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Advancing the science of health research capacity strengthening in low- and middle-income countries: A scoping review of the published literature, 2000-2016.

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Authors:

Laura Dean[1a]

Stefanie Gregorius[1]

Imelda Bates[1]

Justin Pulford[1]

1. Department of International Public Health, Capacity Research Unit, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool, L3 5QA, UK.

[a] Corresponding Author: laura.dean@lstmed.ac.uk Tel: 01517053793

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Abstract

Objectives: Substantial development assistance and research funding are invested in health research capacity strengthening (HRCS) interventions in many low- and middle-income countries, yet the effectiveness, impact and value for money of these investments is not well understood. Arguably, the major constraint to evidence-informed HRCS intervention has been the disparate nature of the research effort to date. This review aims to map and critically analyse the existing HRCS effort to better understand the level, type, cohesion and conceptual sophistication of the current evidence base.

Methods: We utilised a scoping review methodology to develop standardised search terms to identify empirical and theoretical HRCS literature within the following databases: PubMed, Global Health, and Scopus. HRCS publications available in English between the period 2000-2016 were included. 1195 articles were retrieved of which 172 met the final inclusion criteria. A-priori thematic analysis of all included articles was completed. Content analysis of identified HRCS definitions was also conducted.

Results: The number of HRCS publications has increased exponentially between 2000 and 2016. Most publications during this period have been perspective, opinion or commentary pieces, however publications presenting original research findings have been the primary publication type since 2013. Three comprehensive definitions that explicitly align with current HRCS guidelines were evident, although all three pertain to the broader notion of 'research capacity' strengthening.

Conclusions: The review findings indicate a HRCS research field with a focus on implementation science is emerging, although the conceptual and empirical bases are not yet sufficiently advanced to effectively inform HRCS programme planning. Consolidating a HRCS implementation science therefore presents as a viable option that may accelerate the development of a useful evidence-base to inform HRCS programme planning. Identifying an agreed operational definition of HRCS,

standardising HRCS-related terminology, developing a needs-based HRCS-specific research agenda and synthesising currently available evidence may be useful first steps.

Strengths and Limitations of the Study

- This scoping review brings together various studies and reviews focused on HRCS to provide the impetus and direction for a dedicated HRCS implementation science to emerge and to foster a common identity for HRCS researchers.
- This review critically analysed current definitions of HRCS to contribute toward the identification of a consolidated, evidence based, operational definition of HRCS on which future HRCS interventions and evaluations can be based.
- Some articles published in non-Anglophone journals, in non-health related journals, or in a lexicon outside of the key word terms employed herein would not have been retrieved by the search methodology.
- Relevant work that remains unpublished, published outside of academic peer-reviewed journals or published prior to 2000 would also have been omitted.
- The review did not critically examine the quality of the research effort (in original research publications) or analyse the output (findings) of the collective research effort.

Introduction

Health research capacity in many low- and middle-income countries (LMICs) is poor [1-4], undermining LMIC ability to identify and respond to local health needs or to equitably participate in the international response to global health challenges. Numerous health research capacity strengthening (HRCS) interventions have been employed in LMICs ranging from simple training programmes to currently advocated 'systems' approaches that focus on developing the capacity of individual researchers, research institutions and the wider research environment [5-7]. The international research community has a dual role in LMIC HRCS. The first role is that of a HRCS *implementer* and centres on the transfer of expertise in specialist subject areas pertinent to LMIC health research priorities, typically from higher- to lower-capacitated individuals or organisations and may be facilitated through such mechanisms as scholarship schemes, technical assistance, research networks or research consortia. The second role is that of an HRCS *scientist* and centres on the creation of robust theory and evidence to inform optimal HRCS interventions. Here, the researcher is not an expert in the subject matter of a specific HRCS intervention (e.g. increasing capacity in operational research to support national malaria control programmes), but is concerned with providing the evidence-base to inform HRCS funders and implementing partners how their respective programme goals may best be achieved (e.g. what investments would produce the greatest, most sustainable gain in operational research capacity to support a national malaria control programme).

The extent to which the research community is fulfilling this latter role (i.e. HRCS scientist), as compared to the former role (i.e. HRCS implementer), is questionable at present. A recent paper described the existing HRCS evidence-base as 'confusing, controversial and poorly defined' [8] despite a long recognised need to support HRCS in LMICs [9]. Fundamental questions remain largely unanswered such as; how to reliably assess existing capacities at different levels of a health research

system; which interventions facilitate sustainable capacity gains in which circumstances; and which capacity term (building, strengthening or development) is the most nuanced and appropriate to reflect developmental discourse and baseline capacities [10]. The international research community is therefore in the awkward position of being a highly active participant in the transfer of scientific theory and method within the context of subject-specific HRCS interventions, yet largely inactive in rigorously applying scientific theory and method to the HRCS process.

The paucity of evidence available to inform HRCS implementation reflects, in part, the difficulties in measuring an inherently multi-faceted, long-term, continuous process (i.e. HRCS) subject to a diverse range of influences and assumptions. A greater constraint has been the sparse and disparate nature of the HRCS-related research effort to date. HRCS-related research has involved multiple academic disciplines, employing diverse frameworks, concepts, methods and terminologies, working in isolation and publishing in different fields (e.g. medical education, communication, operational research and evaluation). A dedicated, multi-disciplinary, implementation-focused research approach is undoubtedly required to improve the effectiveness, impact and value for money of current and future HRCS implementation activities in LMICs. However, there is little evidence of a unified HRCS implementation science emerging to date.

The overall goal of this paper is to advance the development of a unified, implementation-focused HRCS science. To achieve this goal, a scoping review of HRCS-related publications for the period 2000-2016 was conducted and operational definitions of HRCS within this literature critically examined. The review findings are not presented as a definitive account of HRCS activity across this period as relevant material may be unpublished, may be found in the grey literature or may be published in a lexicon outside of the search terms employed herein. The review is better understood as an attempt to critically analyse the collective HRCS effort regarding the level, type, cohesion and conceptual sophistication of the current evidence base. The review may be considered an initial

attempt to map the HRCS research effort, providing the impetus and direction for a dedicated HRCS implementation science to emerge and fostering a common identity for HRCS researchers.

Methods

This review was conducted according to stages 1-5 of the advanced 'scoping' methodology proposed by Levac et al [11], based on the original framework of Arksey and O'Malley [12]. A scoping review was considered appropriate given the primary focus was on examining the extent, range and nature of an emerging literature. The critical examination of operational definitions of HRCS falls outside of the 'scoping review' approach, yet is included as a means of 'revealing' (in part) the conceptual sophistication and cohesion of the reviewed literature.

Identification of Data Sources

The first two steps of the scoping review method include identifying a research question and relevant studies. To explore the breadth, concepts, definitions and methods currently prioritised in the HRCS literature, we searched for empirical and theoretical literature within the following databases: PubMed, Global Health, and Scopus. Search terms used were: ("capacity strengthening", OR "capacity development", OR "capacity building") combined with ("global health" OR, "international health" OR, "global public health", OR "health research" OR, "health development"). Additional search criteria included: papers published between 01/01/2000 and 31/12/2016 and both abstract and full paper available in English. Searches began from the year 2000 as a reflection of the stepwise change in the profile and investment in HRCS. Results were stored within an EndNote library.

Selection of Data Sources

Study selection (step 3) included reviewing article title, abstract and key words against the following inclusion criteria: peer reviewed, including primary research, reviews (including but not exclusively systematic reviews), commentaries and opinion pieces; contained the words 'capacity strengthening', 'capacity building' or 'capacity development' or a term with an equivalent meaning; related to global health, international health, health research or health development; and were based in full, or part, on an LMIC context. Articles were kept for full text review if all inclusion criteria were present.

Data Charting and Analysis

Data charting (step 4) involved JP and SG independently screening publications included for full text review. The independent review process was designed to: 1) eliminate publications that did not meet the selection criteria; 2) assign included publications into one of three pre-determined publication 'typologies' (Box 1); and 3) to identify common groupings of publications within the 'original research' typology based on emergent themes or article focus e.g. HRCS programme evaluation or HRCS methods for implementation. Articles categorised differently between JP and SG, were independently coded by LD and category definitions and assignment finalised by mutual consent. Publication categories were then divided amongst LD, JP and SG for subsequent analysis (step 5). Each member of the research team conducted a detailed review of articles within their category. A-priori information was extracted across all categories as well as inductive category-specific data (listed in Tables 1 and 2 and S2-S8 Tables). Quality of publications was not formally assessed; however, some aspects such as study design, methods and analysis were considered where appropriate.

Box 1. HRCS Publication Typologies

Original Research: Publications in which a) a hypothesis, research question or study purpose was stated; b) research methods described; c) results reported; and d) the results and their possible implications discussed.

Perspectives, Opinion or Commentary: Publications expressing the authors' viewpoint on some aspect of HRCS based on anecdotal evidence, personal experience and/or (in a very few cases) original data that were not presented in an 'original research' format (i.e. did not include a formal description of the research aims, methods, results and discussion).

Systematic Review: Publications in which a) research objectives/questions were clearly stated; b) explicit and systematic methods were used; c) methods were limited to the systematic identification and analysis of some form of literature; and d) results were reported and discussed. Non-systematic reviews were included within the original research section.

During in-depth analysis of each publication any operational definition of (health) research capacity strengthening was extracted and analysed for content. To identify commonalities, definition content was independently coded by JP and SG per the a-priori content criteria identified in Table 4. Coding disagreements were resolved by the same process described above. A content score, defined as the number of domains (out of 10) present, was calculated for each definition to identify the most inclusive working definition of HRCS within the current evidence base.

Results

1195 papers were retrieved via the search methodology of which 172 (see S1 Table) met the final inclusion criteria. The number of HRCS publications identified increased over time, from 0 in the year 2000 to a maximum of 32 in 2016 (Fig 1).

Fig 1. Number of publications per year by publication type.

HRCS Publication Typologies

Overall, 51% of publications presented a perspective, opinion or commentary, 46% original research and 3% findings from a systematic review (Table 1). The first and/or last author was from an institute located in an LMIC in 58% of publications, 'capacity building' was the favoured term in 59% and 19% presented an operational definition of HRCS.

Table 1. Selected characteristics of reviewed publications

Publication Type	No.	LMIC Authorship[1]			Capacity Term[2]				Defined HRCS[3]
		First	Last	Either	CB	CD	CS	Oth.	
Original Research	79	31	32	41	38	18	24	0	17
Pers. Opin. Commentary	88	36	42	56	63	6	19	0	16
Systematic Review	5	3	1	3	1	1	2	0	0
Total	**172**	**70**	**75**	**100**	**102**	**25**	**45**	**0**	**33**

1 Based on location of listed organisational affiliation of first and last authors; 'either' = either first or last. 2 capacity term used in title and then keywords given priority. (CB=capacity building, CD=capacity development, CS=capacity strengthening, Oth.=other). 3 Number of papers that provided an operational definition of HRCS.

Original Research

The 79 publications that met 'original research' criteria were sub-categorised into research typologies including: learning and evaluation, assessment, HRCS methods for implementation, evidence synthesis for HRCS implementation and evaluation, and miscellaneous. Table 2 presents selected methodological characteristics of the original research publications both overall and by sub-category. Additional data, not all of which are described below, are included in S2-S8 Tables.

Table 2. Selected methodological characteristics of original research publications

Sub-Category	No.	Setting[1]							Design[2]			Data Collection[3,4]					Data Analysis[4,5]		
		Af	Am	Se	Eu	Em	Wp	Gl	Quan	Qual	Mix	Sur	IDI	FGD	Rev	Oth	The	Des	Inf
Learning & Evaluation	36	14	1	4	0	1	4	14	8	9	19	20	18	5	16	10	28	18	1
Assessments	27	16	0	0	1	2	3	5	6	7	14	15	13	5	15	7	19	22	0
HRCS Methods	7	6	0	0	0	0	0	1	1	5	1	2	1	1	4	4	6	1	1
Evidence Synthesis	5	0	0	0	0	0	0	5	0	4	1	1	0	0	5	4	5	0	0
Miscellaneous	4	2	0	0	0	0	0	2	0	2	2	2	3	0	2	1	4	0	0
Total	**79**	**38**	**1**	**4**	**1**	**3**	**7**	**27**	**15**	**27**	**37**	**40**	**35**	**11**	**42**	**26**	**62**	**41**	**2**

1. WHO region where the study was located: African (Af), Americas (Am), South-East Asia (Se), European (Eu), Eastern Mediterranean (Em), Western Pacific (Wp) or Global (Gl)(defined as 3 or more WHO regions). 2. Quantitative (Quan.), qualitative (Qual.) or mixed methods (Mix.). 3. Survey (Sur.), in-depth interview (IDI), focus group discussion (FGD), literature/document review (Rev.) or other methodology (Other). 4. Categories are not mutually exclusive. 5. Thematic (Them.), descriptive (Desc.) or inferential (Infer.).

Learning & evaluation

This category included 36 publications that presented findings from a formal evaluation of an HRCS initiative or described 'learnings' obtained from HRCS implementation (Table 2 and S2 Table). Sixty-four percent were 'education' based HRCS programmes in which some form of training (inclusive of postgraduate awards) was provided to strengthen individual capacity and, in some cases, was inclusive of the development and transfer of a course curriculum at an institutional level e.g. [13]. Other HRCS programme types included collaborative research (n=12), time-limited work placement (n=2), strengthening the broader health research system (n=2), infrastructure development (n=1) or strengthening financial management (n=1). The respective HRCS programmes involved North-South collaboration in 83% of cases. Seventy-five percent of programmes sought to strengthen research capacity in a specific subject area, most commonly health systems (n=6).

Box 2. Learning and Evaluation Typologies

Lessons Learned: publications focused on broad, programme(s)-level experiences in setting up and/or participating in an HRCS initiative and/or providing a largely qualitative account of programme achievements.

Programme Outputs: publications focused on HRCS programme outputs, where outputs were defined as a quantification of activities that occurred during the programme and/or related professional activities that occurred after the programme (e.g. no. of publications).

Programme Outcomes: publications that focused on improvements in individual-, institutional- or environmental-level health research capacity following an HRCS initiative and employed quantitative measures designed to attribute improved performance to the respective HRCS intervention.

The objective of each 'learning and/or evaluation' publication was coded per the typologies presented in Box 2. Overall, 67% of the learning and evaluation publications were given a single code and 33% were given 2 or more codes. 'Lessons learned' was allocated to 44% of publications,

'programme outputs' to 33%, 'programme outcomes' to 28% and unique codes were allocated to 33%. Quantitative outcome indicators varied among publications that employed them, although were generally: variants of some form of citation analysis to measure influence of research publication (that followed the HRCS intervention) on health policy [14-16]; measures of knowledge change pre- and post-HRCS intervention or knowledge gained from an intervention [17-20]; some form of 'attributional' measure designed to assess the relationship between capacity improvement and the respective HRCS intervention [17 18 21 22].

Sixty-four percent of studies were retrospective, 64% were a type of (quasi-) formative evaluation, 53% were mixed methods and 17% were authored by individuals independent of the organisation implementing the respective HRCS initiative (study design data not presented in Table 2 are shown in S2 Table). Sampling was primarily purposive (n=20).

Assessments

This category included 27 original research publications that presented the outcome of some form of health research capacity assessment (Table 2 and S3 Table). Capacity assessment focus varied; the largest proportion (9/27) focused on assessing capacity to carry out research, often in a specific subject area (18/27), most commonly health policy and systems research (6/27).

Capacity assessments were conducted within the context of a research institution(s), including universities or research network in 59% of publications. Eleven percent focussed on the capacities of ethics committees and one involved health care providers. The remaining 26% focused on national and/or regional capacity in specific research and/or geographical areas through reviewing literature and publication trends.

Thirty-seven percent (10/27) of assessments were conducted as part of a consortium based research programme, consisting of European and African partners.

HRCS methods for implementation

This category includes 7 articles that present a methodological approach to HRCS or evaluation of HRCS (S4 Table). Two articles focus on HRCS within the frame of North-South partnerships and 4 prioritised general HRCS, often embedded in a specific subject area e.g. policy analysis. The remaining article focused on the development and validation of a questionnaire for evaluation of HRCS training activities.

The numbers of steps in methodological approach varied; however, consistent phasing or process can be identified. In all publications, the purpose of the HRCS activity was initially established although this was only stated as an explicit methodological step in one paper [23]. Three articles then developed bespoke 'optimal health research' criteria or 'ideal partnership capacity' criteria through a combination of literature searches and interactions with key stakeholders. The remaining 4 publications adapted an existing tool or framework that could be used as a common ideal for health research or partnership capacity. Once developed, 3 papers described these measures as 'standardised'. The remaining 4 papers described these measures as 'semi-standardised' to allow for flexibility in context. Two papers described this flexibility in approach as linked to theory of change or quality assurance (QA) cycle methodology.

Papers then presented the methods used to conduct the assessment. One described a fixed point of quantitative measurement, and six described a phased or developmental approach to identification of both health research capacity strengths and weaknesses, anticipating that as HRCS methods were implemented, weaknesses may be identified and certain areas strengthened. One partnership focused paper described this developmental approach to ensure equity within partnership development. Two papers described assessments that were solely 'self-assessments' (i.e. relied solely on internal institution staff). Four papers described assessments that involved collaborative assessments between partners inside (usually LMIC) and outside (usually high income country (HIC))

the institution. Four of the papers that took a developmental approach described the end of this process as the collaborative development of continuously evolving capacity strengthening plans which HRCS activities should be implemented against.

Evidence synthesis for HRCS implementation and evaluation

This category included 5 articles that focused on the synthesis of evidence to enhance learning for the implementation or evaluation of HRCS programmes (S5 Table). Four articles concentrated on understanding multi-programme experience to harmonise learning for HRCS evaluation. All 4 of these articles focus on the experience of funders of HRCS activities, with 3 extending their exploration to the views of HRCS experts, evaluators and/or implementers. The fifth article focused on understanding multi-programme experience to aid in more effective HRCS programme design and implementation for nurses. All articles had a global focus, with four prioritising LMICs.

The nuanced nature of each article in this category made identification of core typologies challenging. The 4 articles focused on evidence harmonisation for HRCS [24-27], argued that evaluations should be underpinned by theory, using logic or theory of change models. However, 3 articles reflected that these models are rarely employed in practice due to time constraints on the evaluation process [24 25 27]. Furthermore, where potential frameworks for evaluation do exist, 2 articles described these as being driven by the goal of the funder with limited stakeholder engagement [26 27]. Two articles linked lack of stakeholder engagement in evaluation design to issues of equity [24 26], arguing that for HRCS activities to be equitable, members of the most marginalised populations should be involved in evaluation design and indicators should reflect equity issues.

Miscellaneous

Four original research articles could not be assigned to any sub-category (Table 2 and S6 Table). The first publication was a qualitative cross sectional study that investigated the challenges and benefits of research capacity strengthening through North-South research partnerships from a Ugandan perspective. The second publication was a qualitative case study of health research commissioning among different organisations in East Africa. The third, investigated researchers' (involved in collaborative networks across LMICs) experiences regarding science and ethics in global health research collaborations. The fourth publication discussed different experiences of mentoring health researchers across HICs and LMICs, as effective mentorship of researchers is crucial for research capacity strengthening.

Perspectives, Opinion or Commentary

The 88 'perspective' publications were coded based on the primary subject matter. Codes included the three previously described in Box 2 and the additional codes 'programme description' and 'recommendations'. Publications were coded 'programme description' if they presented a description of a specific HRCS programme or activity. Publications were coded 'recommendations' if a primary purpose of the publication was to describe steps, processes, approaches and/or activities that, per the authors' views and experiences, would enhance capacity strengthening initiatives. There is significant overlap between the categories 'lessons learned' and 'recommendations'. The key point of difference is that the lessons or recommendations presented in publications coded 'recommendations' are largely based on broad experience or reading of the literature rather than reference to a specific HRCS programme or programme type (in which case they would be coded 'lessons learned').

Overall, 73% of the perspective, opinion or commentary publications were given a single 'focus' code and 27% were given 2 or more codes. 'Lessons learned' was allocated to 49% of publications,

'programme description' to 26%, 'recommendations' to 25%, 'programme outputs' to 19%, 'programme outcomes' to 2% and unique codes were allocated to 8%. The quantitative outcome indicators included a measure of knowledge change pre- and post-HRCS intervention [28] and an 'attributional' measure designed to assess the relationship between capacity improvement and the respective HRCS intervention [29].

The content of the various perspective, opinion or commentary publications was derived from HRCS experience in 76% of publications, although in the majority commentary pertained to experience from a single HRCS programme (59/67). Content was also drawn from reviews of HRCS-related literature or documentation (12/88), HRCS-related workshops (5/88) and in 8 cases the basis of the commentary was not stated. The HRCS programme or activity types varied widely, ranging from a broad emphasis on HRCS in LMICs to specific aspects of HRCS in specified countries.

Systematic Review

Five publications fitted this category (S8 Table). Two publications reviewed tools and approaches to assess capacity needs and monitor and evaluate capacity strengthening activities [30 31]. Three publications did not focus on specific HRCS activities, but used bibliometric and scientometric techniques to investigate health research capacity in specific subject areas focussing on publication trends, author affiliations, geographical areas of the study, study design and thematic focus [32-34].

Two publications searched a single database, 2 searched 2 and 1 searched 3. Four publications searched PubMed as the main database. Four publications followed a single systematic search strategy, whereas 1 employed a systematic search and snowball-sampling to identify publications after considering inclusion and exclusion criteria. The number of papers included in each review varied from 14–690.

HRCS Definitions

Nineteen percent (33/172) of publications presented an operational definition of 'capacity' (S9 Table). The definition specifically pertained to 'health research capacity' in 7 publications; in the remaining publications' broader definitions of 'research capacity' (n=10), 'capacity' (n=6) or 'organisational capacity' (n=1) were presented and in 2 publications capacity was operationally defined as 'progress'. Twenty-five separate definitions were presented of which 9 were original (Table 3). Seven of the 25 definitions were cited by 2 (n=4), 3 (n=2) or 4 (n=1) publications. In all other cases the definition was presented in a single publication. Three publications presented 2 definitions.

Thirty-six percent of the definitions included explicit reference to all 3 levels of capacity strengthening, 12% included explicit reference to all 3 aspects of the research process (defining research questions, conducting research and communicating/applying research outcomes) and 28% included explicit reference to at least 2 of the 4 'other' content domains assessed, the most common of which included reference to HRCS as improving research quality or ability (n=11) or HRCS as a process (n=9) (Table 3). Out of the 10 content domains assessed, the median number present across all definitions was 4 (range 2-9). Variation in median 'content' score was evident across the definition types: the median score for 'health research capacity' definitions was 3 (range 2-6), 5 (range 2-9) for 'research capacity' definitions, 4 (range 3-5) for 'capacity' definitions and 2 (range 2) for the 'organisational capacity' and 'progress' definitions.

213 **Table 3. Content analysis of 'capacity' definitions**[1]

Subject Defined	Capacity Term	Content Domains[2]									
		Ind.	Ins.	Env.	Def.	Car.	App.	Qua	Sus.	Pro.	Con
Health Research Capacity	Building [30], Strengthening [70]	x	x	x		x	x		x		
	Building [166], Strengthening [74, 126]		x		x	x			x		
	Strengthening [123]			x				x			
	Development [45]		x					x		x	
	Strengthening [48]					x	x				
	Building [139]	x	x				x		x		
	Building [97]	x	x					x			
Research Capacity	Building [164], Strengthening [29, 123, 159]	x	x	x	x	x	x			x	x
	Strengthening [16, 72]	x	x			x		x		x	
	Development [4], Strengthening [31, 74]	x	x	x	x	x	x	x	x	x	
	Building [132]					x	x				
	Building [91, 96]	x	x			x	x	x			
	Building [130]	x	x	x						x	x
	Strengthening [165]	x	x			x		x			

	Building [46]	x	x	x	x	x	x	x		
	Strengthening [79]	x	x	x						
	Building [166]	x				x		x		
Capacity	Building [25]	x	x	x				x		x
	Building [133]		x	x			x			x
	Strengthening [66]	x	x	x						x
	Strengthening [65]	x	x	x				x		x
	Building [150]		x	x					x	
	Strengthening [47]	x				x			x	
Organisational Capacity	Development [27]		x						x	
Progress	Building [142], Development[143]					x	x			

1. Numbered citations pertain to the reference list in S1 Table. 2. The content of each definition was independently coded according to the following criteria: explicit reference to individual (ind.), institutional (Ins.) or environmental (Env.) level capacity strengthening; explicit reference to strengthening capacity in terms of defining research questions or identifying research priorities (Def.), conducting research or applying research methods (Car.) or communicating and applying research outcomes (App.); explicit reference to facilitating an improvement in research abilities/quality (Qua.) sustainability (Sus.), reference to HRCS as a process (Pro.) and/or HRCS as a continuous activity (Con.).

Variation between a capacity definition and favoured capacity 'term' (i.e. building, strengthening or development) was evident where a definition had been cited by more than 1 paper. For example, "an ability of individuals, organisations or systems to perform and utilise health research effectively, efficiently and sustainably" [35] was variously presented as a definition of health research capacity 'strengthening' [35] and health research capacity 'building' [16].

An additional content analysis was conducted to examine the possible relationship between favoured capacity term and choice of capacity definition (S10 Table). Of the definitions used in the 14 publications that favoured the term 'capacity building', the median content score was 4 (range 2-8), 36% (5/14) included a specific reference to all 3 levels of capacity strengthening, 14% (2/14) included explicit reference to all 3 aspects of the research process and 21% (3/14) included explicit reference to at least 2 of the 4 'other' content domains assessed. Comparative results for the 12 publications that favoured the term 'capacity strengthening' were: 4 (2-9), 50% (6/12), 17% (2/12) and 33% (4/12) and 2.5 (range 2-9), 25% (1/4), 25% (1/4), 25% (1/4) for the 4 publications that favoured the term 'capacity development'.

Discussion

The purpose of this scoping review was to map the current HRCS research effort since the year 2000 and to critically examine how HRCS has been defined within the literature. With regards to the level and type of HRCS-related publication, the study revealed that the number of HRCS publications has increased exponentially between 2000 and 2016. Most publications during this period have been perspective, opinion or commentary pieces. Publications presenting original research findings also increased over this period and have been the primary publication type since 2013, indicating an emerging field of predominantly implementation-focused HRCS science. Almost half of the original

research papers pertained to the African region as did a large proportion of commentary papers (S7 Table). An Afrocentric evidence base may reflect current HRCS funding priorities [36] and need; however, such Afrocentrism renders it difficult to generalise the collective findings to LMIC settings in other geographical regions.

The findings and recommendations presented in this paper should be considered alongside limitations in the review methodology. HRCS research, reviews and commentaries published in non-Anglophone journals, in non-health related journals or in a lexicon outside of the key word terms employed herein would not have been retrieved by the search methodology. Relevant work that remains unpublished, published outside of academic peer-reviewed journals or published prior to 2000 would also have been omitted. Thus, the reported findings should not be considered a comprehensive representation of the existing literature pertaining to HRCS in LMICs. The analysis of retrieved publications was limited to identifying the typologies within, and key characteristics of, the collective literature as well as the frequency and type of operational HRCS definitions. The review did not critically examine the quality of the research effort (in original research publications) or analyse the output (findings) of the collective research effort. These tasks were outside the scope of this review, but warrant future attention to inform a fuller assessment of the 'value' of published HRCS research. All authors on this publication have considerable experience working in and/or with health research institutions in LMICs. However, all authors originate from, were educated in and are currently based in a high-income country context. Interpretation of the reported findings may reflect this reality.

Our findings suggest conceptual representations of HRCS within the published literature are inconsistent and infrequently applied. Capacity was rarely defined across the publications and the definitions that were presented varied widely in content and scope. Broader definitions of 'research capacity' or 'capacity', rather than specific 'health research capacity' definitions, were most

commonly employed and no 'one' specific definition of health research capacity was consistently applied. There appeared to be no relationship between a favoured capacity term, such as 'building' or 'strengthening', and the type of capacity definition used or the content of that definition. There was no apparent difference between operational definitions of (health) research capacity building, strengthening or development even though distinctions between these terms and the concepts they represent have previously been drawn [8 10 37]. The content analysis identified a divide between many of the capacity definitions presented and current conceptualisations of a multi-level 'systems' approach to HRCS [5 6]. For example, only 36% of the proffered definitions made explicit reference to individual, institutional and environmental level capacity strengthening and only 12% explicitly applied the definition to all stages of the research process from conception to subsequent uptake.

There was little sign of cohesion or 'connectedness' across the HRCS-related literature. Greater use of theory of change or logic models in HRCS programme and evaluation design was advocated [31-34] and evident among the sub-set of articles focusing on HRCS methods for implementation [27 28 30 32]. However, systematic reviews or syntheses of available evidence were uncommon, despite the relatively narrow focus of the collective literature, and the available conceptual models and methodologies were rarely applied in practice. For example, learning and evaluation studies were typically retrospective and capacity assessments limited to a single 'fixed' time point, in contrast to the prospective, phased approaches deemed necessary to advance our understanding of what works well in HRCS implementation [28 32]. Furthermore, while multi-level, systems wide HRCS interventions are increasingly advocated [5-7], learning and evaluation studies commonly centred on individual-level education-based activities. This may reflect intervention or evaluation design, but either way highlights the absence of a widely accepted overarching (H)RCS framework to promote prevailing theories and concepts or to link the increasingly active HRCS research community.

Collectively, findings suggest the existing (published) evidence-base is not yet sufficiently developed to reliably inform HRCS interventions in LMICs. The disjointed research effort is exacerbated by the absence of a recognisable HRCS research 'field' and the lack of a defined, needs-based HRCS-specific research agenda. Published research primarily consists of anecdotal, qualitative or descriptive accounts of single interventions not readily generalizable across different types of HRCS or to regions outside of Africa. While research quality was not formally assessed in the context of this review, the body of evidence needs further development when considered against relevant standards such as the Medical Research Council's guidance for developing and evaluating complex interventions [38] or against common hierarchies of evidence [39], inclusive of hierarchies specifically for assessing qualitative health research [40]. Good research practice would further suggest that no new 'learning' studies should be completed without first reviewing the existing evidence of 'what works' or 'lessons learned' from previous investments or interventions [41].

Three comprehensive definitions that explicitly align with current HRCS guidelines were evident across the reviewed publications, although all three pertain to the broader notion of 'research capacity' strengthening. These included: "the ongoing process of empowering individuals, institutions, organisations, and nations to: define and prioritise problems systematically; develop and scientifically evaluate appropriate solutions; and share and apply the knowledge generated" [42]; "the process by which individuals, organisations, and societies develop abilities (individually and collectively) to perform functions effectively, efficiently and in a sustainable manner to define problems, set objectives and priorities, build sustainable institutions and bring solutions to key national problems" [43]; and "strengthening the abilities of individuals, institutions, and countries to perform research functions, defining national problems and priorities, solving national problems, utilizing the results of research in policy making and programme delivery" [44].

In our opinion, the RCS definition presented by Lansang and Dennis [42] is the best among those presented in this review. This definition not only reflects current HRCS 'best practice' (i.e. encompasses all three levels of research capacity and spans the research process from conception to uptake) but also positions RCS as an 'ongoing process' and places few parameters on the focus of the research to be supported (beyond defining and prioritising 'problems' systematically). Alternative definitions, such as those provided by the Global Forum for Health Research [43] or the United Nations Development Program [44], limit the HRCS focus to '(key) national problems'. Whilst a focus on national problems is undoubtedly important, these definitions suggest restrictions on what types of research capacity should be strengthened. The more comprehensive, and more frequently used, 'research capacity' definitions further raise the possibility that a health-specific RCS definition may not be needed. Arguably, a comprehensive, rather than sector-specific, RCS definition would suitably reflect contemporary HRCS approaches and illuminate the potential for health-specific RCS interventions to enhance capacity for all/additional (i.e. non-health) research areas within a target institution or environment (where applicable). Whilst discipline specific nuance may sometimes be required, promoting this kind of inter-sectoral, systems level thinking and discouraging vertical, parallel processes that can arise from topic-specific interventions, is increasingly advocated in the health sector [45 46] and is equally applicable in the context of a national research system.

Determining a needs-based HRCS-specific research agenda would ideally involve input from influential HRCS funders, implementers and researchers from multiple disciplines. Technical working groups, specialist meetings and the creation of networking and resource sharing platforms would be required to establish and promote the research agenda and a common HRCS implementation science. Funding to support these activities for strengthening research systems could be modelled on existing mechanisms operating for strengthening health systems, where it is recommended that global development partners involved in health systems strengthening dedicate 5-10% of programme funds to data collection, monitoring and evaluation and implementation research [47].

Without an agreed definition and understanding of HRCS, it is difficult to calculate annual investment in HRCS in LMICs, but the sum is likely to be substantial. For example, the United Kingdom's 'Global Challenges Research Fund' totals 1.5 billion pounds over a five-year period to support cutting edge research addressing challenges faced by developing countries, a significant proportion of which is allocated for strengthening capacity for research and innovation within LMICs (http://www.rcuk.ac.uk/funding/gcrf/). Thus, a 5% investment in (H)RCS implementation science could support a substantial research effort and rapidly accelerate learning about how to do HRCS more effectively.

Crucially, given the aim of the HRCS research endeavour, ensuring equitable participation by LMIC partners in the development of an HRCS implementation science is essential. Metrics that better account for LMIC contribution may assist this. Despite promising findings, such as relatively high levels of LMIC authorship, questions can be raised as to what extent such indicators reliably reflect equitable contribution in HRCS implementation and research [48]. Relatively few studies examined North-South HRCS partnerships (a dominant form of HRCS implementation) from an exclusively southern perspective, or contrasted North-South models with South-South variants, suggesting an absence of critical reflection on the experiences and realities of those for whom HRCS interventions are intended. Such 'silencing' in intervention design and development should be rectified if ownership (an essential element of sustainability for HRCS interventions) [49-51] is to be promoted. Conversely, it is widely acknowledged that equitable and effective partnerships should be of mutual benefit to all parties [52], yet benefits to the more strongly capacitated partners in HRCS implementation (e.g. those in HIC) were rarely discussed. Consideration of such issues will likely afford deeper insights into how power and politics influence equity in the design and development of HRCS theory and implementation, as well as allowing more rigorous examination as to which models of implementation provide the most equitable, efficient and sustainable gains for HRCS.

Conclusions & Recommendations

The review findings indicate a HRCS research field with a focus on implementation science is emerging, although the conceptual and empirical bases are not yet sufficiently advanced to effectively inform HRCS programme planning. The constituent parts for a coherent and conceptually driven research effort are present (if somewhat embryonic), but are not yet aligned under a recognisable 'HRCS implementation science' framework. Consolidating a HRCS implementation science therefore presents as a viable option that may accelerate the development of a useful evidence-base to inform HRCS programme planning. Identifying an agreed operational definition of HRCS, standardising HRCS-related terminology, developing a needs-based HRCS-specific research agenda and synthesising currently available evidence may be useful first steps. Crucially, given the aim of the HRCS research endeavour, ensuring equitable participation by LMIC partners in the development of an HRCS implementation science is essential. Advancing a dedicated HRCS implementation science will require specialist meetings (e.g. technical working groups, research priority setting forums) with representation from influential HRCS researchers, key LMIC partners, funders and implementers as well as the creation and maintenance of networking and resource sharing fora. The continued, substantial investment in HRCS in LMICs suggests apportioning a fraction of the various research and development budgets to support HRCS implementation science would represent a good 'buy'.

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Competing Interests

We have read and understood BMJ policy on declaration of interests and declare that we have no competing interests.

Authors Contributions

LD, SG and JP were all involved in the search, screening and analysis of research articles. IB provided technical oversight and expertise throughout the screening processes. All authors contributed to the content, drafting, review and revisions to the manuscript.

Data Sharing Statement

Supplementary files as listed in the main manuscript are available to the reader. There is no other unpublished data that links to this research.

Supporting Information

S1 Table. List of publications included in the review by typology

S2 Table. Supplementary and detailed data for 'learning and evaluation' original research publications.

S3 Table. Supplementary and detailed data for 'assessments' original research publications

S4 Table. Supplementary and detailed data for 'HRCS methods for implementation' original research publications.

S5 Table. Supplementary and detailed data for 'Evidence synthesis for RCS implementation and evaluation' original research publications.

S6 Table. Supplementary and detailed data for 'miscellaneous' publications.

S7 Table. Supplementary and detailed data for 'Perspective, Opinion & Commentary' publications.

S8 Table. Supplementary and detailed data for 'systematic review' publications.

S9 Table. HRCS definitions, sources and citing papers[1]. 1. Numbered citations in italics pertain to the reference list in Supplementary Table 1. Numbered citations in normal (non-italicised) font are listed below. 2. Presented as a definition of 'Health Systems Research' capacity. 3. Presented as a definition of 'research capacity' in citing publication, but included in the 'health research capacity' definition list as contains specific reference to 'health research'. 4. Cited as definition of 'health' research capacity in [123]. 5. Presented as a definition of 'capacity' in citing publication, but included in the 'research capacity' definition list as contains specific reference to 'research'

S10 Table. Content analysis of capacity definitions by capacity term[1]. 1. Numbered citations pertain to the reference list in Supplementary Table 1. 2. The content of each definition was independently coded according to the following criteria: explicit reference to individual (ind.), institutional (Ins.) or environmental (Env.) level capacity strengthening; explicit reference to strengthening capacity in terms of defining research questions or identifying research priorities (Def.), conducting research or applying research methods (Car.) or communicating and applying research outcomes (App.); explicit reference to facilitating an improvement in research abilities/quality (Qua.) sustainability (Sus.), reference to HRCS as a process (Pro.) and/or HRCS as a continuous activity (Con.).

Supplementary Table 1. List of publications included in the review by typology

Original Research: Learning & Evaluation

1. Abawi K, Chandra-Mouli V, Toskin I, Festin MP, Gertiser L, Idris R, Hamamy H, Ali M, Bonventure AM, Temmerman M *et al*: **E-learning for research capacity strengthening in sexual and reproductive health: The experience of the Geneva Foundation for Medical Education and Research and the Department of Reproductive Health and Research, World Health Organization**. *Human resources for health* 2016, **14**(1).
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Original Research: Assessment

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Systematic Review

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Supplementary Table 9. HRCS definitions, sources and citing papers[1]

Subject Defined	Capacity Term	Definition & Source	Cited In
Health Research Capacity	Building *[30]* Strengthening *[70]*	"an ability of individuals, organisations or systems to perform and utilise health research effectively, efficiently and sustainably" *[70]*	*[30, 70]*
	Building *[166]* Strengthening *[74, 126]*	"the ability to define problems, set objectives and priorities, build sustainable institutions and organisations, and identify solutions to key national health problems" [1]	*[74, 126, 166]*
	Strengthening	"'a strategy that is implemented worldwide to improve the ability of developing countries to tackle the persistent and disproportionate burdens of disease they face" [2]	*[123]*
	Development	"the process required for building capacity in health research would be define the institutional systems needed to support research, enumerate existing and missing resources and improve research support by addressing the identified gaps" *[70]*	*[45]*
	Strengthening	"the level of expertise and resources needed for the production of new knowledge and its application" [3][2]	*[48]*
	Building	"an approach to the development of sustainable skills, organisational structure, resources and commitment to health improvement…to multiply health gains many times over" [4][3]	*[139]*
	Building	"a systematic, purposeful and goal-oriented effort to strengthen human resources and infrastructure to enable local scientists and institutions to become independent and responsive to existing and emerging health needs and threats" *[97]*[2]	*[97]*
Research Capacity	Building *[164]* Strengthening *[29, 123, 159]*	"the ongoing process of empowering individuals, institutions, organisations, and nations to: define and prioritise problems systematically; develop and scientifically evaluate appropriate solutions; and share and apply the knowledge generated" *[164]*[4]	*[29, 123, 159, 164]*
	Strengthening *[16, 72]*	"process of individual and institutional development which leads to higher levels of skills and greater ability to perform useful research" [5]	*[16, 72]*
	Development *[4]* Strengthening *[31, 74]*	"the process by which individuals, organisations, and societies develop abilities (individually and collectively) to perform functions effectively, efficiently and in a sustainable manner to define problems, set objectives and priorities, build sustainable institutions and bring solutions to key national problems" [6]	*[4, 31, 74]*
	Building	"the ability to conduct, manage, disseminate, and apply research in policy and practice" *[132]*	*[132]*
	Building *[91, 96]*	"Includes any efforts to increase the ability of individuals and institutions to undertake high-quality research and to engage with the wider community of stakeholders" [7]	*[91, 96]*
	Building	"a long-term process that requires a systematic and inter-sectoral approach to developing appropriate regulatory frameworks, building and maintaining physical infrastructure, and investing in human resources, equipment and training in an environment conducive to research commitment and institutional support" [8]	*[130]*

	Strengthening	"consists of two main closely inter-related and inter-dependent activities, which, together, form the basis of institutional development. The two parts are: improving, through appropriate training, the capabilities of scientists to undertake quality research; improving institutional support – equipment, supplies and other logistic support to the institution in which the trained scientists have to work" *[165]*	*[165]*
	Building	"strengthening the abilities of individuals, institutions, and countries to perform research functions, defining national problems and priorities, solving national problems, utilizing the results of research in policy making and programme delivery." [9]	*[46]*
	Strengthening	"goes beyond facilitating or funding a research project to the broader objectives of nurturing the prerequisites of the research process, such as state and institutional support, specialized training, infrastructural development, networking opportunities, publications and career paths." *[79]*	*[79]*
	Building	"a deliberate effort to augment health and social science research outputs as well as human capital, so as to favourably impact upon a research focus area" *[166]*[5]	*[166]*
Capacity	Building	"a process that improves the ability of a person, group, organisation or system to meet its objectives or perform better" [10]	*[25]*
	Building	"the process of helping communities and organisations harness human, technical and financial resources, which allows them to respond adequately to health issues in ways that inform such policies" [11]	*[133]*
	Strengthening	''process through which people, organisations, and society as a whole are enabled to shape their own development and adapt it to changing conditions and frameworks'' [12]	*[66]*
	Strengthening	''process of improving individual skills, processes, and structures at the organisational level and the networks and context in which the organisation functions'' *[65]*	*[65]*
	Building	"helping recipient countries to invent, develop and maintain institutions and organisations which are capable of learning and bringing about their own transformation, so that they can play a dynamic role in supporting national development processes" [13]	*[150]*
	Strengthening	"the ability of individuals or groups to perform tasks in a sustainable manner" *[47]*	*[47]*
Organisational capacity	Development	"the capacity of research departments in universities, think tanks and so on to fund, manage and maintain themselves" [14]	*[27]*
Progress	Building *[142]* Development *[143]*	"ability to understand, interpret, select, adapt, use, transmit, diffuse, produce and commercialise scientific and technological knowledge in ways appropriate to culture, aspirations and level of development" [15]	*[142, 143]*

1. Numbered citations in italics pertain to the reference list in Supplementary Table 1. Numbered citations in normal (non-italicised) font are listed below. 2. Presented as a definition of 'Health Systems Research' capacity. 3. Presented as a definition of 'research capacity' in citing publication, but included in the 'health research capacity' definition list as contains specific reference to 'health research'. 4. Cited as definition of 'health' research capacity in [123]. 5. Presented as a definition of 'capacity' in citing publication, but included in the 'research capacity' definition list as contains specific reference to 'research'

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Supplementary Table 10. Content analysis of capacity definitions by capacity term[1]

Subject Defined	Capacity Term	Content Domains[2]									
		Ind.	Ins.	Env.	Def.	Car.	App.	Qua	Sus.	Pro.	Con
Health Research Capacity	Building [139]	x	x				x		x		
Health Research Capacity	Building [97]	x	x					x			
Research Capacity	Building [132]					x	x				
Research Capacity	Building [91, 96]	x	x			x	x	x			
Research Capacity	Building [130]	x	x	x						x	x
Research Capacity	Building [46]	x	x	x	x	x	x	x			
Research Capacity	Building [166]	x				x		x			
Capacity	Building [25]	x	x	x				x		x	
Capacity	Building [133]		x	x			x			x	
Capacity	Building [150]		x	x					x		
Progress	Building [142], Development [143]					x	x				
Health Research Capacity	Building [30], Strengthening [70]	x	x	x		x	x		x		
Health Research Capacity	Building [166], Strengthening [74, 126]		x		x	x			x		
Research Capacity	Building [164], Strengthening [29, 123, 159]	x	x	x	x	x	x			x	x
Health Research Capacity	Strengthening [123]			x				x			
Health Research Capacity	Strengthening [48]					x	x				
Research Capacity	Strengthening [16, 72]	x	x			x		x		x	
Research Capacity	Strengthening [165]	x	x			x		x			
Research Capacity	Strengthening [79]	x	x	x							
Capacity	Strengthening [66]	x	x	x						x	
Capacity	Strengthening [65]	x	x	x				x		x	
Capacity	Strengthening [47]	x				x			x		
Research Capacity	Development [4], Strengthening [31, 74]	x	x	x	x	x	x	x	x	x	
Health Research Capacity	Development [45]		x					x		x	
Organisational Capacity	Development [27]		x						x		
Progress	Building [142], Development [143]					x	x				

1. Numbered citations pertain to the reference list in Supplementary Table 1. 2. The content of each definition was independently coded according to the following criteria: explicit reference to individual (ind.), institutional (Ins.) or environmental (Env.) level capacity strengthening; explicit reference to strengthening capacity in terms of defining research questions or identifying research priorities (Def.), conducting research or applying research methods (Car.) or communicating and applying research

outcomes (App.); explicit reference to facilitating an improvement in research abilities/quality (Qua.) sustainability (Sus.), reference to HRCS as a process (Pro.) and/or HRCS as a continuous activity (Con.).

BMJ Open

Advancing the science of health research capacity strengthening in low- and middle-income countries: A scoping review of the published literature, 2000-2016.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-018718.R1
Article Type:	Research
Date Submitted by the Author:	20-Sep-2017
Complete List of Authors:	Dean, Laura; Liverpool School of Tropical Medicine, Department of International Public Health Gregorius, Stefanie; Liverpool School of Tropical Medicine, Department of International Public Health bates, imelda Pulford, Justin; Liverpool School of Tropical Medicine, Department of International Public Health
Primary Subject Heading:	Global health
Secondary Subject Heading:	Evidence based practice
Keywords:	Capacity Strengthening, LMIC, Scoping Review

Title: Advancing the science of health research capacity strengthening in low- and middle-income countries: A scoping review of the published literature, 2000-2016

Authors:

Laura Dean[1a]

Stefanie Gregorius[1]

Imelda Bates[1]

Justin Pulford[1]

1. Department of International Public Health, Capacity Research Unit, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool, L3 5QA, UK.

[a] Corresponding Author: laura.dean@lstmed.ac.uk Tel: 01517053793

Key Words: LMIC, Capacity Strengthening, Scoping Review

Word Count: 5721

Abstract

Objectives: Substantial development assistance and research funding are invested in health research capacity strengthening (HRCS) interventions in low- and middle-income countries, yet the effectiveness, impact and value for money of these investments are not well understood. A major constraint to evidence-informed HRCS intervention has been the disparate nature of the research effort to date. This review aims to map and critically analyse the existing HRCS effort to better understand the level, type, cohesion and conceptual sophistication of the current evidence base. The overall goal of this paper is to advance the development of a unified, implementation-focused HRCS science.

Methods: We utilised a scoping review methodology to identify peer-reviewed HRCS literature within the following databases: PubMed, Global Health, and Scopus. HRCS publications available in English between the period 2000-2016 were included. 1195 articles were retrieved of which 172 met the final inclusion criteria. A-priori thematic analysis of all included articles was completed. Content analysis of identified HRCS definitions was conducted.

Results: The number of HRCS publications increased exponentially between 2000 and 2016. Most publications during this period were perspective, opinion or commentary pieces; however, original research publications were the primary publication type since 2013. Twenty-five different definitions of research capacity strengthening were identified, of which three aligned with current HRCS guidelines.

Conclusions: The review findings indicate a HRCS research field with a focus on implementation science is emerging, although the conceptual and empirical bases are not yet sufficiently advanced to effectively inform HRCS programme planning. Consolidating a HRCS implementation science therefore presents as a viable option that may accelerate the development of a useful evidence-base to inform HRCS programme planning. Identifying an agreed operational definition of HRCS,

standardising HRCS-related terminology, developing a needs-based HRCS-specific research agenda and synthesising currently available evidence may be useful first steps.

Strengths and Limitations of the Study

- This scoping review brings together various studies and reviews focused on HRCS to provide the impetus and direction for a dedicated HRCS implementation science to emerge and to foster a common identity for HRCS researchers.
- This review critically analysed current definitions of HRCS to contribute toward the identification of a consolidated, evidence based, operational definition of HRCS on which future HRCS interventions and evaluations can be based.
- Some articles published in non-Anglophone journals, in non-health related journals, or in a lexicon outside of the key word terms employed herein would not have been retrieved by the search methodology.
- Relevant work that remains unpublished, published outside of academic peer-reviewed journals or published prior to 2000 would also have been omitted.
- The review did not critically examine the quality of the research effort (in original research publications) or analyse the output (findings) of the collective research effort.

Introduction

Health research capacity in many low- and middle-income countries (LMICs) is poor [1-4], undermining LMIC ability to identify and respond to local health needs or to equitably participate in the international response to global health challenges. Numerous health research capacity strengthening (HRCS) interventions have been employed in LMICs ranging from simple training programmes to currently advocated 'systems' approaches that focus on developing the capacity of individual researchers, research institutions and the wider research environment [5-7]. The international research community has a dual role in LMIC HRCS. The first role is that of a HRCS *implementer* and centres on the transfer of expertise in specialist subject areas pertinent to LMIC health research priorities, typically from higher- to lower-capacitated individuals or organisations and may be facilitated through such mechanisms as scholarship schemes, technical assistance, research networks or research consortia. The second role is that of an HRCS *scientist* and centres on the creation of robust theory and evidence to inform optimal HRCS interventions. Here, the researcher is not an expert in the subject matter of a specific HRCS intervention (e.g. increasing capacity in operational research to support national malaria control programmes), but is concerned with providing the evidence-base to inform HRCS funders and implementing partners how their respective programme goals may best be achieved (e.g. what investments would produce the greatest, most sustainable gain in operational research capacity to support a national malaria control programme).

The extent to which the research community is fulfilling this latter role (i.e. HRCS scientist), as compared to the former role (i.e. HRCS implementer), is questionable at present. A recent paper described the existing HRCS evidence-base as 'confusing, controversial and poorly defined' [8] despite a long recognised need to support HRCS in LMICs [9]. Fundamental questions remain largely unanswered such as; how to reliably assess existing capacities at different levels of a health research

system; which interventions facilitate sustainable capacity gains in which circumstances; and which capacity term (building, strengthening or development) is the most nuanced and appropriate to reflect developmental discourse and baseline capacities [10]. The international research community is therefore in the awkward position of being a highly active participant in the transfer of scientific theory and method within the context of subject-specific HRCS interventions, yet largely inactive in rigorously applying scientific theory and method to the HRCS process.

The paucity of evidence available to inform HRCS implementation reflects, in part, the difficulties in measuring an inherently multi-faceted, long-term, continuous process (i.e. HRCS) subject to a diverse range of influences and assumptions. A greater constraint has been the sparse and disparate nature of the HRCS-related research effort to date. HRCS-related research has involved multiple academic disciplines, employing diverse frameworks, concepts, methods and terminologies, working in isolation and publishing in different fields (e.g. medical education, communication, operational research and evaluation). A dedicated, multi-disciplinary, implementation-focused research approach is undoubtedly required to improve the effectiveness, impact and value for money of current and future HRCS implementation activities in LMICs. However, there is little evidence of a unified HRCS implementation science emerging to date.

The overall goal of this paper is to advance the development of a unified, implementation-focused HRCS science. To achieve this goal, a scoping review of HRCS-related publications for the period 2000-2016 was conducted and operational definitions of HRCS within this literature critically examined. The review findings are not presented as a definitive account of HRCS activity across this period as relevant material may be unpublished, may be found in the grey literature or may be published in a lexicon outside of the search terms employed herein. The review is better understood as an attempt to critically analyse the collective HRCS effort regarding the level, type, cohesion and conceptual sophistication of the current evidence base. The review may be considered an initial

attempt to map the HRCS research effort, providing the impetus and direction for a dedicated HRCS implementation science to emerge and fostering a common identity for HRCS researchers.

Methods

This review was conducted according to stages 1-5 of the advanced 'scoping' methodology proposed by Levac et al [11], based on the original framework of Arksey and O'Malley [12]. A scoping review was considered appropriate given the primary focus was on examining the extent, range and nature of an emerging peer-reviewed literature. The critical examination of operational definitions of HRCS falls outside of the 'scoping review' approach, yet is included as a means of 'revealing' (in part) the conceptual sophistication and cohesion of the reviewed literature.

Identification of Data Sources

The first two steps of the scoping review method include identifying a research question and relevant studies. To explore the breadth, concepts, definitions and methods currently prioritised in the HRCSpeer-reviewed literature, we searched for empirical and theoretical publications within the following databases: PubMed, Global Health, and Scopus. Search terms used were: ("capacity strengthening", OR "capacity development", OR "capacity building") combined with ("global health" OR, "international health" OR, "global public health", OR "health research" OR, "health development"). Additional search criteria included: papers published between 01/01/2000 and 31/12/2016 and both abstract and full paper available in English. Searches began from the year 2000 as a reflection of the stepwise change in the profile and investment in HRCS. Results were stored within an EndNote library.

Selection of Data Sources

Study selection (step 3) was an iterative process in which selected abstracts and full texts were initially reviewed to identify and agree upon inclusion criteria, which were then subsequently 'tested' and refined through further review. All article titles, abstracts and key words were reviewed against the final inclusion criteria (Figure 1). Publications that met these criteria following abstract review were then subjected to a more intensive full text review. Publications in which a conclusive inclusion/exclusion decision could not be made on the basis of abstract review were also included for full text review. SG and JP independently screened publications included for full text review with LD providing a third review to determine inclusion/exclusion status in cases of disagreement.

Figure 1. Summary of search and selection process

Data Charting and Analysis

The variables extracted from each publication included in the final review were determined by an iterative 'data charting' process (step 4) SG & JP independently reviewed a selection of publications and identified potential variables to extract. Target variables were then agreed by consensus opinion. Target variables included publication 'typologies' (Box 1) and the wide range of programme-, author- and research-type data listed in Tables 1, 2 and S1-S7. Research quality was not formally assessed; however, some aspects such as study design, methods and analysis were considered where appropriate., Data extraction was conducted independently by at least two reviewers, with the third providing a deciding opinion in cases of disagreement. Following data extraction, each member of the review team was assigned a sub-set of publications for subsequent summary analysis (step 5). Final analysis and reporting of all data were agreed by mutual consent.

Box 1. HRCS Publication Typologies

Original Research: Publications in which a) a hypothesis, research question or study purpose was stated; b) research methods described; c) results reported; and d) the results and their possible implications discussed.

Perspectives, Opinion or Commentary: Publications expressing the authors' viewpoint on some aspect of HRCS based on anecdotal evidence, personal experience and/or (in a very few cases) original data that were not presented in an 'original research' format (i.e. did not include a formal description of the research aims, methods, results and discussion).

Systematic Review: Publications in which a) research objectives/questions were clearly stated; b) explicit and systematic methods were used; c) methods were limited to the systematic identification and analysis of some form of literature; and d) results were reported and discussed. Non-systematic reviews were included within the original research section.

During in-depth analysis of each publication any operational definition of (health) research capacity strengthening was extracted and analysed for content. To identify commonalities, definition content was independently coded by JP and SG per the a-priori content criteria identified in Table 3. Coding disagreements were resolved by the same process described above. A content score, defined as the number of domains (out of 10) present, was calculated for each definition to identify the most inclusive working definition of HRCS within the current evidence base.

Results

1195 papers were retrieved via the search methodology of which 172 (see S8 Table) met the final inclusion criteria. The number of HRCS publications identified increased over time, from 0 in the year 2000 to a maximum of 32 in 2016 (Fig 2).

Fig 2. Number of publications per year by publication type.

HRCS Publication Typologies

Overall, 51% of publications presented a perspective, opinion or commentary, 46% original research and 3% findings from a systematic review (Table 1). The first and/or last author was from an institute located in an LMIC in 58% of publications, 'capacity building' was the favoured term in 59% and 19% presented an operational definition of HRCS.

Table 1. Selected characteristics of reviewed publications

Publication Type	No.	LMIC Authorship[1]			Capacity Term[2]				Defined HRCS[3]
		First	Last	Either	CB	CD	CS	Oth.	
Original Research	79	31	32	41	38	18	24	0	17
Pers. Opin. Commentary	88	36	42	56	63	6	19	0	16
Systematic Review	5	3	1	3	1	1	2	0	0
Total	**172**	**70**	**75**	**100**	**102**	**25**	**45**	**0**	**33**

1 Based on location of listed organisational affiliation of first and last authors; 'either' = either first or last. 2 capacity term used in title and then keywords given priority. (CB=capacity building, CD=capacity development, CS=capacity strengthening, Oth.=other). 3 Number of papers that provided an operational definition of HRCS.

Original Research

The 79 publications that met 'original research' criteria were sub-categorised into research typologies including: learning and evaluation (from research initiatives), capacity assessment, HRCS methods for implementation, evidence synthesis for HRCS implementation and evaluation, and miscellaneous. Table 2 presents selected methodological characteristics of the original research publications both overall and by sub-category. Additional data, not all of which are described below, are included in S1-S7 Tables.

Table 2. Selected methodological characteristics of original research publications

Sub-Category	No.	Setting[1]							Design[2]			Data Collection[3,4]					Data Analysis[4,5]		
		Af	Am	Se	Eu	Em	Wp	Gl	Quan	Qual	Mix	Sur	IDI	FGD	Rev	Oth	The	Des	Inf
Learning & Evaluation	36	14	1	4	0	1	4	14	8	9	19	20	18	5	16	10	28	18	1
Capacity Assessment	27	16	0	0	1	2	3	5	6	7	14	15	13	5	15	7	19	22	0
HRCS Methods	7	6	0	0	0	0	0	1	1	5	1	2	1	1	4	4	6	1	1
Evidence Synthesis	5	0	0	0	0	0	0	5	0	4	1	1	0	0	5	4	5	0	0
Miscellaneous	4	2	0	0	0	0	0	2	0	2	2	2	3	0	2	1	4	0	0
Total	**79**	**38**	**1**	**4**	**1**	**3**	**7**	**27**	**15**	**27**	**37**	**40**	**35**	**11**	**42**	**26**	**62**	**41**	**2**

1. WHO region where the study was located: African (Af), Americas (Am), South-East Asia (Se), European (Eu), Eastern Mediterranean (Em), Western Pacific (Wp) or Global (Gl)(defined as 3 or more WHO regions). 2. Quantitative (Quan.), qualitative (Qual.) or mixed methods (Mix.). 3. Survey (Sur.), in-depth interview (IDI), focus group discussion (FGD), literature/document review (Rev.) or other methodology (Other). 4. Categories are not mutually exclusive. 5. Thematic (Them.), descriptive (Desc.) or inferential (Infer.).

Learning & evaluation

This category included 36 publications that presented findings from a formal evaluation of an HRCS initiative or described 'learnings' obtained from HRCS implementation (Table 2 and S1 Table). Sixty-four percent were 'education' based HRCS programmes in which some form of training (inclusive of postgraduate awards) was provided to strengthen individual capacity and, in some cases, was inclusive of the development and transfer of a course curriculum at an institutional level e.g. [13]. Other HRCS programme types included collaborative research (n=12), time-limited work placement (n=2), strengthening the broader health research system (n=2), infrastructure development (n=1) or strengthening financial management (n=1). The respective HRCS programmes involved North-South collaboration in 83% of cases. Seventy-five percent of programmes sought to strengthen research capacity in a specific subject area, most commonly health systems (n=6).

Box 2. Learning and Evaluation Typologies

Lessons Learned: publications focused on broad, programme(s)-level experiences in setting up and/or participating in an HRCS initiative and/or providing a largely qualitative account of programme achievements.

Programme Outputs: publications focused on HRCS programme outputs, where outputs were defined as a quantification of activities that occurred during the programme and/or related professional activities that occurred after the programme (e.g. no. of publications).

Programme Outcomes: publications that focused on improvements in individual-, institutional- or environmental-level health research capacity following an HRCS initiative and employed quantitative measures designed to attribute improved performance to the respective HRCS intervention.

The objective of each 'learning and/or evaluation' publication was coded per the typologies presented in Box 2. Overall, 67% of the learning and evaluation publications were given a single code and 33% were given 2 or more codes. 'Lessons learned' was allocated to 44% of publications,

'programme outputs' to 33%, 'programme outcomes' to 28% and unique codes were allocated to 33%. Quantitative outcome indicators varied among publications that employed them, although were generally: variants of some form of citation analysis to measure influence of research publication (that followed the HRCS intervention) on health policy [14-16]; measures of knowledge change pre- and post-HRCS intervention or knowledge gained from an intervention [17-20]; some form of 'attributional' measure designed to assess the relationship between capacity improvement and the respective HRCS intervention [17 18 21 22].

Sixty-four percent of studies were retrospective, 64% were a type of (quasi-) formative evaluation, 53% were mixed methods and 17% were authored by individuals independent of the organisation implementing the respective HRCS initiative (study design data not presented in Table 2 are shown in S1 Table). Sampling was primarily purposive (n=20).

Capacity Assessment

This category included 27 original research publications that presented the outcome of some form of health research capacity assessment (Table 2 and S2 Table). Capacity assessment focus varied; the largest proportion (9/27) focused on assessing capacity to carry out research, often in a specific subject area (18/27), most commonly health policy and systems research (6/27).

Capacity assessments were conducted within the context of a research institution(s), including universities or research network in 59% of publications. Eleven percent focussed on the capacities of ethics committees and one involved health care providers. The remaining 26% focused on national and/or regional capacity in specific research and/or geographical areas through reviewing literature and publication trends.

Thirty-seven percent (10/27) of capacity assessments were conducted as part of a consortium based research programme, consisting of European and African partners.

HRCS methods for implementation

This category includes 7 articles that present a methodological approach to HRCS or evaluation of HRCS (S3 Table). Two articles focus on HRCS within the frame of North-South partnerships and 4 prioritised general HRCS, often embedded in a specific subject area e.g. policy analysis. The remaining article focused on the development and validation of a questionnaire for evaluation of HRCS training activities.

The numbers of steps in methodological approach varied; however, consistent phasing or process can be identified. In all publications, the purpose of the HRCS activity was initially established although this was only stated as an explicit methodological step in one paper [23]. Three articles then developed bespoke 'optimal health research' criteria or 'ideal partnership capacity' criteria through a combination of literature searches and interactions with key stakeholders. The remaining 4 publications adapted an existing tool or framework that could be used as a common ideal for health research or partnership capacity. Once developed, 3 papers described these measures as 'standardised'. The remaining 4 papers described these measures as 'semi-standardised' to allow for flexibility in context. Two papers described this flexibility in approach as linked to theory of change or quality assurance (QA) cycle methodology.

Papers then presented the methods used to conduct the capacity assessment. One described a fixed point of quantitative measurement, and six described a phased or developmental approach to identification of both health research capacity strengths and weaknesses, anticipating that as HRCS methods were implemented, weaknesses may be identified and certain areas strengthened. One partnership focused paper described this developmental approach to ensure equity within partnership development. Two papers described assessments that were solely 'self-assessments' (i.e. relied solely on internal institution staff). Four papers described assessments that involved collaborative assessments between partners inside (usually LMIC) and outside (usually high income

country (HIC)) the institution. Four of the papers that took a developmental approach described the end of this process as the collaborative development of continuously evolving capacity strengthening plans which HRCS activities should be implemented against.

Evidence synthesis for HRCS implementation and evaluation

This category included 5 articles that focused on the synthesis of evidence to enhance learning for the implementation or evaluation of HRCS programmes (S4 Table). Four articles concentrated on understanding multi-programme experience to harmonise learning for HRCS evaluation. All 4 of these articles focus on the experience of funders of HRCS activities, with 3 extending their exploration to the views of HRCS experts, evaluators and/or implementers. The fifth article focused on understanding multi-programme experience to aid in more effective HRCS programme design and implementation for nurses. All articles had a global focus, with four prioritising LMICs.

The nuanced nature of each article in this category made identification of core typologies challenging. The 4 articles focused on evidence harmonisation for HRCS [24-27], argued that evaluations should be underpinned by theory, using logic or theory of change models. However, 3 articles reflected that these models are rarely employed in practice due to time constraints on the evaluation process [24 25 27]. Furthermore, where potential frameworks for evaluation do exist, 2 articles described these as being driven by the goal of the funder with limited stakeholder engagement [26 27]. Two articles linked lack of stakeholder engagement in evaluation design to issues of equity [24 26], arguing that for HRCS activities to be equitable, members of the most marginalised populations should be involved in evaluation design and indicators should reflect equity issues.

Miscellaneous

Four original research articles could not be assigned to any sub-category (Table 2 and S5 Table). The first publication was a qualitative cross sectional study that investigated the challenges and benefits of research capacity strengthening through North-South research partnerships from a Ugandan perspective. The second publication was a qualitative case study of health research commissioning among different organisations in East Africa. The third, investigated researchers' (involved in collaborative networks across LMICs) experiences regarding science and ethics in global health research collaborations. The fourth publication discussed different experiences of mentoring health researchers across HICs and LMICs, as effective mentorship of researchers is crucial for research capacity strengthening.

Perspectives, Opinion or Commentary

The 88 'perspective' publications were coded based on the primary subject matter. Codes included the three previously described in Box 2 and the additional codes 'programme description' and 'recommendations'. Publications were coded 'programme description' if they presented a description of a specific HRCS programme or activity. Publications were coded 'recommendations' if a primary purpose of the publication was to describe steps, processes, approaches and/or activities that, per the authors' views and experiences, would enhance capacity strengthening initiatives. There is significant overlap between the categories 'lessons learned' and 'recommendations'. The key point of difference is that the lessons or recommendations presented in publications coded 'recommendations' are largely based on broad experience or reading of the literature rather than reference to a specific HRCS programme or programme type (in which case they would be coded 'lessons learned').

Overall, 73% of the perspective, opinion or commentary publications were given a single 'focus' code and 27% were given 2 or more codes. 'Lessons learned' was allocated to 49% of publications,

'programme description' to 26%, 'recommendations' to 25%, 'programme outputs' to 19%, 'programme outcomes' to 2% and unique codes were allocated to 8%. The quantitative outcome indicators included a measure of knowledge change pre- and post-HRCS intervention [28] and an 'attributional' measure designed to assess the relationship between capacity improvement and the respective HRCS intervention [29].

The content of the various perspective, opinion or commentary publications was derived from HRCS experience in 76% of publications, although in the majority commentary pertained to experience from a single HRCS programme (59/67). Content was also drawn from reviews of HRCS-related literature or documentation (12/88), HRCS-related workshops (5/88) and in 8 cases the basis of the commentary was not stated. The HRCS programme or activity types varied widely, ranging from a broad emphasis on HRCS in LMICs to specific aspects of HRCS in specified countries.

Systematic Review

Five publications fitted this category (S7 Table). Two publications reviewed tools and approaches to assess capacity needs and monitor and evaluate capacity strengthening activities [30 31]. Three publications did not focus on specific HRCS activities, but used bibliometric and scientometric techniques to investigate health research capacity in specific subject areas focussing on publication trends, author affiliations, geographical areas of the study, study design and thematic focus [32-34].

Two publications searched a single database, 2 searched 2 and 1 searched 3. Four publications searched PubMed as the main database. Four publications followed a single systematic search strategy, whereas 1 employed a systematic search and snowball-sampling to identify publications after considering inclusion and exclusion criteria. The number of papers included in each review varied from 14–690.

HRCS Definitions

Nineteen percent (33/172) of publications presented an operational definition of 'capacity' (S9 Table). The definition specifically pertained to 'health research capacity' in 7 publications; in the remaining publications' broader definitions of 'research capacity' (n=10), 'capacity' (n=6) or 'organisational capacity' (n=1) were presented and in 2 publications capacity was operationally defined as 'progress'. Twenty-five separate definitions were presented of which 9 were original (Table 3). Seven of the 25 definitions were cited by 2 (n=4), 3 (n=2) or 4 (n=1) publications. In all other cases the definition was presented in a single publication. Three publications presented 2 definitions.

Thirty-six percent of the definitions included explicit reference to all 3 levels of capacity strengthening, 12% included explicit reference to all 3 aspects of the research process (defining research questions, conducting research and communicating/applying research outcomes) and 28% included explicit reference to at least 2 of the 4 'other' content domains assessed, the most common of which included reference to HRCS as improving research quality or ability (n=11) or HRCS as a process (n=9) (Table 3). Out of the 10 content domains assessed, the median number present across all definitions was 4 (range 2-9). Variation in median 'content' score was evident across the definition types: the median score for 'health research capacity' definitions was 3 (range 2-6), 5 (range 2-9) for 'research capacity' definitions, 4 (range 3-5) for 'capacity' definitions and 2 (range 2) for the 'organisational capacity' and 'progress' definitions.

212 **Table 3. Content analysis of 'capacity' definitions**[1]

Subject Defined	Capacity Term	Content Domains[2]									
		Ind.	Ins.	Env.	Def.	Car.	App.	Qua	Sus.	Pro.	Con
Health Research Capacity	Building [30], Strengthening [70]	x	x	x		x	x		x		
	Building [166], Strengthening [74, 126]		x		x	x			x		
	Strengthening [123]			x				x			
	Development [45]		x					x		x	
	Strengthening [48]					x	x				
	Building [139]	x	x				x		x		
	Building [97]	x	x					x			
Research Capacity	Building [164], Strengthening [29, 123, 159]	x	x	x	x	x	x			x	x
	Strengthening [16, 72]	x	x			x		x		x	
	Development [4], Strengthening [31, 74]	x	x	x	x	x	x	x	x	x	
	Building [132]					x	x				
	Building [91, 96]	x	x			x	x	x			
	Building [130]	x	x	x						x	x
	Strengthening [165]	x	x			x		x			

	Building [46]	x	x	x	x	x	x	x		
	Strengthening [79]	x	x	x						
	Building [166]	x				x		x		
Capacity	Building [25]	x	x	x				x		x
	Building [133]		x	x			x			x
	Strengthening [66]	x	x	x						x
	Strengthening [65]	x	x	x				x		x
	Building [150]		x	x					x	
	Strengthening [47]	x				x			x	
Organisational Capacity	Development [27]		x						x	
Progress	Building [142], Development[143]					x	x			

1. Numbered citations pertain to the reference list in S8 Table. 2. The content of each definition was independently coded according to the following criteria: explicit reference to individual (ind.), institutional (Ins.) or environmental (Env.) level capacity strengthening; explicit reference to strengthening capacity in terms of defining research questions or identifying research priorities (Def.), conducting research or applying research methods (Car.) or communicating and applying research outcomes (App.); explicit reference to facilitating an improvement in research abilities/quality (Qua.) sustainability (Sus.), reference to HRCS as a process (Pro.) and/or HRCS as a continuous activity (Con.).

Variation between a capacity definition and favoured capacity 'term' (i.e. building, strengthening or development) was evident where a definition had been cited by more than 1 paper. For example, "an ability of individuals, organisations or systems to perform and utilise health research effectively, efficiently and sustainably" [35] was variously presented as a definition of health research capacity 'strengthening' [35] and health research capacity 'building' [16].

An additional content analysis was conducted to examine the possible relationship between favoured capacity term and choice of capacity definition (S10 Table). Of the definitions used in the 14 publications that favoured the term 'capacity building', the median content score was 4 (range 2-8), 36% (5/14) included a specific reference to all 3 levels of capacity strengthening, 14% (2/14) included explicit reference to all 3 aspects of the research process and 21% (3/14) included explicit reference to at least 2 of the 4 'other' content domains assessed. Comparative results for the 12 publications that favoured the term 'capacity strengthening' were: 4 (2-9), 50% (6/12), 17% (2/12) and 33% (4/12) and 2.5 (range 2-9), 25% (1/4), 25% (1/4), 25% (1/4) for the 4 publications that favoured the term 'capacity development'.

Discussion

The purpose of this scoping review was to map the current HRCS research effort since the year 2000 and to critically examine how HRCS has been defined within the peer-reviewed literature. With regards to the level and type of HRCS-related publication, the study revealed that the number of HRCS publications has increased exponentially between 2000 and 2016. Most publications during this period have been perspective, opinion or commentary pieces. Publications presenting original research findings also increased over this period and have been the primary publication type since 2013, indicating an emerging field of predominantly implementation-focused HRCS science. Almost

half of the original research papers pertained to the African region as did a large proportion of commentary papers (S6 Table). An Afrocentric evidence base may reflect current HRCS funding priorities [36] and need; however, such Afrocentrism renders it difficult to generalise the collective findings to LMIC settings in other geographical regions.

The findings and recommendations presented in this paper should be considered alongside limitations in the review methodology. HRCS research, reviews and commentaries published in non-Anglophone journals, in non-health related journals or in a lexicon outside of the key word terms employed herein would not have been retrieved by the search methodology. Relevant work that remains unpublished, published outside of academic peer-reviewed journals or published prior to 2000 would also have been omitted. Thus, the reported findings should not be considered a comprehensive representation of the existing literature pertaining to HRCS in LMICs. The analysis of retrieved publications was limited to identifying the typologies within, and key characteristics of, the collective peer-reviewed literature as well as the frequency and type of operational HRCS definitions. The review did not critically examine the quality of the research effort (in original research publications) or analyse the output (findings) of the collective research effort. These tasks were outside the scope of this review, but warrant future attention to inform a fuller assessment of the 'value' of published HRCS research. All authors on this publication have considerable experience working in and/or with health research institutions in LMICs. However, all authors originate from, were educated in and are currently based in a high-income country context. Interpretation of the reported findings may reflect this reality.

Our findings suggest conceptual representations of HRCS within the published literature are inconsistent and infrequently applied. Capacity was rarely defined across the publications and the definitions that were presented varied widely in content and scope. Broader definitions of 'research capacity' or 'capacity', rather than specific 'health research capacity' definitions, were most

commonly employed and no 'one' specific definition of health research capacity was consistently applied. There appeared to be no relationship between a favoured capacity term, such as 'building' or 'strengthening', and the type of capacity definition used or the content of that definition. There was no apparent difference between operational definitions of (health) research capacity building, strengthening or development even though distinctions between these terms and the concepts they represent have previously been drawn [8 10 37]. The content analysis identified a divide between many of the capacity definitions presented and current conceptualisations of a multi-level 'systems' approach to HRCS [5 6]. For example, only 36% of the proffered definitions made explicit reference to individual, institutional and environmental level capacity strengthening and only 12% explicitly applied the definition to all stages of the research process from conception to subsequent uptake.

There was little sign of cohesion or 'connectedness' across the HRCS-related peer-reviewed literature. Greater use of theory of change or logic models in HRCS programme and evaluation design was advocated [31-34] and evident among the sub-set of articles focusing on HRCS methods for implementation [27 28 30 32]. However, systematic reviews or syntheses of available evidence were uncommon, despite the relatively narrow focus of the collective literature, and the available conceptual models and methodologies were rarely applied in practice. For example, learning and evaluation studies were typically retrospective and capacity assessments limited to a single 'fixed' time point, in contrast to the prospective, phased approaches deemed necessary to advance our understanding of what works well in HRCS implementation [28 32]. Furthermore, while multi-level, systems wide HRCS interventions are increasingly advocated [5-7], learning and evaluation studies commonly centred on individual-level education-based activities. This may reflect intervention or evaluation design, but either way highlights the absence of a widely accepted overarching (H)RCS framework to promote prevailing theories and concepts or to link the increasingly active HRCS research community.

Collectively, findings suggest the existing (published) evidence-base is not yet sufficiently developed to reliably inform HRCS interventions in LMICs. The disjointed research effort is exacerbated by the absence of a recognisable HRCS research 'field' and the lack of a defined, needs-based HRCS-specific research agenda. Published research primarily consists of anecdotal, qualitative or descriptive accounts of single interventions not readily generalizable across different types of HRCS or to regions outside of Africa. While research quality was not formally assessed in the context of this review, the body of evidence needs further development when considered against relevant standards such as the Medical Research Council's guidance for developing and evaluating complex interventions [38] or against common hierarchies of evidence [39], inclusive of hierarchies specifically for assessing qualitative health research [40]. Good research practice would further suggest that no new 'learning' studies should be completed without first reviewing the existing evidence of 'what works' or 'lessons learned' from previous investments or interventions [41].

Three comprehensive definitions that explicitly align with current HRCS guidelines were evident across the reviewed publications, although all three pertain to the broader notion of 'research capacity' strengthening. These included: "the ongoing process of empowering individuals, institutions, organisations, and nations to: define and prioritise problems systematically; develop and scientifically evaluate appropriate solutions; and share and apply the knowledge generated" [42]; "the process by which individuals, organisations, and societies develop abilities (individually and collectively) to perform functions effectively, efficiently and in a sustainable manner to define problems, set objectives and priorities, build sustainable institutions and bring solutions to key national problems" [43]; and "strengthening the abilities of individuals, institutions, and countries to perform research functions, defining national problems and priorities, solving national problems, utilizing the results of research in policy making and programme delivery" [44].

In our opinion, the RCS definition presented by Lansang and Dennis [42] is the best among those presented in this review. This definition not only reflects current HRCS 'best practice' (i.e. encompasses all three levels of research capacity and spans the research process from conception to uptake) but also positions RCS as an 'ongoing process' and places few parameters on the focus of the research to be supported (beyond defining and prioritising 'problems' systematically). Alternative definitions, such as those provided by the Global Forum for Health Research [43] or the United Nations Development Program [44], limit the HRCS focus to '(key) national problems'. Whilst a focus on national problems is undoubtedly important, these definitions suggest restrictions on what types of research capacity should be strengthened. The more comprehensive, and more frequently used, 'research capacity' definitions further raise the possibility that a health-specific RCS definition may not be needed. Arguably, a comprehensive, rather than sector-specific, RCS definition would suitably reflect contemporary HRCS approaches and illuminate the potential for health-specific RCS interventions to enhance capacity for all/additional (i.e. non-health) research areas within a target institution or environment (where applicable). Whilst discipline specific nuance may sometimes be required, promoting this kind of inter-sectoral, systems level thinking and discouraging vertical, parallel processes that can arise from topic-specific interventions, is increasingly advocated in the health sector [45 46] and is equally applicable in the context of a national research system.

Determining a needs-based HRCS-specific research agenda would ideally involve input from influential HRCS funders, implementers and researchers from multiple disciplines. Technical working groups, specialist meetings and the creation of networking and resource sharing platforms would be required to establish and promote the research agenda and a common HRCS implementation science. Specialist meetings and HRCS research networks would also serve to raise the profile of HRCS science, increasing its standing and recognition as a legitimate field of scientific investigation and attracting greater involvement from the broader health research community. Funding to support these activities for strengthening research systems could be modelled on existing

mechanisms operating for strengthening health systems, where it is recommended that global development partners involved in health systems strengthening dedicate 5-10% of programme funds to data collection, monitoring and evaluation and implementation research [47]. Without an agreed definition and understanding of HRCS, it is difficult to calculate annual investment in HRCS in LMICs, but the sum is likely to be substantial. For example, the United Kingdom's 'Global Challenges Research Fund' totals 1.5 billion pounds over a five-year period to support cutting edge research addressing challenges faced by developing countries, a significant proportion of which is allocated for strengthening capacity for research and innovation within LMICs (http://www.rcuk.ac.uk/funding/gcrf/). Thus, a 5% investment in (H)RCS implementation science could support a substantial research effort and rapidly accelerate learning about how to do HRCS more effectively.

Crucially, given the aim of the HRCS research endeavour, ensuring equitable participation by LMIC partners in the development of an HRCS implementation science is essential. Metrics that better account for LMIC contribution may assist this. Despite promising findings, such as relatively high levels of LMIC authorship, questions can be raised as to what extent such indicators reliably reflect equitable contribution in HRCS implementation and research [48]. Relatively few studies examined North-South HRCS partnerships (a dominant form of HRCS implementation) from an exclusively southern perspective, or contrasted North-South models with South-South variants, suggesting an absence of critical reflection on the experiences and realities of those for whom HRCS interventions are intended. Such 'silencing' in intervention design and development should be rectified if ownership (an essential element of sustainability for HRCS interventions) [49-51] is to be promoted. Conversely, it is widely acknowledged that equitable and effective partnerships should be of mutual benefit to all parties [52], yet benefits to the more strongly capacitated partners in HRCS implementation (e.g. those in HIC) were rarely discussed. Consideration of such issues will likely afford deeper insights into how power and politics influence equity in the design and development

of HRCS theory and implementation, as well as allowing more rigorous examination as to which models of implementation provide the most equitable, efficient and sustainable gains for HRCS.

Conclusions & Recommendations

The review findings indicate a HRCS research field with a focus on implementation science is emerging, although the conceptual and empirical bases are not yet sufficiently advanced to effectively inform HRCS programme planning. The constituent parts for a coherent and conceptually driven research effort are present (if somewhat embryonic), but are not yet aligned under a recognisable 'HRCS implementation science' framework. Consolidating a HRCS implementation science therefore presents as a viable option that may accelerate the development of a useful evidence-base to inform HRCS programme planning. Identifying an agreed operational definition of HRCS, standardising HRCS-related terminology, developing a needs-based HRCS-specific research agenda and synthesising currently available evidence may be useful first steps. Crucially, given the aim of the HRCS research endeavour, ensuring equitable participation by LMIC partners in the development of an HRCS implementation science is essential. Advancing a dedicated HRCS implementation science will require specialist meetings (e.g. technical working groups, research priority setting forums) with representation from influential HRCS researchers, key LMIC partners, funders and implementers as well as the creation and maintenance of networking and resource sharing fora. The continued, substantial investment in HRCS in LMICs suggests apportioning a fraction of the various research and development budgets to support HRCS implementation science would represent a good 'buy'.

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Competing Interests

We have read and understood BMJ policy on declaration of interests and declare that we have no competing interests.

Authors Contributions

LD, SG and JP were all involved in the search, screening and analysis of research articles. IB provided technical oversight and expertise throughout the screening processes. All authors contributed to the content, drafting, review and revisions to the manuscript.

Data Sharing Statement

Supplementary files as listed in the main manuscript are available to the reader. There is no other unpublished data that links to this research.

Supporting Information

S1 Table. Supplementary and detailed data for 'learning and evaluation' original research publications.

S2 Table. Supplementary and detailed data for 'assessments' original research publications

S3 Table. Supplementary and detailed data for 'HRCS methods for implementation' original research publications.

S4 Table. Supplementary and detailed data for 'Evidence synthesis for RCS implementation and evaluation' original research publications.

S5 Table. Supplementary and detailed data for 'miscellaneous' publications.

S6 Table. Supplementary and detailed data for 'Perspective, Opinion & Commentary' publications.

S7 Table. Supplementary and detailed data for 'systematic review' publications.

S8 Table. List of publications included in the review by typology

S9 Table. HRCS definitions, sources and citing papers[1]. 1. Numbered citations in italics pertain to the reference list in Supplementary Table 1. Numbered citations in normal (non-italicised) font are listed below. 2. Presented as a definition of 'Health Systems Research' capacity. 3. Presented as a definition of 'research capacity' in citing publication, but included in the 'health research capacity' definition list as contains specific reference to 'health research'. 4. Cited as definition of 'health' research capacity in [123]. 5. Presented as a definition of 'capacity' in citing publication, but included in the 'research capacity' definition list as contains specific reference to 'research'

S10 Table. Content analysis of capacity definitions by capacity term[1]**.** 1. Numbered citations pertain to the reference list in Supplementary Table 1. 2. The content of each definition was independently coded according to the following criteria: explicit reference to individual (ind.), institutional (Ins.) or environmental (Env.) level capacity strengthening; explicit reference to strengthening capacity in terms of defining research questions or identifying research priorities (Def.), conducting research or applying research methods (Car.) or communicating and applying research outcomes (App.); explicit reference to facilitating an improvement in research abilities/quality (Qua.) sustainability (Sus.), reference to HRCS as a process (Pro.) and/or HRCS as a continuous activity (Con.).

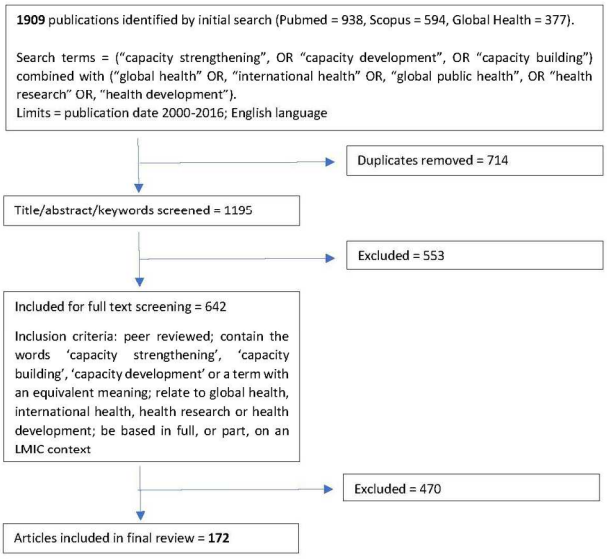

Figure 1. Summary of search and selection process

Figure One: Summary of search and selection process

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Figure 2. Number of publications per year by publication type

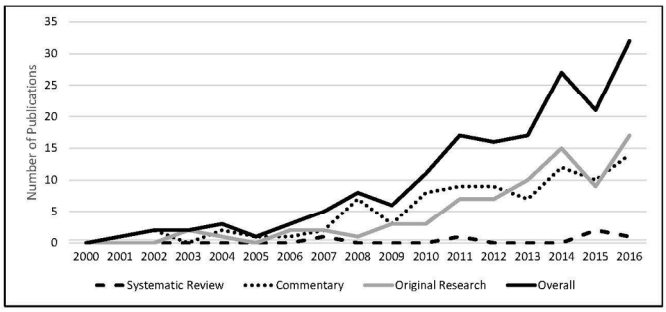

Figure Two: Number of publications per year by publication type

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Table S1. Supplementary and detailed data for 'learning and evaluation' (from research initiatives) original research publications

Publication		Publication Characteristics			Programme Characteristics				Global = 3+regions
Author	Year	LMIC Authorship	Capacity Term	HRCS Definition	Name	Type		Focus	WHO Region
Byrne et al	2016	Co-author	Capacity Development	Yes	Development and delivery of a Masters programme	Education	Nth-Sth	Community Systems Health Research	African
Aidam & Sombie	2016	First, last	Capacity Development	No	West African Health Organisation research development program	Health research system	Sth-Sth	Health research	African
Cole et al	2016	Co-author	Capacity Strengthening	No	Malawi's Health research Capacity Strengthening Initiative	health research system	National	Health research	African
Elmusharaf et al	2016	First. Co-author	Capacity Development	No	Connecting health research in Africa and Ireland Consortium	Education; collaborative research	Nth-Sth	Health systems strengthening	African
Kaser et al	2016	Nil	Capacity Strengthening	No	WHO/TDR Career Development Fellowship Programme	Placement	Nth-Sth	Clinical research	Global
Abawi et al	2016	Nil	Capacity Strengthening	No	E-learning for RCS	Education	Nth-Sth	Sexual and reproductive health	Global
Varshney et al	2016	First, last, co-author	Capacity Building	No	Asian Regional Capacity Development programme	Education; collaborative research	Nth-Sth	Social determinants of health	South-East Asia; Western Pacific
Thomson et al	2016	First, last, co-author	Capacity Building	No	Applied statistical training to strengthen HRC	Education	Nth-Sth	Statistical training	African
Atkins et al	2016	Co-author	Capacity Building	No	Africa/Asian Regional Capacity Development programme	Education; collaborative research	Nth-Sth	Health systems; Social determinants of health	Global
Protsiv & Atkins	2016	Co-author	Capacity Building	No	Africa/Asian Regional Capacity Development programme	Education; collaborative research	Nth-Sth	Health systems; Social determinants of health	Global
Farnman et al	2016	Co-author	Capacity Building	No	Africa/Asian Regional Capacity Development programme	Education; collaborative research	Nth-Sth	Health systems; Social determinants of health	Global
Protsiv et al	2016	Co-author	Capacity Building	No	Africa Regional Capacity Development programme	Education; collaborative research	Nth-Sth	Health systems; Social determinants of health	Global
Mahendradhata et al	2016	First, last	Capacity Building	No	Good Health Research Practice training programme	Education	Nth-Sth	Good health research practice	Global
Daniels et al	2015	Co-author	Capacity Building	No	AIDS International Training and Research Program	Education	Nth-Sth	HIV epidemiology and basic science	African
Heller et al	2015	Co-author	Capacity Building	No	People's Open Access Education Initiative, Peoples-uni	Education	Nth-Sth	Public health	Global

Agar & Zarowsky	2015	Last	Capacity Strengthening	No	Multiple HRCS initiatives (*)	NA	NA	NA	African
Dean et al	2015	Nil	Capacity Strengthening	Yes	RCS Award Scheme (un-named)	Collaborative Research	Nth-Stu	Life and physical sciences	African
Ndebele et al	2014	First, co-author	Capacity Building	No	FIC research ethics capacity building initiatives (*)	Education	Nth-Stu	Research ethics	African
Zachariah et al	2014	Co-author	Capacity Building	No	Structured Operational Research and Training InitiaTive	Education	Nth-Stu	Operational research	Global
Saenz et al	2014	Co-author	Capacity Building	No	FIC bioethics training	Education	Nth-Stu	Research ethics	Americas
Miiro et al	2013	First, co-author, last	Capacity Building	No	EDCTP Regional Networks of Excellence	Research collaboration	Nth-Stu	Clinical trials	African
Vian et al	2013	Nil	Capacity Building	Yes	Pfizer Global Health Fellows Program	Placement	Nth-Stu	Global health	Global
Wilson et al	2013	Nil	Capacity Building	No	Promoting Enhanced Research Capacity for Global Health	Education	Nth-Stu	Clinical research management	Global
Bennett et al	2013	Last, co-author	Capacity Development	No	FIC research training programs(*)	Education	Nth-Stu	Health research	African
Bennett et al	2013	Last, co-author	Capacity Development	No	FIC research training programs(*)	Education	Nth-Stu	Health research	African
Marjanovic et al	2013	Nil	Capacity Building	No	Africa Institutions initiative	Collaborative Research	Nth-Stu	Health research	African
Bennett et al	2012	Last, co-author	Capacity Development	Yes	Health policy analysis institutes (*)	NA	NA	NA	Global
Redman-McLaren et al	2012	Co-author	Capacity Strengthening	Yes	Introduction to Health Research Workshop	Education	Nth-Stu	Operational research	Western Pacific
Bissell et al	2012	Co-author	Capacity Building	No	Int. Union Against TB & Lung Disease & MSF OR training	Education	Nth-Stu	Operational research	Global
Mahmood et al	2011	First, co-author, last	Capacity Building	Yes	Int. Centre for Diarrhoeal Disease Research, Bangladesh	Financial management	Institutional	Research funding & perform. monitoring	South East Asia
Minja et al	2011	First	Capacity Strengthening	Yes	WHO/TDR Programmes (*)	Education; Infrastructure	Nth-Stu	Health research	Global
Goto et al	2010	Last, co-author	Capacity Development	No	Epidemiology training course for physicians	Education	National	Epidemiology research	Western Pacific
Mayhew et al	2008	Last, co-author	Capacity Strengthening	No	Health Economics & Financing Programme	Research collaboration	Nth-Stu	Health economics	African; South-East Asia
Jonsson et al	2007	Co-author	Capacity Development	No	Health systems research training programmes	Collaborative Research	Nth-Stu	Health systems	Western Pacific
Hyder et al	2003	First, co-author, last	Capacity Development	No	Doctoral trainings grants (*)	Education	Nth-Stu	Health research	Eastern Mediterranean
Jentsch & Pilley	2003	Nil	Capacity Building	No	Multinational research project	Collaborative research	Nth-Stu	Maternal and Child Health	South East Asia

	Learning & Evaluation Characteristics				
Activities	Objective	Study Design	Data Collection	Sampling	Data Analysis
Development and delivery of belended (largely web-based) Masters programme; teacher training (to support delivery)	Use of blended learning	Prospective; formative; mixed methods	Online surveys (n=17); IDIs (n=11)	Population	Thematic
Research stewardship, financing, creating or sustaining resources, prod. Or using research & dev. partnerships	Programme outputs; lessons learned	Retrospective; formative; mixed methods	Document review; IDIs (n=180); consultation	Purposive	Thematic
National priority setting, decision-making on funding, health research actor mobilisation	Lessons learned	Retrospective; formative; mixed methods; independent	Document review; IDIs (n=30)	Purposive; random	Thematic
PhD scholarship; capacity assessment; project specific capacity building and/or research activities	Lessons learned	Prospective; summative; qualitative	Reflection; document review	Convenience	Thematic
12-month placement at pharmaceutical company or PDP; administrative grant; networking	Programme outputs; outcomes; lessons learned	Retrospective; summative; mixed methods	Survey (n=33); IDIs	Population; purposive	Descriptive; thematic
Online education	Programme outputs; outcomes	Retrospective; summative; quantitative	Online survey (n=175)	Population	Descriptive
Short-term training; long-term training; joint research	Research partnerships	Prospective; formative; qualitative	IDIs (n=16)	Population	Thematic
Short-term training	Programme outcomes	Prospective; summative; quantitative	Surveys (n=14-21)	Population	Descriptive
Short-term training; long-term training; joint research	Use of blended learning	Prospective; summative; quantitative	Survey (n=82)	Population	Inferential
Short-term training; long-term training; joint research	Use of blended learning	Prospective; formative; qualitative	IDIs (n=11)	Purposive	Thematic
Short-term training; long-term training; joint research	Lessons learned	Prospective; formative; mixed methods	IDIs (n=16); document review	Population	Thematic
Short-term training; long-term training; joint research	Use of blended learning	Prospective; formative; mixed methods	Group discussions (n=3); participant observation (n=11); survey (n=18); IDIs (n=?)	Population; purposive; convenience	Descriptive; thematic
Short-term training	Lessons learned; programme outcomes	Prospective; formative; mixed methods	Course feedback (multiple methods; n=58); qualitative assessment	Population	Descriptive; thematic
Short-term training; long-term training (MS, MPH, PhD)	Transfer of a health research training programme	Retrospective; formative; qualitative	IDIs (n=10)	Purposive	Thematic
Distance learning MPH	Alumni collaboration	Retrospective; formative; mixed methods	Survey (n=68); online discussion forums	Population; convenience	Descriptive; thematic

NA	Lessons learned	Prospective; formative; qualitative	Document review; reflection; consultation (n=37)	Convenience	Thematic
Funding to support delivery of a collaborative research project	Research partnerships	Retrospective; formative; mixed methods; independent	Online surveys (n=23); IDIs/FGDs (n=42)	purposive; convenience	Descriptive; thematic
Training; mentorship; placements; web/electronic resources; public lectures, symposia; curriculum development	Lessons learned	Retrospective; formative; mixed methods	Survey (n=9); document review	Purposive	Thematic
Workshop	Programme outputs; outcomes	Retrospective; summative; quantitative	Document review; survey (n=88)	Population	Descriptive
Training (inclusive of certificate, diploma, masters) and fellowships	Programme outputs; lessons learned	Retrospective; formative; mixed methods	Document review; survey; consultation	Purposive	Thematic
Training; infrastructure development; research funding; research collaboration	Programme outputs; lessons learned	Retrospective; formative; mixed methods	Direct observation; document review	Convenience	Descriptive; thematic
Training; technical assistance	Lessons learned	Retrospective; formative; qualitative; independent	Document review; IDIs (n = 9)	Purposive	Thematic
Online continuing education course	Programme outputs; outcomes; lessons learned	Prospective; summative; quantitative	Surveys (x4, n= 71-166)	Population	Descriptive
Training (Masters and PhD) and fellowships	Mentorship	Retrospective; formative; qualitative	IDIs/FGDs (n=72)	Purposive	Thematic
Training (Masters and PhD) and fellowships	Programme outcomes	Retrospective; summative; mixed methods	IDIs/FGDs (n=52); survey, (n=29); document review	Purposive; random	Descriptive; thematic
Funding to support delivery of a collaborative research project. Funding to support advanced research training	Lessons learned	Prospective; formative; mixed methods; independent	Document review; consultation; survey (n=51)	Purposive	Thematic
NA	Lessons learned	Retrospective; formative; mixed methods; independent	IDIs (n=80); document review	Purposive	Descriptive; thematic
Workshop	Workshop participation dynamics	Retrospective; formative; qualitative	IDIs (n=5); written responses (n=5)	Purposive	Thematic
Workshop	Programme outputs; lessons learned	Retrospective; summative; quantitative	Survey (n=12); document review	Population	Descriptive
Implementation of a revised funding and performance monitoring framework	Programme outputs; outcomes	Retrospective; summative; mixed methods	KII; document review; survey	Purposive	Descriptive; thematic
Research training grants; research re-entry grants; institution strengthening grants	Programme outcomes	Retrospective; summative; mixed methods	Survey (n=92); IDIs (n=10)	Population; purposive	Descriptive; thematic
Workshop	Programme outputs; outcomes	Prospective; summative; quantitative	Surveys (x2, n =53-70)	Population	Descriptive
Joint research, publication & funding applications; staff exchanges/training; teaching & TA; small grants	Programme outputs; lessons learned	Retrospective; formative; mixed methods	Document review; IDIs (n=25)	Purposive	Descriptive; thematic
Training; funding to support delivery of a collaborative research project	Informing policy and practice	Retrospective; formative; mixed-methods	IDIs/FGDs (n=28); survey (n=56)	Purposive	Thematic
Doctoral training	Programme outputs	Retrospective; summative; quantitative; independent	Survey (n=54)	Convenience	Descriptive
Funding to support delivery of a collaborative research project	Research partnerships	Retrospective; formative; qualitative	IDIs (n=7)	purposive; convenience	Thematic

Table S2. Supplementary and detailed data for 'Capacity Assessment' original research publications

Publication		Publication Characteristics			
Author	Year	LMIC Authorship	Capacity Term	HRCS Definition	Assessment of
Erasmus et al	2016	First, co-author, last	Capacity Strengthening	No	Postgraduate teaching capacity
Uzochukwu et al	2016	First, co-author, last	Capacity Building	No	Capacity needs for health systems policy and systems research and analysis
Motari et al	2015	First, co-author, last	Capacity Strengthening	No	Readiness of national ethics committees to respond to challenges posed by a globalised biomedical research system
Agyepong et al	2015	First, co-author, last	Capacity Strengthening	No	Capacity needs for health policy and system research and analysis, conduct and teaching
Oliver et al	2015	Last	Capacity Strengthening	No	Capacity for conducting systematic reviews
Haafkens et al	2014	Nil	Capacity Building	No	Training needs of researchers to conduct research
Kilic et al	2014	First, co-author, last	Capacity Building	Yes	Research capacity and training needs
Kebede et al	2014	First, co-author	Capacity Development	Yes	Human capacity and staff movement

Simba et al	2014	First, co-author, last	Capacity Strengthening	Yes	Human and financial resources capacities, policies and organisational support
Ekeroma et al	2014	Nil	Capacity Building	No	Clinical research activity and audit
Kanoute et al	2014	First, co-author	Capacity Strengthening	No	Current status of oral health research
Franzen et al	2013	Co-author	Capacity Strengthening	No	Barriers and enablers to investigator-initiated trials
Mirzoev et al	2014	Last, co-author	Capacity Strengthening	Yes	Capacity for health policy and systems research and analysis
Hofman et al	2013	First, co-author	Capacity Building	No	Current status of health equity and Social Determinants of Health training
Nachega et al	2012	First, co-author, last	Capacity Building	No	Epidemiology and public health capacity
Paulus et al	2012	Co-author	Capacity Development	No	Global training priorities, unmet needs and potential cross-cohort solutions
Peykari et al	2012	First, co-author, last	Capacity Building	No	Health Systems Research – ranking of institutions
Magesa et al	2011	First, co-author, last	Capacity Building	No	Capacity building process of Tanzanian National Institute for Medical Research
Mohammadi et al	2011	First, co-author, last	Capacity Building	No	Representation of different nations in international public health journals
Nakanjaro et al	2011	First, co-author, last	Capacity Building	No	Status and nature of mentoring practices

Pepping	2010	Nil (1)	Capacity development	No	Training capacity in public health nutrition
Redman-MacLaren et al	2010	Co-author	Capacity Building	No	Public Health literature in Salomon Island
Nyika et al	2009	First, co-author, last	Capacity Building	No	Composition, training needs and independence of ethics committees
Malekafzali et al	2009	First, co-author, last	Capacity Building	No	Research activities in medical universities and their affiliated institutions
Moodley & Myer	2007	First, last (2)	Capacity Development	No	Composition, operations, and training needs of health research ethics committees
Singh	2006	First (1)	Capacity Development	No	Mental health research activities in LMICs
Cuboni et al	2004	First, co-author, last	Capacity Development	No	Participation of Fijians in health research publications

Focus	Name of programme	Region	Assessment location/level	Study Design	Data Collection	Data Analysis
Health systems policy and systems research and analysis	Consortium for Health Policy and Systems Analysis in Africa (CHEPSAA)	Africa	Multiple instiutions involved in research (universities and research instiutions)	Cross-sectional; mixed methods	Document review; surveys	Descriptive; thematic
Health systems policy and systems research and analysis	CHEPSAA	Africa	University	Cross-sectional; mixed methods	Document review; interviews (n=9); survey (n=123)	Thematic
Health research ethics	N.A.	Africa	Ethic committees (national level)	Cross-sectional; quantitative	Survey (n=33)	Descriptive
Health systems policy and systems research and analysis	N.A.	Africa	University	Cross-sectional; mixed methods	Document review; interview (n=1); focus group discussions (n=3); survey (n=67)	Descriptive; thematic
Systematic reviews	N.A.	Global	Multiple instiutions involved in research (systematic review centres)	Rapid appraisal; mixed methods	Routine management data; document review; consultation of key informants; surveys (n=22)	Descriptive; thematic
Causes of health inequities	INDEPTH Network	Global	Multiple instiutions involved in research (research network)	Qualitative	Online concept mapping (n=82)	Descriptive thematic
Non-Communicable Diseases research	RESCAP-Med	Europe	Multiple institutions involved in research	Mixed methods	Literature review; interviews (n=10); Survey (n=46)	Descriptive; thematic
National health research institutions	N.A.	Africa	Multiple institutions involved in research (health research institutions)	Quantitative	Surveys (n=847)	Descriptive

Health systems research	Higher Education Alliance for Leadership Through Health (HEALTH)	Africa	Universities	Mixed methods	Document review; self-assessment (n=123); interviews (n=73)	Descriptive; thematic
Reproductive health research	Building Reproductive health Research and Audit Capacity and Activity in the Pacific Islands (BRRACAP)	Western Pacific	Health care providers	Mixed methods	Interviews, questionnaires, focus group discussions; online survey (n=28)	Descriptive; thematic
Oral health research	N.A.	Africa	National and regional level	Mixed methods	Delphi survey (n=30); literature review	Descriptive; thematic
Informing and directing capacity strengthening initiatives	N.A.	Africa	Multiple institutions involved in research (research institute, university, NGO, hospital)	Qualitative	Interviews (n=7); focus group discussions (n=3)	Thematic
Health systems policy and systems research and analysis	CHEPSAA	Africa	Universities	Mixed methods	Document reviews; interviews; surveys	Thematic
Social Determinants of Health and health equity	INDEPTH Training and research centres of Excellence (INTREC)	Africa	Universities (Schools of Public Health)	Qualitative	Document reviews; interviews (n=30), online searches	Thematic
Training, research, funding, human resources	N.A.	Africa	Regional level	Qualitative	Interviews (n=10); literature review	Descriptive; thematic
Cohort studies	World Cohort Integration Workshop	Global	Regional level	Mixed methods	Survey (n=42); FGDs (n=1)	Descriptive; thematic
Stewardship, capacity building, knowledge production	N.A.	Eastern Mediterranean	Universities	Cross-sectional; quantitative	Survey	Descriptive
Critical mass of multidisciplinary research scientists	N.A.	Africa	Institute involved in research	Cross-sectional; mixed-methods	Document review; interviews (n=78)	Descriptive; thematic
Equity in access to health research capacity development	N.A.	Global	Regional level	Qualitative	Review of health journals (n=37)	Descriptive
Effective mentoring	N.A.	Africa	University	Qualitative	Survey (n=22)	Thematic

Public health nutrition	N.A.	Africa	Multiple institutions involved in research (research institutes and universities)	Mixed methods	Document review; survey (n=15); consultations; interviews; websites review	Descriptive; thematic
Equitable research agenda	N.A.	Western Pacific	National level	Qualitative	Literature review (n=218); focus group (n=1)	Descriptive
Capacity building programmes for effective ethic review processes	African Malaria Network Trust (AMANET)	Africa	Ethic committees (national, institutional level)	Quantitative	Survey (n=312)	Descriptive
Capacity building programmes for effective ethic review processes	N.A.	Eastern Mediterranean	Multiple institutions involved in research (universities and research institutes)	Quantitative	Bibliometric assay	Descriptive
Biomedical research	N.A.	Africa	Ethic committees (national level)	Mixed methods	Interviews; survey (n=12)	Descriptive; thematic
Publication bias	N.A.	Global	Regional level	Quantitative	Number of manuscripts submitted to 8 journals	Descriptive
Health priorities and research capacity in Fiji	N.A.	Western Pacific	Regional level	Mixed methods	Literature review (298 papers included); interviews	Descriptive; thematic

Table S3. Supplementary and detailed data for 'HRCS methods for implementation' original research publications

Publication		Publication Characteristics			Programme Characteristics		
Author	Year	LMIC Authorship	Capacity Term	HRCS Definition	Focus	Region	Study Design
Murphy et al	2015	Co-author	Capacity Development	No	Partner assessment toolkit (PAT) to discuss partnership ethics and put accountability measures in place.	Global	Qualitative
Le et al	2014	Co-author	Capacity Strengthening	No	Strengthening capacity for health policy and systems research and analysis (HPSR+A) in Universities.	Africa	Mixed Methods
Huber et al	2014	Co-author	Capacity Strengthening	Yes	Training evaluation for training related to HRCS.	Africa	Quantitative

Jessani et al	2014	Co-author	Capacity Development	No	Capacity assessment tool for schools of public health to reflect on institutional strengths and weaknesses for health systems research.	Africa	Qualitative
Bates et al	2014	Nil	Capacity Strengthening	Yes	Development of a practical approach for the design and evaluation of health capacity strengthening programmes.	Africa	Qualitative
Birch et al	2013	Co-author	Capacity Building	No	North-South clinical nursing partnership for CS.	Africa	Qualitative

Bates et al	2006	Last	Capacity Building	Yes	Evidence based tool to determine infrastructural capabilities and design and evaluation of capacity building programmes in health research.	Africa	Qualitative

Data Collection	Data Analysis	Steps in HRCS Process	Methods Used in Process
Stakeholder workshops situated around case studies and briefing papers	Thematic	1. Common understanding of PAT components developed through workshops with sub-Saharan African partners. 2. PAT modified by expert team and circulated to partners in all country contexts for comment. 3. PAT finalised and tested in existing partnership.	Qualitative point self-assessment. Phased/developmental approach. Standardised
FGD, IDI, Stakeholder workshop, survey, document review	Thematic and Descriptive	1. Develop shared understanding of capacity and CS across consortium. 2. Map contextual environment for HPSR+A, including desk review, and key informant interviews/discussions. 3. Self-assessment against core thematic areas identified. 4. Comparative synthesis by UK partner and cross-consortium comparison.	Mixed-method self-assessment by African partners and 'external' assessment by UK partner. Phased/developmental approach. 'Semi-standardised' to allow for flexibility in context.
Survey	Inferential	1. Domains for evaluation selected based on existing framework. 2. Development of questionnaire. 3. Testing of questionnaire. 4. Validation of questionnaire.	Quantitative self-survey. Fixed-point. Standardised

Stakeholder workshop	Thematic	1. Capacity assessment questions based on previous instruments but adapted for focus. 2. Meeting with capacity focal points at universities to be assessed to refine tool to context. 3. Implementation of tool. 4. Dissemination and reflection on findings to develop capacity strengthening plan in workshop.	Quantitative self-assessment. Qualitative institutional profiling and priority identification. Phased/developmental. 'Semi-standardised' to allow for flexibility in context.
Review and case studies	Thematic	1. Establish goal of capacity strengthening programme 2. Describing ideal capacity to achieve goal- synthesis of relevant evidence 3. Determination of existing capacity against 'ideal' identified in step 2. 4. Devise and implement an action plan to fill gaps. 5. Learn through doing and adapt the action plan regularly.	Mixed-method joint assessment and priority identification. Phased/developmental. 'Semi-standardised' to allow for flexibility in context.
Review	Thematic	1. Systematic literature search for partnership measures. 2. Screening of partnership measures for applicability. 3. Selection and modification of existing appropriate measure. 4. Piloting of measure.	Mixed-method self-assessment. Phased/developmental. Standardised.

Review	Thematic	1. Literature search for existing tools and models 2. Using best practice examples to design the evaluation programme 3. Develop and adapt an evaluation tool (links to QA cycle): define institutional systems needed to support research; enumerate existing and missing resources; address identified gaps.	Qualitative self-assessment and priority identification. Phased/developmental 'Semi-standardised' to allow for flexibility in context.	

Table S4. Supplementary and detailed data for 'Evidence synthesis for RCS implementation and evaluation' original research publications

Publication		Publication Characteristics			Programme Characteristics
Author	Year	LMIC Authorship	Capacity Term	HRCS Definition	Focus
Bates et al	2015	Nil	Capacity Strengthening	No	Enhance understanding in difficulties of evaluating health research capcity strengthening and make reccomendations for improvement
Cole et al	2014	Nil	Capacity Strengthening	Yes	Describe the design of health research capacity strenghtening evaluations, indicators, outputs and outcomes.
Boyd et al	2013	Nil	Capacity Strengthening	No	Describe and compare key characteristics of exisitng health research capacity strengthening evaluaiton frameworks
Gadsby	2011	Nil	Capacity Strengthening	Yes	Understand the way in which research capacity strengthening is understood and approached through examination of methods for monitoring and evaluation of research capacity strengthening.
Edwards et al	2009	Co-author	Capacity Building	No	Identification of factors that have influenced research capacity development amongst nurses in LMICs.

Region	Study Design	Data Collection	Data Analysis	Participants/Target Group
Global	Qualitative	Informal discussion and review	Thematic	HRCS Funders, evaluators and implementers
Global	Qualitative	Review	Thematic	LMIC Health Research Funders
Global	Mixed methods	telephone discusison, stakeholder meetings, online survey, review	Thematic	HRCS Funders, evaluators and implementers
Global	Qualitative	Review, informal discussions, semi-structured interview	Thematic	Donor Organisations and experts in HRCS
Global	Qualitative	Review, informal interviews/discussions	Thematic	Senior Nurse Leaders (HRCS Intervention Target Group)

Table S5. Supplementary and detailed data for 'miscellaneous' publications

Publication		**Publication Characteristics**		
Author	Year	LMIC Authorship	Capacity Term	HRCS Definition
Cole et al	2016	Last, co-author	Capacity Strengthening	No
Parker & Kingori	2016	Nil	Capacity Building	No
Muldoon et al	2012	Co-author	Capacity Building	No
Nurse & Wight	2011	First	Capacity Strengthening	Yes

Aim	Region	Study Design	Data Collection	Data Analysis
Mixed methods examination of mentorship experiences in Global Health	Global	Mixed methods	Document review; case	Thematic
Qualitative examination of researcher's views on good and bad international research collaborations	Global	Qualitative	Interviews (n=22)	Thematic
Documenting North-South research collaborations and provide insights into ongoing benefits and challenges of engaging in the research process from the Southern perspective	Africa	Mixed methods	Surveys (n=19), Intervie	Thematic
Analysing the political economy of health research commissioning among bilateral, multilateral, non-governmental and philanthropic organisations	Africa	Qualitative	Document review; inter	Thematic

Table S6. Supplementary and detailed data for 'Perspective, Opinion & Commentary' publications

Publication		Publication Characteristics		
Author	Year	LMIC Authorship	Capacity Term	HRCS Definition
Airhihenbuwa et al	2016	Nil	Capacity Building	No
Bloomfield et al	2016	Last, co-author	Capacity Building	No
Hyder et al	2016	Last, co-author	Capacity Strengthening	No
Hawkes et al	2016	Co-author	Capacity Strengthening	No
Winchester et al	2016	Co-author	Capacity Building	No
Dossou et al	2016	First, co-author	Capacity Strengthening	No
Cubaka et al	2016	First, co-author	Capacity Building	No
Davies & Mullen	2016	Nil	Capacity Building	No
Bloomfield et al	2016	Nil	Capacity Building	No
Sturke et al	2016	Nil	Capacity Building	Yes
Atkins et al	2016	Last, co-author	Capacity Building	No
Osanjo et al	2016	First, co-author, last	Capacity Building	No
Atkins et al	2016	Co-author	Capacity Building	No
O'Connor et al	2016	Co-author	Capacity Building	No
Berman et al	2015	First, co-author, last	Capacity Building	No
Cash-Gibson et al	2015	Last, co-author	Capacity Building	Yes
Koso-Thomas et al	2015	Last	Capacity Building	No
MacLaren et al	2015	Co-author	Capacity Building	No
Langlois et al	2015	Co-author	Capacity Strengthening	No
Miranda et al	2015	First, co-author, last	Capacity Building	No
Adanu et al	2015	First, co-author	Capacity Strengthening	No
Cottler et al	2015	Co-author	Capacity Building	Yes
McGregor et al	2015	Nil	Capacity Building	No
Kombe	2015	First, co-author, last	Capacity Strengthening	No
Anderson et al	2014	Last, co-author	Capacity Building	No
Hanney & Gonzalez-Block	2014	Last (2)	Capacity Building	No
Cole et al	2014	Nil	Capacity Strengthening	No
Kabiru et al	2014	First, co-author, last	Capacity Building	No
Chu et al	2014	Last, co-author	Capacity Building	No
Sweetland et al	2014	Co-author	Capacity Building	No
Adedokun et al	2014	First, co-author, last	Capacity Building	No
Harries et al	2014	Co-author	Capacity Building	No
Carothers et al	2014	Nil	Capacity Building	No
Klinkenberg et al	2014	Last, co-author	Capacity Building	No
Mandala et al	2014	First, co-author, last	Capacity Strengthening	No

Ramsay et al	2014	Co-author	Capacity Building	No
Pratt & Loff	2013	Nil	Capacity Strengthening	No
Noormahomed et al	2013	First, co-author, last	Capacity Strengthening	No
Sanchez et al	2013	Last, co-author	Capacity Strengthening	No
Sanchez et al	2013	Last, co-author	Capacity Strengthening	No
Shaji	2013	First (1)	Capacity Building	No
Ekeroma	2013	Nil	Capacity Building	No
Vasquez et al	2013	Last, co-author	Capacity Strengthening	Yes
Osei-Atweneboana et al	2012	First, co-author	Capacity Building	Yes
Ijsselmuiden et al	2012	First, co-author, last	Capacity Strengthening	Yes
Mckee et al	2012	Nil	Capacity Building	No
Nwaka et al	2012	First, co-author, last	Capacity Building	No
Kasonde & Campbell	2012	First	Capacity Building	No
Thornicroft et al	2012	Last, co-author	Capacity Building	Yes
Pratt & Loff	2012	Nil	Capacity Strengthening	No
de-graft Aikins et al	2012	First, co-author	Capacity Building	No
Greenwood et al	2012	Nil	Capacity Development	No
Airhihenbuwa et al	2011	Last, co-author	Capacity Building	Yes
Farquhar et al	2011	Last	Capacity Building	No
Forde et al	2011	Last, co-author	Capacity Development	No
Laabes et al	2011	First, co-author	Capacity Building	No
Kariuki et al	2011	First, co-author	Capacity Building	No
Pinto et al	2011	Co-author	Capacity Building	No
Wilson et al	2011	Last	Capacity Building	No
Manabe et al	2011	First, co-author, last	Capacity Building	Yes
Gezmu et al	2011	Co-author	Capacity Building	No
Brown et al	2010	First, co-author, last	Capacity Development	No
Kabiru et al	2010	First, co-author, last	Capacity Development	Yes
Ezeh et al	2010	First, co-author, last	Capacity Building	Yes
Lazarus et al	2010	Last	Capacity Development	No
Kutcher et al	2010	Last, co-author	Capacity Building	No
Maher et al	2010	First, co-author, last	Capacity Strengthening	No
Ntoumi	2010	First (1)	Capacity Building	No
Zumla et al	2010	First, co-author, last	Capacity Development	No
Kilama	2009	First (1)	Capacity Building	Yes
Kilama	2009	First (1)	Capacity Building	No
Coloma & Harris	2009	Nil	Capacity Building	No
Hussein	2008	First (1)	Capacity Building	No
Kumar et al	2008	First, co-author, last	Capacity Building	No
Malomo et al	2008	First, co-author, last	Capacity Building	No

Sheikh	2008	First (1)	Capacity Building	No
Tindana & Boateng	2008	First, last (2)	Capacity Building	No
Upshar	2008	Nil (1)	Capacity Building	No
Whitworth et al	2008	Last, co-author	Capacity Strengthening	No
Schulz-Baldes et al	2007	Nil	Capacity Building	No
Nuyens	2007	Nil	Capacity Strengthening	Yes
Stillman et al	2006	Co-author	Capacity Building	No
Goto et al	2005	First, co-author, last	Capacity Building	No
Andruchow et al	2004	Nil	Capacity Building	No
Lansang & Dennis	2004	First,last (2)	Capacity Building	Yes
Reddy et al	2002	First, last	Capacity Building	Yes
Varkevisser et al	2001	Nil	Capacity Building	No
Nchinda	2002	Nil	Capacity Strengthening	Yes

Commentary Content

HRCS Focus	Commentary Purpose	Commentary Informed By
HRCS leadership development	Recommendations	Experience
Global health centres of excellence training programme	Programme outputs; lessons learned	Experience (single programme)
Road traffic injuries research network	Programme description; programme outputs	Experience (single programme)
Capacity development for evidence uptake	Lessons learned	Experience; review
Development of a global health network	Programme description; lessons learned	Experience (single programme)
Implementing a sexual and reprodcutive health network in Africa	Programme description; lessons learned	Experience (single programme)
Twinning' model for PhD students	Programme description; lessons learned	Experience (single programme)
HRCS funding for Africa	Advocacy	Experience (single programme)
Capacity building in Global Health research	Lessons learned	Experience (single programme)
NIH International Tobacco and Health Research and Capacity Building Programme	Programme description; lessons learned	Experience (single programme)
Online journal clubs for student mentoring	Programme description; lessons learned	Experience (single programme)
Implementation science research training fellowship	programme description; programme outputs; lessons learned	Experience (single programme)
Africa/Asian Regional Capacity Development programme	Programme description; lessons learned	Experience (single programme)
capacity development in nursing informatics	Programme description; lessons learned	Experience (single programme)
Development of a knowledge translation platform	Lessons learned	Experience (single programme)
Sth-Nth-Sth research collaboration network	Lessons learned	Experience (single programme)
Global network for women and children's health research	Programme outputs; lessons learned	Experience (single programme)
Introduction to health research workshop	Lessons learned	Experience (single programme)
Health systems research synthesis in LMICs	Programme description	Experience (single programme)
Translational research in NCDs	Programme description	Experience (single programme)
HRCS in sexual and reproductive health in Africa	Recommendations	Workshops
HRCS for brain and nervous system disorders research	Recommendations	Experience; review
Bibliometric analysis of authorship HIV treatment/prevention publications	Analysis of LMIC authorship	Review
Field worker capacity strengthening in Africa	Recommendations	Workshops
Creating a charter of collaboration for HRCS partnerships	Process description	Experience (single programme)
Building health research systems	Situation analysis	Review
HRCS evaluation approaches	Recommendations	Review
African doctoral dissertation research fellowships	Programme outputs; lessons learned	Experience (single programme)
HRCS in Africa	Recommendations	Not stated
Mental health research capacity in Mozambique	Programme description	Experience (single programme)
Consortium for advanced research training in Africa	Programme outputs; lessons learned	Experience (single programme)
Mentorship for operational research capacity building	Lessons learned	Experience (single programme)
FIC clinical research scholars and fellows programme	Lessons learned	Experience (single programme)
Ethiopian operational research initiative	Programme outputs; lessons learned	Experience (single programme)
Southern Africa consortium for research excellence	Programme description	Experience (single programme)

Operational research training initiative	Programme outputs; lessons learned	Experience (single programme)
Contribution of product development partnerships to RCS	Programme outputs	Review
Medical education partnership	Programme outputs; lessons learned	Experience (single programme)
Multi-faceted Nth-Sth HRCS project	Programme description	Experience (single programme)
Multi-faceted Nth-Sth HRCS project	Lessons learned	Experience (single programme)
HRCS in mental health research	Recommendations	Not stated
Building reproductive health research and audit capacity in the Pacific	Programme description	Experience (single programme)
HRCS	Recommendations	Experience (single programme); review
HRCS for helminthiasis control	Recommendations	Experience
Developing human resources for health research	Recommendations	Review
HRCS in LMICs	Recommendations	Review
Identification of centres of excellence in health innovation in Africa	Programme description	Experience (single programme)
Creating a knowledge translation platform in Zambia	Lessons learned	Experience (single programme)
HRCS in global mental health research	Recommendations	Experience
Promotion of justice in global health research	Recommendations	Not stated
Nth-Sth research partnership on chronic disease	Programme outputs; lessons learned	Experience (single programme)
Gates malaria partnership	Programme outputs; lessons learned	Experience (single programme)
Nth-Sth RCS partnership	Lessons learned	Experience (single programme)
Afya-Bora consortium	Programme description	Experience (single programme)
Nth-Sth multi-faceted research collaboration	Programme outputs; lessons learned	Experience (single programme)
HRCS for biomedical research	Recommendations	Not stated
HRCS for NTD control in Africa	Recommendations	Workshops
Development of international research partnerships	Lessons learned	Experience (single programme)
NTD collaborative teaching and learning	Programme description	Experience (single programme)
PhD training in Africa	Programme description	Experience (single programme)
Strengthening biostatistics resources in Africa	Deliberations	Workshops
Public health nutrition research and training capacity in Africa	Deliberations	Workshops
African doctoral dissertation research fellowships	Lessons learned	Experience (single programme)
Consortium for advanced research training in Africa	Programme description	Experience (single programme)
HRCS in Africa	Recommendations	Experience; review
Nth-Sth clinical research development project	Programme outputs; programme outcomes; lessons learned	Experience (single programme)
ALPHA network programme of HIV epidemiology workshops	Programme outputs; lessons learned	Experience (single programme)
HRCS in Africa	Programme description(s)	Experience
Nth-Sth research collaboration	Programme outputs; lessons learned	Experience (single programme)
Research translation	Recommendations	Not stated
HRCS in Africa	Situation analysis	Review
HRCS in LMICs	Programme description	Experience (single programme)
FIC sponsored bioethics MHSc	Lessons learned	Experience (single programme)
FIC sponsored bioethics MHSc	Lessons learned	Experience (single programme)
FIC sponsored bioethics MHSc	Lessons learned	Experience (single programme)

FIC sponsored bioethics MHSc	Lessons learned	Experience (single programme)
FIC sponsored bioethics MHSc	Lessons learned	Experience (single programme)
FIC sponsored bioethics MHSc	Programme description	Experience (single programme)
HRCS in Africa	Recommendations	Not stated
Benefit sharing in international health research	Recommendations	Not stated
10 best resources for HRCS	Recommendations	Not stated
FIC tobacco HRCS programme	Lessons learned	Experience (single programme)
Reproductive health research in-service training course	Programme outputs; programme outcomes; lessons learned	Experience (single programme)
Cancer training and research collaboration	Lessons learned	Experience (single programme)
HRCS in LMICs	Recommendations	Review
Nth-Sth research collaboration	Lessons learned	Experience (single programme)
Nth-Sth joint health systems research project	Programme outputs; lessons learned	Experience (single programme)
HRCS in LMICs	Recommendations	Experience

Table S7. Supplementary and detailed data for 'systematic review' publications

Publication		Publication Characteristics			
Author	Year	LMIC Authorship	Capacity Term	HRCS Definition	Aim
Adedokun et al	2016	First	Capacity Building	No	Examine author affiliations of genomic epidemiology publications
Mugabo et al	2015	First, co-author, last	Capacity Strengthening	No	Describe different training approaches to research capacity strengthening
Huber et al	2015	Nil	Capacity Development	No	Support researchers and stakeholders in systemising future efforts in the HRDC field
Gonzalez-Block et al	2011	First, co-author	Capacity Strengthening	No	Assess the capacity of research collaborations and implementation research in strengthening networks and institutions in developing countries
San Sebastian & Hurtig	2006	Nil	Capacity Building	No	Review of health research on indigenous populations in Latin America between 1995-2004

Region	Searched databases	Search terms	Final no. of reviewed papers
Africa	Humane Genome Epidemiology (HuGE) Pub	Sub-Saharan Africa	508
Africa	PubMed	Capacity building; building capacity; capacity strengthening; strengthening capacity; capacity development; skills development; research; building research capacity; research training; operational research training; health; Africa	14
Global	PubMed; Google Scholar	Capacity development; research; health professuin fields; monitoting and evaluation; level of needs assessment, monitoring and evaluation	42
Global	PubMed; African Index Medicus; Literatura Latinoamericana y del Caribe En Ciencia de la Salud (LILACS)	Translational research; operations research; community based participatory research; process assessment; health plan implementation; government programmes; national health programmes; efficiency organisational; patient acceptance of health care; health service accessibility; reproductive health services; disease and health conditions; communicable diseases; malnutrition; malnutrition; maternal mortality	237
Americas	PubMed and LILACS	Indian; indigenous; aboriginal; native; amazon and all the different countries of Latin America	690

Supplementary Table 8. List of publications included in the review by typology

Original Research: Learning & Evaluation (from research initiatives)

1. Abawi K, Chandra-Mouli V, Toskin I, Festin MP, Gertiser L, Idris R, Hamamy H, Ali M, Bonventure AM, Temmerman M *et al*: **E-learning for research capacity strengthening in sexual and reproductive health: The experience of the Geneva Foundation for Medical Education and Research and the Department of Reproductive Health and Research, World Health Organization**. *Human resources for health* 2016, **14**(1).
2. Aidam J, Sombie I: **The West African Health Organization's experience in improving the health research environment in the ECOWAS region**. *Health research policy and systems* 2016, **14**:30.
3. Atkins S, Yan W, Meragia E, Mahomed H, Rosales-Klintz S, Skinner D, Zwarenstein M: **Student experiences of participating in five collaborative blended learning courses in Africa and Asia: a survey**. *Global health action* 2016, **9**:28145.
4. Byrne E, Donaldson L, Manda-Taylor L, Brugha R, Matthews A, MacDonald S, Mwapasa V, Petersen M, Walsh A: **The use of technology enhanced learning in health research capacity development: lessons from a cross country research partnership**. *Globalization and health* 2016, **12**(19):
5. Cole DC, Nyirenda LJ, Fazal N, Bates I: **Implementing a national health research for development platform in a low-income country - a review of Malawi's Health Research Capacity Strengthening Initiative**. *Health research policy and systems* 2016, **14**(24):
6. Elmusharaf K, Tahir H, D OD, Brugha R, Homeida M, Abbas AM, Byrne E: **From local to global: a qualitative review of the multi-leveled impact of a multi-country health research capacity development partnership on maternal health in Sudan**. *Globalization and health* 2016, **12**(1):20.
7. Farnman R, Diwan V, Zwarenstein M, Atkins S: **Successes and challenges of north-south partnerships - key lessons from the African/Asian Regional Capacity Development projects**. *Global health action* 2016, **9**:30522.
8. Kaser M, Maure C, Halpaap BM, Vahedi M, Yamaka S, Launois P, Casamitjana N: **Research Capacity Strengthening in Low and Middle Income Countries - An Evaluation of the WHO/TDR Career Development Fellowship Programme**. *PLoS neglected tropical diseases* 2016, **10**(5):e0004631.
9. Mahendradhata Y, Nabieva J, Ahmad RA, Henley P, Launois P, Merle C, Maure C, Horstick O, Elango V: **Promoting good health research practice in low- and middle-income countries**. *Global health action* 2016, **9**:32474.
10. Protsiv M, Atkins S: **The experiences of lecturers in African, Asian and European universities in preparing and delivering blended health research methods courses: a qualitative study**. *Global health action* 2016, **9**:28149.
11. Protsiv M, Rosales-Klintz S, Bwanga F, Zwarenstein M, Atkins S: **Blended learning across universities in a South-North-South collaboration: a case study**. *Health research policy and systems* 2016, **14**(67):
12. Thomson DR, Semakula M, Hirschhorn LR, Murray M, Ndahindwa V, Manzi A, Mukabutera A, Karema C, Condo J, Hedt-Gauthier B: **Applied statistical training to strengthen analysis and health research capacity in Rwanda**. *Health research policy and systems* 2016, **14**(1).
13. Varshney D, Atkins S, Das A, Diwan V: **Understanding collaboration in a multi-national research capacity-building partnership: a qualitative study**. *Health research policy and systems* 2016, **14**(1):64.
14. Ager A, Zarowsky C: **Balancing the personal, local, institutional, and global: multiple case study and multidimensional scaling analysis of African experiences in addressing complexity and political economy in health research capacity strengthening**. *Health research policy and systems* 2015, **13**(5):
15. Daniels J, Nduati R, Kiarie J, Farquhar C: **Supporting early career health investigators in Kenya: a qualitative study of HIV/AIDS research capacity building**. *Pan African Medical Journal* 2015, **20**:192-192.
16. Dean L, Njelesani J, Smith H, Bates I: **Promoting sustainable research partnerships: a mixed-method evaluation of a United Kingdom-Africa capacity strengthening award scheme**. *Health research policy and systems* 2015, **13**(81):
17. Heller RF, Machingura PI, Musa BM, Paramita S, Myles P: **Mobilising the alumni of a Master of Public Health degree to build research and development capacity in low- and middle-income settings: the Peoples-uni**. *Health research policy and systems* 2015, **13**(71):
18. Ndebele P, Wassenaar D, Benatar S, Fleischer T, Kruger M, Adebamowo C, Kass N, Hyder AA: **Research ethics capacity building in sub-saharan Africa: A review of NIH fogarty-funded programs 2000-2012**. *Journal of Empirical Research on Human Research Ethics* 2014, **9**(2):24-40.

19. Saenz C, Heitman E, Luna F, Litewka S, Goodman KW, Macklin R: **Twelve years of fogarty-funded bioethics training in latin America and the caribbean: Achievements and challenges**. *Journal of Empirical Research on Human Research Ethics* 2014, **9**(2):80-91.
20. Zachariah R, Guillerm N, Berger S, Kumar AMV, Satyanarayana S, Bissell K, Edginton M, Hinderaker SG, Tayler-Smith K, Bergh Rvd *et al*: **Research to policy and practice change: is capacity building in operational research delivering the goods?** *Tropical Medicine and International Health* 2014, **19**(9):1068-1075.
21. Bennett S, Paina L, Ssengooba F, Waswa D, M'Imunya JM: **Mentorship in African health research training programs: an exploratory study of Fogarty International Center Programs in Kenya and Uganda**. *Education for health (Abingdon, England)* 2013, **26**(3):183-187.
22. Bennett S, Paina L, Ssengooba F, Waswa D, M'Imunya JM: **The impact of Fogarty International Center research training programs on public health policy and program development in Kenya and Uganda**. *BMC public health* 2013, **13**(770):
23. Marjanovic S, Hanlin R, Diepeveen S, Chataway J: **Research capacity-building in Africa: Networks, institutions and local ownership**. *Journal of International Development* 2013, **25**(7):936-946.
24. Miiro GM, Oukem-Boyer OO, Sarr O, Rahmani M, Ntoumi F, Dheda K, Pym A, Mboup S, Kaleebu P: **EDCTP regional networks of excellence: initial merits for planned clinical trials in Africa**. *BMC public health* 2013, **13**:258.
25. Vian T, Koseki S, Feeley FG, Beard J: **Strengthening capacity for AIDS vaccine research: analysis of the Pfizer Global Health Fellows Program and the International AIDS Vaccine Initiative**. *BMC health services research* 2013, **13**(378):
26. Wilson LL, Rice M, Jones CT, Joiner C, Laborde J, McCall K, Jester PM, Carter SC, Boone C, Onwuzuligbo U *et al*: **Enhancing research capacity for global health: Evaluation of a distance-based program for international study coordinators**. *Journal of Continuing Education in the Health Professions* 2013, **33**(1):67-75.
27. Bennett S, Corluka A, Doherty J, Tangcharoensathien V: **Approaches to developing the capacity of health policy analysis institutes: a comparative case study**. *Health research policy and systems* 2012, **10**(7):
28. Bissell K, Harries AD, Reid AJ, Edginton M, Hinderaker SG, Satyanarayana S, Enarson DA, Zachariah R: **Operational research training: the course and beyond**. *Public health action* 2012, **2**(3):92-97.
29. Redman-Maclaren M, MacLaren DJ, Harrington H, Asugeni R, Timothy-Harrington R, Kekeubata E, Speare R: **Mutual research capacity strengthening: a qualitative study of two-way partnerships in public health research**. *International journal for equity in health* 2012, **11**(79):
30. Mahmood S, Hort K, Ahmed S, Salam M, Cravioto A: **Strategies for capacity building for health research in Bangladesh: Role of core funding and a common monitoring and evaluation framework**. *Health research policy and systems* 2011, **9**.
31. Minja H, Nsanzabana C, Maure C, Hoffmann A, Rumisha S, Ogundahunsi O, Zicker F, Tanner M, Launois P: **Impact of health research capacity strengthening in low- and middle-income countries: the case of WHO/TDR programmes**. *PLoS neglected tropical diseases* 2011, **5**(10):e1351-e1351.
32. Goto A, Nguyen Quang V, Nguyen Thi Tu V, Yokokawa H, Yasumura S, Nguyen Thy K: **Epidemiology research training in Vietnam: evaluation at the five year mark**. *Fukushima journal of medical science* 2010, **56**(1):63-70.
33. Mayhew SH, Doherty J, Pitayarangsarit S: **Developing health systems research capacities through north-south partnership: an evaluation of collaboration with South Africa and Thailand**. *Health research policy and systems* 2008, **6**(8):
34. Jönsson K, Tomson G, Jönsson C, Kounnavong S, Wahlström R: **Health systems research in Lao PDR: capacity development for getting research into policy and practice**. *Health research policy and systems* 2007, **5**(11):
35. Hyder AA, Akhter T, Qayyum A: **Capacity development for health research in Pakistan: The effects of doctoral training**. *Health policy and planning* 2003, **18**(3):338-343.
36. Jentsch B, Pilley C: **Research relationships between the South and the North: Cinderella and the ugly sisters?** *Social Science and Medicine* 2003, **57**(10):1957-1967.

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37. Erasmus E, Lehmann U, Agyepong IA, Alwar J, de Savigny D, Kamuzora P, Mirzoev T, Nxumalo N, Tomson G, Uzochukwu B *et al*: **Strengthening post-graduate educational capacity for health policy and systems research and analysis: the strategy of the Consortium for Health Policy and Systems Analysis in Africa**. *Health research policy and systems* 2016, **14**:29.

38. Uzochukwu B, Mbachu C, Onwujekwe O, Okwuosa C, Etiaba E, Nyström ME, Gilson L: **Health policy and systems research and analysis in Nigeria: examining health policymakers' and researchers' capacity assets, needs and perspectives in south-east Nigeria**. *Health research policy and systems* 2016, **14**(13):
39. Agyepong IA, Anniah K, Aikins M, Akweongo P, Esena R, Mirzoev T: **Health Policy, Health Systems Research and Analysis Capacity Assessment of the School of Public Health, University of Ghana**. *Ghana medical journal* 2015, **49**(3):200-213.
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41. Oliver S, Bangpan M, Stansfield C, Stewart R: **Capacity for conducting systematic reviews in low- and middle-income countries: a rapid appraisal**. *Health research policy and systems* 2015, **13**(23):
42. Ekeroma AJ, Kenealy T, Shulruf B, McCowan LM, Hill A: **Building reproductive health research and audit capacity and activity in the pacific islands (BRRACAP) study: Methods, rationale and baseline results**. *BMC medical education* 2014, **14**(1).
43. Haafkens J, Blomstedt Y, Eriksson M, Becher H, Ramroth H, Kinsman J: **Training needs for research in health inequities among health and demographic researchers from eight African and Asian countries**. *BMC public health* 2014, **14**(1254):
44. Kanoute A, Faye D, Bourgeois D: **Strategies to promote better research on oral health in Africa: a Delphi consensus study**. *Contemporary clinical dentistry* 2014, **5**(1):13-19.
45. Kebede D, Zielinski C, Mbondji PE, Sanou I, Kouvividila W, Lusamba-Dikassa PS: **Human resources in health research institutions in sub-Saharan African countries: results of a questionnaire-based survey**. *Journal of the Royal Society of Medicine* 2014, **107**(Suppl. 1):85-95.
46. Kilic B, Phillimore P, Islek D, Oztoprak D, Korkmaz E, Abu-Rmeileh N, Zaman S, Unal B: **Research capacity and training needs for non-communicable diseases in the public health arena in Turkey**. *BMC health services research* 2014, **14**:373.
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Supplementary Table 9. HRCS definitions, sources and citing papers[1]

Subject Defined	Capacity Term	Definition & Source	Cited In
Health Research Capacity	Building *[30]* Strengthening *[70]*	"an ability of individuals, organisations or systems to perform and utilise health research effectively, efficiently and sustainably" *[70]*	*[30, 70]*
	Building *[166]* Strengthening *[74, 126]*	"the ability to define problems, set objectives and priorities, build sustainable institutions and organisations, and identify solutions to key national health problems" [1]	*[74, 126, 166]*
	Strengthening	"'a strategy that is implemented worldwide to improve the ability of developing countries to tackle the persistent and disproportionate burdens of disease they face" [2]	*[123]*
	Development	"the process required for building capacity in health research would be define the institutional systems needed to support research, enumerate existing and missing resources and improve research support by addressing the identified gaps" *[70]*	*[45]*
	Strengthening	"the level of expertise and resources needed for the production of new knowledge and its application" [3][2]	*[48]*
	Building	"an approach to the development of sustainable skills, organisational structure, resources and commitment to health improvement…to multiply health gains many times over" [4][3]	*[139]*
	Building	"a systematic, purposeful and goal-oriented effort to strengthen human resources and infrastructure to enable local scientists and institutions to become independent and responsive to existing and emerging health needs and threats" *[97]*[2]	*[97]*
Research Capacity	Building *[164]* Strengthening *[29, 123, 159]*	"the ongoing process of empowering individuals, institutions, organisations, and nations to: define and prioritise problems systematically; develop and scientifically evaluate appropriate solutions; and share and apply the knowledge generated" *[164]*[4]	*[29, 123, 159, 164]*
	Strengthening *[16, 72]*	"process of individual and institutional development which leads to higher levels of skills and greater ability to perform useful research" [5]	*[16, 72]*
	Development *[4]* Strengthening *[31, 74]*	"the process by which individuals, organisations, and societies develop abilities (individually and collectively) to perform functions effectively, efficiently and in a sustainable manner to define problems, set objectives and priorities, build sustainable institutions and bring solutions to key national problems" [6]	*[4, 31, 74]*
	Building	"the ability to conduct, manage, disseminate, and apply research in policy and practice" *[132]*	*[132]*
	Building *[91, 96]*	"Includes any efforts to increase the ability of individuals and institutions to undertake high-quality research and to engage with the wider community of stakeholders" [7]	*[91, 96]*
	Building	"a long-term process that requires a systematic and inter-sectoral approach to developing appropriate regulatory frameworks, building and maintaining physical infrastructure, and investing in human resources, equipment and training in an environment conducive to research commitment and institutional support" [8]	*[130]*

	Strengthening	"consists of two main closely inter-related and inter-dependent activities, which, together, form the basis of institutional development. The two parts are: improving, through appropriate training, the capabilities of scientists to undertake quality research; improving institutional support – equipment, supplies and other logistic support to the institution in which the trained scientists have to work" *[165]*	*[165]*
	Building	"strengthening the abilities of individuals, institutions, and countries to perform research functions, defining national problems and priorities, solving national problems, utilizing the results of research in policy making and programme delivery." [9]	*[46]*
	Strengthening	"goes beyond facilitating or funding a research project to the broader objectives of nurturing the prerequisites of the research process, such as state and institutional support, specialized training, infrastructural development, networking opportunities, publications and career paths." *[79]*	*[79]*
	Building	"a deliberate effort to augment health and social science research outputs as well as human capital, so as to favourably impact upon a research focus area" *[166]*[5]	*[166]*
Capacity	Building	"a process that improves the ability of a person, group, organisation or system to meet its objectives or perform better" [10]	*[25]*
	Building	"the process of helping communities and organisations harness human, technical and financial resources, which allows them to respond adequately to health issues in ways that inform such policies" [11]	*[133]*
	Strengthening	''process through which people, organisations, and society as a whole are enabled to shape their own development and adapt it to changing conditions and frameworks'' [12]	*[66]*
	Strengthening	''process of improving individual skills, processes, and structures at the organizational level and the networks and context in which the organisation functions'' *[65]*	*[65]*
	Building	"helping recipient countries to invent, develop and maintain institutions and organisations which are capable of learning and bringing about their own transformation, so that they can play a dynamic role in supporting national development processes" [13]	*[150]*
	Strengthening	"the ability of individuals or groups to perform tasks in a sustainable manner" *[47]*	*[47]*
Organisational capacity	Development	"the capacity of research departments in universities, think tanks and so on to fund, manage and maintain themselves" [14]	*[27]*
Progress	Building *[142]* Development *[143]*	"ability to understand, interpret, select, adapt, use, transmit, diffuse, produce and commercialise scientific and technological knowledge in ways appropriate to culture, aspirations and level of development" [15]	*[142, 143]*

1. Numbered citations in italics pertain to the reference list in Supplementary Table 1. Numbered citations in normal (non-italicised) font are listed below. 2. Presented as a definition of 'Health Systems Research' capacity. 3. Presented as a definition of 'research capacity' in citing publication, but included in the 'health research capacity' definition list as contains specific reference to 'health research'. 4. Cited as definition of 'health' research capacity in [123]. 5. Presented as a definition of 'capacity' in citing publication, but included in the 'research capacity' definition list as contains specific reference to 'research'

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Supplementary Table 10. Content analysis of capacity definitions by capacity term[1]

Subject Defined	Capacity Term	Content Domains[2]									
		Ind.	Ins.	Env.	Def.	Car.	Appl	Qua	Sus.	Pro.	Con
Health Research Capacity	Building [139]	x	x				x		x		
Health Research Capacity	Building [97]	x	x					x			
Research Capacity	Building [132]					x	x				
Research Capacity	Building [91, 96]	x	x			x	x	x			
Research Capacity	Building [130]	x	x	x						x	x
Research Capacity	Building [46]	x	x	x	x	x	x	x			
Research Capacity	Building [166]	x				x		x			
Capacity	Building [25]	x	x	x				x		x	
Capacity	Building [133]		x	x			x			x	
Capacity	Building [150]		x	x					x		
Progress	Building [142], Development [143]					x	x				
Health Research Capacity	Building [30], Strengthening [70]	x	x	x		x	x		x		
Health Research Capacity	Building [166], Strengthening [74, 126]		x		x	x			x		
Research Capacity	Building [164], Strengthening [29, 123, 159]	x	x	x	x	x	x			x	x
Health Research Capacity	Strengthening [123]		x					x			
Health Research Capacity	Strengthening [48]					x	x				
Research Capacity	Strengthening [16, 72]	x	x			x		x		x	
Research Capacity	Strengthening [165]	x	x			x		x			
Research Capacity	Strengthening [79]	x	x	x							
Capacity	Strengthening [66]	x	x	x						x	
Capacity	Strengthening [65]	x	x	x				x		x	
Capacity	Strengthening [47]	x				x			x		
Research Capacity	Development [4], Strengthening [31, 74]	x	x	x	x	x	x	x	x	x	
Health Research Capacity	Development [45]		x					x		x	
Organisational Capacity	Development [27]		x						x		
Progress	Building [142], Development [143]					x	x				

1. Numbered citations pertain to the reference list in Supplementary Table 1. 2. The content of each definition was independently coded according to the following criteria: explicit reference to individual (ind.), institutional (Ins.) or environmental (Env.) level capacity strengthening; explicit reference to strengthening capacity in terms of defining research questions or identifying research priorities (Def.), conducting research or applying research methods (Car.) or communicating and applying research outcomes

(App.); explicit reference to facilitating an improvement in research abilities/quality (Qua.) sustainability (Sus.), reference to HRCS as a process (Pro.) and/or HRCS as a continuous activity (Con.).