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Determining frailty index thresholds for older people across multiple countries in sub-Saharan Africa

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Abstract

Background Despite the increasing attention on frailty as a global public health concern, frailty screening among older people in Sub-Saharan Africa (SSA) continues to rely on instruments and thresholds from high-income countries. These instruments and thresholds may not be useful in SSA due to contextual differences. We explored the development of a frailty threshold for older people in SSA.

Methods We utilized pooled cross-sectional data from four SSA countries (Kenya, Ghana, Uganda and Côte d'Ivoire) to determine a frailty index threshold for 5527 older people (50 years and above) using a two-step approach. The mean ages of the participants ranged from 62.13 (SD: 9.60) to 74.00 (SD: 9.40) years. The participants were mostly females across the four countries, ranging from 50.1% in Côte d'Ivoire to 65.3% in Kenya. Country-specific frailty thresholds were developed using the Receiver Operating Characteristics (ROC) method. The primary thresholds were further combined into a single threshold using random effects meta-analysis. Subgroup analyses and meta-regression were conducted to explore potential sources of heterogeneity in the pooled frailty threshold.

Results Here we show the Area Under the Curves from the ROC analyses ranging between 0.91 (CI: 0.89, 0.93) and 0.94 (CI: 0.92, 0.97), with sensitivities ranging from 0.83 to 0.94 and specificities from 0.72 to 0.87. An overall threshold of 0.29 (95% CI: 0.25, 0.33) was obtained after pooled analysis of the country-specific thresholds.

Conclusions This work demonstrates that using context-specific data can yield valuable insights into frailty thresholds among older people in SSA, enabling more culturally relevant interventions. Effective frailty screening must account for population-level differences, including demographic, health, and socio-cultural factors.

Plain language summary

Frailty is a common problem which makes older people weak and unable to carry out daily activities. While this has been well researched in high-income countries, there is limited evidence about frailty among older people in Sub-Saharan Africa, where the older population is increasing quickly. Most studies conducted in sub-Saharan Africa rely on thresholds developed and validated in high-income countries, which may not capture the important things that contribute to frailty in Sub-Saharan Africa. We developed a frailty threshold by combining data from four African countries. Our results show that it is possible to develop thresholds that reflect the realities of older people in Sub-Saharan Africa, though attention to each population's aging profile is still required for effective frailty screening.

Frailty is a common problem associated with increasing age characterized by decreased physiological reserves and increased vulnerability to adverse health outcomes[1,2]. Frailty has been associated with an increased risk of falls, hospitalization, morbidity and mortality[3–5]. As the global population of older people continues to rise[6], frailty is increasingly becoming the focus of public health and healthcare planning[2,7]. Frailty was formally defined in 2001 with the introduction of the Frailty Phenotype (FP)[8], yet ongoing debates about its measurement and variability in prevalence rates persist[9,10]. Frailty, therefore, remains a complex and evolving concept that requires ongoing research.

More importantly, the available frailty screening approaches measure different domains of health, with an older person being classified as frail by one frailty screening instrument, and robust (not frail) by another frailty screening instrument[11]. Currently, the two main frailty screening approaches used globally are the FP[8] and the Frailty Index (FI)[12]. The FP uses five specific physical criteria (unintentional weight loss, weakness, slow walking

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speed, low physical activity, and self-reported exhaustion). An individual is classified as frail if they meet three or more of the five frailty criteria. In contrast, the FI adopts a deficit accumulation model, considering frailty as the result of declines across physical, psychological, and physiological health domains, acknowledging frailty as a multidimensional condition. The FI is a flexible instrument that has been adapted globally, with modifications to the number of items (from as low as 5)[13], and varying optimal thresholds (between 0.18 and 0.41) at which frailty is determined[14]. Recent evidence has also demonstrated that, despite not being included in the original FI by Rockwood and colleagues[12], aspects of well-being, particularly social connectedness, are strongly linked to frailty and represent valuable additions to the FI[15–17].

Despite the global attention and increasing geriatrics and gerontology research, the global prevalence of frailty remains unclear due to the ongoing contention on the best approach to frailty screening[18]. A recent systematic review using data from 242 studies across 62 countries reported prevalence of about 12% using the FP and 24% using the FI[19]. In addition to these inconsistencies, the application of frailty screening instruments across different populations has also become an important area of concern, with several versions of instruments being applied in different regions and countries[20,21]. While this may be considered an advancement in frailty research, the validity and applicability of these instruments in Low-and Middle-Income countries (LMICs) have not been fully explored[22,23]. More recently, the diagnostic accuracy of these screening instruments has become a subject of concern, even in High Income Countries (HICs) where they were developed and validated[24,25]. Frailty is increasingly recognized as a modifiable condition. Although not all cases are entirely preventable, early identification of at-risk individuals and timely, targeted interventions can delay the onset of frailty, slow its progression, or reverse it in some cases[26,27]. Identifying frailty in LMICs using LMIC specific instruments can potentially enhance the well-being of older people in these settings.

Recently, countries such as India, Brazil, and Mexico have made progress in adapting and validating frailty screening instruments for their local contexts[28]. However, similar efforts remain scarce in Sub-Saharan Africa (SSA)[29]. A recent attempt by Lewis and colleagues to adapt the FP in Tanzania found that certain components were difficult to measure or interpret in the African context[30], highlighting the need for localized instruments and thresholds.

Research on frailty in SSA is increasing, albeit at a slower pace than most parts of the world[31]. Like many parts of the world, the prevalence of frailty in SSA also remains unknown due to the ongoing contentions around the best approach to frailty screening. This phenomenon is further compounded by the limited data on older people in the SSA region[32,33]. Integrating aging-related perspectives into established research domains such as HIV/AIDS and chronic non-communicable diseases is essential to addressing the evolving needs of older populations[33,34]. SSA is currently experiencing one of the fastest-growing older populations globally[6,35]. The World Health Organization (WHO), for instance estimates that the number of older people in the region will increase from 43 million in 2010, to about 67 million by 2025 and 163 million by 2050[36]. This demographic shift is likely to cause a commensurate increase in frailty rates among older people in the sub-region.

It is by now known that the factors that contribute to frailty in SSA may differ from HICs due to regional variations in the demographic, social and economic landscapes[34]. Screening for frailty in this region, therefore, requires further exploration, especially regarding the instruments and thresholds used for identifying older people at risk for frailty. Consequently, this study aims to develop a regional specific frailty threshold for older people in SSA using pooled data from multiple countries. The findings of our study indicate that frailty thresholds vary across SSA countries, with country-specific thresholds ranging between 0.24 and 0.32. A pooled threshold of 0.29 was established through meta-analysis, accounting for heterogeneity across populations. Developing a frailty threshold for older people in SSA can help in the early detection of frailty with improved accuracy and relevance, as well as enhance effective allocation of resources to improve the well-being of older people.

Methods

Study design and participants

We employed a cross-sectional design using multiple datasets from four countries in SSA (Kenya, Ghana, Uganda and Côte d'Ivoire). The datasets were sourced from various population-based studies focusing on older people (50 years and above) in SSA[33,37–39]. We used data from the Health and Well-being of Older Persons study in Kenya (HWOPs-1), Wave 2 of the WHO Study on Global AGEing and adult health (SAGE) Ghana, the WHO SAGE-WOPS HIV sub-study in Uganda, and the Living Condition, Health and Resilience among the Elderly study in Côte d'Ivoire. Overall, 783 older people (60 years and above) were included from Kenya, 3266 older people (50 years and above) from Ghana, 461 (50 years and above) from Uganda and 1017 (50 years and above) from Côte d'Ivoire. Demographic information (age and sex) and health information were obtained from the respective datasets for this study. Access to the datasets was granted upon formal application to the respective data custodians. Each request included a description of the study objectives and data use agreements. This study was approved by the Torrens University Australia Human Research Ethics Committee (Approval number: 0353).

Data description

Health and Well-being of older persons in Kenya study (HWOPs-1). This study was designed to develop a research framework for routine generation of evidence on the health and well-being of older people (60 years and above) in Kenya and developing and piloting an essential research tool with key indicators to enable rapid and routine assessment of the health of older people. The specific objectives of the study were to develop and validate a research tool to assess the health and well-being of older people in Kenya, examine the disease and disability burden among older people in a selected county, identify health and socio-economic concerns and needs that affect the well-being of the older persons, identify strategies that will enhance the health, psycho-social and general well-being of older people, and strengthen the research capacity of the collaborating institutions through designing a policy-focused study and production of research. The study was conducted in Kiambu County in the central region of Kenya. Kiambu is one of the counties bordering Nairobi, the capital city of Kenya. A cross-sectional survey design was used, where households were selected through a multi-stage random sampling of households with older persons. The first stage involved a random selection of 30 clusters in the National Sample Survey and Evaluation Programme (NASSEP). The second stage involved the identification of households with older persons in each of the selected clusters, and 10 households were randomly selected per cluster. About 300 households were selected using random sampling with replacement to account for non-response. Data were collected electronically using tablets and uploaded daily to central servers which were monitored for completeness and quality. The dataset is owned and hosted by the African Population and Health Research Centre, Nairobi, Kenya. HWOPs-1 was approved by the Kenyatta University Ethical Review Committee and the Scientific Steering Committee (Ref. No. PKU/8691934). Oral informed consent was obtained from the participants.

The WHO study on global AGEing and adult health (SAGE)—Ghana. The WHO Study on Global AGEing and adult health (SAGE) is a nationally representative survey conducted in Ghana through multistage cluster sampling strategies. The survey is a multi-country longitudinal study that collects data to complement existing ageing data sources to inform policy and programmes. WHO and the University of Ghana Medical School through Department of Community Health collaborated to implement SAGE Wave 2 in 2014–2015. Individuals aged ≥50 years were interviewed regarding their chronic health conditions and health services coverage; subjective well-being and quality of life; health care

utilization; risk factors and preventive health behaviours; perceived health status; socio-demographic and work history; social cohesion; and household characteristics. Similar information was collected on smaller sample of persons aged 18–49 years. In households identified as "older" for sampling purposes, all household members aged 50 years and older were invited to participate in the study. SAGE was approved by the World Health Organization's Ethical Review Board (reference number RPC149) and the Ethical and Protocol Review Committee, College of Health Sciences, University of Ghana, Accra, Ghana. Written informed consent was obtained from all study participants.

The WHO SAGE-WOPS HIV sub-study in Uganda. The Well-Being of Older People Study is the second round of the survey (WOPS)−2013. WOPS surveys are designed by the WHO and the Medical Research Council of Uganda and implemented by the Medical Research Council of Uganda. The objectives of the data collection were to describe the roles, health problems (physical and mental) and social well-being of older people who are directly and indirectly affected by HIV/AIDS, with special attention to the effects of the introduction of Anti-Retroviral Therapy (ART), and to develop recommendations for policy and practice that can be expected to improve the well-being of older people affected by or infected with HIV/AIDS. Individuals aged ≥50 years were interviewed regarding respondent and household characteristics, health state description, chronic conditions and health service coverage, health care utilization and risk factors and behaviour, health measurements, care giving and care receiving roles. SAGE-WOPS HIV sub-study was approved by Uganda Virus Research Institute Research and Ethics Committee, the Uganda National Council for Science and Technology and the WHO Ethical Review Committee (RPC-149). All study respondents gave a written/thumb printed consent to participate in the study.

The living condition, health and resilience among the elderly study in Côte d'Ivoire. The dataset was obtained by combining data from three surveys in 3 regions of Côte d'Ivoire. The first survey was conducted in the department (sub-region) of Toumodi, Central Côte d'Ivoire, in July 2018. The second survey was conducted in the sub-prefecture of Daloa, western Côte d'Ivoire in November 2023, while the third survey was conducted in the sub-prefecture of Korhogo, Northern Côte d'Ivoire in May 2024. A two-stage sampling strategy was used. At the first stage, 51 enumeration areas for Toumodi, 22 enumeration areas for Daloa, and 29 enumeration areas for Korhogo were randomly selected. At the second stage, 30 households were randomly selected in each enumeration area. In each selected household, all individuals aged 50 years and above were pre-selected as participants in the aging questionnaire. Participants in the survey were definitely included upon oral consent. The final sample sizes were 557 in Toumodi, 278 in Daloa, and 242 in Korhogo. These surveys used the same questionnaire. Information on both perceived and observed health conditions and health behaviour, perceived survival, socioeconomic and demographic characteristics of participants was collected. Face to face interviews were conducted by ENSEA students in French under the supervision of their assistant professors. On average, each interview took approximately 35 min to complete. Data were collected using tablets loaded with CSPro software and subsequently imported into Stata v.17.0. The Living Condition, Health and Resilience among the Elderly study was approved by the National Ethics Committee of Côte d'Ivoire (Comité Consultatif National de Bioéthique de la République de Côte d'Ivoire).

Frailty assessment

The FI[12] was adopted for frailty assessment in this study. The FI is a validated tool adopted globally to assess frailty among older people across community, acute and subacute settings. The FI is based on the accumulation of health deficits, which include a range of physical, social and cognitive indicators. Each deficit contributes equally to the overall score, and the index is calculated as the ratio of the number of deficits present to the total number of deficits considered[12].

In this study, the FI was developed from the four datasets following the recommendations by Rockwood and colleagues[40,41]. Deficits included in our FI covered a range of health domains (physical health, functional ability, mental health, sensory function and social well-being). We developed our FI considering the contextual factors (culture, healthcare access, social integration, etc.) in the SSA region. We also considered the limited healthcare access in most parts of SSA[42,43], and accordingly limited the number of chronic diseases included in our FI. The FI items were discussed among the team of authors who are familiar with aging and healthcare in SSA.

We identified 30 items in each dataset that met the standard technical criteria[40,41]. Each of the FI items was scored such that 0=deficit absent and 1 = deficit present. The scores were added and divided by the number of items (30) to create a variable between 0.00 (no deficits present) and 1.00 (all deficits present). The FI items were largely consistent across the four datasets, ensuring a high level of consistency in the variables used for the analysis. The internal consistency (Cronbach's α values) was high across all datasets, ranging from 0.89 (Côte d'Ivoire) to 0.94 (Ghana), indicating good reliability of the FI. Details of the respective FI items across the datasets are presented in the Supplementary Information (see Supplementary Tables 1–4).

Outcome variables

A 6-item outcome variable assessing dependency and independence in Activities of Daily Living (ADLs) was derived from the datasets from Kenya (Cronbach's α: 0.85), Ghana (Cronbach's α: 0.84), Uganda (Cronbach's α: 0.74), and Côte d'Ivoire (Cronbach's α: 0.71) indicating acceptable internal consistency of the items[44]. We coded ADL performance as a binary variable, where participants who reported independence in all six ADLs were coded as 1 (independent), and those reporting dependence in one or more ADLs were coded as 0 (dependent). Frailty is a strong predictor dependency[26].

Determining thresholds

Receiver Operating Characteristic (ROC) analysis was performed on each dataset to determine the optimal thresholds. The FI was used as test variables, and the binary outcome measures (dependency versus independence with ADL) were used as state variables. The Area Under the ROC Curve (AUC) was calculated to assess the overall performance of the FI in discriminating frailty status in each of the datasets. The AUC summarizes the overall diagnostic accuracy of a classification test, with a value of 0.50 suggesting no discrimination, 0.50 to 0.70 being poor discrimination, 0.70–0.80 suggesting good discrimination, 0.80–0.90 suggesting very good discrimination, and 0.90–1.00 suggesting excellent discriminatory power[45,46]. The optimal thresholds were determined using the AUC, and J statistics (Youden Index) which maximizes the sum of sensitivity and specificity. This process involved plotting the true positive rate (sensitivity) against the false positive rate (1-specificity) at various threshold levels[47]. This process helped to prevent the influence of disease prevalence on predictive values often seen in Positive and Negative Predictive Values (PPV and NPV)[48,49]. The ROC analysis was conducted under non-parametric assumption using IBM SPSS version 29.20. Statistical significance for all analyses was set at P value < 0.05.

Combining thresholds through meta-analysis

After determining thresholds from each dataset, we explored the possibility of combining these thresholds into a single, unified threshold to overcome the spectrum effect (variation in diagnostic test performance across different populations and subgroups due to disease prevalence, severity of condition, and other population characteristics) often associated with single population ROC based thresholds[50,51]. This involved using a random-effects (Restricted Maximum Likelihood) meta-analysis technique to aggregate the ROC results from the different datasets. Heterogeneity was assessed using tau-squared (τ^2), the I^2 statistic, and Cochran's Q test. By pooling the AUC,

Table 1 | Summary descriptive statistics of country specific samples

Variable	Kenya	Ghana	Uganda	Côte d'Ivoire
Sample Size (*n*)	783	3266	461	1017
Age (Years) (Mean ± SD)	74.00 ± 9.40	65.02 ± 10.70	64.56 ± 10.40	62.13 ± 9.60
Gender				
Male	34.70%	41.20%	37.50%	49.95%
Female	65.30%	58.80%	62.50%	50.05%
ADL status				
Independent	72.30%	90.00%	75.70%	68.40%
Dependent	27.70%	10.00%	24.30%	31.60%
Frailty index				
Median	0.30	0.13	0.20	0.27
Variance	0.03	0.02	0.03	0.03
IQR	0.25	0.20	0.24	0.27
Cronbach's α	0.93	0.94	0.93	0.89

Cronbach's α indicates internal consistency of the frailty index. Age is presented as mean ± SD. Gender and ADL status are presented as percentages. Median, variance, and IQR describe the distribution of the frailty index in each sample.
ADL activities of daily living, *IQR* interquartile range, *SD* standard deviation.

sensitivity, specificity, standard error and threshold values from each dataset, we derived a unified threshold. Meta-analysis of diagnostic accuracy tests has been recommended and utilized in several epidemiological and clinical literature[52–54]. Subgroup analyses were conducted to explore potential sources of heterogeneity in our frailty threshold estimates. First, countries were grouped into two regional categories: West Africa (Ghana, Côte d'Ivoire) and East Africa (Kenya, Uganda) to assess geographical differences. Second, the frailty thresholds derived from the ROC analyses were used to classify countries into high threshold (above the pooled threshold) and low threshold (below the pooled threshold) groups, allowing for comparisons based on frailty burden. The meta-analyses were conducted using STATA version 16.0.

To evaluate the practical utility of the pooled threshold, we applied it to each country-specific dataset and calculated the corresponding sensitivity and specificity values. This step provided a secondary validation of the pooled threshold's discriminative performance across the diverse national contexts.

Assessment of study-level moderators

We conducted a meta-regression using a random-effects model with Restricted Maximum Likelihood (REML) estimation to explore study-level factors contributing to the observed heterogeneity in the pooled threshold. The moderators examined included mean-centred values for age and percentage of female participants. We tested each moderator in a separate model to assess their independent association with the reported threshold. The Knapp–Hartung adjustment was applied to improve the accuracy of confidence intervals given the small number of studies. Between-study variance explained by each model was quantified using the R^2 statistic. Residual heterogeneity was assessed using tau-squared (τ^2), the I^2 statistic, and Cochran's Q test.

Statistics and reproducibility

All statistical analyses were conducted using IBM SPSS version 29.20 and STATA version 16.0. ROC analyses were performed independently for each country dataset to determine optimal FI thresholds using Youden's Index (sensitivity + specificity – 1), with dependency in ADLs as the binary outcome. For each model, AUC, sensitivity, specificity, standard errors, and 95% confidence intervals were calculated under non-parametric assumptions.

To obtain a unified threshold, a random-effects meta-analysis using REML estimation was conducted. Statistical heterogeneity was assessed using I^2, τ^2, and Cochran's Q test. Statistical significance was set at $p < 0.05$ for all analyses. Subgroup analyses were performed by region (West vs. East Africa) and frailty burden (low vs. high thresholds). Meta-regression was conducted to examine study-level moderators (mean age and percentage of female participants), with the Knapp–Hartung adjustment applied to improve inference precision. Model performance was quantified using R^2, and residual heterogeneity was reported.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Results

Descriptive statistics

The age distribution showed that the average age was highest in Kenya (74 years) and lowest in Côte d'Ivoire (62.13 years), as shown in Table 1. There was a higher percentage of females across all datasets, with the highest proportion in Kenya (65.30%) and the most balanced distribution in Côte d'Ivoire (50.05% female). The median FI values across the four countries suggest varying levels of frailty. Kenya has the highest median FI (0.30), and Ghana has the lowest FI median (0.13). The FI interquartile range (IQR) is broadest in Côte d'Ivoire (0.27), and narrowest in Ghana (0.20). The summary descriptive statistics are presented in Table 1.

ROC analyses and frailty thresholds across countries

The results from the ROC analyses are presented in Table 2. The AUC values ranged from 0.91 (95% CI:0.89, 0.93) in Côte d'Ivoire to 0.94 (95% CI: 0.92, 0.97) in Uganda. Sensitivity values range from 0.83 (Ghana) to 0.94 (Kenya), with specificity values ranging from 0.72 (Kenya) to 0.87 (Ghana). The cut-off points for identifying frailty in individual datasets were between 0.24 (95% CI: 0.22, 0.26) in Ghana and 0.32 (95% CI: 0.34, 0.38 and 95% CI: 0.29, 0.34) in Kenya and in Côte d'Ivoire, respectively. These thresholds determined the point at which individuals can be classified as frail or non-frail in the individual datasets. The AUC standard errors ranged from 0.007 (Ghana) to 0.011 (Uganda), indicating the most variability and least precision in AUC estimates. The ROC curves illustrating the discriminative ability of the frailty index across the four countries are presented in Fig. 1a–d.

The standard errors and confidence intervals were computed for the Youden Index values (thresholds) from each dataset. The standard errors were relatively small across the datasets indicating a high precision in the threshold estimates. The threshold from the Ghana dataset has the lowest standard error (0.0087) and the Ugandan threshold has the largest standard error (0.0148). The confidence intervals were narrow for all the datasets with

Table 2 | Diagnostic performance of the frailty index in four sub-Saharan African countries

Country	Sample Size	AUC	Sensitivity	Specificity	Youden Index	Threshold	Standard Error (AUC)	95% CI (AUC)	Standard Error (Threshold)	95% CI (Threshold)
Kenya	783	0.92	0.94	0.72	0.66	0.32	0.010	(0.90 – 0.94)	0.0089	(0.34-0.38)
Ghana	3266	0.93	0.83	0.87	0.70	0.24	0.007	(0.92-0.94)	0.0087	(0.22-0.26)
Uganda	461	0.94	0.89	0.85	0.74	0.30	0.011	(0.92-0.97)	0.0148	(0.27-0.33)
Côte d'Ivoire	1017	0.91	0.89	0.77	0.66	0.32	0.009	(0.89-0.93)	0.01166	(0.29-0.34)

Sensitivity and specificity values correspond to the optimal threshold identified using Youden's Index. Standard errors and confidence intervals are reported for both AUC and threshold estimates. Threshold values reflect the frailty index cut-off that maximized the sum of sensitivity and specificity. The outcome variable was dependency in Activities of Daily Living (ADLs), operationalized as a binary variable: participants independent in all six ADLs were coded as 1 (independent), and those dependent in one or more ADLs were coded as 0 (dependent).
AUC area under the curve, *CI* confidence interval.

the Ghana threshold having the narrowest confidence interval (95% CI: 0.22, 0.25), and Uganda having the widest confidence interval (95% CI: 0.27, 0.33).

Pooled frailty threshold estimates

The results of the random-effects meta-analysis to determine the pooled frailty threshold across the four country datasets are presented in Fig. 2. The pooled estimate for the frailty threshold was 0.29 (95% CI: 0.25,0.33). Heterogeneity was substantial, with an I^2 of 92.81%, and the Q-test for heterogeneity was significant ($Q(3) = 53.76$, $p < 0.001$). indicating that true differences exist between study thresholds beyond random chance. The test for overall effect also yielded a significant z-score ($z = 14.77$, $p < 0.001$).

The pooled threshold demonstrated good discriminative capacity, with high sensitivity and moderate to high specificity across all countries. The sensitivity values ranged from 82.00% in Ghana to 95.40% in Kenya. The Specificity values ranged from 64.70% in Kenya to 83.70% in Uganda.

Subgroup analyses

The findings from the subgroup analysis by geographic location are presented in Fig. 3. The estimated frailty threshold for West African countries (Ghana and Côte d'Ivoire) was 0.28 (95% CI: 0.20, 0.36), with a high degree of heterogeneity ($I^2 = 96.69\%$). In contrast, the estimated threshold for East African countries (Kenya and Uganda) was 0.31 (95% CI: 0.29, 0.33), with lower heterogeneity ($I^2 = 48.22\%$). The pooled frailty threshold across all four countries was 0.29 (95% CI: 0.25, 0.33), with substantial heterogeneity ($I^2 = 92.81\%$). The test for subgroup differences ($Qb = 0.68$, $p = 0.41$) revealed no statistically significant difference between the two regional groups, although within-group heterogeneity was notably higher in West Africa compared to East Africa.

The results from the subgroup analysis by frailty threshold (high FI thresholds vs. low FI thresholds) are presented in Fig. 4. The high FI group, which included studies from Kenya, Uganda, and Côte d'Ivoire (FI ≥ 0.29), had an estimated threshold of 0.31 (95% CI: 0.30, 0.33), with minimal heterogeneity ($\tau^2 = 0.00$, $I^2 = 0.12\%$, $H^2 = 1.00$). The low FI group, consisting only of Ghana (FI < 0.29), had an estimated threshold of 0.24 (95% CI: 0.22, 0.25), with no observed between-study variability ($\tau^2 = 0.00$). The overall pooled threshold across all studies was 0.29 (95% CI: 0.25, 0.33), but significant heterogeneity was detected ($\tau^2 = 0.00$, $I^2 = 92.81\%$, $H^2 = 13.91$). A test for subgroup differences showed a statistically significant difference between the High and Low FI groups ($Qb(1) = 51.74$, $p < 0.001$).

Study level meta-regression

Meta-regression analyses showed that both age and gender composition independently contributed to the variability in reported frailty thresholds across the studies. Higher mean age was significantly associated with lower thresholds ($\beta = -0.005$, 95% CI: −0.010 to −0.001, $p = 0.041$), explaining 88.0% of the between-study variance. However, substantial residual heterogeneity remained ($\tau^2 = 0.004$; $I^2 = 97.6\%$). Similarly, a greater proportion of female participants was linked to lower thresholds ($\beta = -0.006$, 95% CI: −0.011 to −0.001, $p = 0.036$), with 89.4% of the variance explained and residual heterogeneity also evident ($\tau^2 = 0.004$; $I^2 = 97.3\%$).

Discussion

In this study, we conducted a secondary analyses of pooled cross-sectional datasets from four countries in SSA to determine optimal frailty threshold for older people using the deficit accumulation method[12]. First, we computed frailty thresholds using the ROC based approach in each of the datasets. The thresholds were subsequently combined using a random effect meta-analysis technique to determine a homogenized threshold. Using ROC-derived thresholds from multiple SSA specific datasets and pooling them through meta-analysis allowed us to synthesize diagnostic performance across diverse populations, assess discriminative accuracy of the FI, and account for between-country heterogeneity[50,55]. While previous studies have proposed frailty thresholds using Item Response Theory (IRT), such methods rely on strict assumptions and often underrepresent the

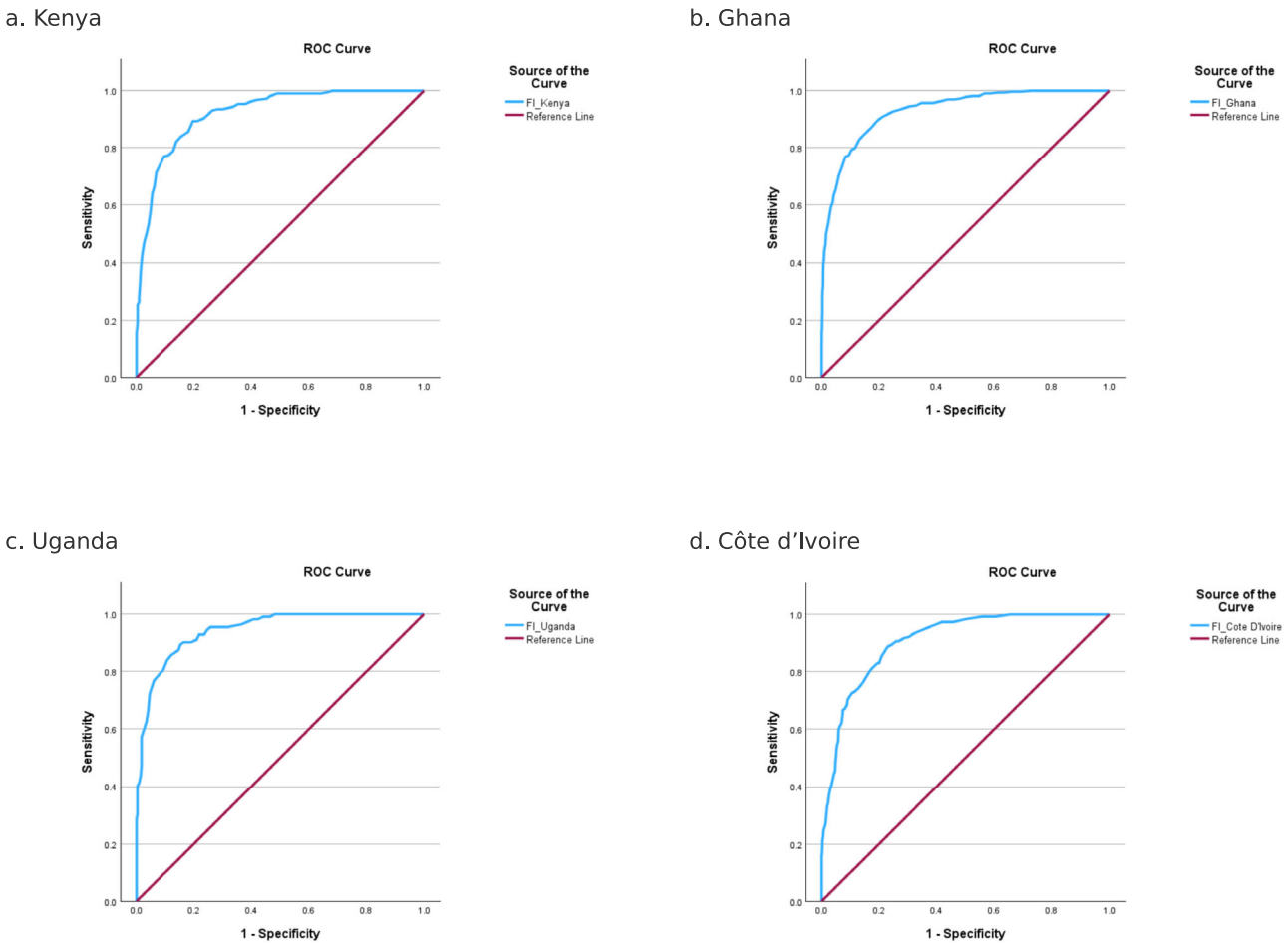

Fig. 1 | Receiver operating characteristic (ROC) curves for the frailty index across four sub-Saharan African countries. Panels represent ROC curves for: **a** Kenya, **b** Ghana, **c** Uganda, and **d** Côte d'Ivoire. ROC receiver operating characteristic, AUC area under the curve. ROC curves illustrate the diagnostic ability of the frailty index to distinguish between frail and non-frail individuals across different thresholds. The Y-axis represents sensitivity (true positive rate), and the X-axis represents 1–specificity (false positive rate). The closer the curve is to the top-left corner, the better the discriminative ability of the index.

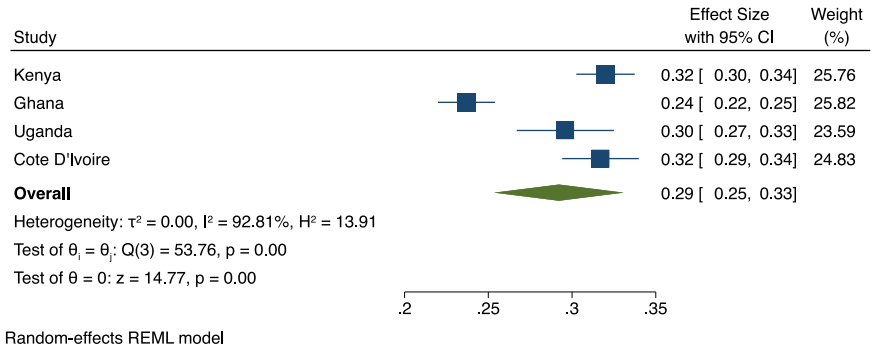

Fig. 2 | Forest plot of pooled estimate of optimal frailty index thresholds across four Sub-Saharan African countries. Effect sizes represent the optimal frailty index thresholds identified through ROC analysis in each country. Boxes represent the point estimates with their 95% confidence intervals; the size of the box reflects the study weight. The diamond indicates the pooled effect size with corresponding 95% CI, calculated using a random-effects REML model. Heterogeneity statistics include τ^2 (between-study variance), I^2 (percentage of variation due to heterogeneity), and H^2 (relative excess in Q over degrees of freedom).

complexity of multidimensional constructs like frailty[50,56]. Our current approach offers a more flexible and empirically grounded alternative, suited for population-level screening. To the best of our knowledge, this is the first study to use a meta-analytic approach to determine a regional level frailty threshold from multiple data sources.

Our initial findings revealed that, despite having good reproducibility and responsiveness potentials[57,58], the FI thresholds varied across the datasets. Within the frailty literature, FI thresholds have been reported to differ depending on the methods used to derive them[50,59]. Despite the variability, our country specific thresholds (0.24– 0.32) fall within the wide range of existing global FI thresholds (0.18-0.41)[14]. This is not surprising as the concept and process of developing our FI was consistent with the gold standard[40,41]. The differences in our FI medians and IQR are likely due to a combination of demographic, healthcare access, and the methods used in data collection[7,34,41,60]. Understanding these differences, especially the demographic level differences, could be useful for future policy formulation and resource allocation for older people. In addition, the varying burden of chronic conditions, particularly HIV/AIDS in SSA, may also play a role in shaping frailty patterns across countries. HIV/AIDS is known to accelerate aging processes and

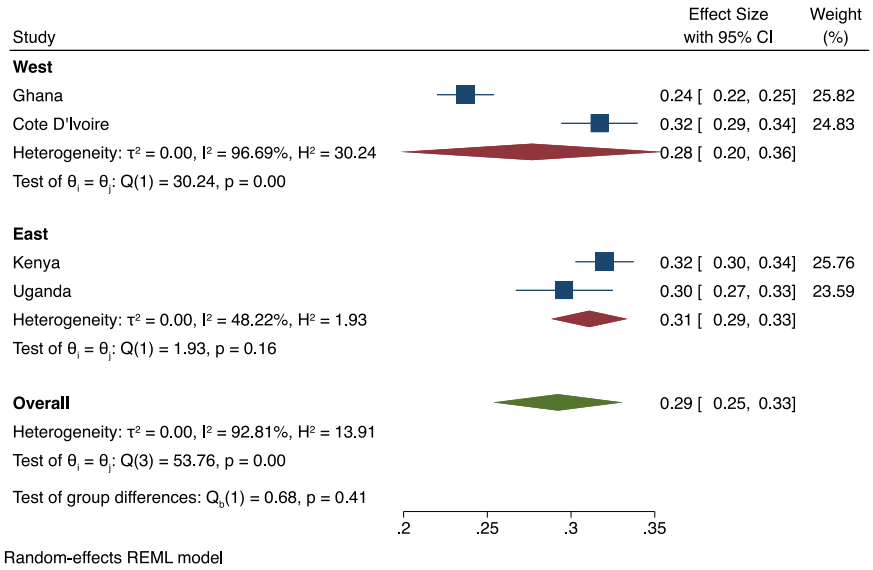

Fig. 3 | Forest plot showing subgroup analysis of optimal frailty index thresholds across four Sub-Saharan African countries, grouped by region (West vs. East Africa). Effect sizes are optimal frailty index thresholds. Squares show point estimates with 95% CIs; diamonds indicate pooled estimates. Results are based on a random-effects REML model. τ^2, I^2, and Q test values reflect heterogeneity within and between subgroups.

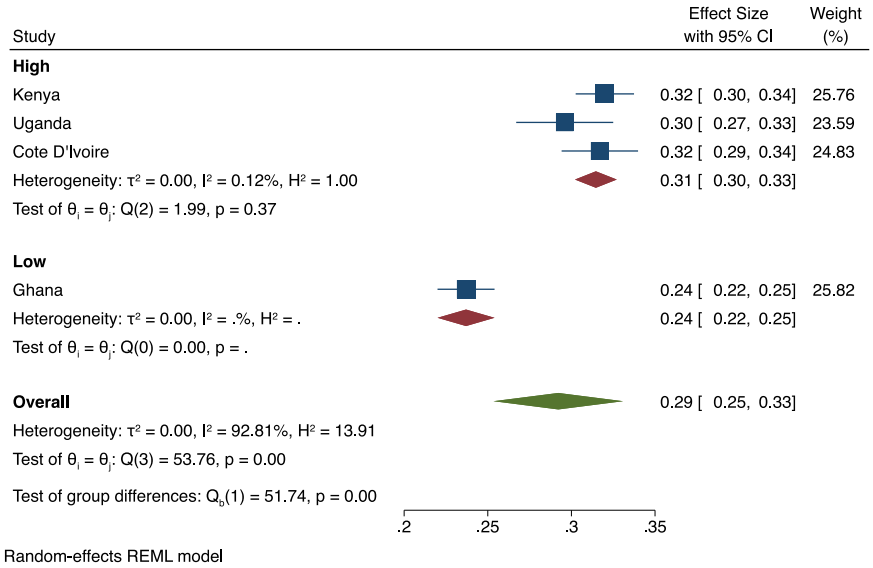

Fig. 4 | Forest plot of frailty thresholds by high and low threshold subgroups. Effect sizes represent optimal frailty index thresholds. Squares indicate point estimates with 95% confidence intervals; diamonds show pooled estimates. Estimates are based on a random-effects REML model. τ^2, I^2, and Q statistics describe within- and between-group heterogeneity.

increase the risk of frailty, alongside other chronic diseases common in SSA such as hypertension and diabetes[29,37]. These disease patterns may further contribute to the observed differences in study-level frailty prevalence and highlight the need for integrated care approaches for older people living with chronic conditions.

With the aim of overcoming population-level biases in frailty thresholds, our meta-analytic approach of homogenizing a regional level frailty threshold presents as a unique advancement in frailty research. Combining thresholds has been recommended and adopted across other several public health and epidemiological domains, and noted to provide precision in threshold values[61–63], albeit not extensively explored in gerontology and frailty research. This omission may be due to the existing controversies and inconsistencies surrounding frailty concept and frailty screening methods[21,64]. Our meta-analysis generated a pooled frailty threshold of 0.29 (95% CI: 0.25–0.33). This pooled estimate is consistent with, but slightly higher than, the widely cited 0.25 threshold[9,58,65], and markedly higher than the more conservative 0.21 threshold used in other studies[66].

More importantly, our analysis revealed substantial heterogeneity between country estimates, reinforcing the idea that a one-size-fits-all threshold may be insufficient for global frailty screening efforts. We observed variation across countries, with higher thresholds in countries with greater overall frailty burden. Our subgroup analyses revealed that populations with higher median FI values had higher thresholds, while countries with a lower median FI had a distinctly lower threshold. These differences were not random but reflected meaningful variation in baseline health and population aging profiles.

Our meta-regression results showed that both age and gender composition substantially influenced frailty thresholds across the countries studied. Countries with older participants and higher proportions of females tended to report lower frailty thresholds. This suggests that advanced age and female gender are associated with greater vulnerability and an increased risk of frailty, such that fewer health deficits are required to classify individuals in these groups as frail. These findings provide empirical support for the hypothesis that frailty instruments and thresholds should scale in relation to a population's demographic profile and underlying frailty burden[67,68]. Variations in frailty thresholds can substantially impact prevalence estimates. Even small differences in thresholds may translate into large changes in the absolute number of older people classified as frail, which, in turn, may affect projections for healthcare services and long-term care needs. Higher estimated frailty prevalence increases the expected demand for clinical

management, rehabilitation, and social support, underscoring the importance of selecting appropriate, context-specific thresholds to inform resource allocation and policy development.

Noteworthy, the application of the pooled threshold 0.29 (95% CI: 0.25–0.33) to each dataset demonstrated consistently strong performance, with high sensitivity (82.64% to 95.42%) and moderate to high specificity (64.71% to 83.73%). While this discriminatory accuracy reinforces the practical value of our threshold as a regional benchmark, local calibrations are still required in certain settings to achieve optimal results from routine frailty screening.

Our study introduces a regionally grounded approach to developing frailty threshold for SSA. By pooling data from both Anglophone and Francophone countries, we increased statistical power and improved generalizability. Our analysis was strengthened by robust statistical methods, including ROC, meta-analyses and meta-regression, which helped us to explore and explain threshold variability. Also, our FI was tailored to the local context, incorporating culturally relevant items like social participation and excluding less applicable measures such as difficulty in climbing flight stairs. This enhanced the practical relevance of the findings for frailty screening across diverse SSA settings. This notwithstanding, several limitations are acknowledged. First, we used cross-sectional data which limits causal interpretation and prevents the assessment of changes in frailty over time. Moreover, the datasets used in this study were collected at different time points, which may affect comparability and reduce relevance to evolving population health patterns. In addition, our study included only four countries, which may limit the generalizability of the findings across the wider SSA region. Lastly, although meta-regression explained much of the between-study variability, high residual heterogeneity remained, indicating that other unmeasured contextual or methodological factors may be influencing frailty thresholds. Future research should incorporate longitudinal data, expand to more countries across diverse settings, and explore additional study-level moderators such as prevalence of chronic diseases, healthcare access and social determinants to strengthen regional standardization of frailty screening.

Conclusion

In this study involving multiple SSA countries, we identified country-specific frailty thresholds based on diagnostic accuracy metrics. The country specific thresholds varied between 0.24 in Ghana and 0.32 in Côte d'Ivoire and Kenya. We pooled the country specific thresholds through a random-effects meta-analysis to achieve an overall threshold of 0.29 (95% CI: 0.25,0.33). Through sub-group-analyses and meta-regression, we explored the underlying heterogeneity across the diverse populations in our study. Our pooled threshold proposed here offers a practical benchmark for countries without local data, while also highlighting the need for tailored thresholds that reflect each population's specific health and aging context. We recommend further validation of our threshold across additional SSA countries and encourage broader adoption of population and context-driven methods to improve the accuracy, equity, and prognostic utility of frailty screening instruments and thresholds.

Data availability

The data used in this study were sourced from different organizations, including the African Population and Health Research Centre, Nairobi, Kenya, World Health Organization, and Ecole Nationale Supérieure de Statistique et d'Economie Appliquée (ENSEA). HWOPs-1 can be obtained with formal application to the African Population and Health Research Centre https://aphrc.org/microdata-portal/. The SAGE Wave 2 in Ghana and the SAGE-WOPS HIV sub-study in Uganda can both be obtained from the World Health Organization at https://www.who.int/data/data-collection-tools/study-on-global-ageing-and-adult-health/sage-waves. A subset of the Living Condition, Health and Resilience among the Elderly study in Côte d'Ivoire can be found at https://data.mendeley.com/datasets/fhc7n2947t/1, and the rest can be made available with formal application to the data custodian. The source data for Figs. 1a–d, 2–4 are in Supplementary Data.

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Author contributions

Gideon Dzando: Conceptualization, Methodology, Formal analysis, Project administration, Software, Writing-Original draft, Writing—Review and Editing, Validation. Paul R. Ward: Conceptualization, Methodology, Validation, Writing—review and editing. Lillian Mwanri: Methodology, Validation, Writing—review and editing. Richard K. MOUSSA: Methodology, Formal Analysis, Validation, Writing—review and editing. Justice Moses K. Aheto: Methodology, Validation, Writing—review and editing. Rachel C. Ambagtsheer: Conceptualization, Validation, Methodology, Writing—review and editing.

Competing interests

The authors declare no competing interests.

Additional information

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