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Original article

Miscellaneous

Equity in global health research in the new millennium: trends in first-authorship for randomized controlled trials among low- and middle-income country researchers 1990-2013

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Abstract

Background: Developing the research capacity of low- and middle-income countries (LMICs) has been shown to be one of the key ways that international health programmes and health research can create sustained benefit in these countries. The aim of this study was to examine trends in first-authorship for researchers from LMIC institutions (LMIC first-authors) over the period 1990-2013.

Methods: This study systematically reviewed research articles about randomized controlled trials (RCTs) in HIV/AIDS, malaria and tuberculosis (TB) conducted in LMICs from 1990 to 2013, and identified the institutional affiliations of the authors. Key variables extracted from the articles included author affiliation, funding source, disease, intervention type, region and year of publication. Poisson regression was used to explore the impact of these key variables on LMIC first-authorship over time.

Results: A total of 1593 articles were identified, of which 49.8% had LMIC first-authors. From 1990 to 2000 a total of 222 trials were published, and from 2001 to 2013 a total of 1371 trials were published, with a steady year-on-year increase over the period particularly evident in trials conducted in Africa. Whereas the absolute total number of LMIC first-authors has increased, as a proportion of all authors it declined. The relative rate increase in first-authorships post 2000 was 11.8-fold for non-LMIC first-authors and 2.8-fold for LMIC authors. LMIC first-authorship increased over time for research funded from LMIC; but LMIC first-authorship declined over time for research funded from high income countries (HIC).

Conclusions: The absolute increase in the number of trials in HIV/AIDS, malaria and tuberculosis in Africa has led to a modest increase in LMIC first-authors, and a much larger increase in non-LMIC authors. The findings suggest that more inclusive policies by international funders are important in shifting research control to LMICs and improving research equity in the future.

Key words: global health, capacity building, randomized controlled trial, low middle income country.

Key Messages

- Developing research capacity in LMICs is one of the key ways in which international health programmes and health research can create sustained benefit and contribute to improved global health equity.
- The number of articles about randomized controlled trials in HIV/AIDS, malaria and tuberculosis (TB) conducted in LMICs since 2000 was over five times greater than in the 10 years before.
- The number of LMIC first-authors has increased since 2000, but the proportion of LMIC first-authors declined: for non-LMIC first-authors, 11.8-fold increase; for LMIC authors, 2.8-fold increase.
- The proportion of LMIC first-authorship increased over time for LMIC fully funded research and decreased over time for research funded by US and non-US high income country (HIC) sources.
- More inclusive policies by international funders are needed to improve research equity in the future.

Introduction

There has been an explosive growth in global commitments for health and human development in low- and middle-income countries (LMICs) over the past 15 years, most notably demonstrated in the establishment of the Millennium Development Goals (MDGs) in 2000.[1,2] There is evidence that a focus on building research capacity has had an important role in strengthening health systems, the development, implementation and evaluation of health programmes and providing the evidence base to support population health planning and responses to health crises.[3–8] Therefore developing LMIC research capacity is one of the key ways that international health programmes and health research can create sustained benefit in these countries.[5] In particular, national health research capacity is a critical component that enables LMICs to identify and progress their national health priorities.[5]

Despite the increased understanding of the importance of research capacity building, few studies have examined changes in research capacity since 2000. A 2005 international survey of research capacity in LMICs identified significant deficits in all but one of the 12 countries surveyed.[3] In particular, the survey found that data on financing of research was lacking for most countries. There is some evidence of positive changes in research capacity within the remit of specific initiatives;[6,8] however there is also evidence that longstanding training initiatives have failed to effectively reduce workforce shortages in health research.[9]

Randomized controlled trials (RCTs) are considered the best experimental design for assessing the effectiveness of interventions and are the focus of the present study. Several previous studies have investigated characteristics of RCTs conducted in LMICs. In a study looking at HIV/AIDS RCTs in Africa, Zani *et al.* found that of the 68 trials investigated most were funded from the USA, and the majority of the principal researchers were from outside Africa.[10] Siegfried *et al.* compared the methodological quality of all HIV/AIDS RCTs conducted in Africa with those conducted in North America. The authors found that most of the African trials considered were externally funded.[11] Smith *et al.* examined research partnerships between LMIC and other country researchers and made some recommendations, most importantly emphasizing the importance of empirical research into capacity building in LMICs.[10,12]

In order to better understand research capacity building, we systematically reviewed research articles about RCTs focused on HIV/AIDS, malaria and tuberculosis (TB) conducted in LMICs from 1990 to 2013 and identified the institutional affiliations of the authors. The aim of this study was to examine trends in first-authorship by researchers from LMIC institutions over time (LMIC first-authors hereafter). If capacity building initiatives in recent years have been successful, then the number and proportion of articles with first-authors from LMIC institutions would be expected to have increased. To this end we systematically reviewed research articles about RCTs focused on HIV/AIDS, malaria and TB conducted in LMICs from 1990 to 2013 and identified the institutional affiliations of the authors. First-authorship is used as an indicator of capacity building because it reflects the opportunities afforded to more junior researchers by senior researchers to move into research leadership roles. We also examined trends in

last (senior)-authorship in order to better understand the overall context of research leadership.

Methods

Inclusion and exclusion criteria

The study focused on RCTs because the requirement to register the studies means that they are clearly identifiable. Studies were included on the following criteria:

i. published in a peer-reviewed journal in the period from January 1990 to December 2013;
ii. conducted in an LMIC, or LMICs with recruitment of participants exclusively from the local population;
iii. outcome variable related to HIV, malaria or TB;
iv. evidence of randomization of the intervention, either individual or group assignment;
v. funding disclosure.

We excluded studies if the source RCTs did not describe methods of random allocation or participant characteristics at baseline, failed to disclose funding sources or author affiliation, or were conducted in multiple countries. Early terminated RCTs were included, subject to the same criteria as above.

Search strategy and data extraction

We conducted an extensive electronic literature search to locate relevant RCT-sourced studies on Medline (OVID), Embase (OVID), HIV/AIDS Database (Informit), CINAHL (EBSCOHost), PsycInfo (ProQuest) and Web of Science (ISI). The search strategy to identify the studies was as follows: (clinical trial, phase ii/ or clinical trial, phase iii/ or clinical trial, phase iv/ or controlled clinical trial/ or randomized controlled trial/) or ((random$ or randomi?ed) and (clinical or control$)).mp. and (trial or experiment).ab,kw,ot,pt. [mp = ti, ab, ot, nm, hw, kf, ps, rs, ui, sh, tn, dm, mf, dv, kw]) or clinical trial.pt. The search was restricted by condition, human subjects, a list of LMICs[13] and a publication period from 1 January 1990 to 31 December 2013. The complete search strategy is outlined in Annex 1, available as Supplementary data at *IJE* online. The search was performed January-February 2014.

There were 6405 unique citations with information on authors and publication year identified from the databases. Once the inclusion and exclusion criteria were applied there were a total 1583 individual papers reporting baseline results and having funding disclosure, sourced from single- and multi-country RCTs published from 1990 to 2013. Most exclusions occurred because the study was not an RCT (93%), a further 4% were excluded because of lack of funding disclosure and 3% were excluded because they reported on more than one country in a multi-country studies. The PRISMA diagram is included in Annex 1.

Two of the authors (A.R. and L.E.) extracted information pertaining to study country, year of publication, disease, intervention type, first-author, co-authors and funding source categories as outlined above. Disagreements in classification were resolved involving a third person (M.K.). An Excel spreadsheet was developed to code information and execute the algorithms for classifying types of first-authorship and co-authorship (that is an author who is neither first nor last), as well as funding source.

An LMIC first-authorship variable (yes/no) was developed based on a researcher's institutional affiliations. Researchers with institutional affiliations from both an LMIC and a high-income country (HIC) were classified as HIC. Funding sources were classified based on the country affiliations of the funding body (LMIC co-financing, LMIC full-funding, USA and other HIC). In-kind contributions were not considered in classifying funding type.

The types of interventions included in the RCTs were coded into five categories including: pharmaceutical and vaccine; nutritional and dietary; preventive and diagnostics; lifestyle and living conditions; and education. All studies were coded into WHO regional groupings: Africa, Americas, Western Pacific, South-East Asia, and Pacific and Eastern Mediterranean, [http://www.who.int/healthinfo/global_burden_disease/definition_regions/en/].

Analysis

Frequencies were examined for funder, disease, intervention type, region and year of publication (before or after 2000) by LMIC first-authorship. Chi-square analysis was used to examine differences between groups. Analysis of variance (ANOVA) was used to assess changes in numbers of co-authors per publication over time by funding source.

Multiple Poisson regression with a log-link function was performed to examine the effect of funding source, publication year, intervention type and regions on the probability of local first-authorship (yes/no) for single-country studies. The robust variance estimator was used to account for clustering among articles associated with the same study. The Wald test was used to evaluate the interaction terms for all funding categories in the adjusted models for all diseases in combination or singly. The probability of LMIC first-authorship by funding sources and year was plotted using the margins and marginsplot commands in STATA version 13,[14] with a caveat that the upper limit of probabilities could exceed one (i.e. certainty) due to the equal interval space emanating from the data

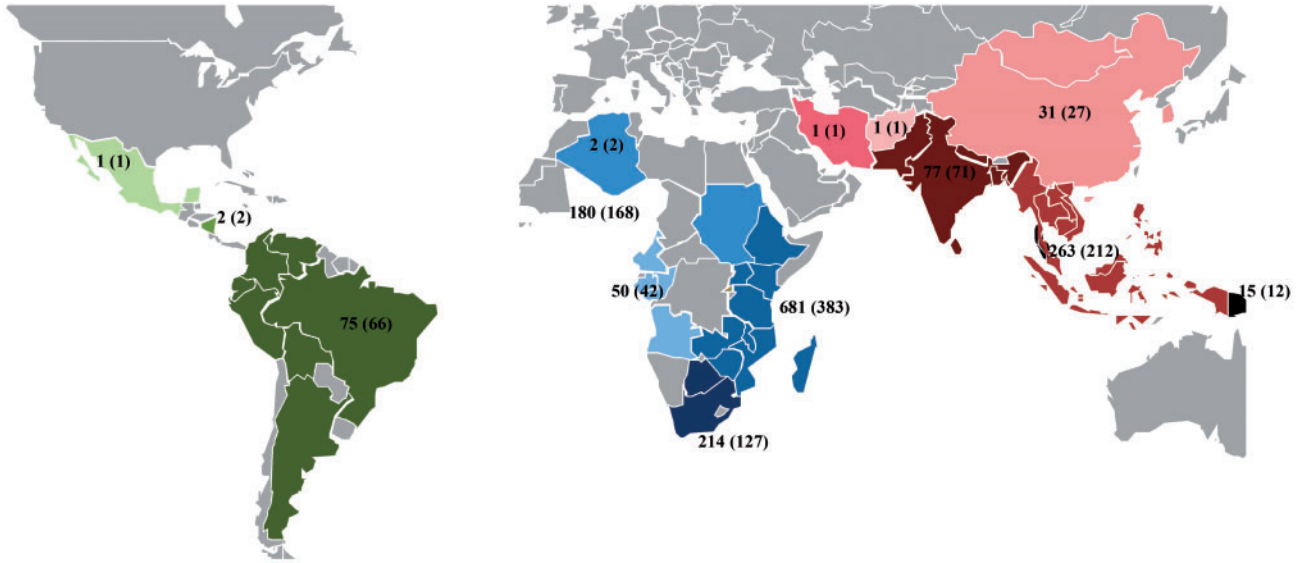

Figure 1. Global Distribution of Source RCTs - Total number of identified articles and number of LMIC first authored publications.

points to the lower and upper boundaries of the confidence interval.[15] These analyses were repeated using LMIC last-authorship as a dependent variable.

Sensitivity analyses were conducted to assess the impact of potential misclassifications of first-authors and last-authors on the results of the respective analyses. This approach was selected because the extent to which institutional affiliations are completely or accurately reported, particularly for those with multiple institutional affiliations, is unknown.

For each disease, the impact of misclassifications was assessed by assuming 20%, 50% and 80% of non-cases for positive findings and cases for negative findings. Top and bottom ranges for the outcome group were varied.

Results

Overall, it was found that 49.8% of the 1593 identified articles had LMIC first-authors. Figure 1 shows the distribution of these identified publications globally, with the number of LMIC-authored publications in parentheses. Of particular note in this figure is the high concentration of global RCTs in Africa. Table 1 shows the relationship between each of the various identified study characteristics and whether or not the first-author was affiliated with an institution in an LMIC. It can be seen that the proportion of articles with LMIC first-authorship was higher for articles published before 2000 (73.9%) compared with articles published after 2000 (46.0%). In terms of study funding, the proportion of LMIC first-authored articles was highest for studies funded from LMICs (89.8%) and lowest for US-funded research (31.9%). The percentage of LMIC first-authored articles was highest for malaria research (67.4%) and lowest for HIV/AIDS (33.3%). For intervention types, LMIC first-authors comprised a higher proportion of studies investigating pharmaceutical and vaccine interventions (63.5%), compared with other intervention types (all <= 40.0%). LMIC first-authorship was much lower in articles for African and Eastern Mediterranean-based research compared with research based in other regions.

There was no evidence of a change in the number of co-authors on articles where the trial was US-funded (< 2000 = 6.8, 5.41-8.19; >= 2000 = 8.02, 7.64-8.4), co-financed (< 2000 = 6.67, 5.34-8; >= 2000 = 7.41, 6.78-8.03) or LMIC-funded (< 2000 = 5, 3.37-6.63; >= 2000 = 5.69, 4.82-6.55) before 2000 compared with after 2000. There was however a significant increase in the number of co-authors on articles trials that were funded by other HIC sources (< 2000 = 6.42, 5.79-7.05; >= 2000 = 8, 7.63-8.37). There was no evidence that this was associated with an increase in the proportion of LMIC co-authors per article (< 2000 = 47.37, 41.13-53.61; >= 2000 = 47.2, 44.65-49.75).

The stratified relative risk results showed that LMIC first-authorship was associated with year of publication, disease, funding type, intervention type, and region (see Table 2). In particular, LMIC first-authorship was less likely in studies of HIV/AIDS when compared with studies investigating TB and malaria. LMIC first-authorship was twice as likely among studies that were fully LMIC-funded compared with studies with non-US HIC funding. LMIC first-authorship was also more common among co-financed trials than trials with non-US HIC funding. In

Table 1. Study characteristics by LMIC first-authorship

Study characteristic	No. of articles with LMIC first author / all publications	LMIC author proportion	χ^2	*P*-value
Year of publication				
<= 2000	164/222	73·9	59·6	<0.001
> 2000	630/1371	46·0		
Funder Type				
USA only	173/543	31·9	164·2	<0.001
Other HIC only	381/713	53·4		
LMIC only	115/128	89·8		
Co-financing (LMIC & HIC)	125/209	59·8		
Disease				
HIV/AIDS	254/763	33·3	167·6	<0.001
TB	92/165	55·8		
Malaria	448/665	67·4		
Intervention Type				
Pharmaceutical & vaccine	587/925	63·5	173·4	<0.001
Nutritional, hygiene, dietary & herbal	74/185	40·0		
Non-pharmaceutical, prevention & diagnostics	86/322	26·7		
Lifestyle & living structure	5/26	19·2		
Educational, behavioural & promotional	42/135	31·1		
Region				
Africa	484/1126	43·0	79·3	<0.001
Americas	60/79	76.0		
Western Pacific	64/106	60.4		
South-East Asia & Pacific	184/276	66.7		
Eastern Mediterranean	2/6	33·3		

contrast, LMIC first-authorship was less likely for US-funded research than non-US HIC funding. Research addressing preventive and diagnostic interventions and, to a lesser extent, behavioural interventions was associated with lower levels of LMIC first-authorship than pharmaceutical and vaccine research. Finally, LMIC first-authorship was more likely in the Americas and South-East Asia and Pacific than in Africa. There were no differences in LMIC first-authorship between the Western Pacific and Eastern Mediterranean and Africa.

Figure 2 shows the change in the number of publications across the period 1990-2013, by author affiliation. It can be seen that the total number of RCTs and associated publications increased dramatically during this period and that this trend was evident for both LMIC and non-LMIC authorship. From 1990 to 2000, a total of 222 trials were published, and for 2001 to 2013, 1371 trials were published, with a steady year-on-year increase over the period, particularly evident in trials conducted in Africa. Importantly, Figure 2 shows that the yearly number of publications with a non-LMIC first-author grew at a faster rate from approximately 2005, and overtook the number of LMIC-authored publications in 2008. The relative rate increase in first-authorships post 2000 was 11.8-fold for non-LMIC first-authors and 2.8-fold for LMIC first-authors. LMIC first-authorship increased over time for research with LMIC funding; but LMIC first-authorship declined over time for research funded with HIC funding. As such, although starting at a similar level in 1990, non-LMIC authored articles made up a greater proportion of all articles published by the year 2013.

In terms of overall trends, Figure 3 shows the interaction between funding source and time ($X^2 = 46.97$; Wald test $P < 0{\cdot}0001$). The probability of LMIC first-authorship increased over time for LMIC fully funded research, and decreased over time for research funded by HIC sources (both US and non-US). There was a small decline in probability of LMIC authorship for co-financed research. This interaction is predominantly driven by changes in malaria research rather than HIV/AIDS and TB (see Annex 2 for disease-specific results, available as Supplementary data at *IJE* online). Figure 4 shows that the results of the analysis were robust against misclassifications of local authorship of up to 50% (Annex 3).

The stratified relative risk results showed that LMIC last-authorship was associated with disease, funding type and region (see Table 3) In particular, LMIC last-authorship was less likely in studies of HIV/AIDS and malaria when

Table 2. Predictors of LMIC first-authorship by disease type. Adjusted relative risks derived from Poisson regressions

Variables	Total (N = 1593)		HIV/AIDS (N = 763)		TB (N = 165)		Malaria (N = 665)	
	aRR (95% CI)†	*p*-value	aRR (95% CI) †	*p*-value	aRR (95% CI) †	*p*-value	aRR (95% CI) †	*p*-value
Disease								
TB	1·0 (reference)							
HIV/AIDS	0·72 (0·58, 0·89)	0·003						
Malaria	1·21 (1·00, 1·45)	0·047						
Funding source								
Other HIC	1·0 (reference)		1·0 (reference)		1·0 (reference)		1·0 (reference)	
USA	0·81 (0·68, 0·97)	0·019	0·64 (0·45, 0·91)	0·012	1·01 (0·62 1·63)	0·974	0·95 (0·84, 1·08)	0·608
LMIC co-financing	1·40 (1·15, 1·71)	0·001	1·45 (1·01, 2·09)	0·044	1·29 (0·87, 1·92)	0·207	1·28 (1·06, 1·54)	0·009
LMIC full	2·01 (1·75, 2·33)	<0·001	2·76 (1·98, 3·83)	<0·0011	1·50 (1·01, 2·22)	0·047	1·73 (1·46, 2·05)	<0·0011
Year of publication								
Year	0·96 (0·95, 0·98)	<0·0011	0·99 (0·96, 1·02)	0·376	1·01 (0·98, 1·04)	0·574	0·96 (0·95, 0·97)	<0·0011
Intervention type								
Pharmaceutical & vaccine	1·0 (reference)		1·0 (reference)		1·0 (reference)		1·0 (reference)	
Nutritional & supplement	0·82 (0·64, 1·06)	0·124	0·76 (0·52, 1·10)	0·143	0·84 (0·50, 1·41)	0·504	1·08 (0·94, 1·24)	0·297
Preventive & diagnostics	0·50 (0·40, 0·63)	<0·001	0·82 (0·56, 1·21)	0·319	0·85 (0·60, 1·23)	0·393	0·27 (0·18, 0·40)	<0.001
Lifestyle & living structure	0·45 (0·18, 1·09)	0·078	0·52 (0·18, 1·47)	0·217	1·72 (1·07, 2·78)	0·025	–	
Educational, behavioural	0·72 (0·52, 1·01)	0·055	0·97 (0·67, 1·39)	0.861	0·26 (0·05, 1·24)	0·090	–	
Host region								
Africa	1·0 (reference)		1·0 (reference)		1·0 (reference)		1·0 (reference)	
Americas	1·26 (1·08, 1·48)	0·003	1·28 (0·92, 1·78)	0·141	1·64 (1·06, 2·54)	0·026	1·05 (0·90, 1·23)	0·534
Western Pacific	1·05 (0·90, 1·22)	0·555	0·87 (0·59, 1·29)	0·489	1·18 (0·66, 2·11)	0·578	1·04 (0·90, 1·19)	0·629
South-East Asia & Pacific	1·14 (1·02, 1·28)	0·022	1·04 (0·74, 1·45)	0·836	1·77 (1·27, 2·48)	0·001	1·04 (0·95, 1.14)	0·400
Eastern Mediterranean	0·56 (0·20, 1·45)	0·232	1·09 (0·80, 1·48)	0·577	–		0·40 (0·09, 1·80)	0·234
Funding source x Year of Publication								
Year x Other HIC	1·0 (reference)		1·0 (reference)		1·0 (reference)		1·0 (reference)	
Year x USA	1·00 (0·98, 1·03)	0·698	1·02 (0·93, 1·10)	0·727	0·97 (0·88, 1·07)	0·581	1·00 (0·98, 1·02)	0·935
Year x LMIC co-financing	1·04 (1·02, 1·06)	0·001	1·01 (0·94, 1·07)	0·946	0·99 (0·91, 1·07)	0·772	1·03 (1·02, 1·05)	<0·0001
Year x LMIC full	1·06 (1·04, 1·08)	<0·0001	1·03 (0·97, 1·09)	0·373	0·97 (0·90, 1·03)	0·287	1·07 (1·05, 1·10)	<0·0001

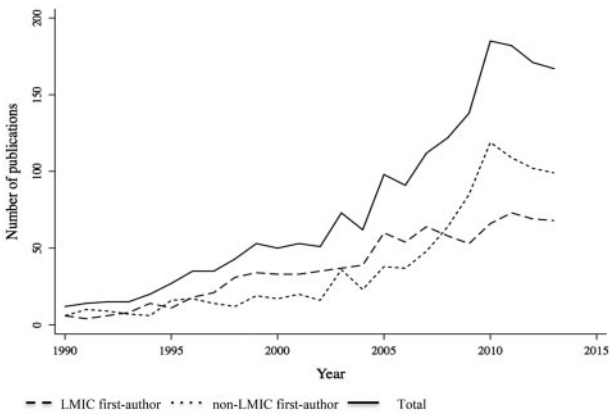

Figure 2. Number of articles published by author affiliation (1990-2012).

compared with studies investigating TB. LMIC last-authorship was twice as likely among studies that were fully LMIC-funded or co-financed compared with studies with non-US HIC funding. LMIC first-authorship was also more common among co-financed trials than trials with non-US HIC funding. There were no differences in LMIC last-authorship among HIC funders. LMIC last-authorship was more likely in the Americas and South-East Asia and Pacific than in Africa. There were no differences in LMIC last-authorship between the Western Pacific and Eastern Mediterranean and Africa. LMIC last-authorship did not vary over time; nor did it interact with type of funding ($X^2 = 4.45$; Wald test $P < 0·22$). There were also no differences in LMIC last-authorship due to funding type. The results of the analyses were similar across disease types. The only exception was that for HIV, all other regions had a higher probability of LMIC last-authorship than Africa. A sensitivity analysis demonstrated that the results of the analysis were robust against misclassifications of local authorship from 20-80% (see Annex 3).

Discussion

Over the past 25 years, debate around global health research has shifted from questioning the value of health

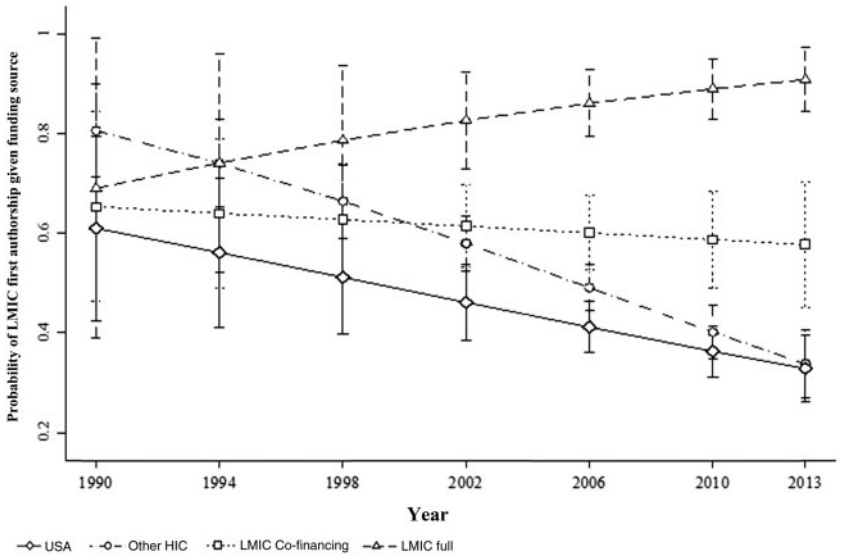

Figure 3. Probability of LMIC first-authorship incorporating funding source and time (1990-2012).

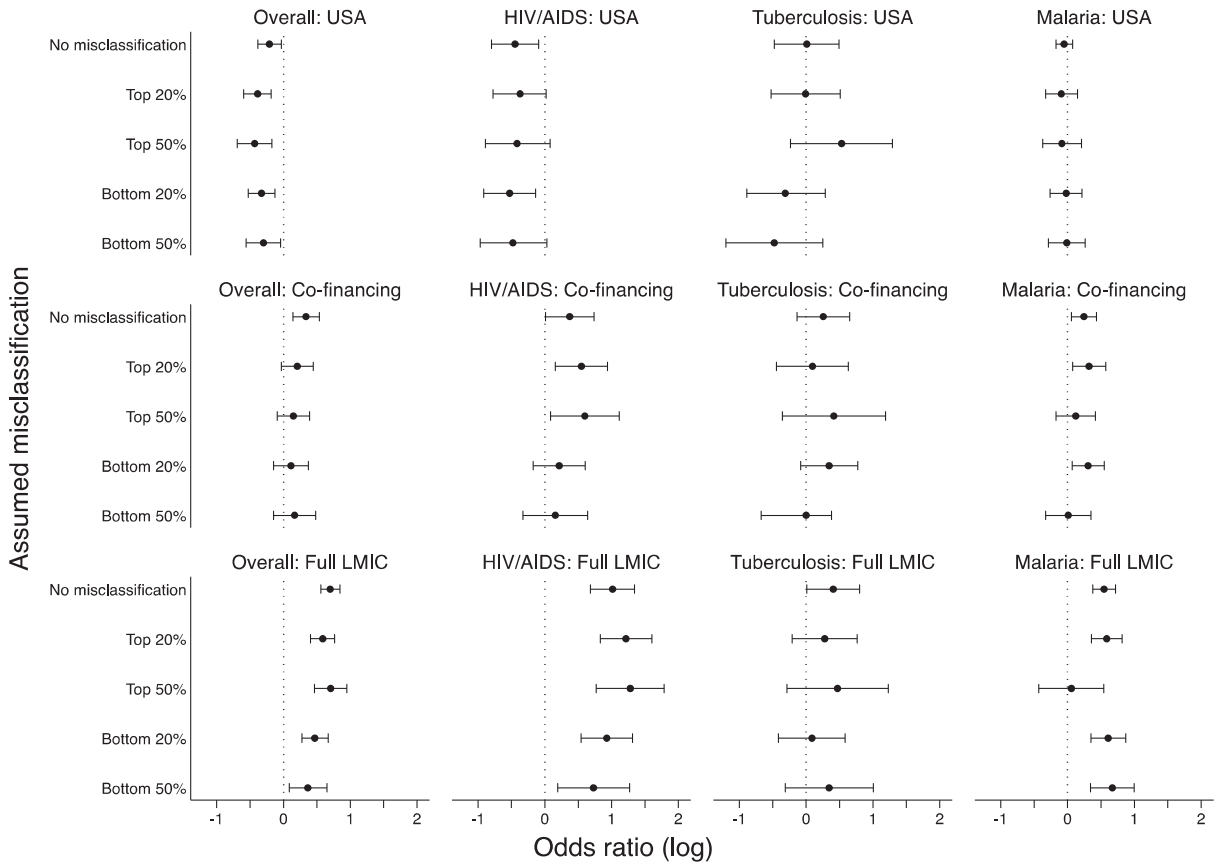

Figure 4. Sensitivity analysis LMIC first-authorship.

research for LMIC[12] to better understanding of how global health research benefits LMIC countries.[13] The results of this study demonstrate both positive progress and areas for improvement in developing research capacity. The number of articles published increased dramatically for all authors in the post 2000 period; however, this increase disproportionately benefited non-LMIC first-authors. This suggests that although some positive LMIC capacity building has occurred, there is still room for improvement.[5] The proportion of LMIC first-authors increased over time where

Table 3. Predictors of LMIC last-authorship by disease type. Adjusted relative risks derived from Poisson regressions

Variables	Total (N = 1593)		HIV/AIDS (N = 763)		TB (N = 165)		Malaria (N = 665)	
	aRR (95% CI)†	*p*-value	aRR (95% CI)	*p*-value	aRR (95% CI)	*p*-value	aRR (95% CI) †	*p*-value
Disease								
TB	1·0 (reference)							
HIV/AIDS	0·78 (0·61, 1·00)	0·049						
Malaria	0·75 (0·59, 0·96)	0·023						
Funding source								
Other HIC	1·0 (reference)		1·0 (reference)		1·0 (reference)		1·0 (reference)	
USA	0·93 (0·72, 1·21)	0·582	1·04 (0·69, 1·56)	0·860	1·17 (0·50 2·73)	0·716	0·68 (0·42, 1·13)†	0·135
LMIC co-financing	1·35 (1·04, 1·75)	0·024	1·37 (0·89, 2·12)	0·148	1·75 (0·89, 3·45)	0·107	1·47 (0·92, 2·36)†	0·110
LMIC full	2·77 (2·26, 3·40)	<0·001	3·09 (2·11, 4·54)	<0·001	3·00 (1·66, 5·43)	<0·0001	1·63 (1·07, 2·46)†	0.021
Year of publication								
Year	1·00 (0·98, 1·02)	0·847	1·00 (0·97, 1·03)	0·765	1·00 (0·96, 1·03)	0·775	1·03 (0·99, 1·06)	0.163
Intervention type								
Pharmaceutical & vaccine	1·0 (reference)		1·0 (reference)		1·0 (reference)		1·0 (reference)	
Nutritional & supplement	0·77 (0·52, 1·13)	0·179	0·70 (0·42, 1·16)	0·162	0·83 (0·40, 1·71)	0·611	1·02 (0·55, 1·89)	0·941
Preventive & diagnostics	0·77 (0·60, 1·00)	0·051	0·76 (0·50, 1·15)	0·193	1·01 (0·64, 1·59)	0·982	0·70 (0·45, 1·09)	0·111
Lifestyle & living structure	1·05 (0·52, 2·10)	0·902	0·86 (0·36, 2·06)	0·736	2·63 (1·39, 4·98)	0·003	1.31 (0·29, 6·01)	0·728
Educational, behavioural	1·25 (0·95, 1·66)	0·114	1·08 (0·77, 1·52)	0.637	0·74 (0·29, 1·89)	0·530	2.54 (1·41, 4·58)	0·002
Host region								
Africa	1·0 (reference)		1·0 (reference)		1·0 (reference)		1·0 (reference)	
Americas	1·59 (1·24, 2·03)	<0·0001	2·08 (1·45, 2·99)	<0·0011	1·10 (0·54, 2·25)	0·792	1·21 (0·72, 2·03)	0·465
Western Pacific	1·16 (0·85, 1·57)	0·354	1·74 (1·16, 2·59)	0·007	0·88 (0·40, 1·92)	0·740	0·92 (0·52, 1·62)	0·776
South-East Asia & Pacific	1·54 (1·25, 1·90)	<0·0001	1·80 (1·30, 2·48)	<0·0011	1·70 (1·09, 2·64)	0·019	1·14 (0·82, 1·59)	0·442
Eastern Mediterranean	1·39 (0·56, 3·43)	0·478	1·84 (1·31, 2·58)	<0·0011	N/A		1·02 (0·19, 5·39)	0·984
Funding source x Year of Publication								
Year x other foreign	1·0 (reference)		1·0 (reference)		1·0 (reference)		1·0 (reference)	
Year x USA	0·96 (0·91, 1·00)	0·053	0·97 (0·89, 1·05)	0·463	1·07 (0·93, 1·22)	0·337	0·91 (0·85, 0·97)	0·003
Year x LMIC co-financing	1·00 (0·95, 1·05)	0·981	1·02 (0·93, 1·11)	0·740	1·01 (0·90, 1·13)	0·911	1·00 (0·93, 1·08)	0·972
Year x LMIC full	0·99 (0·95, 1·02)	0.491	1·01 (0·94, 1·09)	0·700	1·03 (0·94, 1·13)	0·287	0·90 (0·83, 0·96)	0·003

research was fully LMIC-funded and decreased over time for research that was funded by HIC sources. The proportion of LMIC first-authors was higher in co-funded initiatives than HIC-funded initiatives; however, there was little evidence of change in authorship over time. Similar patterns were apparent for LMIC last-authorship; however, there was no evidence of changes over time. Overall the results highlight the need to explicitly prioritize capacity building in funding decisions.

The relationship between LMIC first-authorship and different funder types is most likely due to funder's influence on who receives grants rather than on a direct effect on authorship per se. Although one solution would be for a greater proportion of research to be funded by LMIC countries, this solution is unlikely to be practicable in the short term. A more effective approach may be for HIC funders of LMIC research to address explicit (e.g., restrictions based on nationality) and implicit barriers (e.g., failure to consider performance against opportunity). The highly competitive nature of research funding means that funders have a great deal of leverage to shift practice by changing requirements for applications and around research collaborations, to maximize equity.[14] Higher rates of LMIC first-authorship in pharmaceutical trials compared with other types of interventions highlight the benefits of specific attention to improving LMIC benefit from research. Ultimately the contribution of research to human health is likely to be optimized if the best ideas are funded wherever they arise.

Previous research suggests that there may be a number of structural barriers to LMIC researchers assuming leadership roles, including a lack of a secure institutional base which means they may lack the support required to develop funding applications.[9] Developing an institutional base that could support both consultancy research and investigator-driven research may help build capacity for LMIC participation in research leadership. There have also been concerns that LMIC authors may be underrepresented because of the dominance of English in the research literature, perceived or actual bias of editor towards

Western researchers, and cultural difference in understandings around authorship.[15] This study suggests that lower representation of LMIC researchers on research teams is a key cause of lower levels of LMIC first-authorship. An analysis of co-authors suggested that there were LMIC co-authors on 40% of articles for research that was fully LMIC-funded and only 3-4% on articles where research was funded from other sources.

The main limitations of this study were around the classification of research funders and research institutions. These classifications were highly reliant on the quality of the information provided in the research articles. The institutional affiliations are clearly an imperfect proxy for a researcher's country of origin, but they do provide important information about fund-holding and are therefore a reasonable proxy in relation to capacity building. Indeed, the sensitivity analysis suggested that both these limitations would have a minimal impact on the results. We tracked both changes in the number and proportion of articles that are LMIC first-authored. We did not base the analysis solely on numbers of articles because of cases like malaria where, although the number of articles with LMIC first-authors increased, the proportion of articles decreased. It should also be noted that there remains uncertainty as to whether the increases in first-authorship were due to funding that goes to LMICs or because of the growing collaborations between institutions in the HICs and LMICs.

A further limitation is the specific focus on RCTs. In particular, this is because capacity building strategies in LMICs often target graduate students, who generally do not undertake RCTs due to limited funding and time constraints. This means that it is possible that many LMIC graduate student papers would not have been included in the analysis and therefore some of the impacts of capacity building strategies may be underestimated. In addition, first-authorship on RCTs would mostly include investigators with reasonable experience. Those from other professions, such as epidemiology, statistics, laboratory sciences, social research etc., would not appear as first-authors on these articles reporting an RCT but they may appear as middle-authors. It should therefor, be noted that for some researchers, publishing non-randomized studies (or sub-analyses from RCTs) provides opportunities for first-authorship and capacity building; hence the criteria used in this study may grossly underestimate the impact.

This study is the first to our knowledge that has tracked trends in LMIC first-authorship. LMIC first-authorship has increased in absolute terms in the post-2000 period. This was due to increased LMIC first-authorship in fully LMIC-funded research. Similar trends were not observed in HIC-funded research. This suggests that more inclusive policies by international funders are important to developing greater research leadership in LMICs. Specifically, the results suggest that active effort and substantive support is required in order to allow the locus of control of research to shift to the LMICs where the research is conducted.

Supplementary Data

Supplementary data are available at *IJE* online.

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