Educational and Wider Interventions that Increase Research Activity and Capacity of Clinicians in Low to Middle Income Countries: A Systematic Review and Narrative Synthesis

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Abstract

Research capacity building of clinicians in low to middle income countries may be the most powerful intervention to strengthen health systems, improve clinical standards and address inequities in healthcare. Research training in the form of workshops, postgraduate courses and collaborations are interventions that have been used to increase research activity and capacity. The aim of this literature review is to identify educational and other interventions that worked for clinicians, their characteristics and how they may have worked.

Methods: Systematic search of electronic databases was performed for relevant articles from January 2000 to October 2013. Due to the small number of papers, the complex interventions and diverse methods used, a narrative synthesis along themes was used to distil the evidence. The data was collated, reviewed and themed to form four middle-level theories. A theory-driven search of the literature was then performed to identify articles to test the theories. A theoretical framework was then developed to conceptualise how the theories relate in a research capacity building programme.

Results: Of 2833 identified articles, only 20 met the inclusion criteria. Most of the articles had multiple interventions, were descriptive accounts and were of variable quality. The interventions were complex and mostly poorly-described although they could be grouped into four broad classes in training workshops, postgraduate training, support and mentoring by collaboration and enhancements in the research environment. Postgraduate research training courses should be for clinicians who have funded and protected time away from clinical work. Clinical research teams can only thrive in a research-enhanced environment and supportive collaborations.

Conclusion: Despite limited evidence from low to middle income countries, this review has identified that clinician-led research can be increased by focused development of a team of selected individuals and skills through postgraduate training, supported by collaborative networks and an enhanced research environment.

Introduction

There is a broad consensus that research capacity building (RCB) in low to middle income countries (LMIC) can make a fundamentally important contribution [1] to informing policy and practice [2] and addressing disparities in health outcomes [3,4]. There has been a shift in focus from increasing research funding from developed to developing countries to a more self-sustaining model "beyond aid," [5]. The World Health Organization (WHO) and others have emphasised the contribution of research to strengthening health systems [4,6]. For health research to be self-sustaining, research in LMIC requires global cooperation and multi-disciplinary action [6]. Capacity development for health research is comprised of strengthening individual skills, organisational systems and an enabling environment [7]. Most of the efforts at RCB in LMIC have focused on strengthening systems including governance, financing and structural function [8,9]. Tertiary institutions in developed countries have played a part in RCB by collaboration at the organisational and university level building research systems and human resource capacity [10-14]. It seems that most of the interventions at building the capability and capacity of human resources in LMIC has been confined to skilling scientists and the pure researcher workforce [15-17]. Interventions stressing postgraduate courses with the majority of these focusing on Ph.D.

training abound [18,19]. For example, the European and Developing Countries Clinical Trials Partnership [20] and the INDOX cancer research network strengthened networks by developing the capacity of scientists through postgraduate scholarships [21]. The WHO and the fund for Research and Training in Tropical Diseases were aimed at training research scientists [17]. However, most of the doctoral graduates who travel to high-income countries for training remain in these countries [22] where they have better financial rewards and career opportunities. An alternative is to train clinicians (mostly doctors and nurses) to perform clinical research. Clinicians are arguably more likely than research scientists to understand the research questions and

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be aware of the clinical priorities in their locality, leading to clinically relevant research [23] that is likely to be translated into clinical practice [24]. Clinicians who travel to high-income countries for training are often unable to transfer their clinical qualifications and are more likely to return to their place of origin than are research scientists. Training clinicians to perform research has had mixed outcomes in developed countries and processes to address barriers have been proposed [25,26]. There were no long-term studies evaluating training of clinicians to perform research in LMIC. Before planning interventions to increase the research activity and capacity of clinicians in LMIC, we need to understand how and why interventions work and in what context they work [27]. The body of evidence in this area is small [28], therefore reviews of interventions in LMIC need to be intentionally inclusive of all studies including those with a theoretical basis to determine what works for whom, in what context and why. There have been no randomized controlled trials published in this area due to the complexity of educational interventions and the difficulties linking components of interventions with specific outcomes [29]. Most of the papers in this domain have been descriptive in nature [30].

The primary objective of this review was to address the following question: What interventions, educational or otherwise, that have resulted in increased research activity by clinicians in LMIC?

Methods

Systematic search

The population of interest was any clinician (front-line health professional) working in an LMIC. We included any intervention aimed to increase research in LMIC, where research was defined in a broad sense to include clinical audit. Studies aimed at strengthening governance and improving research funding without a specific mention of clinicians as beneficiaries were excluded.

Outcomes were evidence of research capacity or outputs that included but were not limited to: research publication in a peer reviewed journal, presentation at a regional research conference, completion and dissemination of a clinical audit project, obtaining ethics approval for a project, lead author of a research based practice guideline, regional recognition as a researcher, or success at obtaining research funding. We were also interested in outcomes such as a culture of support for clinical staff to perform research, an increase in knowledge of research methods, changes in attitudes and other outcomes suggested by Reed et al. [31] for educational interventions. Outcomes included process measures (e.g. research meetings) as surrogate markers of research activity [32]. For the systematic search and initial review, we followed the methods described in the PRISMA Statement [33]. A narrative synthesis followed using the methods described by Popay et al. [34] and Blank et al. [35]. The following databases were searched-MEDLINE, EMBASE, CINAHL, ERIC, Geobase, Scopus, Google Scholar, PsycINFO, Campbell Collaboration and the Cochrane Library for Systematic Reviews as they were most likely to list studies educational interventions for clinicians. Our search was limited to from January 2000 to October 2013, and limited to the English language. A previous search for studies in health research capacity strengthening to 2010 yielded only four studies that evaluated an intervention [36] A Google search was performed to identify grey literature, using the search terms "interventions that increase research by clinicians" and then followed by the addition of "in LMIC". The headings of the first 100 items in each of the two searches were read for suitability. Reference lists of selected reviews and articles were searched, and experts were contacted by email in order to identify any unpublished reviews. The search was

performed with assistance from a medical librarian and abstracts were downloaded into the EndNote V6 bibliographic software database where duplicates were removed. Author AE screened all titles and abstracts to exclude papers that did not meet the inclusion criteria, leaving 84 papers that were read in full text by authors AE and TK for a final decision on inclusion. Any disagreement was resolved by consensus. PICO criteria and the Medline search query are shown in Table 1. The search criteria were adapted as needed for other databases. Numbers of publications identified in the literature search process are shown in Figure 1.

Study appraisal and review

For the methodological appraisal of the quality of the individual studies, we preferred to use the domains recommended by Reed et al. [31] as it addressed the assessment of educational interventions. Data from included studies were extracted into an Excel spreadsheet to document study rationale, objectives, design, intervention, evaluation and results (Table 2). It was clear from the initial assessment of the data that the small number of studies found would limit our ability to conduct a meta-analysis and that a narrative synthesis was more appropriate.

PICO

Population: any clinician working in a low or middle income country
Intervention: any intervention to build research capacity
Comparator: any
Outcome: any research output

Medline Search

1. clinician OR doctor OR nurse OR midwi*
2. developing countr* OR low to middle income countries OR LMIC
3. build* OR strengthen* OR increase*
4. activity OR capacity
5. research OR clinical audit
6. research knowledge OR publication OR output OR outcome

All the databases searched were with the same search terms in the titles, abstracts and review articles, limited to 2000-October 2013 and the English language.
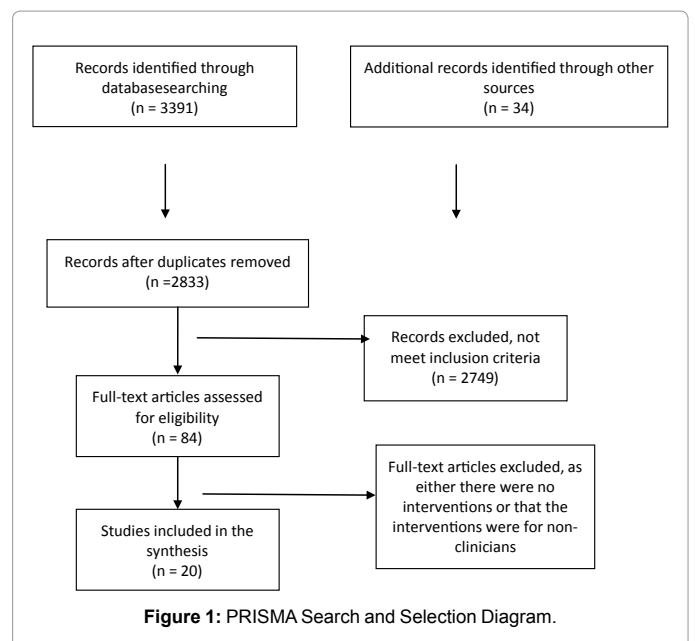

Table 1: PICO and Medline search.

Figure 1: PRISMA Search and Selection Diagram.

Study	Study purpose identified	Design?	Selection bias?	Long-term effects assessed?	Intervention described in detail?	Setting described?	Learner characteristics described?	Required resources described?	Outcomes match objectives?	Data collection described in details?	Effect size assessed?	Conclusions justified b results?	Strengths and limitations given?	Contribution to literature described?
Ajuwon et al.[39]	Process, Outcomes	Quasi-experimental	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Akhtar et al. [44]	Research related activities	Observational	Limited details	No	No	Yes	No	Limited	Yes	No	No	Limited	No	No
Ali et al. [21]	Research Network described	Descriptive	Limited details	Yes	Limited	Yes	No	No	Yes	No	No	Yes	No	Yes
Andruchow et al. [51]	Epidemiology training collaboration	Descriptive	Yes	No	Yes	Yes	Limited	Yes	Limited	No	No	Yes	No	Yes
Bates et al. [7]	Course evaluation	Quasi-experimental	Yes	No	Yes	Yes	Limited	Yes	Limited	Yes	Yes	Yes	Yes	Yes
Beveridge et al. [54]	Number paper downloads	Descriptive/Survey	Limited	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Derbew et al. [13]	Number of papers downloaded	Survey	Limited	No	Yes	Yes	Limited	Yes	Yes	Limited	NA	NA	Yes	Yes
Dodani et al. [38]	Research training effectiveness	Quasi-experimental	Yes	No	Yes	Yes	Yes	Limited	Yes	Yes	No	Yes	Yes	Yes
Dodani et al. [41]	Further data on effectiveness	Cost-comparison	Yes	No	Yes	Yes	Yes	Yes	Limited	Yes	No	Limited	No	No
Goto et al. [56]	Research workshop	Quasi-experimental	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Goto el al [42]	Evaluation partnership outcome	Evaluation	Yes	No	Yes	Yes	No	Limited	No	No	No	Yes	No	No
Hyder et al. [47]	Evaluation doctoral training	Survey	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lutumba et al. [52]	Research strengthening	Descriptive	Yes	Yes	No	Yes	No	No	No	No	Limited	No	No	No
Manabe et al. [48]	Description of institutional development	Descriptive	Yes	Limited	Limited	Yes	No	Yes	Limited	No	Yes	Yes	Limited	No
Mayhew et al. [53]	Assessment of a partnership	Descriptive	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Limited	Yes
Ramos et al. [43]	Health Systems Research	Descriptive	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes
Redman et al. [44]	Describes workshop process	Descriptive	Limited	No	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
Short et al. [49]	Evaluation fellowships project	Descriptive	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Tomatis et al. [45]	Course improving attitudes for evidence	Observational	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No
Zumla et al. [50]	Description research partnership	Descriptive	Yes	No	Yes	Yes	No	No	Yes	No	Yes	Limited	Yes	Yes

Table 2: Details of included studies.

In addition, the 20 included papers had considerable heterogeneity in terms of methods, participant type and number, interventions with the majority being descriptive in nature. A narrative approach to the systematic review focuses on the use of text to summarize and explain the findings of the synthesis. The key elements of a narrative synthesis are: to develop theories of how interventions work, why and for whom; describe patterns across studies, explore relationships between the data; and to draw conclusions on the strength of the evidence [34]. We decided, after reviewing the included literature to contextualize the evidence by deriving our own theories from the patterns we observed. Theory-derivation was an iterative process as we attempted to explain how and why certain identified interventions worked.

Authors AE and TK re-read the papers focusing on

1) How the interventions were conceived, planned and

implemented, participant selection, removal of bias, type of provider;

2) Context such as intervention setting, type of participant, duration of intervention;

3) Any theories suggested by the authors that improved success of their research building program and reflections as to why an intervention may have failed. The key findings were recorded in an Excel spreadsheet using a narrative and interpretive approach [37]. We identified and categorized prominent and recurrent patterns of data and interpreted these as theories arranged in themes to explain their interaction to influence outcomes.

Results

Search results and study characteristics: Of the 2833 articles identified, only 20 satisfied the inclusion criteria. Sixteen of the papers described interventions with multiple components making it difficult to determine which component led to which outcome. Four of the papers had quasi-experimental designs and the rest were descriptive or survey in nature. Seven of the studies were in Africa, five in the Indian subcontinent, three in Asia and two in Latin America and one in both Asia and Africa. None of the papers had an intervention that was compared with another, other than one study that compared two different methods of delivering a research workshop [38]. Studies with an intervention did not have a follow-up that lasted longer than one year. No study attempted to measure the whole range of research outcomes. It was not possible to quantify the number of clinicians who were participants as nearly all the studies had a mixture of professional participants.

Types of interventions

Four broad types of interventions were identified: training workshops (7 papers), postgraduate training [4], supportive-collaborations [6] and environment-enhancers [3]. Table 3 shows the types of interventions and component strategies reported by each paper.

Training workshops: Research workshops aimed to train

clinicians in research skills. There were heterogeneous curriculums, different objectives and expected out comes, some had formal and some informal styles, had varying durations of delivery and some used several delivery platforms. Only seven papers described the training intervention in detail. Not all the participants of workshops were clinicians. Nevertheless, the studies found that significant knowledge was gained and that this knowledge was retained for a month [39-45] regardless of curriculum design and content, duration or mode of instruction.

Postgraduate training: Postgraduate training, for the purposes of this review, where research attachments (fellowships) or training leading to a postgraduate qualification. Four papers reported formal courses, fellowships and Ph.D. training with varying outcomes although there was the impression that those with Ph.D. training were preferred as they had a higher research output [46-49].

Supportive Collaboration: Supportive collaborations, which include mentoring, were any efforts by a network of experienced researchers to support clinicians performing research. Partnerships and collaborations with universities [21,42,50] and international agencies [51] resulted in significant RCB of clinical teams [52] and enduring resourced research Programs [53].

Environment Enhancers: Environment-enhancers in this review included funding, infrastructure, policies, processes, culture and all those factors that enable and support clinicians to perform research. Research enhancing strategies such as improving internet access, research systems, journal clubs, hiring research staff and offering research awards increases research activity of clinicians [13,54,55]. A range of multiple-level enhancers, including funding, resulted in projects becoming sustainable after a median of 66 months [21,50,51].

Intervention strategies

We identified three broad interventions from the selected papers. Table 4 outlines factors that enhance or hinder a research-building program.

Teach research knowledge: All the papers stressed to varying

Authors	Learning Knowledge	Developing Skills/ Attitudes	Collaboration/ Mentoring	Research Environment	Outcomes/Measures
Ajuwon et al. [39]	Yes	No	No	No	Research Ethics knowledge short term
Akhtar et al. [44]	Limited	Limited	No	Yes	Increase in publications
Ali et al. [21]	Yes	Limited	Yes	Yes	Increase in research trials and publications
Andruchow et al. [51]	Yes	Limited	Yes	Limited	Collapsed when funding and experts withdrawn
Bates et al. [7]	Yes	Yes	Limited	Limited	Motivated learners
Beveridge et al. [54]*	Limited	No	No	Limited	Decrease in use of internet login long-term
Dodani et al. [40]*	Yes	No	No	No	Increase in knowledge short-term
Goto et al. [56]	Yes	Yes	Limited	Limited	Increase in knowledge, Skills not measured
Goto et al. [42]	Yes	Yes	Limited	Limited	Increase in research confidence and activity
Hyder et al. [47]**	No	No	No	No	Knowledge on research barriers
Lutumba et al. [52]**	No	No	No	No	View on capacity building
Manabe et al. [48]	No	No	Yes	Limited	None measured
Mayhew et al. [53]	Yes	Yes	Yes	Yes	Increase in PhDs, fellowships, exchanges, publications
Ramos et al. [43]	Yes	Yes	Yes	Limited	Increase in research presentations and publications
Redman et al. [44]	Yes	No	No	No	Increase in research awareness
Short et al. [49]	Limited	Limited	Limited	No	Limited success with some research activity
Tomatis et al. [45]	Yes	No	No	No	Increase in short-term knowledge
Zumla et al. [50]	Yes	Yes	Yes	Yes	Increase in research activity and publications

*repeat paper on same research not included

**interventions described in the two papers were not applied by the authors.

Table 3: Intervention Strategies and Outcome Measures.

Research Workshops	
Supporting factors	Engagement of key stakeholders and participants in a needs assessment to decide content and process of workshops
	Experienced resource people as faculty
	Knowledge was retained if concepts are used frequently in the participants line of work
	Workshops are self-sustaining if part of a course e.g. epidemiology course
	To utilise social learning which includes active learning and reflection
	If there were opportunities for learning and support at work
	If workshops were used to develop research proposals
	If workshops were used to develop different research methodologies
	Face to face instruction is better than video instructions
	Community engagement in research workshops
Hindering factors	Language and cultural barriers between instructors and participants
	Resource constraints, No local research mentors
Postgraduate courses	
Supporting factors	Important to select the right participants – capacity is crucial
	Selected participants to do PhDs overseas to build capacity
	PhD training leads to an increase in research
	Trainees in LMIC want to do recognised overseas courses
Hindering factors	Lack of time, funding, training and resources
	Lack of incentives and career structure for staff
	Those with less research experience do not do as well
	Some trained PhDs do not return home
	Slow internet connection
Supportive collaboration	
Supporting factors	Development of regional networks and with partners in developed countries
	Adequate funding investment to build capacity of local teams
	Ability of programmes to sponsor local researchers to do postgraduate training overseas
	Partnerships that facilitate training and generate funding
	Joint projects enhances collaboration
	Research done as a research capacity building project leads to more postgraduate qualifications and more publications
	Research expertise from overseas benefits local researchers
Hindering factors	Inability to retain scientists locally
	Ad-hoc projects do not lead to capacity building
Environmental enhancers	
Supporting factors	Need to have access to computers, internet and staff
	Need to have research funding
	Availability of peer mentoring
	Availability of computers, internet and online library access
	Local research centre
	Assistance programme and funding incentives
	Whole package of support within a department
Hindering factors	Limited resources, infrastructure and funding
	Contract expiration and the need to compete for funding
	Low wages and limited employment opportunities

Table 4: Factors that may support or hinder efficacy of interventions to increase research activity by clinicians.

degrees the importance of participants acquiring research knowledge and that this could be taught. Most of the papers had training workshops and courses designed to instill knowledge [38-44] and may have formed a part of another intervention [43-55]. Only three studies [38-56] had a quantitative assessment of knowledge before and after the training workshop and one used qualitative methods [44]. The courses ranged from a few days for a workshop to a few years as in the case with those doing higher qualifications (e.g. PhDs). Teach/Mentor research skills and attitudes: Research skills were taught both formally and informally as part of University courses or in-service training. These were effectively done over a longer period, usually associated with higher training such as in a Ph.D. and invariably accompanied by sustained mentoring. Participants tend to develop lasting positive attitudes to research as a result of the long training [21-56].

Enhancement of the research environment: A supportive health research system enabling a research environment may include various enabling functions such as mentoring, funding, collaboration, technical support, infrastructure and policies [42-44].

Properties of training workshops

We decided, due to the wide scope of the interventions and properties, to narrow our review focus to the properties of training workshops. Progressive focusing is a well-established technique in qualitative methods [57]. Training workshops, as in other educational workshops, have generic properties. Those training clinicians for knowledge, skills and attitudes are no exceptions although each workshop may be discipline or topic-specific, which in turn determines objectives, content and delivery. Some of the workshops were designed

to impart knowledge and others were designed to teach skills and a positive attitude for research.

Theories of why the various interventions may or may not work

We identified from the data many potential theories about why interventions may or may not work. Four should be of particular interest to policymakers in LMIC.

Theory 1: Research workshops are more beneficial to clinicians with research experience: The theory is based on the premise that although measurable knowledge is gained from workshops, clinicians without research experience will not be able to build on that knowledge and basic skills without the "learning by doing" [46] and other components of research training and support were in place. Research knowledge in itself does not necessarily translate to intention to perform research let alone actually performing it. A clinician with experience in clinical research will most likely utilise knowledge gained from a workshop. Workshops should not be viewed as an adequate medium to instruct on research methods, but rather, it should be viewed as one medium of instruction in blended learning [58] and should be used as a "booster" for new-but-limited or revised information. Most medical universities in HIC and LMIC offer research workshops in clinical research over a few days with syllabuses covering basic research concepts with coursework aimed at assisting residents and medical students develop research proposals [59,60]. However, no long-term evaluations of these workshops have occurred to determine whether defined outcomes had been achieved [e.g. research projects completed or publications generated]. There were attempts at different measures with one having 9 of its 32 participants "discussing potential research with partners" 9 months after workshop [61]. There was no literature referring to research workshops attended by clinicians with research experience. Therefore, this theory has not been supported but it remains testable. A proven theory would be: Research workshops increases research knowledge of clinicians (albeit for a short time).

Theory 2: Postgraduate training, including Ph.D. training, would benefit clinicians who have been transitioned to perform research work: The theory is based on the observation that longer research training, such as for a Ph.D., increases RCB activity as it increases knowledge, skills and positive attitudes to research [47,48,52]. Secondly, clinicians whose main role were in the clinical area would not be able to do the long training and succeed in performing research until they were transitioned to do less clinical work and more research [25]. The most common barrier to clinician-initiated research was time constraint [62-64] and although it was not clear how much time was adequate for research it seemed that 2.5 days a week for a year was not adequate to sustain research activity [25]. Shorter training in fellowship attachments had variable success in the backdrop of busy clinical workloads [49]. The abovementioned evidence supports this theory. In the LMIC where there is an endemic shortage of clinicians and where research is not deemed important, it may be difficult to convince health managers to allow their clinicians to take time off for Ph.D. training. Management may also deem it unwise to send clinicians away for long and expensive training and when there is a risk of brain drain after the training [65]. Alvaro's theory of conservation of resources suggests that research activity and implementation of evidence suffers when there are tight resources in LMIC [66].

Theory 3: Supportive collaborations, including mentoring, are critical in building research capacity of clinicians: This theory was based on the literature that research collaborations was critical in RCB programmes [43-51] and that novice researchers need mentoring from an experienced researchers in order to succeed [67-69]. Group mentoring in teamwork has been shown to be effective in RCB [70,71]. This would mean that research training, collaboration and mentoring were all critical for the development of clinician researchers. The abovementioned evidence, therefore, supports the theory. In LMIC, it may be better to provide most of the collaboration and mentoring closer to the clinician to improve access. The support might even be better if it was provided in a participatory action-research (PAR) framework where local culture, resources and solutions are understood and acknowledged [72]. A PAR framework may not be easy to implement, as there may not be any local resources, including researchers, to make this happen.

Theory 4: Clinician research capacity can only thrive and become successful where there is a developed health research system (HRS): This theory was based on the analysis of the included literature that researchers and research do better when there is a developed HRS [21,50,52]. The components of a HRS relevant to clinical research can be thought of in the Eight-"P"s: power (political and scientific leadership), policy (enabling legislation, funding, organisational) process (logistics, ethics, reporting, organisational) priority [research priorities identified], property (information systems and infrastructure), practice (clinically relevant), people (skills) and partners (stakeholders, funders, collaborators). Many research efforts had to be aborted due to a lack of funding [51] and failures to address barriers in the working environment [46,49]. Pang et al. [73] encapsulated environmental support in calling for the development of effective health research systems (HRS). The evidence is overwhelmingly supportive of the theory. Micro-HRS can be created in LMIC where resources are limited by the set-up of dedicated research institutions with adequate funding to support research and researchers [74].

Discussion

Most of the literature on research capacity building is on the development of part or whole of health research systems. Efforts on human development, on the other hand, have largely concentrated on non-clinical academics or pure researchers. We found only 20 papers with mixed methodologies, complex and inter-related interventions and they were mostly descriptive reports. The lack of studies in this area had also thwarted a previous attempt at a systematic review [36]. Changing our review from a systematic review to a narrative synthesis enabled us to complete this first focused review of the topic [28] detailed eight items in their taxonomy of interventions for RCB as prioritisation, mentoring, leadership, facilitators, training, funding, networks and infrastructure. We conceptually modified these into four items based on the intervention themes we identified from our search. These are training workshops, postgraduate training, supportive collaborations and environmental enhancers. We would argue that all of Cooke et al.'s items could be viewed as a property or a subset within the four broad categories of interventions in this paper. We have made a clear distinction between short-term and long-term training interventions. The durations of the research training denote a different set of objectives, resource implications, and expected outcomes. Whereas clinicians may readily obtain leave to attend short-term training opportunities, they might find it difficult to participate in long-term training, where a long leave of absence from clinical work is required. Long-term research training is a sign of significant investment in research [47] and may well be approved for those

clinicians who show capability and where replacement clinicians are available to cover the clinical work. For the narrative synthesis, we identified factors that may support or hinder the success of research training, supportive collaborations and an enhancing environment. In addition, we identified properties of training workshops in LMIC and theorized on the contexts, possible properties and effect on outcomes. Four mid-range theories were developed and tested. These theories have been useful in developing a theoretical framework for the development of clinical research teams in LMIC. The strength of our review is that it has elements of both a systematic review and a narrative synthesis. The small number of studies proved a limitation in the exploration of intervention strategies in LMIC context and the progressive focusing of the review to cover only training workshops limited our discussion to that area. We developed a conceptual model of an RCB framework for clinicians in LMIC. The framework (Figure 2) encapsulates how the different interventions interact in building the research capacity of a team of clinicians. We contend that the success of a RCB programme for clinicians is dependent on the complete implementation of each component part. The longer postgraduate training (T2) for those clinicians designated to do research is important at the outset of RCB. Longer training has been shown to increase capacity and outcomes. The workshops act as "boosters" for knowledge, skills and attitudes and these can be numerous and blended in along the development pathway (T1). All the papers described interventions on teams and some discussed a team of researchers especially where there were international collaborations, consistent with Cooke et al.'s theory [28] that a 'designated research team approach' works better. The model reflects this and instead of calling it a team of clinicians, it is called a clinical research team (CRT) emphasising the point that the team will require research skills that clinicians may not possess. A hexagonal ball represents the CRT with each side denoting a single member of the team. Increasing numbers in the CRT would smooth the sides of the ball, making it easier for it to roll up the ramp. The ramp is the development pathway to increased capacity. The CRT ball may stop rolling forward or may roll backwards if the forces (in arrows) that

sustain a research team have not been applied at the right place or the right amount on the development pathway. Supportive collaborations and mentoring (T3) are critical in RCB of clinicians. Mentoring could be from numerous sources, both external and internal, with the latter preferable for improved access. Health research systems (T4) can be developed incrementally and build on previous efforts and may start with the establishment of dedicated research centres to assist clinicians. Maturing system-wide multi-layered health research system could be developed later. Policy makers and funders alike in LMIC can use this framework to guide investment decisions when they seek to create and support successful clinical research teams. As more resources are invested to improve research systems in LMIC, more research is needed into RCB interventions to identify how the various properties of those interventions work in the various contexts. Further synthesis is required of described interventions not covered in this review to identify factors and contexts that can be modified, to improve research outputs and outcomes by clinicians.

Conclusion

From limited research evidence of research capacity building programmes for clinicians in LMIC, a modified taxonomy of interventions was identified in training workshops, postgraduate training, supportive collaborations and environmental enhancers. Properties of these interventions were identified and four middle-range theories were generated for testing. These showed that postgraduate research training, research collaborations, mentoring and a maturing health research system were critical elements in training clinical research teams who have been given the mandate by their employers to perform research. A conceptual framework, derived from the theories and properties of interventions, may further the debate on RCB programmes and inform decision-making by development partners, research collaborators and country managers. The gaps in the literature and this review may also determine the direction of research into capacity building interventions in LMIC.
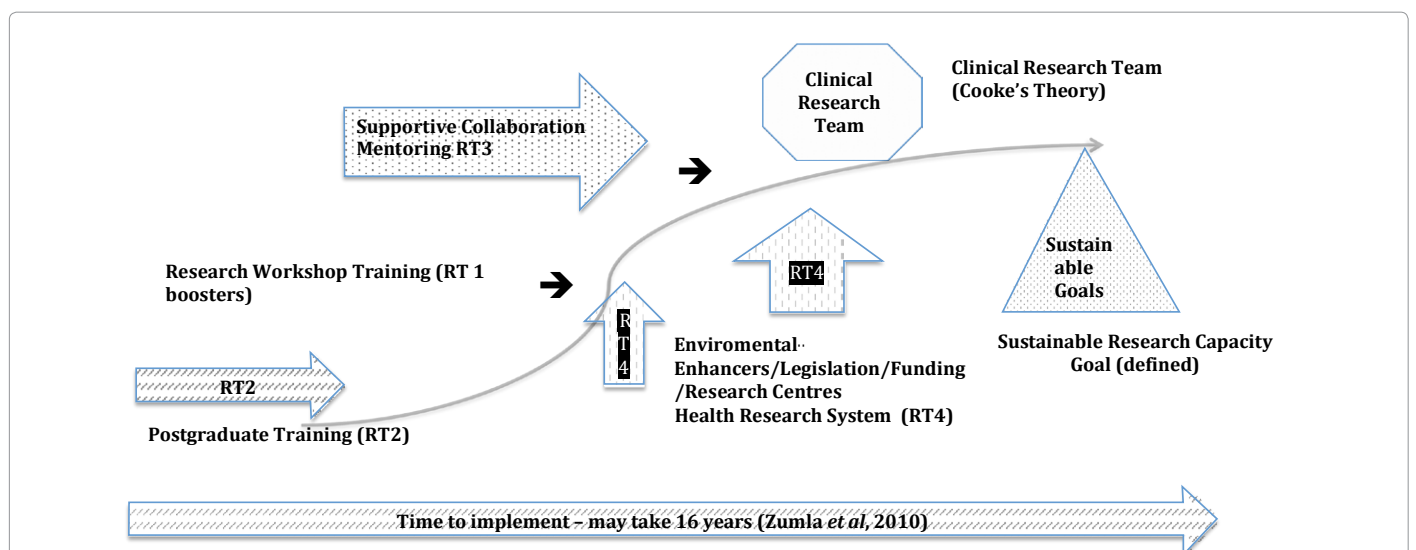

Figure 2: Theoretical Framework linking interventions to successful research capacity building for clinicians in low and middle income countries

Research workshops (Theory 1) and postgraduate training (Theory 2) are ineffective without the collaborations that provide support and mentoring (Theory 3) and enhancement of the research environment (Theory 4) both locally and nationally. A research team works better than individuals (Cookes et al. [71]) and is represented by a polygon, where the sides symbolize different research skills required by a research team. More skills and personnel on a team make the polygon smoother and easier to roll up the research capacity ramp. The size of the arrows represents the most likely effect size of the interventions. Failure of any of these intervention strategies before sustainability is achieved may result in research capacity sliding back to a prior level. It may take 16 years to reach sustainability (Zumla et al. [59]).

Authors' Contribution

AE participated in the conception, design and coordination of the review, performed the literature search, data collection, analysis and drafted the manuscript. TK participated in the design of the review, performed the literature search, conducted the review and helped to edit the manuscript. BS participated in the conception of the review assisted with review design and helped edit the manuscript. AH participated in the conception of the review, assisted with the review design and helped edit the manuscript. All authors read and approved the final manuscript.

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