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An urgent need for African spirometry reference equations: the Paediatric and Adult African Spirometry study

R. Masekela,* G. L. Hall,† S. Stanojevic,‡ B. Sartorius,§ R. MacGinty,¶ H. Benn Saad,# Y. Trabelsi, F. Messan,†† M. Arigliani,‡‡ A. Ketfi,§§ D. Gray,¶ on behalf of the Paediatric and Adult African Spirometry (PAAS) collaborators**

***Department of Paediatrics and Child Health, Nelson R Mandela School of Clinical Medicine, College of Health Sciences, University of KwaZulu-Natal, Durban, South Africa; †Children's Lung Health, Telethon Kids Institute, School of Physiotherapy and Exercise Science, Curtin University and Centre for Child Health Research, University of Western Australia, Perth, Western Australia, Australia; ‡Division of Respiratory Medicine, Translational Medicine, Hospital for Sick Children, Toronto, Ontario, Canada; §Division of Public Health Medicine, School of Nursing and Public Health, University of KwaZulu-Natal, Durban, ¶Department of Paediatrics and Child Health, Red Cross War Memorial Children's Hospital and Medical Research Council Unit on Child and Adolescent Health, University of Cape Town, Cape Town, South Africa; #Université de Sousse, Faculté de Médicine de Sousse, Laboratoire de Recherche Insuffisance Cardiaque (LR12AP09), Hôpital Farhat Hached, Sousse, **Department of Physiology and Lung Function Testing (UR12 ES06), Faculty of Medicine of Sousse, University of Sousse, Tunisia; ††Laboratoire APS et Motricité, Institut National de la Jeunesse de l'Education Physique et du Sport, Université d'Abomey-Calavi, Porto-Novo, Benin; ‡‡Department of Medical, University Hospital of Udine, Udine, Italy; §§Department of Pneumology, Phtthisiology and Allergology, Rouiba Hospital, University of Algiers, Algiers**

SUMMARY

BACKGROUND: The GLI_{2012} (Global Lung Initiative 2012) has provided the largest data set to date for multi-ethnic spirometry reference equations; however, data on African populations are limited. In pulmonary function testing, diagnosis of lung disorder is based on comparing the individual's lung function to a reference appropriate for sex and ethnicity.

METHODS: We conducted a systematic review of studies reporting spirometry results in healthy children and adults in Africa. Data from these studies were collated for *Z*-scores of forced expiratory volume in 1 sec ($zFEV_1$), forced vital capacity (zFVC) and $zFEV_1$/FVC compared to GLI reference equations.

RESULTS: Nine studies, covering a total of 4750 individuals from North, South, East, West and Central Africa (52% were female), were reviewed. Marked differences were noted between individuals from North Africa and sub-Saharan Africa. The Southern $zFEV_1$ (–0.12 ± 0.98), zFVC (–0.15 ± 0.98) and $zFEV_1$/FVC (0.05 ± 0.89), Central $zFEV_1$ (–0.16 ± 0.79), zFVC (–0.09 ± 0.83) and $zFEV_1$/FVC (–0.17 ± 0.71) and East African $zFEV_1$ (0.10 ± 0.88), zFVC (0.16 ± 0.85) and $zFEV_1$/FVC (–0.10 ± 0.95) cohorts had an excellent fit with the GLI-African American. The West African showed a poor fit to all reference equations. The North African group showed the best fit for the GLI Caucasian $zFEV_1$ (–0.12 ± 1.37), zFVC (–0.26 ± 1.36) and $zFEV_1$/FVC (0.25 ± 1.11). The $zFEV_1$/FVC ratios were stable across all the populations.

CONCLUSION: Current evidence seems to support the use of GLI_{2012} reference values in North African and sub-Saharan African populations after taking into account ethnic correction factors.

KEY WORDS: global lung initiative; lung function; healthy; population; Africa

LOW- AND MIDDLE-INCOME countries (LMICs), including African countries, have a disproportionately high burden of infectious respiratory diseases, coupled with an increasing burden of non-communicable respiratory diseases such as chronic obstructive pulmonary disease (COPD), emphysema, bronchiectasis and asthma.[1–3] The management of these colliding epidemics requires accurate diagnosis and care to reduce morbidity and mortality in these resource-scarce settings.

Pulmonary function testing is the most widely used tool for the diagnosis, severity assessment, management, risk factor categorisation and follow-up of patients with chronic lung diseases, provided 'normal' values for healthy individuals can be determined. These vary according to age, sex, height and ethnicity of the relevant population.[4] Reference data should also take into account the normal trajectory of lung growth in childhood, and subsequent physiological decline associated with the aging process.

Correspondence to: Refiloe Masekela, Nelson R Mandela School of Medicine, 719 Umbilo Road, Durban 4000, South Africa. e-mail: masekelar@ukzn.ac.za

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It is well recognised that comparing an individual's results to values from an ethnically inappropriate population may lead to the under- or overdiagnosis of lung diseases, incorrect treatment and increased costs for the individual, the family and the healthcare system.[5–7] A number of reference equations have been published in the literature, but the largest data set produced were the 2012 Global Lung Initiative multi-ethnic reference equations (GLI_{2012}), which included individuals aged 3 to 95 years.[8] The GLI_{2012} included data pooled from four ethnic groups: Caucasians (Caucasians of European descent, as well as South Americans and North Africans), Blacks (African-Americans), South-East Asians and North East Asians. The GLI_{2012} was innovative in that it allowed for the smooth transitioning of data from childhood to adulthood using sophisticated statistical modelling.

Of the large number of data sets collected in GLI_{2012}, data from the African continent were lacking, with only 4.8% of the study sample being from two North African populations; who were included in the Caucasian population dataset.[8,9] It has previously been described that Caucasians have larger static and dynamic lung volumes and forced expiratory flow rates than other ethnicities.[10]

The aim of the present study was to collate previously published African spirometric data to determine the fit of African populations to GLI_{2012} spirometry equations.

METHODOLOGY

Study design

A systematic review of the literature was completed using the following main search terms (MeSH) in combination: Reference ranges, African, Spirometry OR Lung function, Healthy OR Normal, Adult, Paediatric; and using the following variations and synonyms: Prediction equations, Lung function, Normal, Asymptomatic, Paediatric, Women/men. The databases searched included PubMed Central, EMBASE, Medline and Google Scholar. Studies from January 1970 to November 2018 were included. The references of selected studies and relevant review articles were also scanned for further eligible studies.

Inclusion criteria

Studies were considered eligible for inclusion if they involved African adults or children of any age, included $\geq$100 healthy non-smoking subjects, used standardised equipment and testing, documented calibration and quality control, recorded essential clinical information (sex, height, age and ethnic group) and if the contributing investigator had obtained ethical approval from their statutory authority to contribute data to the Paediatric and Adult African Spirometry project. Identified studies were screened for eligibility and the corresponding authors were contacted. Those authors willing to participate signed a data sharing agreement. The data were collected by a central study administrator, collated and stored in a custom password protected data repository. Each contributing site provided information regarding the equipment, methodology and quality control procedures used for data collection. Each site's information and data were checked for eligibility by assuring 1) that compliance with international standards was met, 2) that the relevant clinical data were available, and 3) that the data outcomes were appropriate.

Exclusion criteria

Any outcomes of >5 or ≤ 5 *Z*-scores from the FEV_1 of the specific population mean (forced expiratory volume in 1 sec) FVC (forced vital capacity) <0.5 were excluded from the data set before the data were collated.[11] Any multiple testing was excluded and any participants with known chronic lung disease, known smokers or where smoking status was not recorded were excluded.

Data analyses

Statistical analyses were performed using STATA v13 for Windows (STATA Corporation, College Station, TX, USA). Spirometric values FEV_1, FVC and FEV_1/FVC, were converted to *Z*-scores using the GLI_{2012} software (https://www.ers-education.org/guidelines/global-lung-function-initiative/tools). *Z*-scores were represented as means and standard deviations (SD) and comparisons were shown graphically. Cohort mean $\pm$ SD *Z*-scores for FEV_1 and FVC were compared using the GLI Caucasian, African American and 'Other' equations. 'Goodness of fit' was considered for a *Z*-score difference of <0.5, which was considered a good fit for no physiological or clinical impact.

Ethical approval was granted from the Institutional Review Boards of the University of Pretoria (HREC: 8/2014) Pretoria, South Africa, and University of Cape Town (HREC: 765/2013) Rondebosch, South Africa.

RESULTS

Of 49 articles identified, 39 met the inclusion criteria (Figure). One study included unpublished data from a South African birth cohort.[12] Of these, 21 investigators were contactable and agreed to participate, of whom four withdrew consent and four agreed to participate but did not submit the data. The analysis included data submitted from 11 studies, totalling 33 864 participants[9,12–24] (Table 1 and Supplementary Table S1). Of these, 29 122 participants from four studies were excluded, two of which had no record of smoking status[21,22] and for the other two, the data

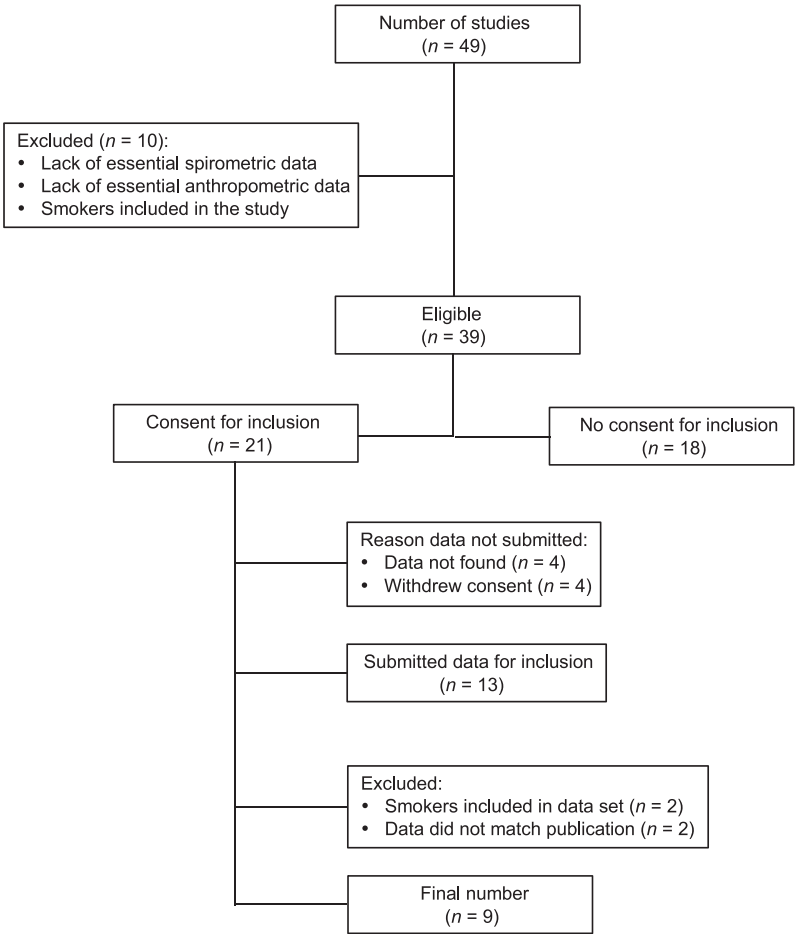

Figure Results of search strategy and eligible studies included in the study.

did not match the sourced publication.[17,18] Eight further individual study participants were excluded due to missing data; the FEV_1 and FVC results were missing for four individuals in Benin and in South Africa, respectively. The outlying data (>5or ≤5 *Z*-scores) were excluded as follows: 77 using the 'Other' GLI equation, 70 using the African-American equation and 64 using the Caucasian equation.

A total of 4750 (52% female) participants aged 5–85 years were included in the final analysis. The demographic characteristics and the fit of the lung function to the GLI references are shown in Table 2A and 2B. The studies included were conducted in urban or peri-urban settings.

The GLI 'Other' reference was the best fit for the collated data set. However, there was marked heterogeneity between regions. For Tunisian and Algerian (North African) subjects the GLI Caucasian reference was the best fit; while the Benin (West African) data had a poor fit to all GLI references. The South African (Southern), Angola (Southern), Madagascar (East) and Democratic Republic (DR) Congo (Central) African data had an excellent fit to GLI African-American.

A comparison of lung function *Z*-scores between the equipment used across the studies was undertaken (Tables 3 and 4). The Tunisian studies showed statistically significant differences between the equipment used. For the Tunisian cohort, consisting of two paediatric studies[14,20] ($n = 1041$), one study[15] of adults aged 19–90 years ($n = 581$)] and another study[16] of adults aged >40 years ($n = 108$)], there were statistically significant differences across the studies for mean ± SD *Z*-scores for FEV_1 –0.09±1.34 vs. 1.19±1.61 and 0.47±1.28; all $P < 0.005$.

DISCUSSION

In this collated dataset of healthy adults and children from across the African continent, we found marked differences in the fit of spirometry data to the GLI spirometry reference equations between North and sub-Saharan African populations. North African (Tunisia and Algeria) data displayed the best fit with GLI Caucasian data. For the Southern African (South Africa and Angola), East African (Madagascar), Central African (DR Congo) data the best fit was for GLI African American equation. The West African paediatric and adolescent data (Benin) showed sub-

Table 1 Demographic and lung function data of the participants included in the final analysed data set by country of origin

Variable	North Africa		West Africa	East Africa	Central Africa	Southern Africa		Total
	Algeria *n* (%)	Tunisia *n* (%)	Benin *n* (%)	Madagascar *n* (%)	DRC *n* (%)	Angola *n* (%)	South Africa *n* (%)	*n*
Participants	491 (10.3)	2362 (49.7)	484 (10.2)	399 (8.4)	377 (7.9)	306 (6.4)	331 (7.0)	4750
Age, years, median [IQR]	47.0 [32.7–60.4]	38.3 [12.0–50.0]	29.0 [21.8–33.0]	8.7 [7.3–10.0]	9.7 [8.3–10.7]	9.4 [8.2–11.7]	26.6 [22.6–31.7]	21.4 [11.0–45.0]
Female sex	245 (49.9)	1226 (51.9)	154 (31.8)	197 (49.4)	170 (45.1)	153 (50.0)	331 (100)	2476 (52.1)
Height, cm, median [IQR]	165.0 [158.0–173.0]	159.0 [147.0–170.0]	153.1 [146–160.9]	124.0 [118.3–130.5]	138.0 [130.0–146.0]	133.0 [126.5–147.0]	159.0 [155.0–164.0]	155.0 [139.0–165.0]
Setting	Urban	Urban/rural*	Urban	Urban	Urban	Urban	Peri-urban	

* Urban population 70–90% in the Tunisian cohort with 10–30% rural.
DRC = Democratic Republic of Congo; IQR = interquartile range.

stantially reduced lung volumes overall, with a poor fit to all the GLI references. The FEV_1/FVC ratios were preserved for all the datasets except for the West African individuals.

There were differences in calculated spirometry *Z*-scores within countries that could be attributable to the equipment utilised across the studies. We would conclude that the application of the GLI_{2012} FEV and FVC equations in African populations should therefore be applied with ethnical and regional consideration, but that as reported previously,[25] FEV_1/FVC ratio is independent of ethnicity and therefore can be used to diagnose obstructive lung diseases (FEV_1/FVC $<$LLN or FEV_1/FVC Z-score $\leq$1.64) with reasonable confidence. The unexpected finding of the West African cohort of school-going children contradicts previously reported data. This may reflect technical challenges in obtaining good quality spirometry from young children and requires further exploration to assess whether these differences are truly due to ethnic variation or other unknown factors, e.g., socio-economic status, nutrition and exposure to indoor and outdoor pollution. A study in Tanzanian men and boys aged 13 to 29 years also showed similar differences in fit to both GLI_{2012} and the Third National Health and Nutrition Examination Survey (NHANES III) references.[26]

Although the GLI network has successfully collated spirometry to develop robust, all age international reference equations, in this study of retrospectively collated data, the heterogeneity across the African regions suggests a need to utilise different ethnic correction factors in North African and sub-Saharan populations. This heterogeneity could be explained by ethnic differences between geographically remote parts of the African continent, although other factors, such as differences in measurement techniques or equipment used, could also account for these differences. In addition, poor quality data cannot be excluded as a contributing factor, as suggested by the variable age-dependence of lung function data. Moreover, it is likely that socio-economic and environmental factors play an important role in lung function at the population level. We were unable to account for these differences in this study.[4]

The reason for the poor fit of the West African children to the African-American reference is unclear. The Bight of Benin was part of the slave trade route to the USA and the Beninese were also part of the original Bantu who populated most of Western and Southern Africa. The sub-Saharan cohort has a good fit to the GLI African-American reference equation, which should be similar to that of the Beninese. With the similar genetic background, the finding of such significant differences is therefore surprising. Other factors, such as poverty, low birth weight and exposure to high levels of pollution, may contribute to these differences, although the impact of these

Table 2A Lung function data by country of origin using GLI African-American, Caucasian and other equations to calculate Z-scores

Variable Z-score	Algeria mean ± SD	Tunisia mean ± SD	Benin mean ± SD	Madagascar mean ± SD	DRC mean ± SD	Angola mean ± SD	South Africa mean ± SD	Total mean ± SD
FEV_1, l	3.2 ± 0.9	2.8 ± 0.9	1.9 ± 0.6	1.3 ± 0.3	1.6 ± 0.4	1.6 ± 0.4	2.7 ± 0.5	2.4 ± 1.0
FVC, l	4.0 ± 1.1	3.2 ± 1.1	2.4 ± 0.7	1.5 ± 0.3	1.9 ± 0.4	1.7 ± 0.4	3.1 ± 0.5	2.9 ± 1.2
FEV_1/FVC	0.8 ± 0.1	0.9 ± 0.1	0.8 ± 0.2	0.9 ± 0.1	0.9 ± 0.0	0.9 ± 0.0	0.9 ± 0.1	0.8 ± 0.1
GLI African-American								
FEV_1 Z-score	1.07 ± 0.95	0.98 ± 1.43	−2.25 ± 1.16	0.10 ± 0.88	−0.16 ± 0.79	−0.32 ± 0.75	0.07 ± 1.13	0.35 ± 1.57
FVC Z-score	1.37 ± 0.94	0.81 ± 1.44	−1.79 ± 1.24	0.16 ± 0.85	−0.09 ± 0.83	−0.38 ± 0.80	0.07 ± 1.08	0.35 ± 1.50
FEV_1/FVC Z-score	−0.50 ± 0.75	0.30 ± 1.14	−1.07 ± 1.56	−0.10 ± 0.95	−0.17 ± 0.71	0.10 ± 0.78	−0.00 ± 0.97	−0.03 ± 1.17
GLI Caucasian								
FEV_1 Z-score	−0.07 ± 0.90	−0.13 ± 1.44	−3.18 ± 1.00	−1.10 ± 0.82	−1.36 ± 0.74	−1.50 ± 0.70	−1.08 ± 1.02	−0.75 ± 1.52
FVC Z-score	0.17 ± 0.88	−0.35 ± 1.42	−2.83 ± 1.11	−1.10 ± 0.79	−1.36 ± 0.78	−1.63 ± 0.76	−1.10 ± 1.01	−0.82 ± 1.45
FEV_1/FVC Z-score	−0.41 ± 0.73	0.39 ± 1.13	−0.86 ± 1.49	0.01 ± 0.94	−0.06 ± 0.70	0.21 ± 0.78	0.09 ± 0.94	0.09 ± 1.13
GLI Other								
FEV_1 Z-score	0.48 ± 0.96	0.39 ± 1.48	−2.83 ± 1.09	−0.56 ± 0.88	−0.83 ± 0.79	−0.99 ± 0.75	−0.54 ± 1.10	−0.25 ± 1.58
FVC Z-score	0.86 ± 0.99	0.26 ± 1.56	−2.49 ± 1.27	−0.49 ± 0.89	−0.78 ± 0.88	−1.08 ± 0.85	−0.51 ± 1.14	−0.23 ± 1.60
FEV_1/FVC Z-score	−0.58 ± 0.78	0.26 ± 1.19	−1.09 ± 1.59	−0.17 ± 0.99	−0.24 ± 0.74	0.04 ± 0.81	−0.07 ± 0.99	−0.08 ± 1.20

Table 2B Lung function data by region of origin using GLI African-American, Caucasian and other equations to calculate Z-scores

Variable	North Africa mean ± SD	West Africa mean ± SD	East Africa mean ± SD	Central Africa mean ± SD	Southern Africa mean ± SD	Total mean ± SD
FEV_1, l	2.8 ± 0.9	1.9 ± 0.6	1.3 ± 0.3	1.6 ± 0.4	2.2 ± 0.7	2.4 ± 1.0
FVC, l	3.4 ± 1.2	2.4 ± 0.7	1.5 ± 0.3	1.9 ± 0.4	2.5 ± 0.8	2.9 ± 1.2
FEV_1/FVC	0.8 ± 0.1	0.8 ± 0.2	0.9 ± 0.1	0.9 ± 0.0	0.9 ± 0.1	0.8 ± 0.1
GLI African-American						
FEV_1 Z-score	0.99 ± 1.36	−2.25 ± 1.16	0.10 ± 0.88	−0.16 ± 0.79	−0.12 ± 0.98	0.35 ± 1.57
FVC Z-score	0.91 ± 1.38	−1.79 ± 1.24	0.16 ± 0.85	−0.09 ± 0.83	−0.15 ± 0.98	0.35 ± 1.50
FEV_1/FVC Z-score	0.16 ± 1.12	−1.07 ± 1.56	−0.10 ± 0.95	−0.17 ± 0.71	0.05 ± 0.89	−0.03 ± 1.17
GLI Caucasian						
FEV_1 Z-score	−0.12 ± 1.37	−3.18 ± 1.00	−1.10 ± 0.82	−1.36 ± 0.74	−1.28 ± 0.91	−0.75 ± 1.52
FVC Z-score	−0.26 ± 1.36	−2.83 ± 1.11	−1.10 ± 0.79	−1.36 ± 0.78	−1.35 ± 0.94	−0.82 ± 1.45
FEV_1/FVC Z-score	0.25 ± 1.11	−0.86 ± 1.49	0.01 ± 0.94	−0.06 ± 0.70	0.14 ± 0.87	0.09 ± 1.13
GLI Other						
FEV_1 Z-score	0.40 ± 1.40)	−2.83 ± 1.09)	−0.56 ± 0.88)	−0.83 ± 0.79)	−0.76 ± 0.97)	−0.25 ± 1.58)
FVC Z-score	0.37 ± 1.49	−2.49 ± 1.27	−0.49 ± 0.89	−0.78 ± 0.88	−0.78 ± 1.05	−0.23 ± 1.60
FEV_1/FVC Z-score	0.11 ± 1.18	−1.09 ± 1.59	−0.17 ± 0.99	−0.24 ± 0.74	−0.02 ± 0.91	−0.08 ± 1.20

GLI = Global Lung Initiative; SD = standard deviation; DRC = Democratic Republic of Congo; FEV_1 = Forced expiratory flow in 1 sec; FVC = forced vital capacity.

Table 3 Lung function equipment by country and study population

Variable	Algeria	Tunisia	Benin	Madagascar	DRC	Angola	South Africa
Contributing studies (reference)		[13–16,20]	[19]				[12]
		PAL-MINATO hotwire anometer[13,14,20]	Cosmed Microquark[19]				Jaeger Carefusion pneumotach[12]
		Spida 5, hot-wire anometer[15]					
		Body Plethysmograph (Pneumotach, ZAN 500 Plethysmograph)[16]					
				Turbine Pony FX, Cosmed Italy[23]	Turbine Pony FX, Cosmed Italy[23]	Turbine Pony FX, Cosmed Italy[23]	
	Plethymograph pneumotach-mometer (Body Box 5500, Medisoft Belgium)[24]						

DRC = Democratic Republic of Congo.

Table 4 Differences in lung function Z-scores according to different equipment in Tunisia using GLI Other

Tunisia	PAL MINATO, hot-wire anometer	Spida 5, hot-wire anometer	Pneumotach, ZAN 500 plethysmograph	*P* value
FEV_1 Z-score, mean ± SD Median [IQR]	−0.09 ± 1.34 −1.50 [−0.92 to 0.83]	1.19 ± 1.61 1.08 [−0.00 to 2.35]	0.47 ± 1.28 0.35 [−0.31 to 1.24]	0.000
FVC Z-score, mean ± SD Median [IQR]	−0.27 ± 1.48 −0.33 [−1.21 to 0.65]	0.67 ± 1.51 0.67 [−0.37 to 1.77]	0.72 ± 1.46 0.62 [−0.28 to 1.71]	0.000
FEV_1/FVC Z-score, mean ± SD Median [IQR]	0.35 ± 1.08 0.41 [−0.24 to 1.05]	0.86 ± 1.01 0.84 [1.50 to 1.57]	−0.32 ± 1.22 −0.49 [−1.25 to 0.34]	0.000

GLI = Global Lung Initiative; FEV_1 = forced expiratory volume in 1 sec; SD = standard deviation; IQR = interquartile range; FVC = forced vital capacity.

factors is controversial in determining 'normality' of lung function based on deprivation status. A study of children in Nigeria in both rural and urban settings, did not find any significant differences between Nigerian and African-American children.[25] Interestingly, a more recent study of Nigerian adults aged 18–65 years showed an increase, although not statistically significant, in FEV_1, FVC and PEF compared to a previous study determining Nigerian references, but found that GLI African-American also over-estimated the references in the local population.[27] Although the children in the sub-Saharan countries were much poorer in comparison to their African-American counterparts, the exclusion of underweight children with body mass index *Z*-scores below –2 may have adjusted for these differences, suggesting a strong genetic contribution to lung function rather than socioeconomics. This is similar to findings comparing UK-Indian children with urban and rural children in the Indian sub-continent.[28]

The strength of the current study is that it attempted to collate data sets from various regions on the African continent using methodology previously utilised by the GLI and gives some credence to the fact that there are indeed differences in the fit of African regional, i.e., North and sub-Saharan populations to the GLI_{2012} equations, which have diverse genetic backgrounds.. This study is limited by the fact that the data collected were retrospective. Not all of the available data could be included due to lack of access to data or lack of consent from authors. We also had to exclude a large number of participants from previous studies due to a lack of information on smoking status.

This study highlights the urgent need for high quality prospectively collected lung function data in healthy African populations for the determination of new local GLI coefficients that are specific to the various regions of Africa. In conclusion, GLI_{2012} is the most robust and physiologically sound reference equation for most populations. The current evidence is still limited but seems to support the use of GLI_{2012} reference values in North and sub-Saharan African populations, taking into account the use of different ethnic correction factors. Prospective spirometry data collection is required as the GLI_{2012} reference values have still to be validated in several African countries.

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Conflicts of interest: none declared.

References

1 Ait-Khaled N, Odhiambo J, Pearce N, et al. Prevalence of symptoms of asthma, rhinitis and eczema in 13- to 14-year-old children in Africa: the International Study of Asthma and Allergies in Childhood Phase III. Allergy 2007; 62(3): 247–258.
2 Global Burden of Disease Study 2015 (GBD 2015). Seattle, WA, USA: Institute for Health Metrics and Evaluation, 2015. http://ghdx.healthdata.org/record/ihme-data/gbd-2015-life-expectancy-all-cause-and-cause-specific-mortality-1980-2015 Accessed June 2019.
3 World Health Organization. Global status report on noncommunicable diseases. Geneva, Switzerland: WHO; 2011.
4 Pellegrino R, Viegi G, Brusasco V, et al. Interpretative strategies for lung function tests. Eur Respir J 2005; 26(5): 948–968.
5 Hankinson J L, Odencrantz J R, Fedan K B. Spirometric reference values from a sample of the general U.S. population. Am J Respir Crit Care Med. 1999; 159: 179–87.
6 Hooper R, Burney P. Cross-sectional relation of ethnicity to ventilator function in a West London population. Int J Tuberc Lung Dis 2013; 17(3): 400–405.
7 Kirby J, Bonner R, Lum S, et al. Interpretation of pediatric lung function: impact of ethnicity. Pediatr Pulmonol 2013; 48(1): 20–16.
8 Quanjer P H, Stanojevic S, Cole R J, et al. Multi-ethnic reference values for spirometry for the 3–95 yr age range: the global lung function 2012 equations. Eur Respir J 2012; 40(6): 1324–1342.
9 Ben Saad H, El Attar M N, Mabrouk K H, et al. The recent multi-ethnic Global Lung Initiative 2012 (GLI_{2012}) reference values don't reflect contemporary adult's North African spirometry. Respir Med 2013; 107: 2000–2008.
10 White N W, Hanley J H, Lalloo U G, Becklake M R. Review and analysis of variation between spirometric studies of healthy African adults. Am J Respir Crit Care Med 1994; 150(2): 348–355.
11 Borghi E, de Onis M, Garza C, et al. WHO Multicentre Growth Reference Study Group. Construction of the World Health Organization child growth standards: selection of methods for attained growth curves. Stat Med 2006; 25(2): 247–265.

12 Zar H J, Barnett W, Myer L, Stein D J, Nicol M. Investigating the early-life determinants of illness in Africa: the Drakenstein Child Health Study. Thorax 2015; 70(6): 592–594.
13 Ben Saad H, Prefaut C, Tabka Z, et al. 6-minute walk test in healthy North Africans older than 40 years: influence of parity. Respir Med 2009; 103: 74–84.
14 Ben Saad G, Prefaut C, Missaoui R, Mohamed I H, Tabka Z, Hayot M. Reference equation for 6 min walk distance in health North African children 6–16 years old. Pediatr Pulmonol 2009; 44: 316–324.
15 Ben Saad H, Selmi H, Mabrouk K H, et al. Spirometric 'Lung Age' estimation for North African population. Egy J Chest Dis Tuberc 2014; 63: 491–503.
16 Ben Saad H, Tfifha M, Harrabl I, et al. Factors influencing the pulmonary function in Tunisian women aged 45 years and more. Rev Mal Respir 2006; 23: 324–338.
17 Bougrida M, Bourahli M-K, Aissaoui A, Rouatbi S, Mehdioui H, Ben Saad H. Spirometric reference values for children living in Constantine (Eastern region of Algeria). Tunis Med 2012; 90(1): 51–61.
18 Bougrida M, Ben Saad H, Kheirenddinne B, Boughzima I, Mehdioui H. Reference spirometric equations in an Algerian population aged between 19 and 73 years. Rev Mal Respir 2008; 25: 577–590
19 Messan F, Dansou P, Marqueste T, et al. First report of FCV and FEV1 reference values for Beninese children aged 11–16 years. ISRN Pulmonol 2013; Article ID 284386.
20 Trabelsi Y, Ben Saad H, Tabka Z, et al. Spirometric reference values in Tunisian children. Respiration 2004; 71: 511–518.
21 Hnizdo E, Churchyard G, Dowd R. Lung function prediction equations derived from health South African gold miners. Occup Environ Med 2000; 57: 698–705.
22 Churchyard G. Personal communication. Unpublished data of Male South African Miners.
23 Arigliani M, Canciani M C, Mottini G, et al. Evaluation of the Global Lung Initiative 2012 reference values for spirometry in African children. Am J Respir Crit Care Med 2017; 195(2): 229–236.
24 Ketfi A, Gharnaout M, Bougrida M, Ben Saad H. The multi-ethnic Global Lung Initiative 2012 (GLI-2012) norms reflect contemporary adult's Algerian spirometry. PLoS One 2018; 13(9): e0203023.
25 Glew R H, Kassam H, Vander Voort J, et al. Comparison of pulmonary function between children living in rural and urban areas in Northern Nigeria. J Trop Pediatr 2004; 50(4): 209–216.
26 Rezbacz-Maron E. The multi-ethnic Global Lung Initiative 2012 and third national health and nutrition examination survey reference values do not reflect spirometric measurements in black boys and men from Tanzania. Clin Physiol Funct Imaging 2018; 38(1): 76–86.
27 Fawibe A E, Odeiganh L O, Saka M J. Reference equations for spirometric indices from a sample of the general adult population in Nigeria. BMC Pulm Med 2017; 17(1): 48.
28 Sonnapa S, Lum S, Kirkby J, et al. Disparities in pulmonary function in healthy children across the Indian urban-rural continuum. Am J Respir Crit Care Med 2015; 191: 79–86.

RÉSUMÉ

CONTEXTE : GLI_{2012} a fourni la plus vaste base de données relative aux équations de référence multiethniques, mais les données émanant d'Afrique sont limitées. Les tests de diagnostic de la fonction pulmonaire sont basés sur la comparaison entre la fonction pulmonaire des individus testés et une référence appropriée en termes de genre et d'ethnicité.

MÉTHODE : Une revue systématique des études rapportant des spirométries chez des enfants et des adultes en bonne santé en Afrique. Les données des études ont été compilées pour le score *Z* du volume expiratoire maximal par seconde ($VEMSz_1$), la capacité vitale forcée (CVFz) et le rapport $VEMSz_1$/CVF comparés aux équations de référence de GLI.

RÉSULTATS : Neuf études comprenant 4750 individus, dont 52% de femmes venant de l'Afrique du Nord, du Sud, de l'Est, de l'Ouest et du Centre. Des différences marquées ont été notées entre les populations d'Afrique du Nord et d'Afrique sub-saharienne. Le $zVEMS_1$ (–0,12 ± 0,98), la zFVC (–0,15 ± 0,98) et le $zVEMS_1$/FVC (0,05 ± 0,89) d'Afrique du Sud, le $zVEMS_1$ (–0,16 ± 0,79), la zFVC (–0,09 ± 0,83) et le $zVEMS_1$/FVC (–0,17 ± 0,71) d'Afrique Centrale et le $zVEMS_1$ (0,10 ± 0,88), la zFVC (0,16 ± 0,85) et le $zVEMS_1$/FVC (–0,10 ± 0,95) d'Afrique de l'Est concordaient très bien avec le GLI-Africain Américain. Les résultats d'Afrique de l'Ouest ont montré une concordance médiocre avec toutes les équations de référence. Le groupe d'Afrique du Nord a montré la meilleure concordance avec le GLI-Caucasien $zVEMS_1$ (–0,12 ± 1,37), la zFVC (–0,26 ± 1,36) et le $zVEMS_1$/FVC (0,25 ± 1,11). Les rapports $zVEMS_1$/FVC ont été stables dans toutes les populations.

CONCLUSION : Les preuves actuelles semblent être en faveur de l'utilisation des valeurs de référence du GLI_{2012} dans les populations d'Afrique du Nord et d'Afrique sub-saharienne, en tenant compte des facteurs de correction des différences ethniques.

RESUMEN

MARCO DE REFERENCIA: La Iniciativa Global de la Función Pulmonar del 2012 (GLI_{2012}, por *Global Lung Iniciative*) ofrece el conjunto de datos más exhaustivo de ecuaciones multiétnicas de referencia de la espirometría, pero los datos de África son escasos. En el contexto de las pruebas de función pulmonar, el diagnóstico de normal o patológico se basa en la comparación de la espirometría de la persona, con una referencia adecuada con respecto al sexo y la etnia.

MÉTODOS: Se llevó a cabo una revisión sistemática de los estudios que comunicaban sobre la espirometría en niños y adultos sanos en África. Los datos de los estudios se recogieron y se expresaron como puntuación Z del volumen espiratorio forzado en el primer segundo ($zVEF_1$), la capacitad vital forzada (zCVF) y el cociente $zVEF_1$/CVF y se compararon con las ecuaciones de referencia de la GLI.

RESULTADOS: Se incluyeron nueve estudios con 4750 participantes, el 52% era de sexo femenino y procedía de África del norte, del sur, del este y África central. Se observaron diferencias considerables entre las personas de África del norte y de África subsahariana. Las cohortes de $zVEF_1$ (–0,12± 0,98), zCVF (–0,15± 0,98) y $zVEF_1$/CVF (0,05± 0,89) del sur; de $zVEF_1$ (–0,16± 0,79), zCVF (–0,09 ± 0,83) y $zVEF_1$/CVF (–0,17± 0,71) del centro; y de $zVEF_1$ (0,10± 0,88), zCVF (0,16± 0,85) y $zVEF_1$/CVF (–0,10± 0,95) del este de África exhibieron un ajuste excelente con las referencias afroamericanas del GLI. En los datos provenientes de África occidental el ajuste fue deficiente con todas las ecuaciones de referencia. El grupo de África del norte presentó el mejor ajuste con las referencias caucásicas del GLI: $zVEF_1$ (–0,12± 1,37), zCVF (–0,26 ± 1,36) y $zVEF_1$/CVF (0,25± 1,11). Los cocientes $zVEF_1$/CVF fueron estables en todas las poblaciones.

CONCLUSIÓN: La evidencia de la presente revisión sistemática parece respaldar la utilización de los valores de referencia de la GLI_{2012} en las poblaciones de África del norte y África subsahariana, teniendo en cuenta la necesidad de aplicar diferentes factores étnicos de corrección.