumed at least one standard serving of alcoholic beverages in the past 30 days (daily; 5–6 days per week; 1–4 days per week; 1–3 days per month; less than once; does not currently drink). While South Africa does not have uniform alcohol consumption guidelines, the American Cancer Society recommends no more than two drinks per day for men and no more than one drink per day for women, and the World Cancer Research Fund recommends

drinking no alcohol or following national guidelines (American Cancer Society 2017; Wiseman 2008). Very few HAALSI participants reported drinking alcohol daily (167/5055; 3%), so the binary outcome variable was coded at the next most frequent level of ≥ 5 versus < 5 days per week.

Body mass index (BMI)

During the study interview, trained fieldworkers measured participants' heights and weights using calibrated instruments. BMI was calculated as weight in kilograms divided by height in meters squared. The binary outcome variable was defined according to the World Health Organization cutoff of having a normal weight BMI (< 25.0) versus an overweight or obese BMI (≥ 25.0) (World Health Organization 2017b).

Covariates

Covariates included in the analyses were age category (40–49; 50–59; 60–69; 70–79; ≥ 80), sex, country of birth (South Africa; Mozambique or other), highest level of educational attainment (no formal education; some primary education [1–7 years]; some secondary education [8–11 years]; secondary education or higher [12 or more years]), current employment status (not employed part time or full time; working; homemaker), literacy (self-reported ability to read or write; yes/no), self-reported health in childhood (very bad, bad, moderate; good, very good), and father's occupation during childhood (skilled, unskilled, other, don't know). Age categories were used instead of continuous age to account for outliers in the oldest age group, and country of birth was included to account for any unmeasured differences between the study participants who were born in South Africa versus those who came to the Agincourt area as refugees during the 1977–1992 civil war in neighboring Mozambique (Sartorius et al. 2013). Father's occupation during childhood was classified as skilled or unskilled according to the International Standard Classification of Occupations 2008; specific job types are detailed elsewhere (Kobayashi et al. 2017).

Statistical analysis

The prevalence of each chronic disease risk behavior was calculated, overall and according to quintiles of household wealth and household consumption. Prevalence ratios (PRs) and associated 95% confidence intervals (CIs) for the relationships between household wealth quintile, household consumption quintile, and each chronic disease risk behavior were estimated using Poisson regression models with a robust error variance and logarithmic link function

for binary outcome data (Zou 2004), adjusting for age, sex, country of birth, self-rated health in childhood, father's occupation during childhood, education, literacy, and employment status. For both wealth and consumption, the first quintiles (i.e., the poorest and the lowest consumption) were used as the reference categories, so that the PRs demonstrated the likelihood of engaging in the harmful versus the protective category of risk behavior associated with each increasing quintile of household wealth or consumption. Trend tests were conducted to assess the presence of linear gradients in the likelihood of engagement in each behavior across household wealth and consumption quintiles. We conducted supplementary analyses to examine the associations across all BMI categories (< 18.5: underweight; 18.5–24.9: normal weight; 25.0–29.9: overweight; 30.0: obese), and separating former and never smokers into separate categories. We also conducted a supplementary analysis to compare reported expenditure on tobacco and alcohol products, according to household wealth quintile. The analyses were conducted using Stata version 15.1 (College Station, TX, USA).

Missing data

No data were missing for household wealth or consumption, 5/5059 participants ($\ll 1\%$) were missing data on physical activity, smoking, or alcohol consumption, and 370/5059 (7%) participants were missing data on BMI. Covariate data were missing for less than 1% of participants. The analytical samples for each regression model included all those with complete data on covariates and the behavior of interest.

Results

Table 1 summarizes the baseline characteristics of all participants. Just over half were female, most were born in South Africa, 42% could not read or write, and 46% had no formal education. Nearly three-quarters were not working, and most reported good or very good childhood health. Overall, 57% of the sample reported engaging in < 210 min per week of MVPA and as such, did not meet internationally recognized physical activity recommendations (Table 1). Nine percent of the samples were current smokers, 6% reported drinking alcohol on at least five days per week in the past 30 days, and 58% had an overweight or obese BMI (Table 1).

As household wealth quintile increased, there was a higher prevalence of low MVPA and overweight/obese BMI, and a lower prevalence of smoking and frequent alcohol intake (Table 2; Fig. 1). The percentage-point differences between the poorest and wealthiest quintiles

Table 1 Characteristics of the sample, "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" (HAALSI), Agincourt, South Africa, 2015

Characteristic	$N = 5059$	100%
Sex		
Male	2345	46.4
Female	2714	53.7
Age		
40–49	918	18.2
50–59	1410	27.9
60–69	1304	25.8
70–79	878	17.4
80 +	549	10.9
Country of birth		
South Africa	3528	69.8
Mozambique or other	1526	30.2
Literacy		
Can read and/or write	2948	58.3
Cannot read or write	2108	41.7
Education level		
No formal education	2306	45.7
Some primary (1–7 years)	1614	32.0
Some secondary (8–11 years)	537	10.7
Secondary or more (12 + years)	585	11.6
Employment status		
Employed (part or full time)	805	16.0
Not working	3719	73.7
Homemaker	521	10.3
Self-rated childhood health		
Moderate, bad, or very bad	621	12.3
Good or very good	4434	87.7
Father's occupation during childhood		
Skilled	2479	49.1
Unskilled	1446	28.7
Other	575	11.4
Don't know	547	10.8
Physical activity		
≥ 210 min of MVPA	2168	42.9
< 210 min of MVPA	2886	57.1
Smoking		
Never smoker	3977	78.6
Former smoker	622	12.3
Current smoker	460	9.1
Alcohol consumption		
< 5 days per week	4751	94.0
≥ 5 days per week	304	6.0
BMI		
< 18.5 (Underweight)	258	5.5
18.5–24.9 (Normal weight)	1719	36.7
25.0–29.9 (Overweight)	1328	28.3

Table 1 (continued)

Characteristic	$N = 5059$	100%
≥ 30.0 (Obese)	1384	29.5

The total N for each covariate may not sum to 5059 due to missing data

INDEPTH International Network for the Demographic Evaluation of Populations and Their Health, *MVPA* moderate-to-vigorous physical activity, *BMI* body mass index

were 4 (low MVPA), 26 (overweight/obese BMI), −8 (smoking), and −9 (frequent drinking) (Table 2; Fig. 1). With respect to household consumption, the only trend that mirrored the trend observed for household wealth was for overweight/obese BMI, with a 10 percentage-point increase in prevalence between the lowest and highest household consumption quintile (Table 2; Fig. 2). The prevalence of low MVPA decreased with increasing household consumption quintile (−6 percentage points), while smoking and frequent alcohol intake negligibly varied by household consumption quintile (Table 2; Fig. 2).

The adjusted prevalence ratios reflected the above findings (Table 3). The likelihood of low MVPA increased with increasing household wealth quintile (*p*-trend < 0.01; PR = 1.11; 95% CI 1.03–1.21 for the richest versus poorest wealth quintile; Table 3). Conversely, smoking steadily decreased with increasing household wealth quintile (*p*-trend < 0.01; PR = 0.34; 95% CI 0.25–0.47 for the richest vs. poorest wealth quintile; Table 3). Frequent alcohol consumption also decreased with increasing household wealth quintile (*p*-trend < 0.01; PR = 0.33; 95% CI 0.22–0.50 for the richest vs. poorest wealth quintile; Table 3). The widest disparity in chronic disease risk behaviors was for BMI, where overweight or obese BMI steadily increased with increasing household wealth (*p*-trend < 0.01) and the prevalence ratio was nearly 50% higher in the richest versus the poorest wealth quintile (PR = 1.48; 95% CI 1.36–1.60; Table 3).

The consumption index was not a consistent independent predictor of differences in chronic disease risk behaviors in the regression models, although some patterns emerged (Table 3). Low MVPA was inversely associated with household consumption (*p*-trend < 0.01; PR = 0.86; 95% CI 0.79–0.93 for the highest vs. lowest consumption quintile) and, as with household wealth, a disparity was observed in overweight/obese BMI (*p*-trend < 0.01; PR = 1.15; 95% CI 1.06–1.25 for the highest vs. lowest consumption quintile; Table 3). Household consumption quintile was not a strong predictor of either smoking or alcohol consumption behaviors.

When smoking status was expanded into each of current, former, and never categories, the gradient according to

household wealth quintile was stronger for current smoking than for former smoking (Supplementary Table 1). Older adults in higher household consumption quintiles appeared moderately more likely to be former smokers than those in the lowest quintile, but the effect estimates were imprecise (Supplementary Table 1). We found that the likelihood of being underweight compared to normal weight decreased with increasing household wealth quintile, although underweight was not associated with household consumption (Supplementary Table 2). The results for overweight and obesity separately were consistent with the main analysis, but the magnitudes of socioeconomic gradients were stronger for obesity than for overweight (Supplementary Table 2). We found that mean monthly reported expenditure on tobacco and alcohol products was higher in relatively wealthier households, but that fewer households reported purchasing these products as household wealth increased (Supplementary Table 3).

Discussion

In this large, population-based study of older adults in rural South Africa, we observed socioeconomic gradients in chronic disease risk behaviors according to relative measures of household wealth and consumption. Household wealth quintile was a stronger and more consistent predictor of chronic disease risk behaviors than household consumption quintile, supporting its use here as an indicator of socioeconomic disparities in chronic disease risk behaviors. Our results indicate that in this low-income context, chronic disease risk behaviors are socioeconomically graded at later stages of life. Further, the overall prevalence of overweight and obesity according to body mass index was high, with nearly one-third being overweight and another one-third being obese. Older adults with greater levels of household wealth and consumption were disproportionately likely to be overweight or obese. This study provides some of the first evidence on socioeconomic gradients in chronic disease risk behaviors in a rural, low-income older population in South Africa. These socioeconomic gradients have been largely overlooked in rural, low-income populations of this region and require urgent public health attention.

Unlike associations observed in high-income settings, greater household wealth was not invariably associated with protective behaviors, but rather predicted a mixed combination of behaviors. For example, greater household wealth was associated with higher odds of low MVPA and with having an overweight or obese body mass index, patterns that are consistent with those observed in the general South African population (Shisana et al. 2013). Indeed, these socioeconomic gradients were consistent

Table 2 Chronic disease risk behaviors according to household wealth and household consumption quintiles, "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" (HAALSI), Agincourt, South Africa, 2015

Household wealth quintiles	Protective risk behavior	Harmful risk behavior
Physical activity	≥ 210 min of MVPA	< 210 min of MVPA
Quintile 1 (N = 1045)	492 (47.1%)	553 (52.9%)
Quintile 2 (N = 1000)	422 (42.2%)	578 (57.8%)
Quintile 3 (N = 990)	430 (43.4%)	560 (56.6%)
Quintile 4 (N = 1006)	390 (38.8%)	616 (61.2%)
Quintile 5 (N = 1013)	434 (42.8%)	579 (57.2%)
Smoking	Former/never smoker	Current smoker
Quintile 1 (N = 1044)	906 (86.8%)	138 (13.2%)
Quintile 2 (N = 1000)	899 (89.9%)	101 (10.1%)
Quintile 3 (N = 989)	899 (90.9%)	90 (9.1%)
Quintile 4 (N = 1007)	926 (92.0%)	81 (8.0%)
Quintile 5 (N = 1014)	964 (95.1%)	50 (4.9%)
Alcohol consumption	Fewer than 5 days per week	Five or more days per week
Quintile 1 (N = 1043)	918 (88.0%)	125 (12.0%)
Quintile 2 (N = 1000)	925 (92.5%)	75 (7.5%)
Quintile 3 (N = 991)	945 (95.4%)	46 (4.6%)
Quintile 4 (N = 1007)	978 (97.1%)	29 (2.9%)
Quintile 5 (N = 1014)	985 (97.1%)	29 (2.9%)
BMI	< 25.0	≥ 25.0
Quintile 1 (N = 960)	520 (54.2%)	440 (45.8%)
Quintile 2 (N = 924)	455 (49.2%)	469 (50.8%)
Quintile 3 (N = 913)	392 (42.9%)	521 (57.1%)
Quintile 4 (N = 934)	344 (36.8%)	590 (63.2%)
Quintile 5 (N = 958)	266 (27.8%)	692 (72.2%)
Household consumption quintiles	Protective risk behavior	Harmful risk behavior
Physical activity	> 210 min of MVPA	< 210 min of MVPA
Quintile 1 (N = 1045)	422 (40.4%)	623 (59.6%)
Quintile 2 (N = 1024)	436 (41.6%)	598 (58.4%)
Quintile 3 (N = 1020)	457 (44.8%)	563 (55.2%)
Quintile 4 (N = 974)	406 (41.7%)	568 (58.3%)
Quintile 5 (N = 991)	457 (46.1%)	534 (53.9%)
Smoking	Former/never smoker	Current smoker
Quintile 1 (N = 1045)	947 (91.1%)	92 (8.9%)
Quintile 2 (N = 1023)	943 (93.0%)	71 (7.0%)
Quintile 3 (N = 1020)	923 (90.3%)	99 (9.7%)
Quintile 4 (N = 975)	892 (89.7%)	102 (10.3%)
Quintile 5 (N = 991)	889 (90.3%)	96 (9.7%)
Alcohol consumption	Fewer than 5 days per week	Five or more days per week
Quintile 1 (N = 1045)	962 (92.6%)	77 (7.4%)
Quintile 2 (N = 1024)	961 (94.8%)	53 (5.2%)
Quintile 3 (N = 1020)	961 (93.9%)	62 (6.1%)
Quintile 4 (N = 975)	930 (93.6%)	64 (6.4%)
Quintile 5 (N = 991)	937 (95.1%)	48 (4.9%)
BMI	< 25.0	≥ 25.0
Quintile 1 (N = 978)	460 (47.0%)	518 (53.0%)
Quintile 2 (N = 952)	427 (44.9%)	535 (55.1%)
Quintile 3 (N = 958)	400 (41.8%)	558 (58.2%)

Table 2 (continued)

Household consumption quintiles	Protective risk behavior	Harmful risk behavior
Quintile 4 (N = 882)	353 (40.0%)	529 (60.0%)
Quintile 5 (N = 919)	337 (36.7%)	582 (63.3%)

Quintile 1 represents the poorest/lowest consumption quintile, and quintile 5 represents the richest/highest consumption quintile

INDEPTH International Network for the Demographic Evaluation of Populations and Their Health, *MVPA* moderate-to-vigorous physical activity, *BMI* body mass index

Fig. 1 Socioeconomic gradients in chronic disease risk behaviors and body mass index, according to household wealth index quintile, "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" (HAALSI), Agincourt, South Africa, 2015, *MVPA* moderate-to-vigorous intensity physical activity
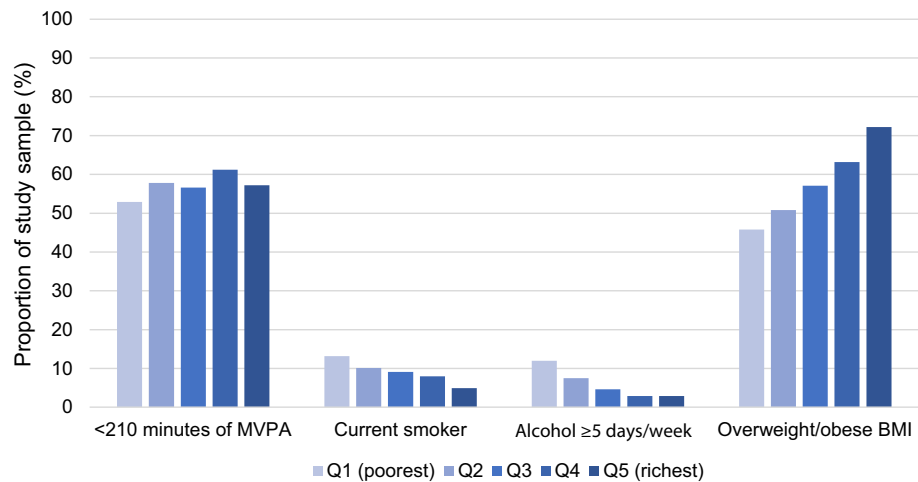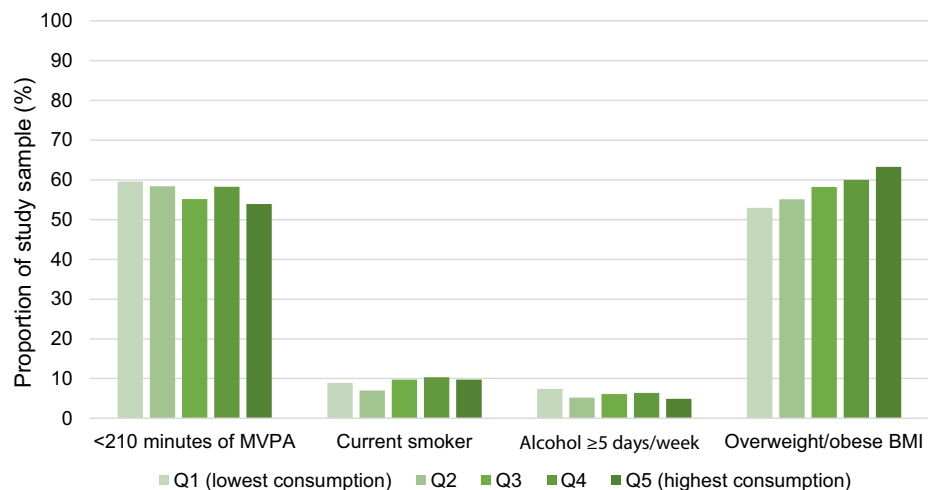

Fig. 2 Socioeconomic gradients in chronic disease risk behaviors and body mass index, according to household consumption quintile, "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" (HAALSI), Agincourt, South Africa, 2015, *MVPA* moderate-to-vigorous intensity physical activity

with well-documented trends that occur as countries increase in economic development and pass through the epidemiologic transition (Akinyemiju et al. 2017; Allen et al. 2017; Popkin et al. 2012; Katzmarzyk and Mason 2009). In this rural study context in particular, the higher prevalence of MVPA and the lower prevalence of overweight and obesity among older adults with less household wealth may be due to a greater need for physically

demanding informal and household labor and walking for transportation to resources.

In this study, 10% of older adults in the poorest household wealth quintile reported less than 1 h per day of walking for transportation, compared with 17% of older adults in the richest household wealth quintile. This finding is consistent with the previous research on the spatial dimension of poverty in the Agincourt sub-district, which showed that poorer households with lower rates of motor

Table 3 Adjusted prevalence ratios (PRs) for the associations between household wealth and household consumption quintiles and chronic disease risk behaviors, "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" (HAALSI), Agincourt, South Africa, 2015

Socioeconomic exposure variable	Chronic disease risk behavior outcome			
	< 210 min/week MVPA (vs. ≥ 210 min/week) PR (95% CI)	Current smoker (vs. former/never) PR (95% CI)	Alcohol ≥ 5 days/week (vs. < 5 days/week) PR (95% CI)	Overweight/obese BMI (vs. normal BMI) PR (95% CI)
Household wealth quintiles				
Quintile 1, poorest (N = 1046)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Quintile 2 (N = 1001)	1.10 (1.01, 1.18)	0.77 (0.62, 0.96)	0.72 (0.55, 0.94)	1.09 (0.99, 1.19)
Quintile 3 (N = 991)	1.08 (1.00, 1.17)	0.68 (0.54, 0.86)	0.48 (0.34, 0.67)	1.20 (1.10, 1.31)
Quintile 4 (N = 1007)	1.19 (1.10, 1.28)	0.59 (0.46, 0.76)	0.32 (0.21, 0.47)	1.32 (1.21, 1.43)
Quintile 5, richest (N = 1014)	1.11 (1.03, 1.21)	0.34 (0.25, 0.47)	0.33 (0.22, 0.50)	1.48 (1.36, 1.60)
p-trend	< 0.01	< 0.01	< 0.01	< 0.01
Household consumption quintiles				
Quintile 1, lowest (N = 1047)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Quintile 2 (N = 1024)	0.91 (0.84, 0.98)	0.86 (0.66, 1.13)	0.77 (0.55, 1.08)	1.07 (0.99, 1.16)
Quintile 3 (N = 1021)	0.94 (0.88, 1.01)	1.03 (0.81, 1.33)	0.92 (0.67, 1.27)	1.11 (1.03, 1.20)
Quintile 4 (N = 975)	0.93 (0.87, 1.00)	1.01 (0.79, 1.29)	0.96 (0.70, 1.32)	1.12 (1.04, 1.21)
Quintile 5, highest (N = 992)	0.86 (0.79, 0.93)	0.88 (0.67, 1.14)	0.83 (0.58, 1.18)	1.15 (1.06, 1.25)
p-trend	< 0.01	0.70	0.65	< 0.01

Quintile 1 represents the poorest/lowest consumption quintile, and quintile 5 represents the richest/highest consumption quintile

All odds ratios are adjusted for age, sex, educational attainment, employment status, country of birth, literacy, self-rated health in childhood, and father's occupation during childhood

INDEPTH International Network for the Demographic Evaluation of Populations and Their Health; *MVPA* moderate-to-vigorous physical activity; *BMI* body mass index, *PR* prevalence ratio, *CI* confidence interval

vehicle ownership and in-home running water and toilet facilities are clustered in specific villages (Sartorius et al. 2013). Only 16% of the HAALSI sample reported being employed part time or full time and these people tended to reside in relatively wealthier households. We did not have measures of energy expenditure in informal, unpaid, or household labor to examine against household wealth or consumption measure; this should be a topic of future investigation in the aging population of rural South Africa. However, it should be noted that the wealth gradient was not steep for MVPA, with only a 4 percentage-point difference between the poorest versus richest quintiles, while there was nearly a 30 percentage-point difference in overweight/obese BMI between the poorest versus richest quintile.

We also found that being in a relatively wealthier household was associated with lower odds of current tobacco use. This finding is consistent with socioeconomic gradients in smoking observed in a range of country contexts, including other sub-Saharan African countries (Akinyemiju et al. 2017; Allen et al. 2017; Pampel 2008; Howe et al. 2012). The evidence to date on socioeconomic gradients in the frequency of alcohol consumption in sub-Saharan African countries is relatively weak, although some studies have reported that frequent alcohol use is less common among more socioeconomically advantaged groups (Akinyemiju et al. 2017; Allen et al. 2017). Education and health knowledge, as well as the influence of local social norms may underlie socioeconomic disparities in smoking and drinking behaviors (Grundy and Sloggett 2003; Tucker 2002). However, most evidence on these relationships comes from high-income settings; further research is needed to confirm the magnitudes and directions of socioeconomic gradients in chronic disease risk behaviors of older adults in rural, low-income settings, and the underlying mechanisms for these gradients.

The value of consumption as a predictor of health behaviors in LMICs has been debated, and some have suggested that wealth and asset indices more accurately predict socioeconomic disparities in health (Howe et al. 2012). The present study suggests that household consumption is not a consistent predictor of chronic disease risk behaviors among older adults in rural South Africa. The mechanisms underlying the associations between each of wealth and consumption and chronic disease risk behaviors may vary, as consumption may not be related to the same social norm and network influences on behavior that could explain wealth-based gradients in behavior (Tucker 2002). Household consumption may influence other behaviors that are less related to lifestyle and are

essential across the socioeconomic gradient, such as the utilization of healthcare services (Howe et al. 2012). Future research should examine the potential mechanisms underlying wealth- and consumption-based gradients in different aspects of the health behavior and care experience for older adults in rural South Africa.

Limitations and strengths

Physical activity, smoking, and alcohol consumption were assessed via self-report in the study interview, and therefore, recall error may bias the results of our study. If error in recall of these behaviors was randomly distributed in the study population, our estimates would be attenuated toward the null. If older adults systematically over- or underreported behavior in a pattern that was associated with wealth or consumption, then our estimates may over- or underreport the true associations in a direction that is difficult to predict. We recognize that our dichotomization of the variables for moderate-to-vigorous physical activity, frequency of alcohol consumption, and body mass index resulted in loss of variation relative to continuous variables. However, we categorized these variables using evidence-based South African and international public health guidelines that correspond to specific cutoff points for levels of behavior where there are threshold effects for risks of chronic disease and mortality (Wiseman 2008; American Cancer Society 2017; World Health Organization 2010, 2017b, 2018).

We adjusted for a range of potential confounding variables, including measures of childhood health and socioeconomic position. However, any residual confounding by childhood circumstances not captured by these two variables could bias our results to a degree that is difficult to ascertain, although the childhood variables included in this analysis negligibly altered effect estimates. Social desirability bias may also be present in our results, which could result in the underreporting of harmful behaviors. Our data described the frequency but not quantity of alcohol consumption, and episodic binge drinking has been associated with a variety of negative health outcomes (Roerecke and Rehm 2010; Jin et al. 2013). Future waves of data collection will assess the number of drinks consumed per drinking episode in addition to drinking frequency. The cross-sectional nature of this study means that the data do not capture changes in either the exposures or the outcomes over time. However, planned longitudinal data collection in HAALSI will allow for future assessment of these relationships.

Strengths of this study include its large, population-based sample of older men and women living in rural South Africa. This is a relatively understudied population in global health and aging and represents some of the "oldest old" adults living in South Africa. This paper presents the first study to examine socioeconomic gradients in chronic disease risk behaviors in older adults living in rural South Africa. As the burden of aging-related chronic diseases continues to rise in South Africa, this study provides useful insights as to how socioeconomic status may influence engagement in health behaviors. Further, we used a validated measure of household wealth based on housing conditions, durable and non-durable assets, land ownership, and livestock, and a validated measure of household consumption based on expenditures and food production. These measures are widely accepted as appropriate for low-income settings where the measurement of financial assets and income can be difficult and problematic.

Conclusions

This study demonstrates the presence of socioeconomic gradients in moderate-to-vigorous physical activity, smoking, alcohol intake, and overweight and obese body mass index among older adults in rural South Africa. These behaviors were more strongly graded according to household wealth than to household consumption. The directions of these gradients were consistent with other findings from LMICs and were mostly opposite to trends observed in higher-income settings. Over half of the study population was measured to have an overweight or obese body mass index, which is a cause for urgent public health concern. As South Africa's population continues to age, equitable health polices and interventions are needed to reduce the growing burden of overweight and obesity and resulting chronic disease risk.

Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to declare.

Ethical approval Ethical approval was granted by the University of Witwatersrand Human Research Ethics Committee (M141159), the Harvard T. H. Chan Harvard School of Public Health, Office of Human Research Administration (C13-1608-02), and the Mpumalanga Provincial Research and Ethics Committee. Informed consent was obtained from all individual participants included in the study. All procedures involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

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