

The Clinician Scientist: How Rehabilitation Fares — A Scoping Review

Inderjit Kaur^{1,*}, Xiao Xi Elsa Pang¹, Mindy Liang¹, Chi Xuan Zhang¹, Ashley Turgeon¹, Jessica Yeung¹, Dina Brooks^{1,2,3,4,5}, Julie Vaughan-Graham^{1,2}

¹School of Rehabilitation Science, McMaster University, Hamilton, Canada

²Department of Physical Therapy, University of Toronto, Toronto, Canada

³Rehabilitation Sciences Institute, University of Toronto, Toronto, Canada

⁴Department of Medicine, University of Toronto, Toronto, Canada

⁵West Park Healthcare Centre, Toronto, Canada

Email address:

kv.indrajit@gmail.com (I. Kaur), julie.vaughan.graham@utoronto.ca (J. Vaughan-Graham)

*Corresponding author

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Abstract: *Background:* Clinician scientists (CS) play a role in bridging the gap between research and practice. However, the role of a CS is less established for healthcare professionals in rehabilitation in comparison to medicine. *Objective:* The purpose of this scoping review was to explore different roles and models of a clinician scientist in rehabilitation and compare this to medicine and nursing. *Methods:* This review was structured according to the Arksey and O'Malley (2005) framework for scoping reviews. A literature search was conducted from the following databases: EMBASE, MEDLINE, AMED and Web of Science; a grey literature search was conducted from MacSphere, ProQuest, Duck DuckGo, and Google. *Results:* 95 articles met the inclusion criteria with 73 studies in medicine, including nursing, 10 articles from rehabilitation and 12 articles with mixed professions. The main barriers identified for rehabilitation involved time constraints and lack of funding for research, whereas primary facilitators included development of formalized training programs and presence of mentorship programs. *Conclusion:* The role of the clinician scientist is more established in medicine compared to rehabilitation. There is a need for an established career trajectory accompanied with training programs. Further studies are required to shape the role and development of secure funding models for CS positions.

Keywords: Clinician Scientist, Medicine, Rehabilitation, Role

1. Introduction

A clinician scientist (CS) is defined as a healthcare professional, with graduate training, who facilitates research within clinical practice, and simultaneously develops clinically relevant research questions [1, 2]. Within the healthcare field, the CS role is developed to facilitate the bi-directional transfer of knowledge between research and clinical practice [1, 3]; this is well established within medicine, hence is synonymous with the term physician scientist [1, 4]. As such, within the context of medicine, CSs play a vital role in developing translational research [1], ensuring clinical and

patient perspectives are integrated into the research agenda. Thus, bridging the gap between research and clinical practice is an essential role of a CS [1]. Within rehabilitation science, CSs may be physiotherapists (PT), occupational therapists (OT), speech language pathologists (SLP), audiologists, respiratory therapists (RT) or others [5]. However, the CS role in rehabilitation sciences is not well established [6].

The literature discusses several barriers for CSs [7, 8]. Specifically, in rehabilitation, identified barriers include the lack of a funding model, limited training available for CSs and the need to maintain competency in both clinical practice as well as in research [5, 7]. Developing the CS role in

rehabilitation is vital for knowledge translation between research and clinical practice, ensuring research is clinically relevant and in developing future leaders in the profession [1, 2].

The purpose of this scoping review was to explore the differing roles and models of CSs in medicine, nursing, and rehabilitation. The objectives were to describe the roles, barriers/facilitators, training/education models and funding to becoming a CS in rehabilitation or medicine. The scoping review process involves the analysis, synthesis, and reinterpretation of a broad range of evidence [9, 10], including different study designs and non-research articles to provide clarity on the breadth of the available evidence [11].

2. Methods

This scoping review was structured based on the framework outlined by Arksey and O'Malley [10] and updated by Levac, Colquhoun, and O'Brien [9], and addressed the following research question: *What is the role of a clinician scientist in rehabilitation compared to medicine and nursing?* The scoping review protocol was registered on the Open Sciences Framework - Centre for Open Science (OSF) Registries (DOI 10.17605/OSF.IO/U7KEH).

2.1. Systematic Search

Searches were conducted from inception of the database to February 2020 from the following electronic databases: EMBASE, MEDLINE, AMED and Web of Science. Boolean operators and truncations were used to ensure the appropriate breadth of publications were captured. Only English language literature, electronically accessible, were included. Inclusion of grey literature was ensured by accessing the databases MacSphere, ProQuest, DuckDuckGo, and Google. Searches were organized on Zotero. The following professions were used for the database searches, and adapted for the grey literature search: physician, doctor, nurse, physiotherapy, occupational therapy, speech language pathology, respiratory therapy, audiology, rehabilitation, and medicine. The terms used for CS included: rehabilitation scientist, rehabilitation researcher, physician scientist and physician researcher. A total of 20,231 studies were identified. 12,441 duplicates were excluded, with 7790 studies remaining [Appendix 1].

2.2. Selection of Publications

The iterative review process included two phases: (a) a title and abstract review of all 7790 studies; and (b) a full-text review of the 171 selected studies. The screening process was organized using the reference manager Covidence. For the purpose of this study a CS was defined as a professional in either medicine or rehabilitation science, with a dual role as a practicing clinician and researcher. Studies that explored CSs in the following professions were included: medicine/physician, nursing, physiotherapy, occupational therapy, audiology, speech language pathology and respiratory therapy. Extracted publications included those that

were specific to the role and responsibilities of a CS, identified barriers and facilitators to becoming a CS, or discussed the training and education involved for this role. Publications were excluded if the article did not specifically discuss the role of the CS, or if the manuscript focused solely on either research, education, or evidence-based practice. The first 10 articles' titles and abstracts were reviewed by the student research group with the supervisors together to develop agreement in the screening process. Any differences in article screening were discussed and resolved collectively amongst the research team. The remaining articles' titles and abstracts were reviewed in pairs. The full text articles were also reviewed in pairs for inclusion and a third reviewer resolved any disagreements. Conflicts between reviewers were resolved by consensus and the reasons for exclusion were recorded at the full-text stage. A total of 95 studies were selected for data extraction [Figure 1] [Appendix 2 – list of excluded publications].

2.3. Charting the Data

Full text extraction was completed individually, followed by review of the research team. Data were abstracted and summarized with respect to journal, country, author profession, healthcare group, healthcare setting/group, demographics, purpose of study, research design, main findings, CS term operationalized, specific roles and responsibilities, training and or education models, funding model, barriers and facilitators, implications of sex and applicability to rehabilitation [Appendix 3].

2.4. Collating, Summarizing, and Reporting the Results

The data were analyzed and synthesized, identifying the scope of the CS literature in rehabilitation science with respect to medicine and nursing, as well as knowledge gaps and issues that may be impacting upon the development of the CS role in rehabilitation. Specifically, the impact of education, training, and funding were considered, including a synthesis of the facilitators and barriers [Tables 1, 2, 3]. A descriptive numerical summary on the characteristics of the included studies was undertaken. Assessment of the quality of the included studies was beyond the scope of this review. The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist was utilized to ensure all components of a scoping review were included [Appendix 4].

3. Results

Of the 95 publications selected for review, 32 articles were published between 1976 - 2010 (62.5% (n=20) focused on medicine), and 63 articles were published between 2011 – 2020 (84.1% (n=53) focused on medicine). The majority of publications originated from North America (n=66), followed by Oceania (n=12), Europe (n=10), and Asia (n=6). Medicine formed almost three quarters of the publications (72%; n=68), whilst nursing and occupational therapy accounted for 5%

(n=5, each), physiotherapy 4% (n=5), and 14% (n=12) of the publications identified mixed groups as the profession of interest [Tables 1, 2, 3]. Of the 95 selected publications, 90

were from the peer-review literature and five were from the grey literature.

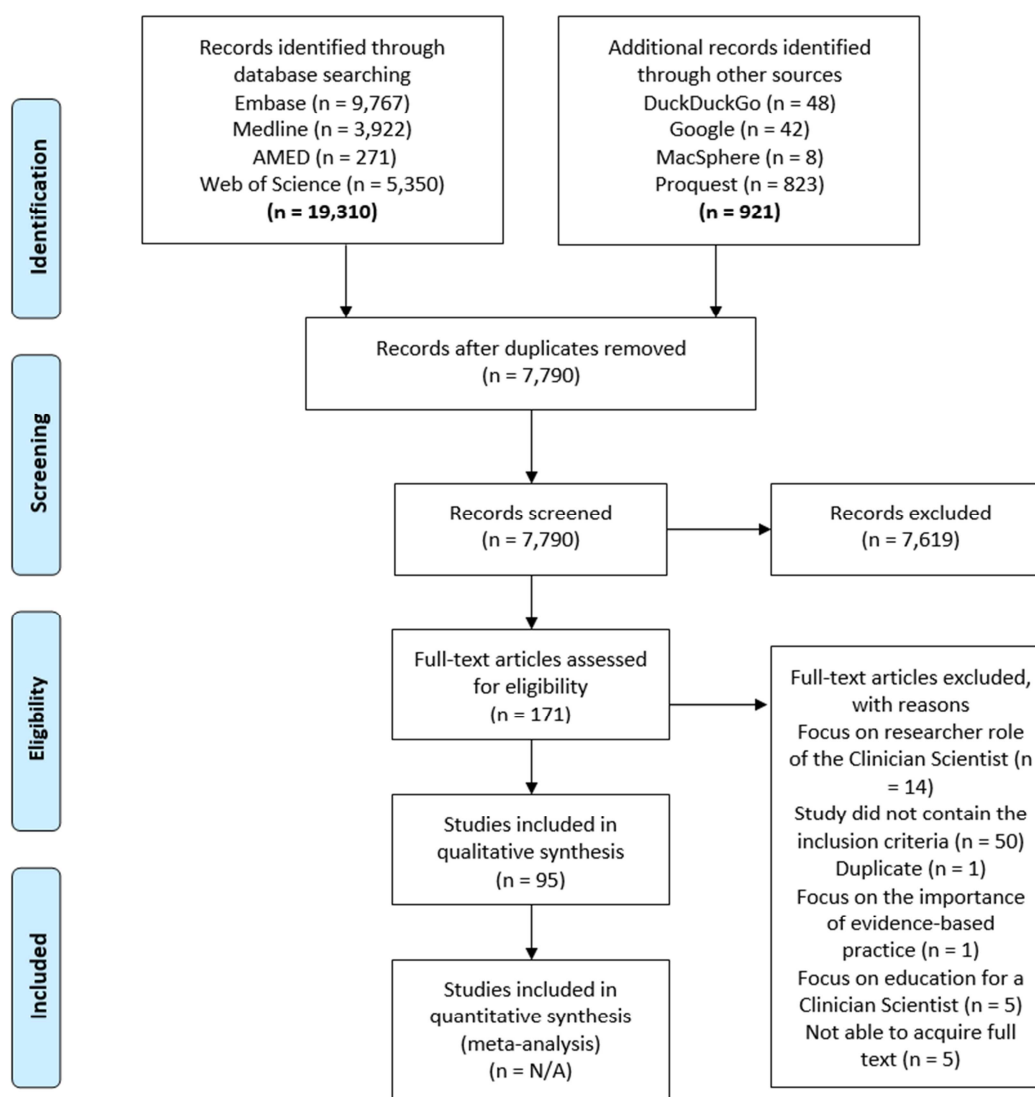


Figure 1. PRISMA flow chart for included and excluded studies.

3.1. Clinician Scientist Operationalized and Roles and Responsibilities

Thirty-six of the 68 medicine publications operationalized CS as individuals who have a MD or MD-PhD degree engaging simultaneously in clinical practice and research [Table 3]. Only three of the 10 rehabilitation publications defined the CS as individuals who provide direct patient care and conduct research. Forty-three publications discussed CS roles and responsibilities, including the development of clinically relevant research questions, promoting ‘bench-to-bedside’ care, and bridging the gap between research and clinical practice [Tables 1, 2, 3].

3.2. Barriers and Facilitators

Barriers and facilitators were discussed in only nine (9%)

rehabilitation-based publications, whereas 69 (73%) publications discussing these issues were related to medicine and nursing. The barriers and facilitators cited were synthesized and re-interpreted forming common themes including time constraints, financial barriers, funding, work life balance, career progression, mentorship, and administrative support [Tables 1, 2, 3]. Time constraints comprised of time management challenges of working in both clinical and research settings, as well as the time required for the education and training required for this role [Table 3: 83]. Additionally, the challenges identified related to work-life balance due to the academic and clinical demands faced by CSs [Table 3: 79] and the financial burden posed by tuition costs and low wages [Table 3: 46]. Funding barriers revolved around the competitive nature of research grants and time commitment associated with grant applications [Table 3: 49]. The lack of a clear career path results in limited opportunities

for CS career progression and advancement [Table 3: 44], which in turn impacts on mentorship and the lack of senior CSs to guide junior CS colleagues [Table 3: 46]. Administrative support represents an infrastructure requirement from organizations to foster an environment that supports the development of the CS role [Table 3: 90]. Sex differences was an unexpected theme, specifically in the medicine-related publications (n=20), in which six publications highlighted family responsibilities as a significant barrier experienced by females [Table 3: 88, 71, 57, 65, 81] [Table 2: 24]. None of the rehabilitation-related publications reported sex as a barrier. The most common barriers identified were time constraints, financial, securing research funding and the lack of mentorship. Specifically, for medicine, securing funding to conduct research (n=40, 51%) was identified as the primary barrier. Whereas for rehabilitation, time constraints (n=5, 55%) was the most common barrier.

Facilitators were discussed to a much lesser extent within the literature, with only three out of the 10 rehabilitation studies each discussing the themes of training (n=3, 30%), funding opportunities (n=3, 30%), as well as the presence of role models (n=3, 30%) as potential facilitators. However, in medicine, mentorship (n=23, 35%) was the primary facilitator.

3.3. Education and Training

Thirty-six publications presented training programs in medicine, however, none identified training programs for rehabilitation, two publications discussed CS education for nursing/midwifery and one for mixed professions [Table 2: 23, 24, 36]. Medicine identified a number of CS programs including combined MD-PHD programs, Medical Scientist Training Program, Clinical investigator Programs, Cloister Programs and The Vanderbilt Physician Scientist Development Programs [Table 3: 62, 46, 8, 60, 65]. For nursing, a Multimodal Program and a Nursing doctoral program were identified [Table 2: 23, 24]. Lastly, one program, Tomorrow's Research Cardiovascular Health Care Professional (TORCH) was mentioned for the mixed professions [Table 2: 36].

4. Discussion

The purpose of this scoping review was to explore the differing roles and models of CSs in medicine, nursing, and rehabilitation. Ninety-five publications were eligible for inclusion with the majority related to medicine. Barriers and facilitators to the CS role were primarily discussed in the medicine-related publications, whilst publications across all

professions discussed CS roles and responsibilities [7].

4.1. Emerging Role of the Clinician Scientist

It would appear that there is an increasing interest in the role of CSs in healthcare, particularly medicine, as the number of publications approximately doubled over the period 2011-2020 compared to the period 1976-2010, with publications from North America being the primary contributor. This suggests that the career choice of CS, or physician-scientist, is more developed within North America, and is possibly related to the emergence of 'evidence-based practice' from McMaster University in Ontario, Canada [101], now forming the basis for 'evidence-informed healthcare' worldwide [102, 103]. Not surprisingly, the medicine-related CS literature is more robust with respect to defining the CS role and responsibilities, however, there are similarities with the nursing and rehabilitation sciences literature. For example, encouraging review, integration, and application of research into clinical practice, initiating clinically relevant research questions, enabling clinical practice to inform research and, facilitating the integration of novel interventions into clinical practice [42, 3]. This review highlights that further development is required with respect to defining the role and responsibilities of CSs in the rehabilitation sciences.

4.2. Barriers and Facilitators

With respect to barriers and facilitators several themes were identified from the medicine-related publications including development of professional identity, training programs, research funding, dedicated research time, mentorship, and sex differences. Awareness and identity formation are considered essential aspects of a CS education/training pathway [66]. A curriculum that combines the values of both a clinician and researcher, fosters professional identity as a CS [66], thus providing CS as a legitimate career choice [75]. Likewise, the absence of a CS professional identity has been identified as a potential barrier limiting credentialing and its potential career pathway [66]. CSs in rehabilitation describe recognition from other researchers being key to developing credibility [18], and our study suggests that CS professional identity in the rehabilitation sciences has undergone limited development and is currently lacking this credibility. The medicine-related literature suggests that a well-developed training program, including a mentoring program and secure funding are integral to the development of the CS role and should inform and guide development for the CS role in rehabilitation.

Table 1. *Physiotherapy and Occupational Therapy.*

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Barriers	Facilitators
12	Ridgway et al., 2019		1) Time 2) Funding 3) Publishing 4) Training	1) Mentoring 2) Support - community 3) Personal characteristics 4) Training opportunities

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Barriers	Facilitators
13	Beamish et al., 2018	✓	5) Administrative support 6) Competency - writing a grant 7) Research partnerships 1) Funding 2) Competing priorities	5) Workplace support/culture 6) Funding opportunities 7) Networking 8) Role modeling 9) Research partnerships
3	Van Dijk et al., 2018	✓	1) Interpersonal barriers 2) Time 3) Clinical workload 4) Training	1) Role modeling 2) Training opportunities
14	Aljadi et al., 2013	✓	1) Time 2) Clinical workload 3) Access to resources	
15	Bernhardt et al., 2008		1) Time 2) Funding 3) Mentoring 4) Career security	
16	Atkinson et al., 2005	✓	1) Competency 2) Bias – between two roles	1) Personal characteristics 2) Defining research guidelines
17	Cusick et al., 2001	✓		1) Exposure to research 2) Role modeling - recognition 3) Role definition 4) Personal characteristics 5) Credibility - for the career 6) Networking
18	Cusick et al., 2000	✓		1) Support - OT's, administration 2) Access to tools 3) Mentoring 4) Funding opportunities 5) Research time 6) Incentives - research
19	Colborn et al., 1993			1) Exposure to research 2) Incentives - publication 3) Training opportunities 4) Funding - information 5) Mentoring
20	Hunter et al., 1976	✓	1) Time 2) Competency 3) Interest	

Table 2. Nursing and Mixed Professions.

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
Nursing						
21	Bookey-Bassett et al., 2019	✓			1. Funding – training, salary 2. Training - length 3. Role uncertainty 4. Mentoring 5. Gaining credibility	1. Support - academic, organizational 2. Exposure to research 3. Training programs - short time 4. Funding opportunities 5. Role definition 6. Incentives - publications
22	Smith et al., 2018	✓				
23	Fry et al., 2017		Multi-Modal program		1. Competency 2. Training 3. Funding 4. Research infrastructure 5. Communication networks	1. Exposure to research 2) Networking
24	Green et al., 2007	✓	Nursing doctoral program	1. Family responsibility 2. Child- bearing years conflict with time to advance career	1. Training 2. Competing priorities 3. Funding - salary, competition 4. Mentoring 5. Older age	1. Incentives - environment for critical thinking 2. Networking 3. Role definition

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
25	Fitzgerald et al., 2003	√	√		1. Research partnerships – building rapport 2. Competing priorities – communicating with 2 teams 3. Time	1. Communication 2. Collaborative team
Mixed Professions (MD/PhDs and surgeon-scientists, MD, nurse, neuroscientist, and exercise physiologist, nursing and midwives, rehabilitation, psychologist, physiotherapist, speech-language pathology, and occupational therapist and others)						
26	Monzer et al., 2019		Specialised Training Program with five 3-day courses on research skills		1. Competency 2. Communication networks 3. Mentoring	
27	Weggemans et al., 2019	√			1. Training - length 2. Funding - debt incurred during training, research 3. Competing priorities 4. Credibility - role	1. Credibility 2. Identity formation 3. Integration of knowledge
28	Kluijtmans et al., 2017				1. Career security 2. Research opportunities	
6	Harvey et al., 2016				1. Competency 2. Clinical workload 3. Research infrastructure 4. Communication networks 5. Interpersonal barriers 6. Training 7. Access to resources 8. Funding - for training 9. Time 10. Administrative support 11. Workplace culture	1. Personal characteristics 2. Support - colleagues, managers 3. Mentoring 4. Personal characteristics 5. Funding opportunities 6. Research time 7. Workplace culture 8. Research partnerships 9. Incentives - rewards system
29	Hay-Smith et al., 2016	√			1. Role uncertainty 2. Competing priorities 3. Bias - research	1. Role modeling - past experiences 2. Increased awareness of role
30	Sakushima et al., 2015	√		Post Graduate Research Training Program	1. Funding - grant support 2. Time 3. Mentoring	Mentoring
31	Hiscock et al., 2014			Lack of female mentors	1. Clinical workload 2. Time 3. Work-life balance 4. Research partnerships, infrastructure 5. Mentoring	1. Research time 2. Research infrastructure 3. Support - administrative 4. Funding opportunity 5. Mentoring
32	MacDonald et al., 2013	√			1. Time 2. Competing priorities	1. Research time 2. Funding opportunities 3. Research opportunities 4. Career responsibilities 5. Mentorship
33	Stevens et al., 2011	√				
34	Mackay et al., 2009	√			1. Training 2. Time 3. Funding - research infrastructure 4. Mentoring 5. Workplace culture - role promotion	
35	Yanos et al., 2006	√			1. Clinical workload - Internal conflict 2. Role uncertainty 3. Competing priorities	1. Exposure to research 2. Collaboration - 2 teams 3. Engage in quality clinical practice

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
36	Armstrong et al., 2004		TORCH - 2-year training program for health care professionals			

Table 3. Medicine (Physician).

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
Medicine						
37	Steinman et al., 2020		Physician Scientist Training Program		1. Mentoring 2. Workplace culture 3. Training programs 4. Time	Personal characteristics 1. Research time 2. Networking- experts 3. Interest 4. Research partnerships 5. Incentives - recognition, appreciation 6. Credibility 7. Goal setting 8. Support - organization 9. Workplace support/culture 10. Clear research guidelines 11. Career progression - self-development 12. Incentives - inspiration
38	Bartelink et al., 2019	√	MD-PHD Program		1. Time 2. Funding 3. Interest 4. Community/peer networking/support 5. Competing priorities 6. Interpersonal barriers 7. Competency	
39	Bensken et al., 2019	√			1. Funding 2. Mentorship 3. Training - for research programs 4. Clinical workload	
40	Ng et al., 2019	√		Discrimination	1. Training - poorly integrated 2. Role uncertainty - competency undefined	1. Tailored/research curriculum 2. Personal characteristics 3. Workplace support/culture 4. Mentoring
41	Sarma et al., 2019	√	MD-PHD Program		1. Training - exposure to research, time 2. Work-life balance	
42	Adufuye et al., 2018	√			1. Training - lack of career path and structures 2. Interest 3. Funding 4. Clinical workload - higher demand	
43	Alves et al., 2018	√			1. Funding 2. Clinical priorities 3. Time - for research 4. Administrative support 5. Career security - research duties undervalued	1. Mentorship 2. Collaboration 3. Networking 4. Goal setting - SMART goals
44	Anderson et al., 2018		BSc MD with BSc surgery course		1. Competing priorities 2. Competency 3. Career security 4. Funding 5. Training - length 6. Bias - negative perceptions	1. Interest 2. Incentives - additional qualifications 3. Career progression 4. Time - flexibility 5. Mentoring 6. Research culture.

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
45	Barton et al., 2018		MD training, leadership coaching program			Personal characteristics - leadership skills
46	Blish et al., 2018		Medical Scientist Training Program		1. Funding - for research 2. Training - length, program bias 3. Financial debt 4. Clinical workload	1. Mentoring 2. Increase MD-PhD enrollees - recruit underrepresented minorities 3. Training programs - shorten length
47	Basgoz et al., 2018	✓			Time	1. Research/clinical experience 2. Networking - conferences 3. Mentoring 4. Clear research guidelines
48	Burns et al., 2018		Pediatrician Scientist Training and Development Program			
49	Cox et al., 2018		MD-PHD program or Physician Scientist Training Program	Make up small portion of MD/PhD grads - less than 40% of students	1. Training - length 2. Research opportunities 3. Funding - high debt, competition 4. Competency 5. Mentoring 6. Time 7. Interest	1. Networking - between trainees and physician-scientists 2. Support - partner at home
50	Eley et al., 2018	✓	Clinician Scientist Track Model of Advanced Curriculum	Compensation inequalities	Training	
51	Hunt et al., 2018	✓				1. Fluency in clinical and research setting 2. Collaboration 1. Training programs - evaluate training models
52	Marbach et al., 2018	✓			1. Competing priorities 2. Competency 3. Funding - grants 4. Training	2. Support 3. Mentoring 4. Tailored curriculum 5. Mentorship 6. Funding opportunities 7. Career progression
53	Ommering et al., 2018	✓				1. Interest 2. Recognize talent 3. Motivation 4. Personal characteristics 5. Motivation 6. Positive beliefs
54	Skinnder et al., 2018	✓	MD-PHD Program	Less involved in research	1. Training 2. Gender differences 3. Funding - debt 4. Bias - research participation	1. Training programs - completion 2. Incentives - successful publications
55	Strong et al., 2018	✓	MD-PHD Program		1. Interest 2. Training - time/length 3. Funding 1. Clinical workloads 2. Time - research 3. Funding - loans, salary 4. Research infrastructure 5. Administrative support 6. Career uncertainty 7. Work-life balance	
56	Yoon et al., 2018	✓				Mentoring

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
57	Eley et al., 2017	✓	MD program with option to pursue research higher degrees	1. Family responsibilities 2. Age	1. Work-life balance 2. Funding 3. Training - during medical school 4. Role uncertainty - autonomy	Career progression - job prospects, professional advancement
58	Harding et al., 2017		Medical Scientist Training Program or MD-PHD training		1. Training - institutional priorities, acceptance, length 2. Funding - schooling, research, salary 3. Research opportunities - decreased grant application success	Training programs - MD-PhD training pipeline
59	Klimas et al., 2017	✓	Medicine Research Fellowship Program		Competing priorities	Training programs - mixture of guided and independent learning
60	Lingard et al., 2017	✓		Different mentorship expectations		1. Mentoring 2. Collaboration 3. Role/career definition/responsibilities 4. Funding opportunities - debt forgiveness 5. Professional/research skills development - management, grant writing
61	McKinney et al., 2017	✓			1. Training - time 2. Role Uncertainty 3. Funding - competition with full-time researchers, salaries 4. Research opportunities - promotion, tenure 5. Clinical workload 6. Career progression Funding Time	Support Networking Mentoring
62	Skinnyder et al., 2017	✓	MD-PHD program		Funding - salaries, research	Training programs - opportunity
63	Yin et al., 2017	✓				
64	DeLuca et al., 2016	✓	Clinician Scientist Training Program			Mentoring
65	Kosik et al., 2016	✓	Medical Scientist Training Program	1. Family responsibilities 2. High representation in literature		
66	Rosenblum et al., 2016	✓	Canadian Child Health Clinician Scientist Program		1. Role uncertainty - identity is threatened 2. Training 3. Competency 4. Mentoring - Lack of role models 5. Gaining credibility	1. Mentoring - role modeling 2. Identity formation 3. Training programs - opportunity 4. Support
67	Smeesters, 2015	✓			1. Interest - resistance to change 2. Funding - on healthcare system 3. Time 4. Training	
68	Abu-Zaid et al., 2014	✓	MD-PHD program	1. Cultural barriers 2. Childbearing years conflict with time to advance career	1. Work-life balance 2. Clinical workload 3. Interest - encouragement 4. Mentoring - Lack of role models, female mentors 5. Gender differences	

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
8	Ballios et al., 2014	√	MD-PHD training or Clinical Investigators Program		1. Clinical workload 2. Funding - grants, compensation 3. Work-life balance 4. Older age 5. Training 6. Time 7. Competing priorities - burnout	1. Mentoring 2. Interest 3. Lifestyle factors 4. Personal characteristics
69	Baumal et al., 2014	√	MD-PHD program		1. Publishing – speed in knowledge translation 2. Economic constraints 3. Funding 4. Competency - change in medical education 5. Training - length 6. Funding - salary	Training programs - shorter times
70	Bhat et al., 2014	√	Research track program	Childbearing years conflict with time to advance career	1. Training - during medical school 2. Funding - salary, debt 3. Time 4. Mentoring 5. Work-life balance	Mentoring Interests - priority lists Time - management
71	Cornfield et al., 2014	√		1. Greater numbers in pediatrics 2. Family responsibilities 3. Poor belief in their success 4. Compensation inequalities	Career uncertainty Mentoring	1. Funding opportunities - equitable compensation for women 2. Lifestyle factors - on-site childcare 3. Mentoring - Role modelling - female colleagues 4. Networking - residents
72	Girgis et al., 2013	√	MD-PHD program, Clinical Investigators Program		1. Time 2. Competency - advances in basic science 3. Training - length 4. Interest - clinical preference 5. Funding - grants, decreased pay	Career progression - benefits to patient care
73	Huang et al., 2013	√			1. Bias - perceived as a difficult role 2. Career uncertainty 3. Time - programs 4. Competing priorities	
74	Megyesi et al., 2013	√			1. Interpersonal barriers 2. Interest 3. Publishing 4. Training - research involvement 5. Mentorship 6. Funding - grant support 7. Competency 8. Bias - perceived lack of reward 9. Administrative support	
75	Atesok et al., 2012	√	MD training with 3-month research rotation		1. Interest 2. Training - priorities of the program 3. Funding 4. Mentorship	1. Exposure to research 2. Funding opportunities 3. Mentoring
76	Olivier Desplantie et al., 2012				1. Time 2. Funding – grants 3. Career security 4. Work-life balance	1. Mentoring – advice on grant application 2. Exposure to research 3. Research time 4. Work life balance

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
77	Roberts et al., 2012	✓	✓	NIH funded MD-PHD Programs	1. Funding - competition, student debt 2. Career progression 3. Competing priorities - balance, added workloads (teaching) 4. Training - length	1. Research infrastructure 2. Support 3. Collaboration
78	Yap et al., 2012	✓	✓	MD-PHD program	1. Time 2. Administrative support 3. Funding - grant proposals 4. Workplace culture - lack of supportive environment	1. Interest 2. Training programs - dual training 3. Incentives - clinical recognition 4. Funding- compensation 5. Research infrastructure 6. Work life balance 7. Personal characteristics - sustain criticism 8. Research culture
79	Huber-Lang et al., 2011		✓		Funding Work-life balance	1. Mentorship 2. Career satisfaction 3. Personal characteristics - self-esteem 4. Career progression 5. Work life balance
1	Lockyer et al., 2011	✓	✓	More males than females in training programs	1. Time - research 2. Research opportunities 3. Training - length, not defined 4. Competency 5. Mentoring 6. Research infrastructure 7. Funding - student loan, salary reduction and delay	1. Tailored/research curriculum 2. Funding opportunities - debt forgiveness, support 3. Training programs 4. Workplace support 5. Role definition
80	Rosen et al., 2011	✓	✓		1. Interest 2. Funding - conflict with scientists	1. Mentoring 2. Workplace support/culture 3. Career satisfaction 4. Personal characteristics 5. Organizational commitment 6. Career progression 7. Work life balance 8. Personal characteristics 9. Training programs 10. Access to tools
81	Rubio et al., 2011			1. Perceived gender bias 2. Lack of female mentors 3. Lack support from institution 4. Family responsibilities		
7	Lander et al., 2010		✓		1. Training - time/length 2. Funding - student loans 3. Research opportunities - competition with full-time scientists	
82	Armstrong et al., 2009	✓			1. Funding - grants, student debt 2. Research opportunities - shortened review cycles, competition 3. Bias - clinical scientist grant proposals 4. Training	Training programs

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
83	Bakken et al., 2009	√		High representation in literature	1. Time 2. Training 3. Funding – compensation 4. Administrative support 5. Clinical workload 6. Research infrastructure 7. Bias - community distrust	1. Career progression 2. Collaboration 3. Incentives - recognition 4. Funding opportunities - education 5. Support - community engagement
84	Donath et al., 2009				1. Economic constraints 2. Work-life balance 3. Role uncertainty 4. Funding	Mentoring Research time
85	Gorski et al., 2009	√			1. Research opportunities - competition for grants 2. Bias 3. Clinical workload 4. Training 5. Time - research 6. Funding - research	Funding opportunities - MD/PhD programs, grant support
86	Olumi et al., 2009		1-year course work, 2-year research in chosen field, 6-week medical grant writing course		1. Mentorship - lack of nurturing environments 2. Funding - educational debt, education 3. Clinical workload 4. Training - grant writing, skills 5. Interest	
87	Andriole et al., 2008	√	MD-PHD program	Make up small portion of MD/PhD grads - only 30%	1. Work-life balance 2. Interest 3. Training opportunities - competition, increased length	Increase MD-PhD enrollees - female students
88	Brown et al., 2008	√	The Vanderbilt Physician Scientist Development Program Hospitalist Academic Support Program	1. Family responsibilities 2. Perceived biases	Underrepresentation of minorities	Mentorship
89	Howell et al., 2008				1. Clinical workload 2. Time 3. Training 4. Competency	
90	Marks et al., 2007	√	√		1. Research infrastructure 2. Administrative support 3. Publishing competition 4. Funding - research programs	1. Teaching rounds 2. Mentoring 3. Role/career definition/responsibilities 4. Identity formation
91	Rosier et al., 2006				1. Training - institutional barriers 2. Funding - government 3. Clinical workload - increase clinical productivity 4. Time - research 5. Communication networks 6. Research infrastructure 7. Mentoring 8. Work-like balance 9. Research opportunities 10. Interest	1. Workplace support/culture 2. Research/clinical practice time 3. Collaboration 4. Interest 5. Research infrastructure 6. Funding opportunities 7. Mentoring - role modeling 8. Research partnerships
92	Bakken et al., 2005			Different mentorship expectations Make up small portion of MD/PhD grads - increased from 27% to 41% of students		Mentoring - Role modeling
93	Ley et al., 2005	√			Funding - debt for students, low wages	1. Established career 2. Funding opportunities - debt forgiveness, support

Reference Number	CS Operationalized	Roles and Responsibilities of a CS	Training Programs	Sex Differences	Barriers	Facilitators
94	Wang et al., 2005	✓			Role uncertainty - identity formation	1. Identity formation 2. Research partnerships 3. Types of research - development in specialties 4. Funding opportunities 5. Organizational history and vision 6. Workplace support/culture
95	Ahn et al., 2004	✓	MSPT or MD-PHD program		Interest - clinical practice	Mentoring - Role modeling
96	Henke et al., 2003					1. Mentoring 2. Positive beliefs - personal satisfaction
97	Faxon et al., 2002				1. Financial debt - from medical school 2. Training - length 3. Funding - greater salaries in private practice 4. Research infrastructure - costs 5. Mentoring	1. Clear research guidelines 2. Funding opportunities - ease student debt 3. Training programs - early career development 4. Mentoring
98	Guelich et al., 2002		Medical Scientist Training Program	Fewer interested in academic positions		
99	Moskowitz et al., 2001	✓	MD-PHD program		1. Training programs 2. Research opportunities 3. Interest	Incentives - encouragement
100	Garfinkel et al., 1989				1. Interest 2. Mentoring 3. Funding	Exposure to research - encouragement

4.3. Education Programs

Several CS training programs were identified within the medicine-related literature, but training was not discussed in the rehabilitation-related CS literature [65]. To our knowledge there are three Canadian universities offering dual masters and PhD five-year degree programs for physiotherapy and occupational therapy [104 – 107]. These programs provide the educational framework for entry to practice and entrance to the CS role, however, a clear CS career pathway is seriously lacking in rehabilitation science. The additional program time, of two years for these dual programs, is a potential barrier to enrolment compounded by the lack of a career pathway [105]. Considerations for a seamless pathway from education and credentialing to career pathway and progression is required for the CS role to develop further in both rehabilitation science and medicine.

4.4. Funding the CS Role

Currently funding for a CS role both in medicine and rehabilitation science is primarily the responsibility of the CS to secure research funds through funding agencies. Thus, a CS is not only developing their clinical practice whilst simultaneously developing and implementing clinically relevant research questions, but also securing ongoing funding

to support their research activities [75]. Although the literature is scarce on CS funding models there is a suggestion that using potential reserved institutional funding and administrative support is a potential approach to enable funding in research teams [12, 19, 20, 55, 91, 54]. To ensure the ongoing development of the CS role in rehabilitation science and medicine establishing secure funding sources are clearly critical. Likewise, allowing adequate time and resources for CSs to develop their clinical practice is necessary to the development of their role. CSs may require more time than their counterparts in this regard as they are also balancing research demands with clinical practice [39, 19]. From this perspective, CSs career progression maybe delayed as the majority of organizations rely on promotional models using clinical metrics [61, 81]. However, the medicine-related literature suggests that many CSs bias their workday towards clinical practice which is likely related to ensuring a consistent income or promotional opportunities, but maybe also due to personal bias towards clinical care [72, 20, 35, 85]. Thus, ensuring appropriate resources such that a CS can maintain and balance clinical practice with research enquiry is essential to the future development of the CS in rehabilitation science [12].

Mentorship opportunities were identified as a primary facilitator both in the medicine and rehabilitation-related literature. CS mentors are essential in fostering the

development of the CS profession [46], with networking, collaboration and research experience being critical features of this process [12, 66]. It is also suggested that CS mentors can assist in navigating the realm of research and clinical practice as well as the balance between personal life and career [12, 3, 18 – 20, 108].

Within the medicine CS literature, sex differences were an unanticipated but recurrent theme, with the discussion primarily focusing on the limited number of females choosing to pursue CS as a career path. Andriole et al. [87], Cox [49] and Ley et al. [93] reported that females make up a smaller proportion of MD-PhD graduates compared to their male counterparts, despite the increasing number of females entering medicine programs. Furthermore, compared to males, fewer female medical students expressed an interest in pursuing research and maintain this perspective by graduation [98]. Balancing family responsibilities along with a career was also cited as a possible reason for less females pursuing a CS career path [78, 88, 71, 57, 24, 65, 81], especially as simultaneously balancing a clinical and research role has previously been identified as a potential CS career barrier. Sex differences were not discussed in the rehabilitation CS literature, perhaps because the rehabilitation sciences are already female-dominated professions [109, 110].

4.5. Strengths and Limitations

This scoping review was the first of its kind to synthesize the available literature on the role of the clinician-scientist in medicine, nursing, and rehabilitation. This review included publications from peer-reviewed literature as well as grey literature. Literature searches, screening, and study selection were completed in duplicate to ensure all relevant publications were included.

Limitations of this study include the use of a relatively small number of databases. Furthermore, there is poor reproducibility of results from the grey literature due to the nature of grey literature searching, which varies by date, time, and location of the search. Additionally, publications that were screened and selected were restricted to English only. Finally, there was one publication that was not accessible at the time of this review, due to the COVID-19 pandemic

restricting access to in-person library resources.

4.6. Implications for Rehabilitation

This review synthesized the current available literature pertaining to the role and available models for the clinician-scientist in rehabilitation compared to medicine and nursing. Although there are a limited number of rehabilitation science/PhD training programs in Canada, there is a requirement for an established CS career path, recognition of the role, development of a rehab CS professional identity, and the development of a robust rehabilitation science CS mentoring program. Future studies should explore funding models and infrastructure requirements, such that a career path for a CS in rehabilitation science is both feasible and viable.

5. Conclusion

In conclusion, this scoping review was the first of its kind to synthesize the available evidence regarding the role of CSs in medicine, nursing and rehabilitation science and provides a foundation for further exploration of CSs in rehabilitation science. The findings of this scoping review highlight the disparities between the CS role in medicine and rehabilitation science and identify the significant barriers faced by those who currently choose this career path. This review highlights that consideration and integration of training programs, mentorship opportunities, as well as sustainable funding sources and infrastructure requirements are essential for the development of the CS role in rehabilitation science.

Declaration of Interest

The authors declare that they have no competing interests.

Acknowledgements

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Appendix

Appendix 1. Inclusion Criteria and Search Strategy

Research Question: What is the role of a clinician scientist in rehabilitation compared to medicine and nursing?

Table 4. Inclusion Criteria.

Participant	Studies that explored the role of a clinician scientist in the following professions: Medicine, Nursing, Rehabilitation. Studies that discussed barriers and facilitators to working as a clinician scientist. Studies that discussed training and education programs for clinician scientists.
Concept	The concept that will be studied in this scoping review will be the role of a clinician scientist in rehabilitation in comparison to medicine.
Context	The context of this review will include all publications across all health care settings.

Search Strategies

AMED <1985 to February 2020>

1. Physician. mp.

2. Doctor.mp.
3. Nurs*.mp.
4. Physiotherap*.mp
5. Occupational Therap*.mp.
6. Speech Language Patholog*.mp.
7. Respiratory Therap*".mp.
8. Audiolog*.mp.
9. Physical Therap*.mp.
- 10.Rehab*.mp.
- 11.Medicine.mp.
- 12.or/1-11
- 13.Clinic* Scientist.mp.
- 14.Clinic* Research*.mp.
- 15.Rehab* Scientist.mp.
- 16.Rehab* Research*.mp.
- 17.Physician Scientist.mp.
- 18.Physician Research*.mp.
- 19.or/13-18
- 20.Role.mp.
- 21.Scope.mp.
- 22.Model.mp.
- 23.or/20-22
- 24.12 and 19 and 23
- 25.Limit 24 to (English or French)

Embase 1974 to 2020 and OVID Medline Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) 1946 to Present

1. Physician m.p
2. Medicine m.p
3. Nurs* m.p
4. Doctor m.p
5. Physiotherap* m.p
6. "Physical therap*" m.p
7. "Occupational therap*" m.p
8. "Speech language patholog*" m.p
9. "Respiratory therap*" m.p
- 10.Audiolog* m.p
- 11.Rehab* m.p
- 12.or/ 1-11
- 13."Clinic* Research*" m.p
- 14."Clinic* Scientist" m.p
- 15."Physician scientist" m.p
- 16."Physician Research*" m.p
- 17."Rehab* scientist" m.p
- 18."Rehab* Research*" m.p
- 19.or/ 13-18
- 20.Scope m.p
- 21.Role m.p
- 22.Model m.p
- 23.or/ 20-22
- 24.12 AND 19 AND 23
- 25.limit 24 to (English or French)

Web of Science <1976 to February 2020>

1. TS=(Physician)
2. TS=(Doctor)
3. TS=(Nurs*)
4. TS=(Physiotherap*)
5. TS=("Occupational Therap*")

6. TS=("Speech Language Patholog*")
7. TS=("Respiratory Therap*")
8. TS=(Audiolog*)
9. TS=("Physical Therap*")
10. TS=(Rehab*)
11. TS=(Medicine)
12. OR/1-11
13. TOPIC: ("Clinician Scientist")
14. TOPIC: ("Clinician Researcher")
15. TOPIC: ("Rehab* Scientist")
16. TOPIC: ("Rehab* Researcher")
17. TOPIC: ("Physician Scientist")
18. TOPIC: ("Physician Researcher")
19. OR/13-18
20. TOPIC: (Role)
21. TOPIC: (Scope)
22. TOPIC: (Model)
23. OR/20-22
24. #12 AND #12 AND #23
25. #12 AND #12 AND #23 Refined by: LANGUAGES: (ENGLISH, FRENCH)

Appendix 2. List of Excluded Studies

Table 5. List of Excluded Studies

Study	Reason for Exclusion
Abouzahra, M. (2017). Exploring the Continuous Use of Knowledge-Based Clinical Decision Support Systems and Its Relationship with Knowledge Translation (Doctoral dissertation).	Study did not contain the inclusion criteria
Adams, J., Barratt, P., Bradley, S., Barbosa-Boucas, S., Lennie, K. H., White, P., & OTTER II Trial working group. (2017). FRI0767-HPR Participating in a musculoskeletal randomised controlled trial: identification of education training needs by occupational therapists and physiotherapists in the uk.	Study did not contain the inclusion criteria
Alamodi, A. A., Abu-Zaid, A., Anwer, L. A., Khan, T. A., Shareef, M. A., Shamia, A. A.,... & Chamseddin, R. A. (2014). Undergraduate research: an innovative student-centered committee from the Kingdom of Saudi Arabia. Medical Teacher, 36 (sup1), S36-S42.	Study did not contain the inclusion criteria
Baker, G. R. (1982). Collaboration and conflict: scientific change and the social structure of biomedical research. Ann Arbor University of Toronto (Dissertation).	Study did not contain the inclusion criteria
Balakas, K., Bryant, T., & Jamerson, P. (2011). Collaborative research partnerships in support of nursing excellence. Nursing Clinics, 46 (1), 123-128.	Focus on researcher role of the Clinician Scientist
Barton, M., & Schifffrin, E. L. (2014). In Memoriam: Wolfgang Kiowski, MD (1949–2012)-Pioneer in clinical endothelin research. Life sciences, 118 (2), 91-96.	Study did not contain the inclusion criteria
Berry, D. A. (2015). The brave new world of clinical cancer research: adaptive biomarker-driven trials integrating clinical practice with clinical research. Molecular oncology, 9 (5), 951-959.	Study did not contain the inclusion criteria
Boudoulas, H. (2006). The physician and the physician scientist. Hellenic Journal of Cardiology, (4): 251-2.	Study did not contain the inclusion criteria
Boyd, C. O. (1993). Toward a nursing practice research method. Advances in Nursing Science, 16 (2): 9-25.	Study did not contain the inclusion criteria
Boydell, K., Shaul, R. Z., D'Agincourt-Canning, L., Da Silva, M., Simpson, C., Czoli, C. D.,... & Schneider, R. (2012). Paediatric physician-researchers: coping with tensions in dual accountability. Narrative Inquiry in Bioethics, 2 (3), 213-221.	Study did not contain the inclusion criteria
Brand, R. A., Chaw, E. S., & Karam, M. D. (2003). The number and the scope of activity of orthopaedic clinician-scientists in the United States. JBJS, 85 (2), 374-379.	Study did not contain the inclusion criteria
Bristow, R. G. (2004). Recommendations for the future of translational radiobiology research: a Canadian perspective. Radiotherapy and oncology, 70 (2), 159-164.	Study did not contain the inclusion criteria
Brody, H., & Miller, F. G. (2003). The clinician-investigator: unavoidable but manageable tension. Kennedy Institute of Ethics Journal, 13 (4), 329-346.	Study did not contain the inclusion criteria
Bryce, J., Falanga, M., Catapano, M., Catania, G., Colussi, A., Connola, M., & Bell, C. (2008). ADVANCING THE PRACTICE OF CLINICAL RESEARCH NURSES: THE NURSE RESEARCHER ROLE.: 2888. In Oncology Nursing Forum, 35 (3): 523-523.	Focus on researcher role of the Clinician Scientist
Carmichael, S. T. (2012). Opinion & special articles: a guide from fellowship to faculty: Nietzsche and the academic neurologist. Neurology, 79 (14), e116-e119.	Focus on researcher role of the Clinician Scientist
Chambers, S. K. (1998). The gynecologic oncology model: Research. Surgical Oncology Clinics of North America, 7 (2): 255-62.	Study did not contain the inclusion criteria
Chute, P. (2013). Clinician-researcher collaborations: Strengthening clinical outcomes through science. ASHA Journals Academy, 1 (1).	Study did not contain the inclusion criteria
Cohen, H. S. (2015). A Career in Inquiry. American Journal of Occupational Therapy, 69 (6), 6906150010p1-6906150010p12.	Study did not contain the inclusion criteria

Study	Reason for Exclusion
Cohen-Mansfield, J., Werner, P., & Braun, J. (1994). Facilitating clinician-initiated research: a program of a research institute based in a nursing home. <i>Journal of applied gerontology</i> , 13 (4), 469-480.	Study did not contain the inclusion criteria
Colborne, A. P. (1992). Learning to combine practice and research: An emerging role in occupational therapy. Polytechnic Institute and State University (dissertation).	Duplicate Study
Cusick, A. T. (1997). Research by occupational therapy clinicians: A phenomenon of role change and diversity. Ann Arbor University of New South Wales (dissertation).	Not able to acquire full text
Czoli, C., Da Silva, M., Shaul, R. Z., d'Agincourt-Canning, L., Simpson, C., Boydell, K.,... & Vanin, S. (2011). Accountability and pediatric physician-researchers: are theoretical models compatible with Canadian lived experience?. <i>Philosophy, Ethics, and Humanities in Medicine</i> , 6 (1), 15.	Study did not contain the inclusion criteria
Darbyshire, P. (2008). Children's nurses' research involvement: making practice-focused research happen. <i>Journal of Clinical nursing</i> , 17 (23), 3238-3244.	Focus on researcher role of the Clinician Scientist
Datt, C. (2017). A Voice for Young People. <i>Nursing Children and Young People</i> .	Study did not contain the inclusion criteria
Delatycki, M. (2014). THE PHYSICIAN RESEARCHER-WHAT CAN BE DONE TO PREVENT THIS SPECIES BECOMING EXTINCT?. <i>Internal Medicine Journal</i> , 44.	Study did not contain the inclusion criteria
Donowitz, M., Germino, G., Cominelli, F., & Anderson, J. M. (2007). The attrition of young physician-scientists: problems and potential solutions. <i>Gastroenterology</i> , 132 (2), 477-480.	Study did not contain the inclusion criteria
Eberli, D., & Atala, A. (2009). Basic science research in urology training. <i>Indian Journal of Urology: IJU: Journal of the Urological Society of India</i> , 25 (2), 217.	Study did not contain the inclusion criteria
Elks, M. L. (1995). Conflict of interest and the physician-researcher. <i>The Journal of laboratory and clinical medicine</i> , 126 (1), 19.	Study did not contain the inclusion criteria
Ernest, M. L. (1972). The changing role of the occupational therapist. University of British Columbia (dissertation).	Study did not contain the inclusion criteria
Ewigman, B., Bland, C., Burge, S., Calmbach, W., Crabtree, B., ...deGury, F. (2002). What does it mean to build research capacity?. <i>Journal of Family Medicine</i> , 34 (9): 678.	Study did not contain the inclusion criteria
Feldman, A. M., Runge, M. S., Garcia, J. G., & Rubenstein, A. H. (2015). American medical education at a crossroads. <i>Science translational medicine</i> , 7 (285), 285fs17-285fs17.	Study did not contain the inclusion criteria
Finch, E., Cornwell, P., Ward, E. C., & McPhail, S. M. (2013). Factors influencing research engagement: research interest, confidence and experience in an Australian speech-language pathology workforce. <i>BMC Health Services Research</i> , 13 (1), 144.	Focus on the importance of evidence-based practice
Fournier, A. M. (1998). Resolving the conflicts between general and subspecialty medicine: the internist as consulting physician-scientist. <i>The American journal of medicine</i> , 104 (3), 259-263.	Study did not contain the inclusion criteria
Froberg, D. G., Holloway, R. L., & Bland, C. J. (1984). A continuity model for research consultation in family medicine. <i>The Journal of Family Practice</i> , 19 (2), 221-224.	Focus on researcher role of the Clinician Scientist
Glickman, R. M. (1985). The future of the physician scientist. Presidential address delivered before the 76th annual meeting of the American Society for Clinical Investigation, Washington, DC, 4 May 1985. <i>The Journal of Clinical Investigation</i> , 76 (4), 1293-1296.	Study did not contain the inclusion criteria
Glickman, R. M. (1999). Why the Physician-Scientist? Why the Association of American Physicians?. <i>Proceedings of the Association of American Physicians</i> , 111 (5), 463-466.	Study did not contain the inclusion criteria
Goldberg, C., & Insel, P. A. (2013). Preparing MD-PhD students for clinical rotations: navigating the interface between PhD and MD training. <i>Academic medicine: journal of the Association of American Medical Colleges</i> , 88 (6).	Focus on education for a Clinician Scientist
Goosby, E. P. (2012). Physician, researcher, and policy maker takes on HIV/AIDS. <i>Health Affairs</i> , 7 (1).	Study did not contain the inclusion criteria
Gotian, R., Raymore, J. C., Rhooms, S. K., Liberman, L., & Andersen, O. S. (2017). Gateways to the laboratory: How an MD-PhD program increased the number of minority physician-scientists. <i>Academic Medicine</i> , 92 (5), 628-634.	Study did not contain the inclusion criteria
Gotian, R. (2017). Optimizing success of physician-scientists. Columbia University (dissertation).	Focus on researcher role of the Clinician Scientist
Grochowski, C. O. C., Halperin, E. C., & Buckley, E. G. (2007). A curricular model for the training of physician scientists: The evolution of the Duke University School of Medicine curriculum. <i>Academic Medicine</i> , 82 (4), 375-382.	Focus on education for a Clinician Scientist
Hayes. (1992). B. S. v.s. M. S. prepared physical therapists: Differences in perceived educational preparation and professional value. Ann Arbor University of Miami (dissertation).	Study did not contain the inclusion criteria
Holliday, E., Griffith, K. A., De Castro, R., Stewart, A., Ubel, P., & Jagsi, R. (2015). Gender differences in resources and negotiation among highly motivated physician-scientists. <i>Journal of general internal medicine</i> , 30 (4), 401-407.	Study did not contain the inclusion criteria
Hosie, A., Fazekas, B., Shelby-James, T., Mills, E., Byfield, N., Margitanovic, V.,... & Phillips, J. (2011). Palliative care clinical trials: how nurses are contributing to integrated, evidence-based care. <i>International journal of palliative nursing</i> , 17 (5), 224-230.	Study did not contain the inclusion criteria
Hostetter, M. K. (2002). Career development for physician-scientists: the model of the Pediatric Scientist Development Program. <i>The Journal of pediatrics</i> , 140 (2), 143-144.	Focus on education for a Clinician Scientist
Itlis, A. S. (2005). Timing invitations to participate in clinical research: preliminary versus informed consent. <i>The Journal of medicine and philosophy</i> , 30 (1), 89-106.	Study did not contain the inclusion criteria
Inness, E. L., Bayley, M., Biasin, L., Brunton, K., Danells, C. J., Mansfield, A.,... & Zee, J. (2017). Fostering Clinical-Research Partnerships to Advance Physiotherapy Practice: The Role of an Innovative Neuro-Rehabilitation Clinic.	Study did not contain the inclusion criteria
Inness, E. L., Bayley, M., Biasin, L., Brunton, K., Danells, C. J., Mansfield, A.,... & Zee, J. (2017). Promoting clinical research partnerships to advance the practice of physiotherapy: the role of an innovative neurorehabilitation clinic. <i>PHYSIOTHERAPY CANADA</i> , 69 (3), 190-192.	Study did not contain the inclusion criteria
Jolly, S., Griffith, K. A., DeCastro, R., Stewart, A., Ubel, P., & Jagsi, R. (2014). Gender differences in time spent on parenting and domestic responsibilities by high-achieving young physician-researchers. <i>Annals of internal medicine</i> , 160 (5), 344-353.	Study did not contain the inclusion criteria
Kennedy, P. G. (2015). My life as a clinician-scientist: trying to bridge the perceived gap between medicine and science. <i>DNA</i>	Focus on researcher role

Study	Reason for Exclusion
and cell biology, 34 (6), 383-390.	of the Clinician Scientist
Kisely, S. (2015). Can the next generation of clinician-scientists please step forward?.	Study did not contain the inclusion criteria
Kurowski, B., Ahmad, A., Colyer, J., Dennison, A. (2015). Advice for Developing a Successful Path as a Clinician Researcher. American Congress of Rehabilitation Medicine.	Study did not contain the inclusion criteria
Lawson McLean, A., Saunders, C., Velu, P. P., Iredale, J., Hor, K., & Russell, C. D. (2013). Twelve tips for teachers to encourage student engagement in academic medicine. Medical Teacher, 35 (7), 549-554.	Study did not contain the inclusion criteria
Ledley, F. D., & Lovejoy Jr, F. H. (1992). Prospects for academically trained pediatricians in academic medicine. Clinical and Investigative medicine. Medecine Clinique et Experimentale, 15 (6), 518-526.	Focus on researcher role of the Clinician Scientist
Lefkowitz, R. J. (2018). A serendipitous scientist. Annual review of pharmacology and toxicology, 58, 17-32.	Study did not contain the inclusion criteria
Lemoine, N. R. (2008). The clinician-scientist: a rare breed under threat in a hostile environment. DOI: 10.1242/dmm.000752	Study did not contain the inclusion criteria
Levine, R. J. (1992). Clinical trials and physicians as double agents. The Yale journal of biology and medicine, 65 (2), 65.	Focus on researcher role of the Clinician Scientist
Linder, S., Blum, D., Oberholzer, R., Widmer, C., & Strasser, F. (2010). Two Roles in the Same Soul: Being Both Clinical Researcher and Specialist Palliative Care (PC) Professional (Nurse/Doctor): Abstract number: 705 Poster number: P276. Palliative Medicine, 24.	Study did not contain the inclusion criteria
March, J. D. (2014). Training of cardiovascular physician-scientists: Results of specific training pathways. Cardiology, 128: 112-112.	Study did not contain the inclusion criteria
McGee, J. (2013). Educating Future Clinical Research Investigators: An 8-Week Clinical Research Education Course for Neurology Residents. AT Still University of Health Sciences.	Focus on researcher role of the Clinician Scientist
Neilson, E. G. (2003). The role of medical school admissions committees in the decline of physician-scientists. The Journal of clinical investigation, 111 (6), 765-767.	Study did not contain the inclusion criteria
Nilsagård, Y., Westerdahl, E., & Forsberg, A. (2019). Engagement in performing clinical physiotherapy research: Perspectives from leaders and physiotherapists. Physiotherapy Research International, 24 (2), e1767.	Focus on researcher role of the Clinician Scientist
Noble, C., Billett, S. R., Phang, D. T., Sharma, S., Hashem, F., & Rogers, G. D. (2018). Supporting resident research learning in the workplace: a rapid realist review. Academic Medicine, 93 (11), 1732-1740.	Focus on researcher role of the Clinician Scientist
Pangerčić, A., Sambunjak, D., Hren, D., Marušić, M., & Marušić, A. (2010). Climate for career choices: survey of medical students' motivation for studying, career preferences and perception of their teachers as role models. Wiener klinische Wochenschrift, 122 (7-8), 243-250.	Study did not contain the inclusion criteria
Peters, M. D., & McLean, A. (1995). The evolution of the clinician-scientist model of neurological rehabilitation. Brain injury, 9 (6), 543-552.	Study did not contain the inclusion criteria
Posporelis, S., Sawa, A., Smith, G. S., Stitzer, M. L., Lyketsos, C. G., & Chisolm, M. S. (2014). Promoting careers in academic research to psychiatry residents. Academic Psychiatry, 38 (2), 185-190.	Focus on researcher role of the Clinician Scientist
Rosengart, T. K., Mason, M. C., LeMaire, S. A., Brandt, M. L., Coselli, J. S., Curley, S. A.,... & Berger, D. A. (2017). The seven attributes of the academic surgeon: critical aspects of the archetype and contributions to the surgical community. The American Journal of Surgery, 214 (2), 165-179.	Study did not contain the inclusion criteria
Sakamoto, K. M., Dipple, K. M. (2009). Becoming a woman physician scientist. Academic Medicine, 84 (7): 817.	Study did not contain the inclusion criteria
Soffer, E., & Hoots, W. K. (2018). Challenges facing the benign hematology physician-scientist workforce: identifying issues of recruitment and retention. Blood advances, 2 (3), 308-308.	Study did not contain the inclusion criteria
Steck, A. J. (2008). The clinician-scientist in neurology. Schweizer Archiv für Neurologie und Psychiatrie, 159 (2): 90-5.	Study did not contain the inclusion criteria
Stefely, J. A., Theisen, E., Hanewall, C., Scholl, L., Burkard, M. E., Huttenlocher, A., & John-Paul, J. Y. (2019). A physician-scientist preceptorship in clinical and translational research enhances training and mentorship. BMC medical education, 19 (1), 1-11.	Focus on education for a Clinician Scientist
Stiller, K., & Haensel, N. (2016). An Initiative to Build Research Capacity within a Physiotherapy Department: Hits and Misses Over a 20-year Period. Internet Journal of Allied Health Sciences and Practice, 14 (4), 1.	Focus on researcher role of the Clinician Scientist
Strong, E. A., De Castro, R., Sambuco, D., Stewart, A., Ubel, P. A., Griffith, K. A., & Jagsi, R. (2013). Work-life balance in academic medicine: Narratives of physician-researchers and their mentors. Journal of general internal medicine, 28 (12), 1596-1603.	Study did not contain the inclusion criteria
Whyte, J., Boninger, M., Helkowski, W., & Braddom-Ritzler, C. (2009). The rehabilitation medicine scientist training program: Impact and lessons learned. American journal of physical medicine & rehabilitation/Association of Academic Physiatrists, 88 (3), 169.	Focus on education for a Clinician Scientist
Yin, C., Blom, J. N., & Lewis, J. F. (2018). The 2nd Annual Clinical Scientist Trainee Symposium, August 22, 2017, London, Canada. Clinical and Investigative Medicine, E34-E36.	Study did not contain the inclusion criteria

Appendix 3. Data Extraction Table

Table 6. Data Extraction Table.

Reference
Author/Title (Journal, country of Publication, author details (profession))
Health Care Group (Health Care Setting/Group Demographics)
Description of Study (Purpose of article/study, research design, main finding of study/article)
Themes Identified in Study

Reference
Clinician Scientist Operationalized (Specific Roles or Responsibilities of the Clinician Scientist)
Training/Education Model
Funding Models
Barriers
Facilitators
Gender/Sex Differences
Applicability to Rehabilitation

Appendix 4. Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) Checklist

Table 7. PRISMA-ScR Check List.

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	Page 1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	Page 1-2
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	Page 1
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	Page 2
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	Page 2
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	Page 2
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix 1
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	Page 2
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	Page 2
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Page 2
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	N/A
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	Page 2
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	Page 2
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	Page 2 – 4
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Tables 1, 2, 3
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Page 2 – 4
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	Page 4, 5, 13, 14
Limitations	20	Discuss the limitations of the scoping review process.	Page 14
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	Page 14

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
FUNDING	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Page 14

JB=Joanna Briggs Institute; PRISMA-ScR=Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

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References

- [1] Lockyer JM, Brzezina S, Thake J, Beck PL, Hollenberg MD, Hemmelgarn B, Taber S, Harris KA, Gorman L, Strong M. Clinician scientists in Canada: supporting innovations in patient care through research. Royal College of Physicians and Surgeons of Canada=Collège royal des médecins et chirurgiens du Canada; 2016.
- [2] Wojkowski S, Unger J, McCaughan M, Cole B, Kho ME. Development, Implementation, and Outcomes of an Acute Care Clinician Scientist Clinical Placement: Case Report. *Physiotherapy Canada*. 2017; 69 (4): 318-22.
- [3] Van Dijk EE, Kluijtmans M, Vulperhorst JP, Akkerman SF. Disseminated learning from clinician-scientists: a multiple case study in physiotherapeutic care. *BMC medical education*. 2018 Dec; 18 (1): 1-9.
- [4] Peters MD, McLean A. The evolution of the clinician-scientist model of neurological rehabilitation. *Brain injury*. 1995 Jan 1; 9 (6): 543-52.
- [5] Morel PA, Ross G. The physician scientist: balancing clinical and research duties. *Nature immunology*. 2014 Dec; 15 (12): 1092-4.
- [6] Harvey D, Plummer D, Nielsen I, Adams R, Pain T. Becoming a clinician researcher in allied health. *Australian Health Review*. 2016 Oct 31; 40 (5): 562-9.
- [7] Lander B, Hanley GE, Atkinson-Grosjean J. Clinician-scientists in Canada: barriers to career entry and progress. *PLoS one*. 2010 Oct 4; 5 (10): e13168.
- [8] Ballios BG, Rosenblum ND. Challenges facing physician scientist trainees: a survey of trainees in Canada's largest undergraduate and postgraduate programs in a single centre. *Clinical and Investigative Medicine*. 2014 Oct 4: E268-83.
- [9] Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implementation science*. 2010 Dec; 5 (1): 1-9.
- [10] Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int. J. Soc. Res. Methodol*. 2005; 8 (1), 19-32.
- [11] Davis K, Drey N, Gould D. What are scoping studies? A review of the nursing literature. *International journal of nursing studies*. 2009 Oct 1; 46 (10): 1386-400.
- [12] Ridgway E, Terilli C, Conly T, Hunt J, Kelly D, Schaaf R. Exploring the Journey of Clinician-to-Clinician Researcher. *American Journal of Occupational Therapy*. 2019 Aug 1; 73 (4_Supplement_1): 7311505072p1-.
- [13] Beamish N. [Internet]. Canada: Physiospot – Physiotherapy and Physical Therapy in the Spotlight; 2018 [June 10, 2020]. Available from: <https://www.physiospot.com/physiopedia/clinician-scientist-spotlight-a-qa-with-dr-jenna-smith-turchyn/>
- [14] Aljadi SH, Alrowayeh HN, Alotaibi NM, Taaqi MM, Alquraini H, Alshatti TA. Research amongst physical therapists in the state of Kuwait: participation, perception, attitude, and barriers. *Medical Principles and Practice*. 2013; 22 (6): 561-6.
- [15] Bernhardt J, Shyn-Li LT. More options and better job security required in career paths of physiotherapist researchers: an observational study. *Australian Journal of Physiotherapy*. 2008 Jan 1; 54 (2): 135-40.
- [16] Atkinson JC. Ethical issues as an occupational therapist and epidemiological researcher. *British Journal of Occupational Therapy*. 2005 May; 68 (5): 235-7.
- [17] Cusick A. The experience of clinician-researchers in occupational therapy. *American Journal of Occupational Therapy*. 2001 Jan 1; 55 (1): 9-18.
- [18] Cusick A. Practitioner-researchers in occupational therapy. *Australian Occupational Therapy Journal*. 2000 Mar; 47 (1): 11-27.
- [19] Colborn AP. Combining practice and research. *American Journal of Occupational Therapy*. 1993 Aug 1; 47 (8): 693-703.
- [20] Hunter JE. Research and occupational therapy. *Canadian Journal of Occupational Therapy*. 1976 Sep; 43 (3): 121-5.
- [21] Bookey-Bassett S, Bianchi A, Richards J, Kelly H. Overcoming Challenges to Support Clinician-Scientist Roles in Canadian Academic Health Sciences Centres. *Healthcare quarterly (Toronto, Ont.)*. 2019 Apr 1; 22 (1): 60-6.
- [22] Smith S, Gullick J, Ballard J, Perry L. Clinician researcher career pathway for registered nurses and midwives: A proposal. *International journal of nursing practice*. 2018 Jun; 24 (3): e12640.
- [23] Fry M, Dombkins A. Interventions to support and develop clinician-researcher leadership in one health district. *International journal of health care quality assurance*. 2017 Aug 14.

- [24] Green TL, Tranmer J. Barriers and supports for development of a clinician scientist role in cerebrovascular nursing: A position paper. *Nurs Leadersh*. 2007; 20 (2): 69-79.
- [25] Fitzgerald M, Milberger P, Tomlinson PS, Peden-Mcalpine C, Meiers SJ, Sherman S. Clinical nurse specialist participation on a collaborative research project: barriers and benefits. *Clinical Nurse Specialist*. 2003 Jan 1; 17 (1): 44-9.
- [26] Monzer N, Herzog W, Löwe B, Zipfel S, Henningsen P, Rose M, Lehmann M. Reviving the Clinician Scientist: A Best Practice Model. *Psychotherapy and psychosomatics*. 2019 Apr 1; 88 (2): 114-6.
- [27] Weggemans MM, Friesen F, Kluijtmans M, Prakken B, Ten Cate O, Woods NN, Rosenblum ND. Critical Gaps in Understanding the Clinician–Scientist Workforce: Results of an International Expert Meeting. *Academic Medicine*. 2019 Oct 1; 94 (10): 1448-54.
- [28] Kluijtmans M, De Haan E, Akkerman S, Van Tartwijk J. Professional identity in clinician-scientists: brokers between care and science. *Medical education*. 2017 Jun; 51 (6): 645-55.
- [29] Hay-Smith EJ, Brown M, Anderson L, Treharne GJ. Once a clinician, always a clinician: a systematic review to develop a typology of clinician-researcher dual-role experiences in health research with patient-participants. *BMC medical research methodology*. 2016 Dec; 16 (1): 1-7.
- [30] Sakushima K, Mishina H, Fukuhara S, Sada K, Koizumi J, Sugioka T, Kobayashi N, Nishimura M, Mori J, Makino H, Feldman MD. Mentoring the next generation of physician-scientists in Japan: a cross-sectional survey of mentees in six academics medical centers. *BMC medical education*. 2015 Dec; 15 (1): 1-7.
- [31] Hiscock H, Ledgerwood K, Danchin M, Ekinci E, Johnson E, Wilson A. Clinical research potential in Victorian hospitals: the Victorian clinician researcher needs analysis survey. *Internal medicine journal*. 2014 May; 44 (5): 477-82.
- [32] MacDonald SE, Sharpe HM, Shikako-Thomas K, Larsen B, MacKay L. Perspective: Entering uncharted waters: Navigating the transition from trainee to career for the nonphysician clinician–scientist. *Academic Medicine*. 2013 Jan 1; 88 (1): 61-6.
- [33] Stevens B, Burrows G, Keatings M, Atkinson S, Riahi S, Mabbott D, Gordon K. Health Clinician-Scientist in Academic Health Centres: Protecting an Endangered Species: A National Symposium; Toronto, Ontario. 2010.
- [34] Mackay M. Why nursing has not embraced the clinician–scientist role. *Nursing Philosophy*. 2009 Oct; 10 (4): 287-96.
- [35] Yanos PT, Ziedonis DM. The patient-oriented clinician-researcher: advantages and challenges of being a double agent. *Psychiatric services*. 2006 Feb; 57 (2): 249-53.
- [36] Armstrong PW, Ezekowitz C, Michelakis E, Anderson T, Archer S, Ghali W, Hayward R, Jensen L, Lopaschuk G, Sheldon R. Innovative strategic canadian research training from tomorrow's Research Cardiovascular Health Care Professionals (TORCH). *Clinical and investigative medicine*. 2004 Feb 1; 27 (1): 33-41.
- [37] Steinman RA, Proulx CN, Levine AS. The highly structured Physician Scientist Training Program (PSTP) for medical students at the University of Pittsburgh. *Academic Medicine*. 2020 Sep; 95 (9): 1373.
- [38] Bartelink ML, Baggen Y, Stevens DE, Smalbrugge M, Scherpbier N, Damoiseaux RA, de Groot E. Facilitators and barriers to brokering between research and care by senior clinical scientists in general practice and elderly care medicine. *Education for Primary Care*. 2019 Mar 4; 30 (2): 80-7.
- [39] Bensken WP, Nath A, Heiss JD, Khan OI. Future Directions of Training Physician–Scientists: Reimagining and Remeasuring the Workforce. *Academic medicine: journal of the Association of American Medical Colleges*. 2019 May; 94 (5): 659.
- [40] Ng E, Jones AA, Sivapragasam M, Nath S, Mak LE, Rosenblum ND. The Integration of Clinical and Research Training: How and Why MD–PhD Programs Work. *Academic Medicine*. 2019 May 1; 94 (5): 664-70.
- [41] Sarma GP, Levey A, Faundez V. Re-examining physician-scientist training through the prism of the discovery-invention cycle. *F1000Research*. 2019; 8.
- [42] Adefuye AO, Adeola HA, Bezuidenhout J. The physician-scientists: rare species in Africa. *The Pan African Medical Journal*. 2018; 29.
- [43] Alves C. Research methodology: how to maximize your research potential. *EFORT open reviews*. 2018 May; 3 (5): 184-91.
- [44] Anderson EM, Johnston K, Gunnarsson R, Larkins S. Perceptions of a research honours programme embedded in a Bachelor of Medicine, Bachelor of Surgery degree: "The worst and best years of my life". *Focus on Health Professional Education: A Multi-disciplinary Journal*. 2018 Jan; 19 (1): 1-1.
- [45] Barton KI, Capozzi LC, Aker G, Yipp BG, Hollenberg MD, Rabi DM, Beck PL. The need for an executive leadership curriculum in scientist-clinician training programs. *Clinical and Investigative Medicine*. 2018 Sep 30; 41 (3): E144-7.
- [46] Blish CA. Maintaining a robust pipeline of future physician-scientists. *The Journal of infectious diseases*. 2018 Aug 14; 218 (suppl_1): S40-3.
- [47] Basgoz N. Supporting the Physician-Scientist in Clinical Practice in Infectious Diseases. *The Journal of infectious diseases*. 2018 Aug 14; 218 (suppl_1): S28-31.
- [48] Burns AM, Thammasitboon S, Turner TL, Ward MA, Orange JS. Implementation of a Novel Curriculum and Conceptual Framework for Pediatrician-Scientist Development. *Academic Pediatrics*. 2018 Jul 1; 18 (5): e27-8.
- [49] Cox AL. Balancing research, teaching, clinical care, and family: can physician-scientists have it all? *The Journal of infectious diseases*. 2018 Aug 14; 218 (suppl_1): S32-5.
- [50] Eley DS. The clinician-scientist track: an approach addressing Australia's need for a pathway to train its future clinical academic workforce. *BMC medical education*. 2018 Dec; 18 (1): 1-9.
- [51] Hunt PW. The Clinical-Translational Physician-Scientist: Translating Bedside to Bench. *The Journal of infectious diseases*. 2018 Aug 14; 218 (suppl_1): S12-5.
- [52] Marbach JA, Almufleh A, Froeschl M, Hibbert B. The next generation of physician-scientists: adapting to academic cardiology in the 21st century. *Canadian Journal of Cardiology*. 2018 Sep 1; 34 (9): 1225-8.

- [53] Ommering BW, van Blankenstein FM, Waaijer CJ, Dekker FW. Future physician-scientists: could we catch them young? Factors influencing intrinsic and extrinsic motivation for research among first-year medical students. *Perspectives on medical education*. 2018 Aug; 7 (4): 248-55.
- [54] Skinnider MA, Twa DD, Squair JW, Rosenblum ND, Lukac CD, Canadian MD/PhD Program Investigation Group. Predictors of sustained research involvement among MD/PhD programme graduates. *Medical education*. 2018 May; 52 (5): 536-45.
- [55] Strong MJ, Busing N, Goosney DL, Harris KA, Horsley T, Kuzyk A, Lingard L, Norman WV, Rosenblum ND, Saryeddine T, Wang X. The rising challenge of training physician-scientists: recommendations from a Canadian national consensus conference. *Academic Medicine*. 2018 Feb 1; 93 (2): 172-8.
- [56] Yoon S, Koh WP, Ong ME, Thumboo J. Factors influencing career progress for early-stage clinician-scientists in emerging Asian academic medical centres: a qualitative study in Singapore. *BMJ Open*. 2018; 8 (3).
- [57] Eley DS, Jensen C, Thomas R, Benham H. What will it take? Pathways, time, and funding: Australian medical students' perspective on clinician-scientist training. *BMC medical education*. 2017 Dec; 17 (1): 1-9.
- [58] Harding CV, Akabas MH, Andersen OS. History and outcomes of fifty years of physician-scientist training in medical scientist training programs. *Academic medicine: journal of the Association of American Medical Colleges*. 2017 Oct; 92 (10): 1390.
- [59] Klimas J, McNeil R, Ahamad K, Mead A, Rieb L, Cullen W, Wood E, Small W. Two birds with one stone: experiences of combining clinical and research training in addiction medicine. *BMC medical education*. 2017 Dec; 17 (1): 1-8.
- [60] Lingard L, Zhang P, Strong M, Steele M, Yoo J, Lewis J. Strategies for supporting physician-scientists in faculty roles: A narrative review with key informant consultations. *Academic Medicine*. 2017; 92 (10).
- [61] McKinney Jr RE. The daunting career of the physician-investigator. *Academic Medicine*. 2017 Oct 1; 92 (10): 1368-70.
- [62] Skinnider MA, Squair JW, Twa DD, Ji JX, Kuzyk A, Wang X, Steadman PE, Zaslavsky K, Dey AK, Eisenberg MJ, Gagné ÈR. Characteristics and outcomes of Canadian MD/PhD program graduates: a cross-sectional survey. *CMAJ open*. 2017 Apr; 5 (2): E308.
- [63] Yin C, Steadman PE, Apramian T, Zhou TE, Ishaque A, Wang X, Kuzyk A, Warsi N. Training the next generation of Canadian Clinician-Scientists: charting a path to success. *Clin Invest Med*. 2017; 40 (2), 95-101.
- [64] DeLuca GC, Ovseiko PV, Buchan AM. Personalized medical education: Reappraising clinician-scientist training. *Science translational medicine*. 2016 Jan 5; 8 (321).
- [65] Kosik RO, Tran DT, Fan AP, Mandell GA, Tarn DC, Hsu HS, Chen YS, Su TP, Wang SJ, Chiu AW, Lee CH. Physician scientist training in the United States: a survey of the current literature. *Evaluation & the health professions*. 2016 Mar; 39 (1): 3-20.
- [66] Rosenblum ND, Kluijtmans M, Ten Cate O. Professional identity formation and the clinician-scientist: A paradigm for a clinical career combining two distinct disciplines. *Academic Medicine*. 2016; 1 (12), 1612-1617.
- [67] Smeesters PR. You'll be a clinician-scientist, my son. 2015.
- [68] Abu-Zaid A, Altinawi B. Perceived barriers to physician-scientist careers among female undergraduate medical students at the College of Medicine-Alfaisal University: A Saudi Arabian perspective. *Medical teacher*. 2014 Apr 1; 36 (sup1): S3-7.
- [69] Bauml R, Benbassat J, Van JA. Reflections on the current and future roles of clinician-scientists. *The Israel Medical Association Journal: IMAJ*. 2014 Aug 1; 16 (8): 475-8.
- [70] Bhat V, Leong K, Lee J, Voineskos D, Daskalakis ZJ, Lam RW, Jollant F. track programs for residents in psychiatry: a review of literature and a report of 3 Canadian experiences. *The Canadian Journal of Psychiatry*. 2014 May; 59 (5): 268-75.
- [71] Cornfield DN, Lane R, Rosenblum ND, Hostetter M, Jobe A, Albertine K, Aschner J, Abman SH. Patching the pipeline: creation and retention of the next generation of physician-scientists for child health research. *The Journal of pediatrics*. 2014 Nov 1; 165 (5): 882-4.
- [72] Girgis F. Feasibility of a dual neurosurgeon-scientist career in Canada: a survey study. *Canadian journal of neurological sciences*. 2013 Jul; 40 (4): 504-11.
- [73] Huang Z, Yong EL. Application of Science to Medicine—The Clinician-Scientist. 2013.
- [74] Megyesi JF. A Role for the Surgeon-Scientist? What Does the "Evidence" tell Us? *Can J Neurol Sci*. 2013; 40, 450-452.
- [75] Atesok KI, Hurwitz SR, Egol KA, Ahn J, Owens BD, Crosby LA, Pellegrini Jr VD. Perspective: integrating research into surgical residency education: lessons learned from orthopaedic surgery. *Academic Medicine*. 2012 May 1; 87 (5): 592-7.
- [76] Olivier Desplante MD. Perspectives on the Clinician-Scientist Pathway: A Survey of Cardiology Fellows. *Canadian Journal of General Internal Medicine*. 2012; 7 (4): 123.
- [77] Roberts SF, Fischhoff MA, Sakowski SA, Feldman EL. Perspective: Transforming Science into Medicine How Clinician-Scientists Can Build Bridges Across Research's "Valley of Death". *Academic Medicine*. 2012 Mar 1; 87 (3): 266-70.
- [78] Yap KK. The clinician-scientist: Uniquely poised to integrate science and medicine. *Aust Med Stud J*. 2012; 3: 10-1.
- [79] Huber-Lang M, Neugebauer E. The dual role of academic surgeons as clinicians and researchers-an attempt to square the circle? 2011; 1-3.
- [80] Rosen MR. The Role of the Physician-Scientist in Our Evolving Society. *Rambam Maimonides medical journal*. 2011 Oct; 2 (4).
- [81] Rubio DM, Primack BA, Switzer GE, Bryce CL, Seltzer DL, Kapoor WN. A comprehensive career-success model for physician-scientists. *Academic medicine: journal of the Association of American Medical Colleges*. 2011 Dec; 86 (12): 1571.
- [82] Armstrong AY, DeCherney A, Leppert P, Rebar R, Maddox YT. Keeping clinicians in clinical research: the clinical research/reproductive scientist training program. *Fertility and sterility*. 2009 Mar 1; 91 (3): 664-6.

- [83] Bakken S, Lantigua RA, Busacca LV, Bigger JT. Barriers, enablers, and incentives for research participation: a report from the Ambulatory Care Research Network (ACRN). *The Journal of the American Board of Family Medicine*. 2009 Jul 1; 22 (4): 436-45.
- [84] Donath E, Filion KB, Eisenberg MJ. Improving the clinician-scientist pathway: a survey of clinician-scientists. *Archives of internal medicine*. 2009 Jul 13; 169 (13): 1241-7.
- [85] Gorski D. The clinician-scientist: Wearing two hats. *Sciencebasedmedicine.Org*. [Internet] 2020 [cited 2020 June 10]. Available from: <https://sciencebasedmedicine.org/the-clinician-scientist-wearing-two-hats/>.
- [86] Olumi AF, DeWolf WC. The hybrid of basic science and clinical training for the urologic oncologist: Necessity or waste? *In Urologic Oncology: Seminars and Original Investigations* 2009; 27 (2) 205-207.
- [87] Andriole DA, Whelan AJ, Jeffe DB. Characteristics, and career intentions of the emerging MD/PhD workforce. *Jama*. 2008 Sep 10; 300 (10): 1165-73.
- [88] Brown AM, Morrow JD, Limbird LE, Byrne DW, Gabbe SG, Balser JR, Brown NJ. Centralized oversight of physician-scientist faculty development at Vanderbilt: Early outcomes. *Academic medicine: journal of the Association of American Medical Colleges*. 2008 Oct; 83 (10): 969.
- [89] Howell E, Kravet S, Kisuule F, Wright SM. An innovative approach to supporting hospitalist physicians towards academic success. *Journal of Hospital Medicine: An Official Publication of the Society of Hospital Medicine*. 2008 Jul; 3 (4): 314-8.
- [90] Marks AR. Physician-scientist, heal thyself. *The Journal of clinical investigation*. 2007 Jan 2; 117 (1): 2-.
- [91] Rosier RN. Institutional barriers to the orthopaedic clinician-scientist. *Clinical Orthopaedics and Related Research®*. 2006 Aug 1; 449: 159-64.
- [92] Bakken LL. Who is physician-scientists' role models? Gender makes a difference. *Academic Medicine*. 2005 May 1; 80 (5): 502-6.
- [93] Ley TJ, Rosenberg LE. The physician-scientist career pipeline in 2005: build it, and they will come. *Jama*. 2005 Sep 21; 294 (11): 1343-51.
- [94] Wang MF. Physician-scientists' learning in communities of practice. [dissertation]. Madison (WI): University of Wisconsin-Madison; 2002.
- [95] Ahn J, Watt CD, Greeley SA, Bernstein J. MD-PhD students in a major training program show strong interest in becoming surgeon-scientists. *Clin. Orthop. Relat. Res.* 2004; 425, 258-263.
- [96] Henke PK. Collaboration based on the clinical model can help grow the physician-scientist. *The American journal of surgery*. 2003 Jan 1; 185 (1): 42-4.
- [97] Faxon DP. The chain of scientific discovery: the critical role of the physician-scientist. *Circulation*. 2002 Apr 16; 105 (15): 1857-60.
- [98] Guelich JM, Singer BH, Castro MC, Rosenberg LE. A gender gap in the next generation of physician-scientists: medical student interest and participation in research. *Journal of Investigative Medicine*. 2002 Nov 1; 50 (6): 412-8.
- [99] Moskowitz J, Thompson JN. Enhancing the clinical research pipeline: training approaches for a new century. *Academic Medicine*. 2001 Apr 1; 76 (4): 307-15.
- [100] Garfinkel PE, Goldbloom DS, Kaplan AS, Kennedy SH. The clinician-investigator interface in psychiatry: I—values and problems. *The Canadian Journal of Psychiatry*. 1989 Jun; 34 (5): 361-3.
- [101] Sackett DL, Rosenberg WM, Gray JM, Haynes RB, Richardson WS. Evidence based medicine: what it is and what it isn't. 1996; 71-72.
- [102] Nasr A. From evidence-based medicine to evidence-based practice: Is there enough evidence? *Middle East Fertility Society Journal*. 2010 Oct 1; 15 (4): 294-5.
- [103] Sur RL, Dahm P. History of evidence-based medicine. *Indian journal of urology: IJU: journal of the Urological Society of India*. 2011 Oct; 27 (4): 487.
- [104] The University of British Columbia [Internet]. Faculty of Medicine Department of Physical Therapy. 2020; [2020, June 29]. Available from: <https://physicaltherapy.med.ubc.ca/programs/mptphd-program-2/>.
- [105] McMaster University [Internet]. Hamilton: School of Rehabilitation Science. 2020 [2020, June 29]. Available from: <https://srs-mcmaster.ca/rehabilitation-science/otpt-rs-phd-program/>.
- [106] Queen's University [Internet]. Faculty of Health Sciences, School of Rehabilitation Therapy; 2020 [2020, June 29]. Available from: <https://www.rehab.queensu.ca/academic-programs/rhbs>.
- [107] University of Toronto. [Internet] Toronto: Physician Scientist Training Programs. 2020; [2020, June 29]. Available from: <https://md.utoronto.ca/PSTP>.
- [108] Littlefield JW. The need to promote careers that combine research and clinical care. *Journal of medical education*. 1986 Oct 1; 61 (10): 785-9.
- [109] Collins J. A Female's Profession: Gender Disparity in Occupational Therapy. 2019; 1.
- [110] Sutherland G. The market profile of physiotherapists in Canada. In Ottawa: Conference Board of Canada 2017.