

Longitudinal Trends in Physical Activity Among Older Adults With and Without HIV in Uganda

Journal of Aging and Health
2026, Vol. 38(1-2) 99–109
© The Author(s) 2025



Article reuse guidelines:

sagepub.com/journals-permissions
DOI: 10.1177/08982643251314064

journals.sagepub.com/home/jah

MaryAnn Liebert
A Part of Sage

Aneeka Ratnayake, PhD¹ , Yao Tong, MS², Zahra Reynolds, MPH², Steffany Chamut, DDS, MPH, FCID^{3,4}, Lien T. Quach, PhD, MD^{2,5} , Phoebe Mbabazi, MBChB, MMED⁶, Shruti Sagar, BA², Samuel Maling, MD⁷, Crystal M. North, MD, MPH^{2,8,10}, Eliza Passell, MPH², Moka Yoo-Jeong, PhD, RN⁹, Alexander C. Tsai, MD, PhD^{10,11,12} , Robert Paul, PhD¹³, Christine S. Ritchie, MD, MSPH^{10,14,15}, Janet Seeley, PhD¹⁶, Susanne S. Hoepfner, PhD^{2,10} , Flavia Atwiine, MPH¹², Edna Tindimwebwa, BS¹⁷, Samson Okello, MD^{12,18} , Noeline Nakasujja, PhD⁷, Deanna Saylor, MD, MHS¹⁹, Meredith L. Greene, MD^{20,21}, Stephen Asimwe, MD, PhD^{11,12,17}, Jeremy A. Tanner, MD, MPH²², Mark J. Siedner, MD, MPH^{2,10,12}, and Brianne Olivieri-Mui, PhD, MPH^{1,23,24}

Abstract

Introduction: Physical Activity (PA) and its links to frailty, quality of life (QoL), and other comorbidities in older Ugandans living with HIV remain under-explored. **Methods:** We analyzed data from three annual assessments of older people living with HIV (PLVH) and age- and sex-similar people not living with HIV (PnLVH). We fitted linear generalized estimating equations

¹The Roux Institute at Northeastern University, USA

²Medical Practice Evaluation Center, Mongan Institute, Massachusetts General Hospital, USA

³Harvard School of Dental Medicine, Boston, USA

⁴Department of Community Dentistry and Population Health School of Dental Medicine, University of Colorado Anschutz Medical Campus

⁵Department of Urban Public Health, University of Massachusetts Boston and Massachusetts Veterans Epidemiology Research and Information Center (MAVERIC), VA Boston Healthcare System

⁶Infectious Diseases Institute - Makerere University, Kampala, Uganda

⁷Department of Psychiatry, Mbarara University, Uganda

⁸Pulmonary and Critical Medicine, Department of Medicine, Massachusetts General Hospital, Boston, MA

⁹School of Nursing, Bouvé College of Health Sciences, Northeastern University, USA

¹⁰Harvard Medical School, USA

¹¹Center for Global Health, Massachusetts General Hospital, USA

¹²Mbarara University of Science and Technology, Uganda

¹³Department of Psychological Sciences, University of Missouri - St Louis, USA

¹⁴Division of Palliative Care and Geriatric Medicine, Department of Medicine, Massachusetts General Hospital, USA

¹⁵Center for Aging and Serious Illness, Mongan Institute, Massachusetts General Hospital, USA

¹⁶Department of Global Health and Development, Faculty of Public Health and Policy, London School of Hygiene & Tropical Medicine, UK

¹⁷Kabwohe Clinical Research Centre, Uganda

¹⁸Harvard T.H.Chan, School of Public Health, USA

¹⁹Department of Neurology, Johns Hopkins University School of Medicine, USA

²⁰Department of Medicine, Indiana University School of Medicine, USA

²¹Indiana University Center for Aging Research at the Regenstrief Institute, USA

²²Glenn Biggs Institute for Alzheimer's & Neurodegenerative Diseases, University of Texas Health San Antonio, USA

²³Department of Health Sciences, Bouvé College of Health Sciences, Northeastern University, USA

²⁴The Marcus Institute for Aging Research, Hebrew SeniorLife, Harvard Medical School, USA

Corresponding Author:

Aneeka Ratnayake, The Roux Institute at Northeastern University, 100 Fore St, Portland, ME 04101, USA.

Email: a.ratnayake@northeastern.edu

(GEE) regression models to estimate the correlates of PA, including demographics, frailty, QoL, HIV, and other comorbidities. **Results:** We enrolled 297 PLWH and 302 PnLWH. Older age ($b = -157.34$, 95% CI $[-222.84, -91.83]$), living with HIV ($b = -979.88$ [95% CI: $-1878.48, -81.28$]), frailty ($b = -3011.14$ [95% CI: $-4665.84, -1356.45$]), and comorbidities ($b = -2501.75$ [95% CI: $-3357.44, -1646.07$]) were associated with lower overall PA. Higher general QoL ($b = 89.96$ [95% CI: $40.99, 138.94$]) was associated with higher PA. **Conclusion:** PA interventions may support wellbeing of older people in the region, and tailored interventions should be explored.

Keywords

HIV, older adults, Uganda, physical activity, frailty, quality of life

Introduction

Engaging in physical activity (PA) brings numerous positive health benefits for older adults, and has been linked to reduced comorbidities associated with aging, such as cardiovascular diseases, cancers, worsened mental health, and cognitive problems. (L. Cheng et al., 2021; Erlandson et al., 2018; Reiner et al., 2013) Additionally, higher levels of PA have been associated with markers of positive aging, such as favorable lipid profiles, improved bone density, and reduced falls. (Vogel et al., 2009) However, extant research on the benefits of PA among older people has primarily been generated from the Global North.

Sub-Saharan Africa is expected to have the fastest growth in older adults globally by 2050 (Velkoff & Kowal, 2006) and is home to nearly 4 million people living with HIV (PLWH) aged 50 or older. Uganda in particular, reported that those aged 45–59 had the highest HIV prevalence of any age group in 2016 (Sherwood-Martin, 2023). Though the widespread scale-up of antiretroviral therapy (ART) has prolonged life expectancy, PLWH are at an increased risk of experiencing multiple poor health indicators associated with aging that have been shown to benefit from PA in the Global North, including frailty, depression, and diminished quality of life (QoL) (Dianatinasab et al., 2020; Heissel et al., 2019). Among older PLWH, PA is also associated with lowering abdominal adiposity, improving walking capacity and visuospatial ability, and improving physical and mental function (Chetty et al., 2021; Shim & Noh, 2022; Webel et al., 2023; Winston et al., 2021). As the population of PLWH ages in the Global South, scalable strategies to help augment QoL are an urgent priority (Siedner, 2019).

However, it is important to consider possible contextual differences in PA between the Global South and Global North. In the Global South, most PA is done for work or travel, not for recreational purposes, and resulting in very high activity levels (Guthold et al., 2011; Guwatudde et al., 2016). While high PA is generally associated with health benefits, excessive PA—particularly in occupational settings—has been shown to have negative health outcomes in other the Global North. (Kim et al., 2012; Li et al., 2013; Paluska & Schwenk, 2000) Whether or not a similar pattern

exists among PLWH and people not living with HIV (PnLWH) residing in Uganda remains unexplored.

To address the gap in knowledge about PA among older PLWH in Uganda, we examined long-term trends in PA, frailty, QoL, comorbidities, and depression in a cohort of older PLWH and PnLWH. We hypothesized that PA would be lower among PLWH than PnLWH and that frailty, low QoL, comorbidities, and depression would be associated with lower levels of PA.

Methods

Study Sample and Data Collection

We analyzed three annual waves of data from the *Quality of Life and Aging with HIV in Rural Uganda Study*, described in detail previously (Siedner, 2019). Briefly, we first recruited individuals over 50 years old, living with HIV, and on ART for at least three years from one of two public health clinics in Uganda. We then used household census data to recruit PnLWH from the same communities matched on age (within quartiles), sex, and clinic catchment area (Takada et al., 2019). The first wave of the study occurred remotely, as it was during the COVID-19 pandemic lockdown (2020), with subsequent data collection occurring in person, annually in 2021 and 2022.

Outcome Measures

Our outcome of interest was PA, which we measured using a modified International Physical Activity Scale (Lee et al., 2011). It was adapted to the Ugandan context, where activities that would be undertaken in this population were added to the questionnaire. (Mabweazara et al., 2023) This scale assesses self-reported physical activity over the past seven days, characterized by both intensity (i.e., low, moderate, and vigorous) and duration in minutes per week. These values are then converted into metabolic equivalents of task (METs), with one MET equal to the amount of oxygen consumed while sitting at rest (3.5 mL O₂ per kg body weight times minutes) (Jetté et al., 1990). One minute of vigorous activity is converted into 8.0 METs; 1 minute of moderate activity was defined at 4.0 METs; 1 minute of walking was

defined at 3.3 METs. (Haskell et al., 2007) For our primary outcome of interest, we considered METs as a continuous measure.

Exposure Measures

Our primary independent variable was HIV status. As described above, PLWH were enrolled directly from clinic. Individuals without HIV were tested annually to confirm their status prior to each study visit. Health-related QoL was measured using the EQ5D visual analogue scale (EQ-VAS), which asks respondents to report their current health on a scale of 0–100 and has been used previously in this population (Cheng et al., 2021; Olivieri-Mui et al., 2023; Quach et al., 2023; Rautenberg et al., 2023a, 2023b; Stanton et al., 2024). We also assessed age-related QoL using the Control, Autonomy, Self-Realization and Pleasure (CASP19) scale (Hyde et al., 2003). This scale asks participants four to five questions in each section (Control, Autonomy, Self-realization, or Pleasure), with a total of 19 items and a total possible score of 57. Frailty was measured using the Fried Frailty phenotype as described previously (Fried et al., 2001). Comorbidities were assessed by self-report, and included the following conditions: high blood pressure, diabetes, high cholesterol, heart attack or heart failure, kidney problems, stroke, cancer, chronic obstructive pulmonary disease (COPD), asthma, pneumonia, and tuberculosis.

Additional covariates of interest included: age, sex, marital status, income, employment, household asset ownership (Filmer & Pritchett, 2001), moderate to severe alcohol use, depressive symptoms, and body mass index. Alcohol consumption was measured using the 3-item consumption subset of the Alcohol Use Disorders Identification Test (AUDIT-C) (Bush et al., 1998) and was classified as low versus moderate to severe risk per standard cutoffs. Depressive symptoms were measured using a version of the depression subscale of the Hopkins Symptom Checklist (Derogatis et al., 1974) modified for the Ugandan context, (Bolton & Ndogoni, 2001; Mushavi et al., 2020) with probable depression defined as a score >1.75 (Ashaba et al., 2018). BMI was calculated based on height and weight, measured by study staff at the second visit.

Ethical Considerations

All study participants provided informed verbal consent over the phone during the first year of data collection, and written consent for subsequent waves. Study procedures were reviewed and approved by the institutional review committees at Mbarara University of Science and Technology and Mass General Brigham. The study also received clearance to conduct the study from the Uganda National Council for Science and Technology and the Research Secretariat in the President's Office.

Analysis

Descriptive statistics were tabulated by HIV status and were compared using chi-squared tests, t-tests, or Wilcoxon Rank-Sum tests as appropriate. Longitudinal linear generalized estimating equations (GEE) regression models were fitted to the data with total number of METs per week as a continuous outcome. The preliminary model included age (continuous), HIV status (binary), EQ-VAS score (continuous), CASP19 score (continuous), depression (binary) frailty status (categorical, with robust, pre-frail, or frail as options), the presence of comorbidities (binary), and visit number (categorical). Interaction terms between HIV status x visit and frailty status x visit were also considered to determine if the relationship between HIV status or frailty and PA changed over time. Variables were retained in the final model if they were statistically significant ($p \leq .05$) and omissions were made if variables were highly correlated with one another ($r \geq 0.50$). All analyses were conducted with SAS version 9.4

Results

There were 599 participants enrolled at baseline, of whom 297 were living with HIV (Table 1). A total of 560 remained under observation between enrollment and year 3, with no differences in losses from observation by HIV status ($p = .17$). The mean participant age was 59 (standard deviation [SD]: 6.54) and just under half (49.3%, $n = 295$) were female. Due to matching, age, sex, and urbanicity did not vary significantly by HIV status. Those living with HIV, however, were more likely to be divorced/separated (PLWH: $n = 32$, 10.8%; PnLWH: $n = 12$, 4.0%) or widowed (PLWH: $n = 101$, 34.0%; PnLWH: $n = 41$, 12.6%; $p < .0001$) and more likely to live alone (PLWH: $n = 21$, 7.1%; PnLWH: $n = 4$, 1.3%; $p < .001$). In terms of socioeconomic characteristics, those living with HIV were more likely to have a water source inside their homes (PLWH: $n = 10$, 3.4%; PnLWH: $n = 8$, 2.6%; $p = .033$) and less likely to own a bike (PLWH: $n = 95$, 32.0%; PnLWH: $n = 130$, 43.0%; $p < .01$). Health-related characteristics (e.g., alcohol use, depressive symptoms, and BMI) had little variability between those living and not living with HIV; however, PnLWH reported a lower health-related QoL in year 1 only. Health-related QoL did not vary by HIV status in Years 2 and 3.

Correlates of PA Throughout the Study

The median weekly METs was 14002.24 (standard deviation [SD] 7890.25) at baseline for the entire cohort. Those living with HIV had lower mean weekly PA output in terms of METs in years 2 (PLWH: 13844.47 [SD: 7234.05], PnLWH: 14157.37 [SD: 8495.55], $p = .02$) and 3 of the study, (PLWH: 12829.95 [SD: 7135.32], PnLWH: 14224.73 [SD: 7542.39], $p = .025$). Additionally, those living with HIV reported fewer mean daily minutes of vigorous activity in year 2 (PLWH: 160.16 [SD: 152.94]; PnLWH: 209.22 [SD: 152.74],

Table 1. Descriptive Statistics of Cohort at Baseline by HIV Status.

	Overall	People living with HIV	People not living with HIV	p-value
Variable (at baseline, unless otherwise indicated)				
n (%)				
Sex				
Male	304 (50.75)	150 (50.51)	154 (50.66)	.93
Female	295 (49.25)	147 (49.49)	148 (49.01)	
Residence				
Urban	249 (41.57)	170 (57.24)	180 (59.60)	.56
Rural	350 (58.43)	127 (42.76)	122 (40.40)	
Marital status				
Single	8 (1.34)	2 (0.67)	6 (1.99)	<.001
Married/cohabitating	405 (67.61)	162 (54.55)	243 (80.46)	
Divorced/separated	44 (7.35)	32 (10.77)	12 (3.97)	
Widowed	142 (23.71)	101 (34.01)	41 (13.58)	
Living arrangement				
Live alone	25 (4.17)	21 (7.07)	4 (1.32)	<.001
Lives with others	574 (95.83)	276 (92.93)	298 (98.68)	
Alcohol use				
Low risk	541 (90.32)	275 (92.59)	266 (88.08)	.07
Moderate-high risk	58 (9.68)	22 (7.41)	36 (11.92)	
Depression				
Below clinical threshold	372 (64.70)	191 (67.49)	181 (61.99)	.18
At or above clinical threshold	203 (35.30)	92 (32.51)	111 (38.01)	
Water source				
Inside home	18 (3.01)	10 (3.37)	8 (2.65)	.03
Outside home	581 (96.99)	287 (96.63)	294 (97.35)	
Employment ^a				
Non-sedentary job	550 (91.82)	267 (89.90)	283 (93.71)	.23
Sedentary job	42 (7.01)	26 (8.75)	16 (5.30)	
Unemployed	7 (1.17)	4 (1.35)	3 (0.99)	
Owns shoes other than slippers				
Yes	568 (94.82)	280 (94.28)	288 (95.36)	.55
No	31 (5.18)	17 (5.72)	14 (4.64)	
Owns a bike				
Yes	225 (37.56)	95 (31.99)	130 (43.05)	<.01
No	374 (62.44)	202 (68.01)	172 (56.95)	
BMI at visit 2 ^b				
<18.5	69 (12.00)	29 (10.32)	40 (13.61)	.30
18.5–<25	288 (50.09)	149 (53.02)	139 (47.28)	
>=25–<30	153 (26.61)	76 (27.05)	77 (26.19)	
>=30	65 (11.30)	27 (9.61)	38 (12.93)	
Comorbidities reported ^c				
Yes	216 (36.06)	107 (36.03)	109 (36.09)	.99
No	383 (63.94)	190 (63.97)	193 (63.91)	
Frailty				
Robust	302 (52.52)	144 (51.25)	158 (53.74)	.78
Pre-frail	235 (40.87)	119 (42.35)	116 (39.46)	
Frail	28 (6.61)	18 (6.41)	20 (6.80)	
Has children aged 0–2				
Yes	39 (6.51)	21 (7.07)	18 (5.96)	.58
No	560 (93.49)	276 (92.93)	284 (94.04)	

(continued)

Table 1. (continued)

	Overall	People living with HIV	People not living with HIV	p-value
Has children aged 3–5				
Yes	157 (26.21)	80 (26.94)	77 (25.50)	.69
No	442 (73.79)	217 (73.06)	225 (74.50)	
Has children aged 6–17				
Yes	440 (73.46)	199 (67.00)	241 (79.80)	<.001
No	159 (26.54)	98 (33.00)	61 (20.20)	
Took the first assessment during lockdown period				
Yes	47 (7.85)	18 (6.06)	29 (9.60)	.11
No	552 (92.15)	279 (93.94)	273 (90.40)	
Meets weekly physical activity requirements ^d				
Yes	575 (95.99)	286 (96.30)	289 (95.70)	0.50
No	24 (4.01)	11 (3.70)	13 (4.30)	
Mean (SD)				
Age	59.34 (6.54)	59.24 (6.20)	59.55 (6.86)	.41
Physical activity in METs				
Year 1	14002.24 (7890.25)	13844.47 (7234.05)	14157.37 (8495.55)	.63
Year 2	12863.44 (7432.34)	12088.26 (7186.60)	13603.99 (7598.37)	.02
Year 3	13544.77 (7373.30)	12829.95 (7135.32)	14224.73 (7542.39)	.03
Average minutes of vigorous activity				
Year 1	218.60 (151.79)	210.77 (143.26)	226.29 (159.60)	0.21
Year 2	185.25 (154.66)	160.16 (152.94)	209.22 (152.74)	0.0001
Year 3	189.72 (153.27)	170.02 (149.52)	208.47 (154.69)	<0.01
Average minutes of moderate activity				
Year 1	166.32 (127.15)	185.69 (137.23)	147.20 (113.36)	<.001
Year 2	183.61 (141.93)	194.18 (143.82)	173.50 (139.60)	.08
Year 3	180.38 (112.83)	182.53 (117.06)	178.34 (108.83)	066
Average minutes of walking				
Year 1	63.35 (105.52)	51.44 (82.28)	75.02 (123.17)	<.01
Year 2	56.20 (72.10)	51.00 (46.69)	61.13 (89.60)	.09
Year 3	65.90 (57.93)	60.67 (49.78)	70.87 (64.44)	.04
Health-related quality of life (0–100 scale)				
Year 1	71.18 (16.91)	74.41 (16.19)	67.99 (17.02)	<.0001
Year 2	75.17 (15.00)	76.41 (15.84)	73.98 (14.08)	.05
Year 3	74.85 (15.57)	75.13 (16.51)	74.59 (14.66)	.68
General quality of life (0–57 scale)				
Year 1	41.71 (9.16)	41.45 (8.63)	41.96 (9.66)	.50
Year 2	42.76 (8.00)	42.59 (8.09)	42.92 (7.93)	.62
Year 3	44.11 (7.92)	43.82 (8.51)	44.38 (7.33)	.41
Median (range)				
Income	120,000 (0–9,000,000)	150,000 (0–2,600,000)	100,000 (0–9,000,000)	.82

^acomorbidities considered included: high blood pressure, diabetes, high cholesterol, heart attack or heart failure, kidney problems, stroke, cancer, chronic obstructive pulmonary disease (COPD), asthma, pneumonia, and tuberculosis.

^bVisit 1 was conducted via telephone due to COVID-19 lockdowns; thus anthropomorphic measurements were first taken at visit 2.

^cSedentary jobs include: student, truck driver/ conductor, business person, government/ clerical/ sedentary. Non-sedentary jobs include: teacher, technician/ artisan, military/ police/ security, construction worker, housekeeper, healthcare worker, farmer, local brew seller/ bar or restaurant attendant, selling goods, mechanic, sex-worker, trader.

^dPer WHO, at least 150 minutes of moderate activity a week or at least 75 minutes of vigorous activity per week.

$p = .0001$) and year 3 (PLWH: 170.02 [SD: 149.52]; PnLWH: 208.47 [SD: 154.69], $p < .01$), and fewer mean daily minutes of walking in year 1 (PLWH: 51.44 [SD: 82.28]; PnLWH: 75.02 [SD: 123.17], $p < .01$) and year 3 (PLWH: 60.67 [SD:

49.78], PnLWH: 70.87 [SD: 64.44], $p = .046$). Those living with HIV reported more mean daily minutes of moderate activity during year 1 of the study (PLWH: 185.69 [SD: 137.23], PnLWH: 147.20 [113.36], $p < .0012$).

Changes in PA Over Time

Overall, PA in METs, minutes of vigorous PA, minutes of moderate PA, and minutes of walking all changed significantly throughout the study period, though the direction of trends was different for different forms of PA (Table 2 and Figure 1). For both PLWH and PnLWH, overall METs, vigorous activity and walking all declined in year 2 compared to year one but rebounded in year 3. In contrast moderate activity was highest in year two across both groups, declining in year 3.

Correlates of PA

The final model included age, HIV status, frailty, reporting comorbidities, general QoL, and visit number. Neither the interaction between HIV and visit ($p = .43$) nor the interaction between frailty and visit ($p = .96$) were statistically significant; thus, neither were retained in the model. Moreover, health-related QoL and depression were omitted from the model, as they were highly correlated with general QoL (depression: $r = -0.56$, $p < .0001$; health related QoL $r = 0.53$, $p < .0001$). In multivariable longitudinal models of PA (Table 3), older age ($b = -157.34$, 95% CI [-222.84, -91.83]), living with HIV ($b = -979.88$ [95% CI: -1878.48, -81.28]), frailty ($b = -3011.14$ [95% CI: -4665.84, -1356.45]), and reporting comorbidities ($b = -2501.75$ [95% CI: -3357.44, -1646.07]) were all associated with lower overall PA in METs. In contrast, reporting higher general QoL ($b = 89.96$ [95% CI: 40.99, 138.94]) was associated with higher overall PA in METs. PA declined in visit 2 compared to baseline

($b = -984.55$, [95% CI: -1702.41, -266.70]), but not in visit 3.

Discussion

In this well-characterized 3-year cohort study of older age people in rural Uganda, our findings revealed that older PLWH were less likely than their counterparts without HIV to engage in PA. We also identified key health and well-being indicators associated with PA levels. Most notably, individuals with comorbidities and frailty were significantly less likely to engage in PA.

Our data underscores the potential for PA interventions to promote healthy aging, including for PLWH on ART. For example, we found that those reporting comorbidities—of which the most prevalent conditions were high blood pressure (21%), high cholesterol (7%), and diabetes (6%)—reported reduced PA. We similarly found reduced PA levels among PLWH and those with the frailty phenotype. These findings demonstrate that the groups who might benefit the most from PA are less likely to engage in optimal levels (Angulo et al., 2020; Colberg et al., 2016; Mann et al., 2014; Rêgo et al., 2019; Xu et al., 2023). We cannot precisely determine whether reduced PA is contributing to these co-morbidities, or vice versa, where comorbidities and frailty may have emerged from reduced levels of PA earlier in life, or where individuals may have reduced their rates of PA in response to these conditions. In either instance, though, programs to help encourage PA for those who might most benefit from it should be considered for development and evaluation in such settings. Although few if any programs are active at scale, there are numerous pilot programs of PA interventions among

Table 2. Trends in Physical Activity Throughout Study Period.

Variable	Estimate	95% CI	p-value
Overall METs			
Year 1	Ref	Ref	<0.01
Year 2	-1138.80	-1810.98, -466.62	
Year 3	-457.47	-1127.02, 212.09	
Minutes of vigorous PA			
Year 1	Ref	Ref	<0.0001
Year 2	-33.35	-47.02, -19.69	
Year 3	-28.87	-42.62, -15.13	
Minutes of moderate PA			
Year 1	Ref	Ref	0.03
Year 2	17.29	3.12, 31.47	
Year 3	14.06	1.91, 26.21	
Minutes of walking			
Year 1	Ref	Ref	0.02
Year 2	-7.15	-17.30, 2.99	
Year 3	2.55	-6.96, 12.06	

Note. Bold values indicate statistically significant results at $p < 0.05$.

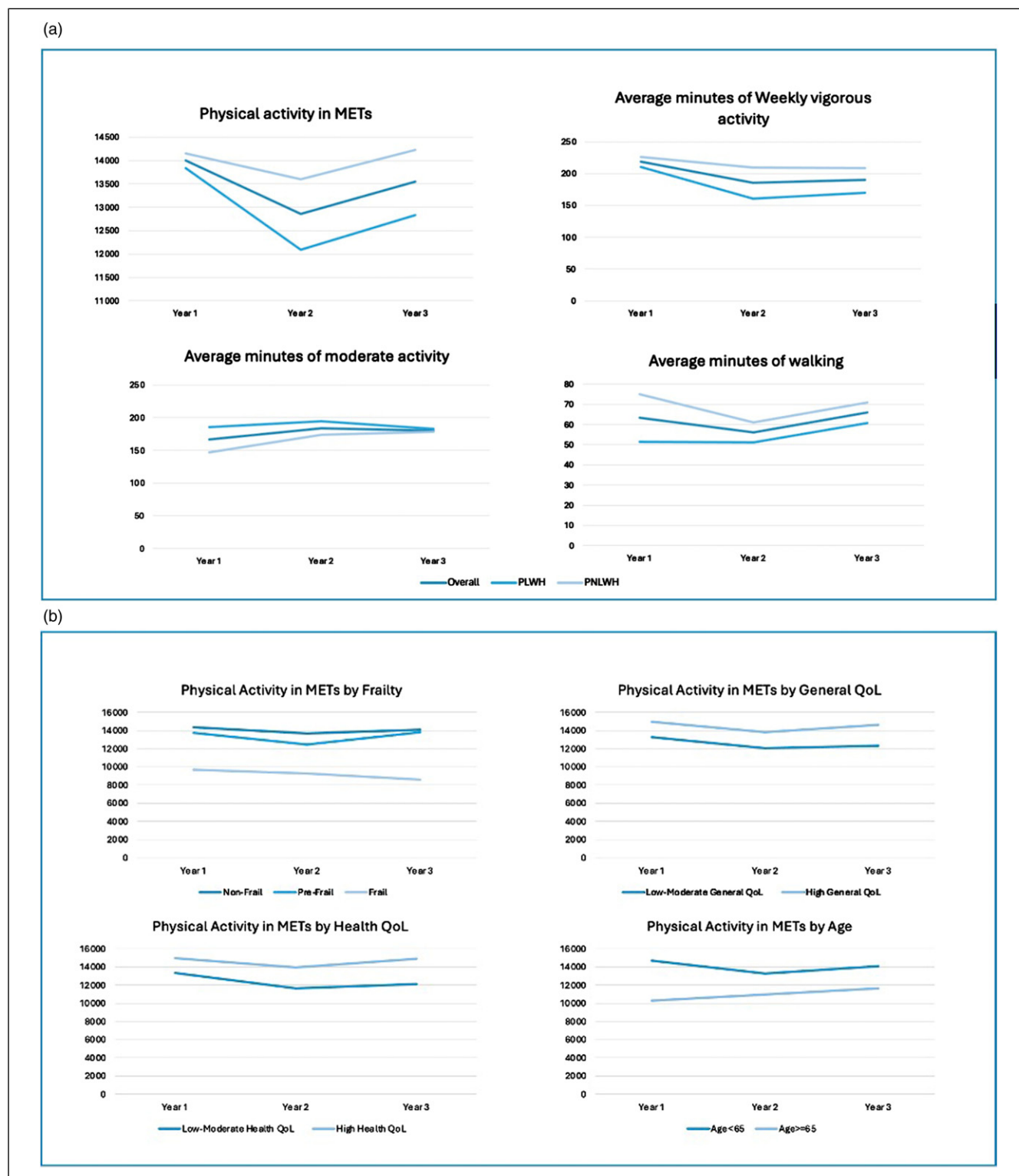


Figure 1. (a) Trends in activity type by HIV status and study year (b) Trends in activity type by frailty, QoL, age, and study year. Caption: The figure demonstrates changes in types of PA throughout the study and changes in overall PA by frailty status, general QoL, health-related QoL, and age. Overall, vigorous PA and walking declined in year two and rebounded in year three; moderate PA, though was highest in year 2. Among nearly all groups and PA declined in year 2 and rebounded in year 3.

Table 3. GEE Model With METs per Week as Continuous Outcome.

	Estimate	95% CI	p-value
Age	−157.34	−222.84, −91.83	<.0001
HIV status (ref = not living with HIV)	−979.88	−1878.48, −81.28	.032
General quality of life	89.96	40.99, 138.94	.0003
Pre-frail (ref = robust)	−67.70	−864.32, 728.91	.87
Frail (ref = robust)	−3011.14	−4665.84, −1356.45	.0004
Comorbidities (ref = none)	−2501.75	−3357.44, −1646.07	<.0001
Visit 2 (ref = visit 1)	−984.55	−1702.41, −266.70	.007
Visit 3 (ref = visit 1)	−197.64	−922.29, 527.00	.59

Note. Bold values indicate statistically significant results at $p < 0.05$.

PLWH, which may be adapted to this specific context and sub-populations.

Additionally, our findings highlight that PA declines with age, which is consistent with other studies (Milanović et al., 2013). In this study, PA declined in year two compared to year one, it did not decline in year three compared to year one. This may be due to the timing of the study, with year one beginning in October 2020. Previous assessments in this cohort have demonstrated that individuals expanded their farming in response to the pandemic during the first year of the study. (Olivieri-Mui et al., 2023) The high levels of PA at baseline may be due to increased farming activities, and decline in PA in year two of the study may represent individuals returning to baseline farming trends. Additionally, though the study dates did not overlap with COVID-19 restrictions in the regions where the study participants resided, the high levels of COVID-19 spread in April and May of 2021 due to the Delta variant may have decreased outdoor activity, and thus PA levels, in year two.

As demonstrated in studies from elsewhere in the world, increased PA was associated with better general QoL in both PLWH and PnLWH enrolled in this study (Bize et al., 2007; Rejeski & Mihalko, 2001). This evidence from older people in Uganda adds to the potential benefits of PA-promoting interventions, including for PLWH who are on ART long term.

We found generally high levels of PA reported by this cohort. Approximately 96% of the present cohort met World Health Organization PA recommendations compared to 8%–44% in cohorts of similar age from the United States and Europe (Keadle et al., 2016; Kruger et al., 2007). We hypothesized that generally high levels of PA are driven by contextual factors that encourage or require PA among the study population. For example, most participants reported not having a water source within their homes and the majority were also employed in non-sedentary jobs, such as agriculture or construction. This is consistent with literature demonstrating higher levels of PA in agrarian societies and lower-income settings where subsistence farming remains common, and the impact of the built environment on PA

levels in sub-Saharan Africa. (Asai et al., 2018; Guwatudde et al., 2016; Kolbe-Alexander et al., 2015; Racine et al., 2012) By contrast, in high-income countries, where the majority of PA is recreational in nature, far higher levels of inactivity are reported in low-income groups (Guthold et al., 2011; Watson et al., 2016) than were seen in the present study.

There were several strengths and limitations of the current analysis. Strengths include longitudinal observation with a relatively large sample direct measurement of frailty via physical tests (such as gait speed and grip strength), data missingness was rare and longitudinal retention as high, with approximately 95% of individuals retained for all three years of observation. A major limitation was the use of self-reported measures for PA, which are known to over-estimate PA compared to direct measurement with pedometers. (Prince et al., 2008) Nonetheless, we have no reason to suspect that measurement bias interacted with HIV serostatus, and the strong association between PA, frailty, age, and measurements of sedentary lifestyle, such as unemployment, offers some measure of internal validity. As with all observational studies there is potential for confounding, which may have occurred if unmeasured factors related to both HIV (or other co-morbidities) and PA explain the relationship between both variables. Finally, our cohort is comprised mainly of rural and peri-urban individuals from an agrarian society, so generalizability should be considered within this context.

In conclusion, our results demonstrate relatively high levels of PA in rural Uganda, but that individuals living with HIV and those with age-related health difficulties, such as frailty and comorbidities, are less likely to continue to engage in PA, despite its known benefits. In future work, contextually relevant PA interventions could be developed and tested among older people and PLWH who do not meet the WHO recommendations. However, ensuring that optimal levels of PA are maintained in this population, including minimizing excessive PA, is important to the maintenance of overall health. Moreover, HIV program developers and public health

practitioners could consider the role for PA for health promotion among these groups in the region.

Acknowledgments

We would like to thank the research participants in Uganda and the study team from Mbarara and Kabwohe in Uganda, and the Medical Practice Evaluation Center in the US for making this work possible.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: ACT reports receiving a financial honorarium from Elsevier, Inc for his work as Co-Editor in Chief of the Elsevier-owned journal *SSM-Mental Health*. MLG reports past grant funding from Gilead Sciences, Inc, which ended in December 2022. The other authors declare no conflicts of interest.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the National Institute on Drug Abuse (K24DA061696-01), National Institute on Aging (R01AG059504), National Heart, Lung, and Blood Institute (K24HL166024), National Heart, Lung, and Blood Institute (R01HL141053).

Ethical Statement

Ethical Approval

All study participants provided informed verbal consent over the phone during the first year of data collection, and written consent for subsequent waves. Study procedures were reviewed and approved by the institutional review committees at Mbarara University of Science and Technology and Mass General Brigham. We also received clearance to conduct the study from the Uganda National Council for Science and Technology and the Research Secretariat in the President's Office.

ORCID iDs

Aneeka Ratnayake  <https://orcid.org/0000-0001-8955-8665>
 Lien T. Quach  <https://orcid.org/0000-0002-8623-4881>
 Alexander C. Tsai  <https://orcid.org/0000-0001-6397-7917>
 Susanne S. Hoepfner  <https://orcid.org/0000-0003-2060-1666>
 Samson Okello  <https://orcid.org/0000-0001-7377-6094>

References

- Angulo, J., El Assar, M., Álvarez-Bustos, A., & Rodríguez-Mañas, L. (2020). Physical activity and exercise: Strategies to manage frailty. *Redox Biology*, 35(1), 101513. <https://doi.org/10.1016/j.redox.2020.101513>
- Asai, Y., Obayashi, K., Oume, M., Ogura, M., Takeuchi, K., Yamagami, Y., Tai, Y., Kurumatani, N., & Saeki, K. (2018). Farming habit, light exposure, physical activity, and depressive symptoms. A cross-sectional study of the HEIJO-KYO cohort. *Journal of Affective Disorders*, 241(1), 235–240. <https://doi.org/10.1016/j.jad.2018.08.003>
- Ashaba, S., Kakuhikire, B., Vořechovská, D., Perkins, J. M., Cooper-Vince, C. E., Maling, S., Bangsberg, D. R., & Tsai, A. C. (2018). Reliability, validity, and factor structure of the Hopkins symptom checklist-25: Population-based study of persons living with HIV in rural Uganda. *AIDS and Behavior*, 22(5), 1467–1474. <https://doi.org/10.1007/s10461-017-1843-1>
- Bize, R., Johnson, J. A., & Plotnikoff, R. C. (2007). Physical activity level and health-related quality of life in the general adult population: A systematic review. *Preventive Medicine*, 45(6), 401–415. <https://doi.org/10.1016/j.ypmed.2007.07.017>
- Bolton, P., & Ndogoni, L. (2001). *Cross-cultural assessment of trauma-related mental illness (phase II): A report of research conducted by world vision Uganda and the Johns Hopkins University*. US Agency for International Development, The Johns Hopkins University.
- Bush, K., Kivlahan, D. R., McDonell, M. B., Fihn, S. D., & Bradley, K. A. (1998). The AUDIT alcohol consumption questions (AUDIT-C): An effective brief screening test for problem drinking. Ambulatory care quality improvement project (ACQUIP). Alcohol use Disorders identification test. *Archives of Internal Medicine*, 158(16), 1789–1795. <https://doi.org/10.1001/archinte.158.16.1789>
- Cheng, L. J., Tan, R. L.-Y., & Luo, N. (2021). Measurement properties of the EQ vas around the globe: A systematic review and meta-regression analysis. *Value in Health*, 24(8), 1223–1233. <https://doi.org/10.1016/j.jval.2021.02.003>
- Chetty, L., Cobbing, S., & Chetty, V. (2021). Physical activity and exercise for older people living with HIV: A scoping review. *HIV*, 13(null), 1079–1090. <https://doi.org/10.2147/HIV.S336886>
- Colberg, S. R., Sigal, R. J., Yardley, J. E., Riddell, M. C., Dunstan, D. W., Dempsey, P. C., Horton, E. S., Castorino, K., & Tate, D. F. (2016). Physical activity/exercise and diabetes: A position statement of the American diabetes association. *Diabetes Care*, 39(11), 2065–2079. <https://doi.org/10.2337/dc16-1728>
- Derogatis, L. R., Lipman, R. S., Rickels, K., Uhlenhuth, E. H., & Covi, L. (1974). The Hopkins symptom checklist (hscl): A self-report symptom inventory. *Behavioral Science*, 19(1), 1–15. <https://doi.org/10.1002/bs.3830190102>
- Dianatinasab, M., Ghahri, S., Dianatinasab, A., Amanat, S., & Fararouei, M. (2020). Effects of exercise on the immune function, quality of life, and mental health in HIV/AIDS individuals. *Advances in Experimental Medicine & Biology*, 1228(1), 411–421. https://doi.org/10.1007/978-981-15-1792-1_28
- Erlandson, K. M., MaWhinney, S., Wilson, M., Gross, L., McCandless, S. A., Campbell, T. B., Kohrt, W. M., Schwartz, R., Brown, T. T., & Jankowski, C. M. (2018). Physical function improvements with moderate or high-intensity exercise among older adults with or without HIV infection. *AIDS*, 32(16), 2317–2326. <https://doi.org/10.1097/qad.0000000000001984>
- Filmer, D., & Pritchett, L. H. (2001). Estimating wealth effects without expenditure data—or tears: An application to educational enrollments in states of India. *Demography*, 38(1), 115–132. <https://doi.org/10.1353/dem.2001.0003>
- Fried, L. P., Tangen, C. M., Walston, J., Newman, A. B., Hirsch, C., Gottdiener, J., Seeman, T., Tracy, R., Kop, W. J., Burke, G., & McBurnie, M. A. (2001). Frailty in older adults: Evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*, 56(3), M146–M156. <https://doi.org/10.1093/gerona/56.3.m146>

- Guthold, R., Louazani, S. A., Riley, L. M., Cowan, M. J., Bovet, P., Damasceno, A., Sambo, B. H., Tesfaye, F., & Armstrong, T. P. (2011). Physical activity in 22 African countries: Results from the world health organization STEPwise approach to chronic disease risk factor surveillance. *American Journal of Preventive Medicine*, 41(1), 52–60. <https://doi.org/10.1016/j.amepre.2011.03.008>
- Guwatudde, D., Kirunda, B. E., Wesonga, R., Mutungi, G., Kajjura, R., Kasule, H., Muwonge, J., & Bahendeka, S. K. (2016). Physical activity levels among adults in Uganda: Findings from a countrywide cross-sectional survey. *Journal of Physical Activity and Health*, 13(9), 938–945. <https://doi.org/10.1123/jpah.2015-0631>
- Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., Macera, C. A., Heath, G. W., Thompson, P. D., & Bauman, A. (2007). Physical activity and public health: Updated recommendation for adults from the American college of sports medicine and the American heart association. *Medicine & Science in Sports & Exercise*, 39(8), 1. https://journals.lww.com/acsm-msse/fulltext/2007/08000/physical_activity_and_public_health_updated.27.aspx
- Heissel, A., Zech, P., Rapp, M. A., Schuch, F. B., Lawrence, J. B., Kangas, M., & Heinzl, S. (2019). Effects of exercise on depression and anxiety in persons living with HIV: A meta-analysis. *Journal of Psychosomatic Research*, 126(1), 109823. <https://doi.org/10.1016/j.jpsychores.2019.109823>
- Hyde, M., Wiggins, R. D., Higgs, P., & Blane, D. B. (2003). A measure of quality of life in early old age: The theory, development and properties of a needs satisfaction model (CASP-19). *Aging & Mental Health*, 7(3), 186–194. <https://doi.org/10.1080/1360786031000101157>
- Jetté, M., Sidney, K., & Blümchen, G. (1990). Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clinical Cardiology*, 13(8), 555–565. <https://doi.org/10.1002/clc.4960130809>
- Keadle, S. K., McKinnon, R., Graubard, B. I., & Troiano, R. P. (2016). Prevalence and trends in physical activity among older adults in the United States: A comparison across three national surveys. *Preventive Medicine*, 89(1), 37–43. <https://doi.org/10.1016/j.ypmed.2016.05.009>
- Kim, Y. S., Park, Y. S., Allegrante, J. P., Marks, R., Ok, H., Ok Cho, K., & Garber, C. E. (2012). Relationship between physical activity and general mental health. *Preventive Medicine*, 55(5), 458–463. <https://doi.org/10.1016/j.ypmed.2012.08.021>
- Kolbe-Alexander, T. L., Pacheco, K., Tomaz, S. A., Karpul, D., & Lambert, E. V. (2015). The relationship between the built environment and habitual levels of physical activity in South African older adults: A pilot study. *BMC Public Health*, 15(1), 518. <https://doi.org/10.1186/s12889-015-1853-8>
- Kruger, J., Carlson, S. A., & Buchner, D. (2007). How active are older Americans? *Preventing Chronic Disease*, 4(3), A53.
- Lee, P. H., Macfarlane, D. J., Lam, T. H., & Stewart, S. M. (2011). Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, 8(1), 115. <https://doi.org/10.1186/1479-5868-8-115>
- Li, J., Loerbroks, A., & Angerer, P. (2013). Physical activity and risk of cardiovascular disease: What does the new epidemiological evidence show? *Current Opinion in Cardiology*, 28(5), 575–583. <https://doi.org/10.1097/HCO.0b013e328364289c>
- Mabweazara, S. Z., Manne-Goehler, J., Bibangambah, P., Kim, J. H., Ruth, S., Hemphill, L. C., Okello, S., Hamer, M., & Siedner, M. J. (2023). Correlates of physical activity among people living with and without HIV in rural Uganda. *Front Reprod Health*, 5(1), 1093298. <https://doi.org/10.3389/frph.2023.1093298>
- Mann, S., Beedie, C., & Jimenez, A. (2014). Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the lipid profile: Review, synthesis and recommendations. *Sports Medicine*, 44(2), 211–221. <https://doi.org/10.1007/s40279-013-0110-5>
- Milanović, Z., Pantelić, S., Trajković, N., Sporiš, G., Kostić, R., & James, N. (2013). Age-related decrease in physical activity and functional fitness among elderly men and women. *Clinical Interventions in Aging*, 8(1), 549–556. <https://doi.org/10.2147/cia.S44112>
- Mushavi, R. C., Burns, B. F. O., Kakuhikire, B., Owembabazi, M., Vořechovská, D., McDonough, A. Q., Cooper-Vince, C. E., Baguma, C., Rasmussen, J. D., Bangsberg, D. R., & Tsai, A. C. (2020). “When you have no water, it means you have no peace”: A mixed-methods, whole-population study of water insecurity and depression in rural Uganda. *Social Science & Medicine*, 245(1), 112561. <https://doi.org/10.1016/j.socscimed.2019.112561>
- Olivieri-Mui, B., Hoeppner, S. S., Tong, Y., Kohrt, E., Quach, L. T., Saylor, D., Seeley, J., Tsai, A. C., Reynolds, Z., Okello, S., Asiimwe, S., Flavia, A., Sentongo, R., Tindimwebwa, E., Meyer, A. C., Nakasujja, N., Paul, R., Ritchie, C., Greene, M., & Siedner, M. J. (2023). Associations of the COVID-19 pandemic with quality of life: A cross-sectional study of older-age people with and without HIV in rural Uganda. *J Glob Health*, 13(1), 06003. <https://doi.org/10.7189/jogh.13.06003>
- Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health. *Sports Medicine*, 29(3), 167–180. <https://doi.org/10.2165/00007256-200029030-00003>
- Prince, S. A., Adamo, K. B., Hamel, M. E., Hardt, J., Gorber, S. C., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, 5(1), 56. <https://doi.org/10.1186/1479-5868-5-56>
- Quach, L. T., Ritchie, C. S., Tsai, A. C., Reynolds, Z., Paul, R., Seeley, J., Tong, Y., Hoeppner, S., Okello, S., Nakasujja, N., Olivieri-Mui, B., Saylor, D., Greene, M., Asiimwe, S., & Siedner, M. J. (2023). The benefits of care: Treated HIV infection and health-related quality of life among older-aged people in Uganda. *Aging & Mental Health*, 27(9), 1853–1859. <https://doi.org/10.1080/13607863.2022.2150143>
- Racine, E. F., Laditka, S. B., Dmochowski, J., Alavanja, M. C. R., Lee, D.-c., & Hoppin, J. A. (2012). Farming activities and carrying and lifting: The agricultural health study. *Journal of Physical Activity and Health*, 9(1), 39–47. <https://doi.org/10.1123/jpah.9.1.39>
- Rautenberg, T. A., Ng, S. K., George, G., Moosa, M. S., McCluskey, S. M., Gilbert, R. F., Pillay, S., Aturinda, I., Ard, K. L., Muyindike, W., Musinguzi, N., Masette, G., Pillay, M., Moodley, P., Brijkumar, J., Gandhi, R. T., Johnson, B., Sunpath, H., Bwana, M. B., Marconi, V. C., & Siedner, M. J. (2023a). Seemingly unrelated regression analysis of the cost and health-related quality of life outcomes of the REVAMP randomized

- clinical trial. *Value Health Reg Issues*, 35(1), 42–47. <https://doi.org/10.1016/j.vhri.2022.12.006>
- Rautenberg, T. A., Ng, S. K., George, G., Moosa, M. S., McCluskey, S. M., Gilbert, R. F., Pillay, S., Aturinda, I., Ard, K. L., Muyindike, W. R., Musinguzi, N., Masette, G., Pillay, M., Moodley, P., Brijikumar, J., Gandhi, R. T., Johnson, B., Sunpath, H., Bwana, M. B., Marconi, V. C., & Siedner, M. J. (2023b). Determinants of health-related quality of life in people with Human Immunodeficiency Virus, failing first-line treatment in Africa. *Health and Quality of Life Outcomes*, 21(1), 94. <https://doi.org/10.1186/s12955-023-02179-x>
- Rêgo, M. L., Cabral, D. A., Costa, E. C., & Fontes, E. B. (2019). Physical exercise for individuals with hypertension: It is time to emphasize its benefits on the brain and cognition. *Clinical Medicine Insights: Cardiology*, 13(1), 1179546819839411. <https://doi.org/10.1177/1179546819839411>
- Reiner, M., Niermann, C., Jekauc, D., & Woll, A. (2013). Long-term health benefits of physical activity – a systematic review of longitudinal studies. *BMC Public Health*, 13(1), 813. <https://doi.org/10.1186/1471-2458-13-813>
- Rejeski, W. J., & Mihalko, S. L. (2001). Physical activity and quality of life in older adults. *The Journals of Gerontology: Series A*, 56(suppl_2), 23–35. https://doi.org/10.1093/gerona/56.suppl_2.23
- Sherwood-Martin, H. (2023). Aging with HIV in sub-saharan Africa. *The Lancet Infectious Diseases*, 1(1), 1. [https://doi.org/10.1016/S1473-3099\(23\)00570-4](https://doi.org/10.1016/S1473-3099(23)00570-4)
- Shim, M.-S., & Noh, D. (2022). Effects of physical activity interventions on health outcomes among older adults living with HIV: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, 19(14), 1.
- Siedner, M. J. (2019). Aging, health, and quality of life for older people living with HIV in sub-saharan Africa: A review and proposed conceptual framework. *Journal of Aging and Health*, 31(1), 109–138. <https://doi.org/10.1177/0898264317724549>
- Stanton, A. M., Boyd, R. L., O’Cleirigh, C., Olivier, S., Dolotina, B., Gunda, R., Koole, O., Gareta, D., Modise, T. H., Reynolds, Z., Khoza, T., Herbst, K., Ndung’u, T., Hanekom, W. A., Wong, E. B., Pillay, D., & Siedner, M. J. (2024). HIV, multimorbidity, and health-related quality of life in rural KwaZulu-natal, South Africa: A population-based study. *PLoS One*, 19(2), e0293963. <https://doi.org/10.1371/journal.pone.0293963>
- Takada, S., Nyakato, V., Nishi, A., O’Malley, A. J., Kakuhikire, B., Perkins, J. M., Bangsberg, D. R., Christakis, N. A., & Tsai, A. C. (2019). The social network context of HIV stigma: Population-based, sociocentric network study in rural Uganda. *Social Science & Medicine*, 233(1), 229–236. <https://doi.org/10.1016/j.socscimed.2019.05.012>
- Velkoff, V. A., & Kowal, P. R. (2006). Aging in sub-Saharan Africa: The changing demography of the region. In *Aging in sub-Saharan Africa: Recommendations for furthering research* (pp. 55–91).
- Vogel, T., Brechat, P.-H., Leprêtre, P.-M., Kaltenbach, G., Berthel, M., & Lonsdorfer, J. (2009). Health benefits of physical activity in older patients: A review. *International Journal of Clinical Practice*, 63(2), 303–320. <https://doi.org/10.1111/j.1742-1241.2008.01957.x>
- Watson, K. B., Carlson, S. A., Gunn, J. P., Galuska, D. A., O’Connor, A., Greenlund, K. J., & Fulton, J. E. (2016). Physical inactivity among adults aged 50 Years and older - United States, 2014. *MMWR Morb Mortal Wkly Rep*, 65(36), 954–958. <https://doi.org/10.15585/mmwr.mm6536a3>
- Webel, A. R., Davey, C. H., Oliveira, V., Cleveland, D., Crane, H. M., Gripshover, B. M., Long, D. M., Fleming, J. G., Buford, T. W., & Willig, A. L. (2023). Physical activity is associated with adiposity in older adults with HIV in the modern HIV era. *AIDS*, 37(12), 1819–1826. <https://doi.org/10.1097/qad.0000000000003635>
- Winston, N., Swanson, B., Fogg, L. F., Capuano, A. W., Wilbur, J., & Barnes, L. L. (2021). Physical activity and cognitive function in African American older adults living with HIV. *Journal of Gerontological Nursing*, 47(12), 27–34. <https://doi.org/10.3928/00989134-20211109-06>
- Xu, L., Gu, H., Cai, X., Zhang, Y., Hou, X., Yu, J., & Sun, T. (2023). The effects of exercise for cognitive function in older adults: A systematic review and meta-analysis of randomized controlled trials. *Int J Environ Res Public Health*, 20(2). <https://doi.org/10.3390/ijerph20021088>