Original Article

Virtual Mentoring for Medical Physicists: Results of a Global Online Survey

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Abstract

Purpose: Medical physics professional development is limited in parts of the globe and can be aided by virtual mentoring. A global online perception survey was conducted to elucidate the characteristics of the preferred virtual mentoring program. **Methods:** Informed by a literature review and pilot testing by focus groups, the survey was electronically disseminated to multiple medical physics organizations, list servers, and professional contacts. It addressed issues including factors and barriers influencing successful mentoring; mentors'/mentees' matching preferences; frequency and length of meetings; importance of defining expectations; formal agreement; and assessment of the mentoring process. Descriptive statistics were used to characterize responses including comparisons by country income level. **Results:** The 396 responders (68% male and 32% female) were from 76 countries with 66% from high-income countries (HICs) and 34% from low- and middle-income countries (L&MICs). Data were provided on experience level as mentors (43% "little [occasional]", 38% "lot [regular or ongoing]") and mentees (53% "little [occasional]", and 23% "lot [regular or ongoing]"), and interest in participating in mentorship program (83% as mentor, mentee, or both). L&MIC responders were generally younger with less work experience (55% <10 years versus 28% for HIC responders). Differences between L&MIC and HIC responses occurred when considering the perceived limitations and barriers to virtual mentoring. Preferences were given to mentoring logistics (formal agreement, frequency, length, and format of meetings). **Conclusions:** Factors to consider in developing a virtual mentorship program are informed by the survey results and are applicable to both HIC and L&MIC contexts, to medical physicists, and to other related professions.

Keywords: Global, medical physics, perception survey, virtual mentoring

Received on: 03-08-2024 **Review completed on: 21-09-2024** **Accepted on: 21-09-2024** **Published on: 18-12-2024**

Introduction

Mentoring is a valuable means of enhancing professional and personal development through a relationship between two people working in partnership. For the purpose of this work, we define the "*mentor*" to be a person with more experience or more knowledge in a specific area who helps guide and support the less experienced or less knowledgeable "*mentee*" in that specific area. Note that two equally knowledgeable and professionally experienced people could have a mentor/mentee relationship, for example, concerning leadership or managerial skills. Mentoring goes beyond the confines of classroom or online teaching since it involves personal guidance, support, and role modeling. Peer-reviewed literature describes and evaluates mentoring, especially in academic and research contexts[1,2] but also within healthcare settings.[3-5] Conventionally, mentoring was conducted with in-person, face-to-face sessions. However, a challenge in providing person-to-person mentoring programs in low- and middle-income countries (L&MICs) is the lack of experienced mentors to bring the required expertise to the mentoring relationship.[6] One approach to address this challenge is "*virtual mentoring*" which refers to a process where mentors and mentees communicate through web-based information and communication technologies (ICTs).[7] The constraints related to geographical distances between mentors and mentees, further increased by the COVID-19 pandemic,

Access this article online	
Quick Response Code:	**Website:** www.jmp.org.in
	DOI: 10.4103/jmp.jmp_137_24

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How to cite this article: Van Dyk J, Jalink M, Schreiner LJ, Jeraj R. Virtual mentoring for medical physicists: Results of a global online survey. J Med Phys 2024;49:687-700.

have enhanced the development and acceptance of *virtual* mentoring.[8,9]

The clinically qualified medical physicist (CQMP) education, training, and career pathway is very regimented and well prescribed.[10] The International Atomic Energy Agency (IAEA) recommends that the entry step toward qualifying for a CQMP is a postgraduate degree in medical physics covering a core syllabus as, for example, given in the IAEA TCS 56 publication.[11] This is to be followed by a structured clinical training (residency) of not <2 years in a clinical environment in one of the specialties of medical physics including radiation therapy, nuclear medicine, and diagnostic radiology.[12-14] This is followed by a certification (credentialing) process which evaluates the appropriate level of knowledge, proficiency, and competency of the trainee based on predetermined criteria.[15] Finally, as one moves into their career as a CQMP, there is an expectation of continuing professional development to keep expert knowledge and skills up to date through participation in educational and scientific activities. In North America, there is a very similar education, training, and career pathway which is well defined by the Commission on Accreditation of Medical Physics Education Programs.[16]

There is a recognized need for a substantive increase in the number of medical physicists around the globe, especially in L&MICs, to respond to the escalating burden of cancer and other noncommunicable diseases.[17-19] Unfortunately, there are limited formalized academic education programs and few practical hands-on (residency) training programs for medical physicists in these low-resourced environments. Furthermore, the clinical environments tend to be scarce in experienced medical physicists for clinically oriented, on-the-job training, and lack the appropriate equipment.[20,21] Not only does the IAEA contribute greatly to the advancement of education programs in L&MICs by developing educational and training materials but it also provides training, individual fellowships, scientific visits, and coordinated research projects (CRPs) some of which include graduate training at the PhD level. The IAEA has also developed an online tool called AMPLE (Advanced Medical Physics Learning Environment), especially for South-East Asia.[22] This tool provides up-and-coming medical physicists with guided learning materials and remote mentorships to enhance their practical clinical training in hospitals. However, the IAEA can only address a small fraction of the total need.[17] Furthermore, organizations such as the IAEA tend to work slowly due to their bureaucratic requirements and a more nimble, fast-acting option is preferred.[23] Thus, additional approaches and resources are required to address this global challenge. One of those approaches is to develop virtual mentoring programs where online support is provided by mentors through ICTs.[24,25] Mentoring has an important role at each stage of this career development although perhaps most importantly in the practical training on the implementation of new techniques and technologies, not only during the residency training but also during the career of the medical physicist as new technologies and methodologies are brought into the department.

Relatively little has been published on mentoring in the medical physics context. Santos *et al*.[26] reviewed a global mentoring program's impact on the professional development and leadership skills of early-career medical physicists and postgraduate students. They determined that mentoring was beneficial to the mentees' careers and thus, should be encouraged. They noted that the success of the virtual program did depend on the participants sharing experience and committing time. Specifically, the mentoring process involved group meetings every 2 or 3 months, in which 1-h presentations were made by the mentors sharing their personal and professional trajectory and their experiences as leaders in medical physics. Further communications occurred between meetings mostly through e-mail or texting applications. Some of the positive aspects achieved in the program included: connecting for group discussions, stepping out of comfort zones, learning to handle international meetings, learning from the joint writing of papers, gaining a global perspective on career development, providing lessons on developing leadership skills, increased self-confidence, reduced anxiety about new stages in one's career, and experience gained by managing the activities for a heterogeneous group.[26] Woods *et al*.[27] reviewed a mentoring program designed to enhance "soft skill" competencies (e.g. communication, ethics, teamwork, altruism, multiculturalism, and accountability) of medical physics and biomedical doctoral students to prepare them for careers in multidisciplinary translational research. All students reported improved understanding and skills in many aspects of work in such team settings including understanding of how scientists work on clinically relevant problems, awareness of concerns facing patients, group interaction skills, and understanding of professional behavior in a clinical setting.

Petit *et al*. evaluated a European Society of Radiotherapy and Oncology (ESTRO) 1-year pilot mentoring program aimed at professional development.[28] Early-stage career ESTRO members under the age of 45 years from all professions (radiation oncologists, physicists, biologists, and radiation therapists) with a minimum of 2 years of postgraduate work experience and being aware of recent developments in their field were invited. Fifteen mentees (3 physicists) and 20 mentors (2 physicists) were selected. Matching was based on shared values and was self-identified. Mentors and mentees were committed to meeting at least once every 3 months online or in person. Key summaries for why mentors like this program include: learned from it; building confidence to mentor others (bidirectional); rewarding; enjoyed personal connection; and international aspect. For the mentees, brought useful recommendations/advice, opened connection to the network of mentor; advice on research; opportunity for feedback; help with prioritization; independent view; reassurance; and an example to follow.

Ng *et al.*[29] reported on the experience and outcomes of a virtual mentorship program aimed at developing the leadership skills of early-career medical physicists. They reviewed various structures required for an effective virtual mentoring program, described some challenges in the remote setting, and noted that mentees reported significant satisfaction with the influence of the program on their career paths.

While not a report on mentoring, Wadi-Ramahi *et al*.[30] described how virtual physics support was an effective tool to improve clinical commissioning and implementation of novel radiation therapy technologies and treatment techniques in a cancer clinic in Jordan (considered by the World Bank to be an upper-middle income country [UMIC]) when COVID-19 restrictions limited conventional on-site visits by vendor trainers and applications staff. The benefit and challenges of virtual medical physics peer-to-peer support have also been reported by van Prooijen and Parker.[31] Similarly, Kavuma *et al*.[32] concluded that remote training provides an excellent and feasible e-learning platform for radiation therapy professionals, including medical physicists, in resource-constrained environments. These reports confirm that mentorship support in a virtual environment can be of significant benefit to mentees.

Medical Physics for World Benefit (MPWB)[33] is a nongovernment, charitable organization devoted to providing medical physics support globally, especially in L&MICs through advising, training, demonstrating, and/or participating in medical physics-related activities.[34] It recently began work on establishing a virtual mentorship program to support effective and safe medical physics services aimed at all career levels of medical physicists, especially those impacting the clinical environment, ranging from graduate students to residents, to early career medical physicists, as well as later career medical physicists. However, multiple questions were generated during implementation regarding the use of virtual mentoring to support academic and clinical training. It was unclear how to best approach virtual mentoring in L&MICs in terms of matching mentors and mentees, whether there was interest in participating in mentorship, and how to overcome inherent challenges to the process. To gather insight into these uncertainties from the perspective of both mentors and mentees from multiple country-income level contexts, an online survey was developed and distributed. Specifically, the survey aims were to address the following questions:

1. What is the best approach to virtual mentoring?
2. What is the best way to match mentor and mentee?
3. Are practicing medical physicists in resource-limited settings interested in having a mentor?
4. Are experienced medical physicists in well-resourced environments interested in being a mentor?
5. For those with virtual mentoring experience (both as mentor and mentee), what are the major challenges and successes?

Materials and Methods

To direct the development of the on-line survey, advice was sought from various professionals and educators who have survey experience and content expertise. The survey development was done using the general concepts of the seven-step survey design scheme summarized by the Association for Medical Education in Europe:[35] (1) conduct literature review; (2) conduct interviews and/or focus groups; (3) synthesize literature review and interviews/focus groups; (4) develop survey items; (5) conduct expert validation; (6) conduct cognitive interviews; and (7) conduct pilot testing.

Three focus group virtual meetings were held with the primary purpose of discussing the project and developing specific questions. The total of 16 participants included both experienced medical physicists and medical physicists in training with representation from low- to high-income countries (HICs) and relevant industry partners. The focus group members were chosen on the basis of their expertise, their professional recognition, or their international or global experience. The industry partners were included since commercial enterprises are involved in clinical application training of their products and they have a real concern about adequately trained staff being available to ensure safe and correct clinical use of their products, especially in contexts where clinical training opportunities are limited. The individuals within the industry partners were chosen based on their positions and their experience with international clinical training concerns for their specific products.

Validation of the survey was accomplished by the members of the focus groups who were given access to the draft survey and were asked for their critique and comment from the perspective of clarity, the importance, and the need of the questions.

The survey questionnaire was implemented using the Qualtrics™ platform through Western University, London, Ontario, Canada. The target audience was anyone in medical physics at any stage of their medical physics career, ranging from medical physics trainee (e.g. the person in graduate studies or medical physics residency), through early career practitioners, to a medical physicist with multiple years of experience in the clinic, university, industry, or government. The responder could be a mentor, a mentee, or both. The final survey had 40 questions with an average estimated time for completion of about 25 min. Responders were free to decline to answer any question or could withdraw from the study at any time. Once the questionnaire was developed and validated by various participants of the focus groups, the online survey was distributed. The invitation to the survey link was disseminated through various channels including (1) contacts with various national (31), international (3), and regional (9) medical physics organizations around the globe, representing nearly 30,000 medical physicists as indicated by the International Organization of Medical Physics (IOMP); (2) announcement on the Global MedPhys List Server which has approximately 6300 members from across the world (http://lists.wayne.edu/cgi-bin/wa?SUBED1=medphys&A=1); (3) announcements through the American Association of Physicists in Medicine (AAPM) (www.AAPM.org), the largest national medical physics association, with nearly 10,000 members; and (4) direct personal contacts of the investigators of this proposal, and the MPWB Board members. The aim was to get responses from both HIC and L&MIC contexts, and medical physicists with experience, as well as those in training. Reminders to complete the survey were made twice at approximately 3-week intervals. The survey was open for 6 months (September 2021 through February 2022). The definitions of HICs and L&MICs were based on the World Bank criteria for 2022[36] which define four country income levels: low-income (LIC), lower-middle-income (LMIC), UMIC, and HIC. We collapsed LIC, LMIC, and UMIC into L&MIC, which is commonly done in the literature.[37] A copy of the survey can be found in the supplemental materials associated with this paper. The survey asked questions about demographics, type, and country of education and training, working experience, medical physics specialty, mentor and mentee experiences and preferences, and motivations and barriers to mentoring. Several questions allowed for optional free-text responses.

Regarding mentoring perceptions, in a number of the questions the responders were asked to rank the level of importance of a specific topic on a five-point Likert scale ranging from "not important" to "very important." For these questions, a weighted average (*WA*) was calculated using the following formula:

$$WA = (N_1 * 1 + N_2 * 2 + N_3 * 3 + N_4 * 4 + N_5 * 5) / (N_1 + N_2 + N_3 + N_4 + N_5)$$

where N_i represent the number of responders for each of the points on the five-point scale, and the digits behind the N_i represent a weighting factor describing the importance of that response. For questions with multiple components, the results can be ordered in decreasing value, with the highest value representing the most "important" response (maximum

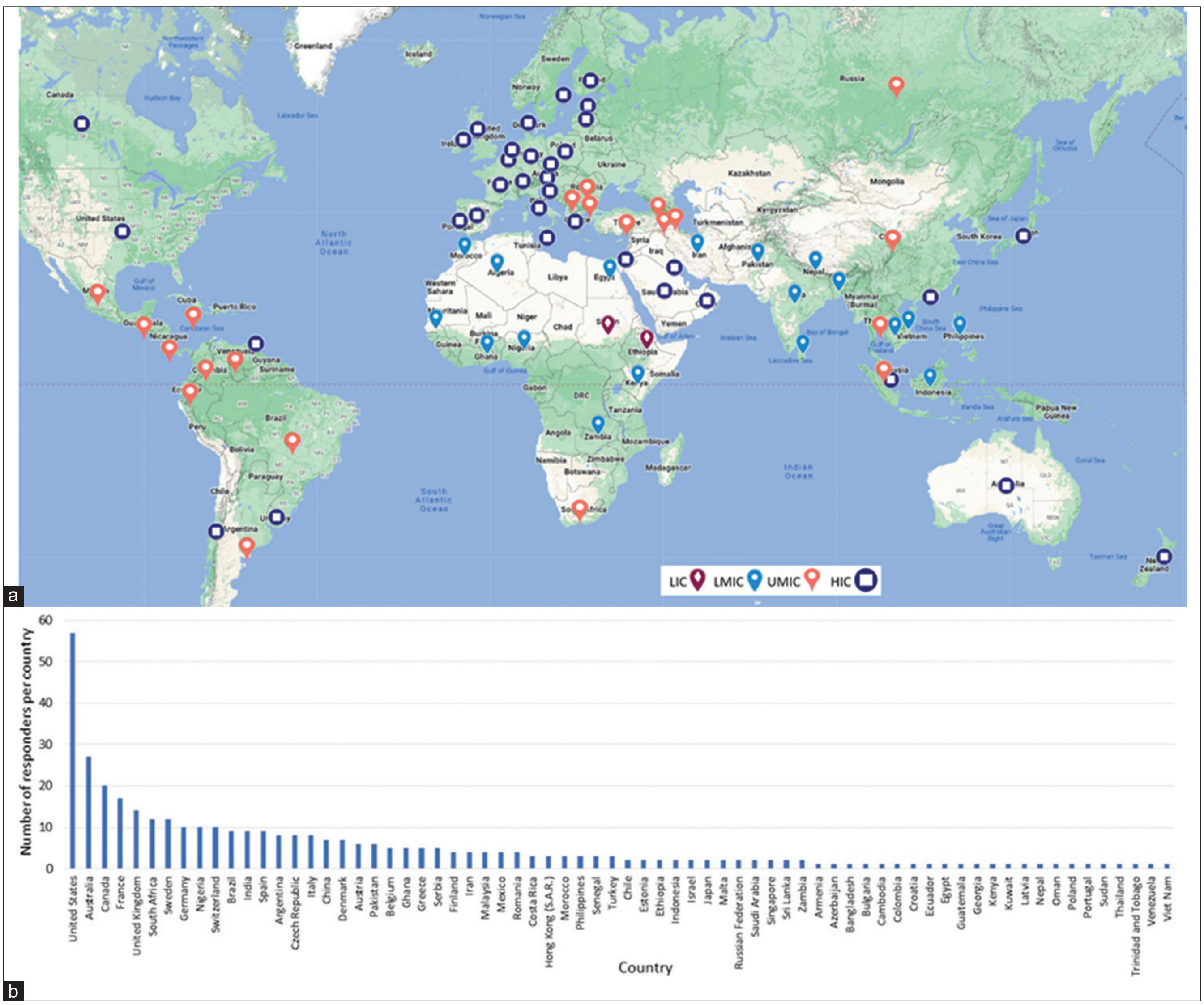

Figure 1: (a) Locations of survey responders with indications of country income level. (b) Number of responders per country. LIC: Low-income country, LMIC: Lower-middle income country, UMIC: Upper-middle income country, HIC: High-income country

WA is 5.0; the closer to 5, the greater the agreement on the importance by the responders).

The Western University Research Ethics Board (WREB), in London, Ontario, Canada reviewed the study and approved it on July 12, 2021.

Results

Demographics

There were 396 responses (68% male and 32% female) from 76 countries [see world map in Figure 1a and number of responders per country in Figure 1b], with 253, 71, 56, and 3 responses from HICs, UMICs, LMICs, and LICs, respectively. The top five countries responding were the USA (57), Australia (27) Canada (20), France (17), and the United Kingdom (14), whereas there were 22 countries with single responders of which seven were from HICs, eight from UMICs, six from LMICs, and one from an LIC. Thirteen (13) responses were designated as "missing data," as the individuals who completed the survey did not indicate a country of current practice, possibly because they were retired or unemployed individuals. When combining the three lower-income groups, there are 253 (66%) from HICs and 130 (34%) from L&MICs. Table 1 provides a summary of the responders' demographics and their interest and experience in mentoring or being mentored.

One of the larger differences between HIC and L&MIC responders relates to age and experience. Figure 2a shows a histogram of age stratified by country income level (HICs and L&MICs), and Figure 2c shows the differences in years of experience by country income level. Figure 2b and d show the decreasing age and experience trends as a fraction of the total numbers responding in each age and experience category. Sixty percent of trainee respondents are from L&MICs, whereas only 20% of respondents with ≥20 years of experience are from L&MICs.

The survey results indicated that 72% of all the respondents are practicing in the countries in which they trained. Of those individuals who did their formal graduate education in a different country from their practical residency training, 56% did both in HICs, 27% were educated in HICs and trained in L&MICs, 14% were educated in L&MICs and trained in HICs, and 3% were educated and trained in L&MICs. The percentage of respondents who were working in the same country as they trained did not depend on whether they were working in HICs (72%) or L&MICs (70%). The description of current positions was similarly distributed for the two country income groups, although proportionately there were more graduate student responders from L&MICs (9%) versus HICs (2%). Regarding medical physics specialties, proportionately, there were more radiation oncology medical physicists compared to imaging and health physicists [Figure 3]. One-hundred and forty-eight respondents indicated that they were in more than one specialty.

In the question on the current time split between academic, clinical, teaching, administration, and other, the responders were asked to provide percentages, with their total time adding up to 100%. Because of the nature of the question, there were approximately 100 different combinations of responses. The resultant mean times are shown in Figure 4.

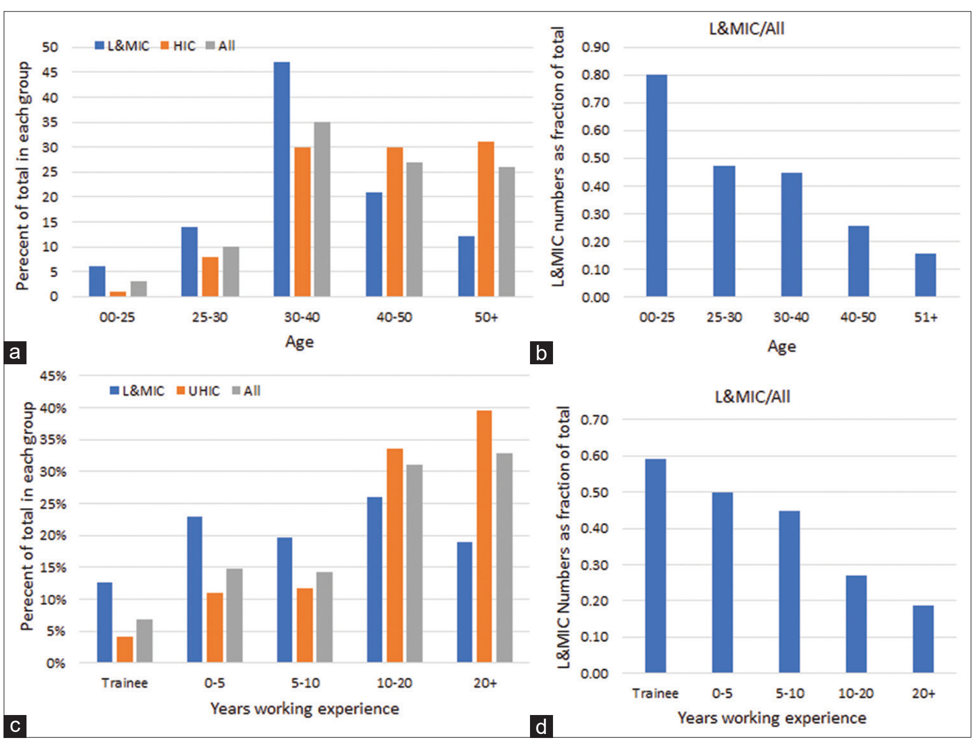

Figure 2: (a) Age distribution by country income level. (b) The ratio of L&MIC over total numbers by age. (c) Distribution of years of working experience by income level. (d) Ratio of L&MIC over total numbers by years of working experience

Table 1: Responders' demographics and interest and experience in mentoring

	L&MIC, *n* (%)*	HIC, *n* (%)*	Missing	Total, *n* (%)*
Gender				
Male	93 (71)	163 (64)	12 (86)	268 (68)
Female	37 (29)	87 (34)	2 (14)	126 (32)
Prefer not to say	0	2 (2)	0	2 (0.5)
Age (years)				
<25	8 (6)	2 (1)	0	10 (3)
26–30	18 (14)	20 (8)	0	38 (10)
31–40	61 (47)	73 (30)	3 (21)	137 (35)
41–50	27 (21)	76 (30)	2 (14)	105 (27)
Over 50	16 (12)	78 (31)	9 (64)	103 (26)
Prefer not to answer	0	3 (1)	0	3 (1)
Percent over 40 years of age	33	61		52
Education**				
Bachelor's degree/equivalent in medical physics	13 (10)	2 (<1)		15 (4)
Bachelor's degree/equivalent in science or engineering	5 (4)	3 (1)		8 (2)
Master's degree or equivalent in medical physics	58 (47)	99 (39)	4 (29)	161 (42)
Master's degree or equivalent in science or engineering	14 (11)	14 (6)	2 (14)	31 (8)
PhD or equivalent in medical physics	26 (20)	89 (35)	2 (14)	117 (30)
PhD or equivalent in science or engineering	8 (6)	41 (16)	6 (43)	55 (14)
Practical, on-the-job training				
Completed formal residency of 1+ year in medical physics	50 (38)	133 (53)	3 (23)	186 (50)
Learned on the job on my own	17 (13)	12 (5)	3 (23)	32 (8)
No formal residency but received on the job training from experienced medical physicist(s)	48 (37)	88 (35)	6 (46)	142 (36)
Not applicable	7 (5)	2 (1)	1 (8)	10 (2)
Country of most recent graduate studies***	127 (100)	265 (100)	4	396
Country of main medical physics training***	133 (100)	263 (100)	0	396
Medical physics specialty****				
Radiation oncology	115 (54)	225 (72)	12	352 (65)
Diagnostic imaging	47 (22)	49 (16)	2	98 (18)
Health physics/radiation protection	50 (24)	40 (13)	4	94 (17)
Country of current position				
Graduate student	12 (9)	4 (<1)	1 (7)	17 (4)
Medical physics resident	4 (3)	15 (6)	0	19 (5)
Medical physicist, public nonacademic	15 (11)	44 (17)	3 (21)	62 (16)
Medical physicist, private nonacademic	26 (20)	35 (14)	0	61 (15)
Medical physicist, public academic	35 (27)	88 (35)	2 (14)	125 (32)
Medical physicist, private academic	10 (8)	22 (9)	1 (7)	33 (8)
Medical physicist, academic nonclinical	5 (4)	14 (6)	1 (7)	20 (5)
Medical physicist, industry	10 (8)	17 (7)	0	27 (7)
Medical physicist, government or regulatory	3 (2)	3 (1)	0	6 (2)
Retired medical physicist	4 (3)	6 (2)	6 (43)	16 (4)
Other	6 (5)	4 (<1)	0	10 (2.5)
Mean years of working experience (SD)	12 (2.1)	18 (5.1)		16 (4.2)
Percent with <10 years of experience	55	28	7	36
Experience as mentor				
None	31 (24)	44 (18)	1 (8)	76 (19)
Little (occasional)	54 (42)	109 (44)	6 (46)	169 (43)
Lot (regular or ongoing)	43 (34)	97 (39)	6 (46)	146 (38)
Experience as mentee				
None	20 (16)	71 (29)	4 (29)	95 (25)
Little (occasional)	70 (56)	127 (52)	6 (43)	203 (53)
Lot (regular or ongoing)	36 (29)	48 (20)	4 (29)	88 (23)

Contd...

Table 1: Contd...

	L&MIC, *n* (%)*	HIC, *n* (%)*	Missing	Total, *n* (%)*
Interest in virtual mentoring				
No	7 (5)	60 (24)	2 (14)	69 (18)
Yes, as mentee	38 (30)	16 (6)	3 (21)	57 (15)
Yes, as a mentor	19 (15)	98 (39)	8 (57)	126 (32)
Yes, as both a mentee and mentor	64 (50)	76 (30)	1 (7)	141 (36)

*Percentages are based on the totals in the respective columns, **Only the top 6 are presented, others only had one respondent, ***Not categorized based on country of respondent's current position, ****Not mutually exclusive (percentages are based on the total of numerical values in the medical physics specialty in that column). *n*: Number of participants, HIC: High-income country, L&MIC: Low- and middle-income country based on respondent's current position, SD: Standard deviation

Table 2: Time allocation for different activities for the top three most frequent time allocation categories for both low- and middle-income countries and high-income countries

L&MIC frequency	HIC frequency	Percent of time allocated				
		Academic	Clinical	Teaching	Admin	Other
6	21	0	100	0	0	0
2	7	0	90	10	0	0
1	5	0	90	0	10	0

HIC: High income country, L&MIC: Low- and middle-income country

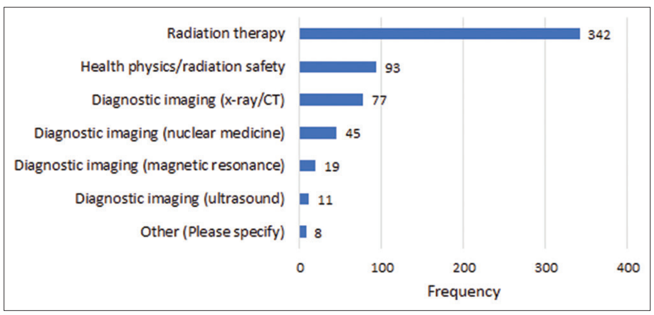

Figure 3: Frequency by specialty. Multiple individuals chose more than one specialty. The frequency for all diagnostic imaging is 152. "Other" included radiology informatics, data science, image processing, industrial R and D, no specialty

Note that these represent statistical averages; however, for each category, there were individuals who devoted 100% of their time to that specific activity. The top three most frequent combinations were the same for both L&MICs and HICs [Table 2].

Mentorship preferences

Table 3 summarizes the responses regarding issues related to the mentoring process, with some situations showing combined percentages in the "Note" column.

Benefits of mentorship

Figure 5 shows the importance of the benefit gained by a mentee from the guidance of a mentor. These results are summarized with WAs in the first block of Table 4.

Limitations and barriers to virtual mentorship

The survey responses addressing potential limitations and barriers to *virtual mentoring* were rank ordered using the *WA*s of the five-point Likert scores reported by the respondents. The ranking results were compared by country income level and are shown in Table 5. Some topics are highlighted by an asterisk when the rank-order comparison between HICs and L&MICs varied by ≥4 levels.

Discussion

The Lancet Oncology Commission report on Expanding Access to Radiotherapy[17] called for new approaches to train radiotherapy professionals globally, with the creation of new core curricula, innovative learning methods, and international credentialing to expand the radiotherapy workforce. The 2015 proposed target was that 6000 medical physicists should be trained in L&MICs by 2025. The more recent Commission report on Medical Imaging and Nuclear Medicine[18] provided clear actions on investing in education and training to expand human resources in L&MICs, with a special emphasis on digital solutions and virtual platforms to enable a rapid scale-up of training. Their proposed target in 2021 was that by 2030, 80% of L&MICs should establish plans for workforce development and for the use of digital platforms for workforce training.

One component of the use of digital platforms is virtual mentoring. The literature review by Iqbal[7] suggests that the effectiveness of virtual mentoring compares well with more conventional in-person mentoring approaches and provides suggested tactics, practices, and strategies to enhance virtual mentoring. While proposing general recommendations, none of these reports provide specifics that are uniquely applicable to medical physicists. Organized virtual mentoring on a global scale is in its infancy for medical physicists. The survey in this report addressed a more broadly based virtual mentorship approach with special considerations for those medical physicists working in clinical environments and in L&MICs.

Table 3: Responses related to the mentoring process

Frequency mentors and mentees should meet	Count	%	Note
Once a week	40	14%	
Once every two weeks	78	28%	56%
Once per month	77	28%	
On an as needed basis	62	22%	
Other (Please specify)	21	7.6%	
Total	278	100%	
Importance of formal agreement at start			
Not important	16	5.7%	
Slightly important	39	14%	
Moderately important	78	28%	
Quite important	101	36%	80%
Very important	45	16%	
Total	279	100%	
How long should meetings be?			
30 minutes	76	27%	86%
one hour	163	58%	
two hours	15	5.4%	
Other (Please specify)	25	9.0%	
Total	279	100%	
Value of mentorship training			
For mentee (Moderate to very important)	219	78%	
For mentor (Moderate to very important)	253	90%	
Importance of defining clear expectations at the outset			
Extremely important	114	41%	
Very important	132	47%	97%
Moderately important	24	8.6%	
Slightly important	8	2.9%	
Not at all important	0	0.00%	
Total	278	100%	

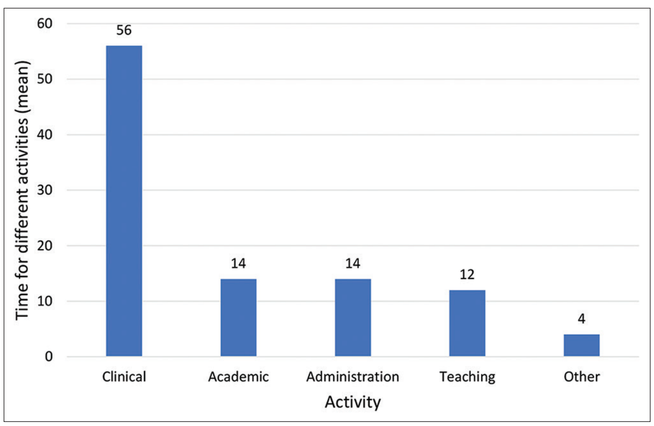

Figure 4: Mean response frequency for various activities. "Other" included research, service, consultancy, wellbeing, and competent person in radiation protection

However, with respondents from both HICs and L&MICs, the findings are relevant for all income contexts as well as the more academic environments.

This survey was voluntary and depended on communications and announcements from various organizations and individuals to cast a wide net to get a representative sample. While we sought responses from various income settings, garnering responses from LICs was difficult, as they have fewer medical physicists (e.g., half of African countries have no radiotherapy facilities and, accordingly, have the smallest number of medical physicists per capita globally[38]). Furthermore, L&MICs have fewer communication channels and less time for mentorship activities due to staff shortages. LICs represent 9% of the world's population in 2021. Thus, considering these factors, a 1% representation from LICs in this highly technical and specialized field is not unreasonable. Since L&MICs represent 84% of the world population and HICs 16%, we did receive proportionally more responses from HICs than from UMICs and LMICs. This may reflect that medical physicists in lower-income settings may not easily be involved in professional organizations within their country, either because of personal constraints or because such organizations do not exist in their country.

Optimal survey development is a balance between the number of questions to yield sufficient data to answer the purpose of the survey and keeping the survey short enough so that enough of the target audience will be willing to respond and thus ensure the quality of data interpretation.[39] In our survey, we noted a drop-off rate of about 25% in a number of responses to questions near the end of the survey. Based on our validation testing, we estimated the expected length of time to fill in the survey would be about 25 min, although it could be longer for people whose first language was not English. Considering the combination of the length of the survey, the voluntary nature of participation with no direct benefit from completing the survey, and the limited communication channels to solicit participation (especially to those in L&MICs), the number of responders was considerable and sufficient to provide meaningful information.

On the whole, the results of the survey yielded similar trends from both HIC and L&MIC responders. Differences were noted in age and experience of responders with HICs representing an older age population, in education with more master's degrees in L&MICs, with fewer completed residencies in L&MICs, and more graduate student responders in L&MICs. Some of these trends were influenced by HIC responders representing a population for physicists who were trained in earlier decades. Furthermore, there was a greater proportional representation of diagnostic imaging and health physics/radiation protection activities in the L&MIC responders [Table 1]. Part of this difference may be due to medical physicists in L&MICs having broader roles, perhaps even multiple roles due to a lack of staffing. In Africa, with multiple countries having no radiotherapy or underdeveloped radiotherapy, there are many fewer radiation oncology medical physicists, and therefore, the medical physicists that are there are more likely related to regulatory or X-ray inspection agencies. The larger relative representation of graduate students from L&MICs may be influenced by the communication channels in these different settings, especially as related to announcements regarding this survey. There appeared to be more experience with mentoring in HICs compared to L&MICs, possibly due to the age difference but also likely due to limited staffing levels in L&MIC contexts. The interest in virtual mentoring as a mentee was substantially higher in L&MICs and as a mentor, it was higher in HICs.

The largest differences between L&MIC and HIC responses occurred when looking at the limitations and barriers to virtual mentoring as summarized in Table 5. That internet challenges ranked near the top for both income domains is consistent with another survey on remote automated treatment planning for

Table 4: Weighted averages for the multiple-choice questions in the survey*

Survey question topic (number of options in survey question)	Possible responses	WA
Benefit gained by mentee (7)	Improve patient and staff safety	4.3
	Solve clinical problems	4.3
	Enhance skills	4.0
	Enhancing research productivity	3.8
	Preparing for examinations	3.4
	Improving industrial commercial relations	3.2
Perception of virtual mentoring (11)	Help to fulfill medical physicist's potential	4.3
	Useful at any stage of career	4.2
	Help solve clinical physics issues	4.1
	Best for medical physicists who are under-performing	2.9
	For those who want to be promoted	2.7
	Best for those considered to have outstanding potential	2.6
Qualities important in mentor (10)	Respects people	4.7
	Is honest	4.6
	Is able to listen	4.6
	Speaks my language	3.4
	Understands my institutional organization	3.1
	Understands my culture	3.1
Importance, mentor's perspective (8)	Share skills and knowledge	4.1
	Sense of value in the workplace	3.9
	Opportunities to develop leadership skills	3.9
	Understanding of mentee's healthcare context	3.6
	Understanding of the mentee's cultural context	3.4
	Appreciation for the mentor's home circumstances	3.1
Importance, mentee's perspective (15)	Interested in being mentored	4.6
	Having respect for the mentor	4.5
	Committing time to being mentored	4.5
	Communicating regularly	4.1
	Having a plan with objectives	4.1
	Being patient	4.1
Importance of the following regarding virtual mentoring (7)	Discussing specific questions	4.3
	Help in solving problems	4.2
	Addressing specific clinical implementation procedures	4.2
	Addressing specific research problems	3.7
	Reviewing internal reports	3.4
	Reviewing drafts of publications	3.4
Benefits, mentee's perspective (5)	Building confidence	3.5
	Exchanging ideas	3.4
	Enhancing patient and staff safety	3.1
	Improving patient care	2.7
	Improving knowledge	2.2
As mentor, motivating qualities (13)	Improving patient care	4.3
	Improving patient and staff safety	4.2
	Interest in helping others (sense of altruism)	4.2
	Advancing research	3.5
	Advancing your career	2.7
	Recognition for being a mentor	2.7
As mentee, motivating qualities (9)	Improving mentee's technical skills	4.3
	Obtaining advice on specific issues	4.3
	Improving patient care	4.2
	Advancing mentee's career	4.0
	Advancing mentee's research	3.8
	Recognition for being mentored	3.1

Contd...

Table 4: Contd...

Survey question topic (number of options in survey question)	Possible responses	WA
Preferences for connecting mentors and mentees (5)	Informal personal connections	4.0
	Local healthcare facility or university	3.9
	Professional local/regional medical physics organization	2.5
	Mentorship program via MPWB	2.3
	Either through MPWB or through a professional/regional organization	2.2
Importance of how mentors and mentees are matched (19)	Mentor's expertise in subject matter of interest to mentee	4.2
	Good follow-up to agreed on activities	4.1
	Similar job role	4.0
	Same or nearby nationality of mentor and mentee	1.6
	Same gender of mentor and mentee	1.5
	Same race of mentor–mentee	1.4
Assessing success (5)	Number of hours connected	4.2
	Independent regular survey	3.9
	Quality of relationship between mentor and mentee	2.5
	Successful implementation of techniques/procedures	2.4
	Amount of knowledge gained	2.1

*The first column provides a summary of the topic and the number of options available in that question. To show the spread, both the top three and the bottom three weighted averages are shown for each topic. MPWB: Medical Physics for World Benefit, WA: Weighted average

Table 5: Rank order comparison of limitations and barriers to virtual mentoring

	L&MIC	HIC	Total
Internet limitations	1	2	1
Lack of direct equipment interaction with mentor*	2	8	7
Lack of hands-on guidance	3	6	4
Differences in time between time zones of the mentor and mentee*	4	9	8
Difficulty in establishing a collaborative relationship	5	4	5
Lack of time*	6	1	2
Lack of motivation*	7	3	3
Lack of special training for mentor	8	10	9
The perception of the value of mentoring by the person you report to	9	11	11
Language limitations*	10	5	6
Lack of recognition for mentoring or being mentored	11	12	12
Communication difficulties due to cultural differences*	12	7	10

The asterisks show topics that were ranked differently by HIC and L&MIC responders by ≥4 levels. The topics are listed in decreasing importance according to the ranking results from L&MICs. The results in the "total" column represent the rankings of all the data when not divided into HICs and L&MICs. HICs: High-income countries, L&MICs: Low- and middle-income countries

L&MICs, where 80% of responders were concerned about a lack of reliable internet.[40] The second greatest concern for L&MIC responders was the lack of direct equipment interaction with the mentor, whereas this was only ranked as the eighth level of concern by the HIC responders. While the reason for this distinction cannot be elucidated from this survey, it does demonstrate one of the significant concerns about the limitations of virtual mentoring in the context of hands-on clinical training. A possible reason for this distinction could be that the HIC trainees and young medical physicists most often work in teams with direct personal access to more experienced medical physicists who can supervise, guide, and answer questions related to practical aspects of equipment quality control, dosimetry, treatment planning, etc., while this is not the case in many facilities in L&MICs. The training of procedural issues and solving practical problems ideally require in-person supervision, and this could be a challenge for virtual mentoring. However, the report by Wadi-Ramahi *et al*.[30] on commissioning of radiotherapy equipment performed during the COVID-19 pandemic does demonstrate that virtual hands-on training can be aided by remote support. More work needs to be done in this area since this is an important component of clinical activities both as residents and as practicing medical physicists.

Other areas of perception discrepancies between L&MIC and HIC responders for both mentors and mentees include the importance of differences in time zones (more important for L&MIC responders), lack of time (more important for HIC responders), lack of motivation (more important for HIC responders), language limitations (more important for HIC responders), and communication difficulties due to cultural differences (more important for HIC responders). The survey did not ask for the rationale for the responses to these questions;

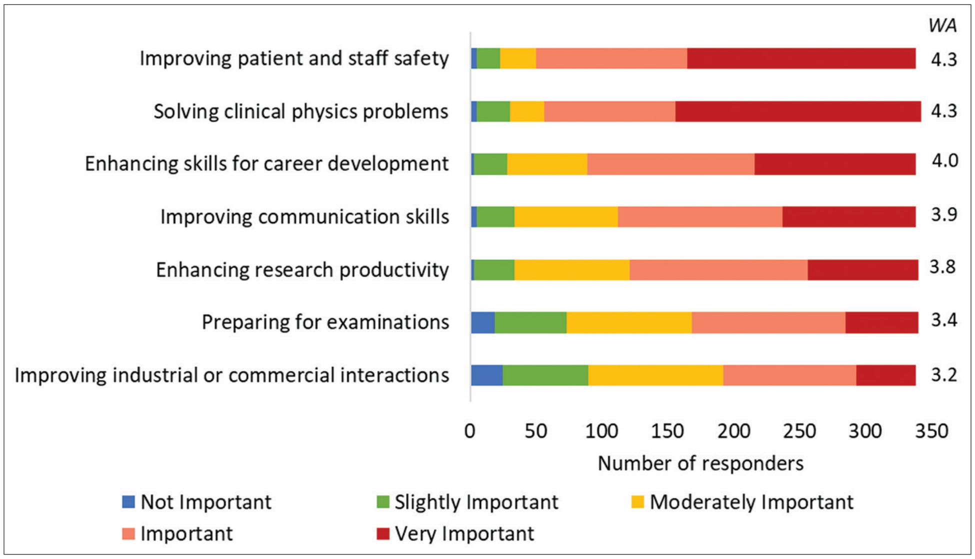

Figure 5: Stacked bar chart for responses to the question on the importance of benefits gained by the mentee from the guidance of a mentor. The responses are rank ordered according to the weighted average shown on the right for each category

however, this does demonstrate differences in perceptions possibly based on local circumstances and cultural contexts. These perception differences should be recognized in the development of cross-cultural virtual mentoring programs, especially as part of the mentorship training for mentors and mentees.

The data of this survey provide useful input into the development of a structured virtual mentoring program for medical physicists. While there is significant literature on "mentoring," also as related to healthcare and research, there is somewhat less literature on "virtual mentoring," and even less on mentoring in association with L&MICs. There is almost no literature on virtual mentoring for medical physicists in L&MICs, especially in the context of experienced medical physicists working in clinical environments in L&MICs.

The results of this survey indicate that the following factors would be important to consider when developing an organized mentorship program, especially in connection with L&MIC contexts:

1. Obtain applications from potential mentors and mentees including details on technical expertise, technologies in use, job role, and expectations
2. Match mentor and mentee through:
   a. Personal connections
   b. Local healthcare facility or university
   c. Professional/regional medical physics associations
   d. MPWB.

Note that while personal connections appear to be the preferred option for many, especially those in lower-income contexts, where there are fewer medical physicists, such connections may not be readily available; hence, a link to an organization may be more amenable.

3. Provide appropriate training for mentor and mentee[41,42]
4. Mentor and mentee should jointly document a formal mentorship agreement. There are multiple sample agreements available on the internet. An example from the University of Alberta can be found here:[43]
   a. Define expectations
   b. Define the expected frequency, length, and format of meetings
   c. Define the review process
      i. Timing and frequency of reviews
      ii. Assess successes and shortcomings.
   d. Define the length of time of mentorship commitment.
      i. Include criteria for continuation or termination.
5. Review the total mentorship program on a mutually established regular basis (possibly annually) and make amendments as needed. Example metrics for review can be found in the literature.[44]

In the context of developing a mentorship program, it is worth looking at what different programs have done even if it is from a slightly different perspective. An entire supplement of the American Journal of Tropical Medicine and Hygiene was devoted to mentorship training for advancing global health research, especially in L&MICs.[45] The supplement included a scoping review by Hansoti *et al*.[46] of toolkits available as aids to systematically guide mentoring relationships and to establish milestones for evaluation and improvement. Of the 18 identified toolkits, three were developed specifically for the L&MIC context. Another article includes a description of the differences between HICs and L&MICs relevant to tailor mentoring efforts.[47]

Two other issues need consideration for mentoring of medical physicists. One relates to equity, diversity, and inclusion. While there seems to be no literature of direct relevance to medical physicists associated with L&MICs, there are recent articles from national organizations in HICs that provide climate surveys and give a great overview of the current status.[48,49] While these provide a national perspective from HICs, one does need to be careful not to push the values of one culture onto another. The other issue relates to ethical considerations. These are addressed, at least from a research perspective, by Bukusi *et al*.,[50] and from a more broadly based global health perspective by Doobay-Persaud *et al*.[51] The latter provides an excellent discussion on concerns related to practicing beyond one's scope of training.

While our survey provides specific preferences from a medical physics perspective, others have provided guidance related to their experiences with mentorship programs. These are useful to consider especially when embarking on a new program and in consideration of L&MIC contexts. For example, it is useful to organize a team to develop and manage a structured mentorship program. Robinson[52] provides a sample guidance document for the US Department of Energy.

Partly as a result of the COVID-19 pandemic, the literature on virtual mentoring is growing rapidly. One example is a paper by Junn *et al*.[53] written from a radiology perspective. These authors discuss the impact of COVID-19 on mentoring. They review the importance of mentorship, describe the characteristics of impactful and successful mentors and mentees, and discuss changes to mentoring in the virtual context to promote career development, diversity, equity, inclusion, and overall wellness. They also note that it is not necessary for there to be a wide gap in experience for the mentorship to be effective but that valuable mentors can be found from people from closer career levels.[53]

Case studies from Peru, Kenya, India, and Mozambique demonstrate that performing a needs assessment early in the development phase of a mentoring program helps to galvanize support for mentoring among both faculty and institutional leadership; these are key ingredients to promote mentoring across an institution.[6]

Mentoring handbooks have been identified as useful tools for aiding mentoring programs by outlining the details of the total process including sample agreements between mentor and mentee.[46] A sample handbook from the University of Iowa is available online.[54]

It is useful to publicize the mentorship program to both potential mentors and mentees using various communication strategies, ranging from social media to specific targeted groups through professional organizations or e-mail correspondence. Such an example of the communication model is given in appendix 2 of the US Department of Energy Mentoring Program.[52] Also, consider the overview given by Treasure *et al*.[55] who used the collective knowledge of four different mentorship programs to describe "ten simple rules for establishing a mentorship program." Additional resources in the form of generic mentoring handbooks are available online and can provide further input into the development of specific mentoring programs.[56,57]

Conclusions

The results of this survey provide important considerations to inform the development of a successful and sustainable global virtual mentoring program for medical physicists. Nearly all respondents agreed that it is important to have clear expectations formalized at the initiation of the mentoring process. Preferences were given to meet once every 2–4 weeks for 30–60 min to discuss and help solve specific problems, to address clinical questions and detailed clinical implementation procedures. A regular review process should be established as part of the mentoring agreement. Mentorship training was considered important for both mentors and mentees. These general concepts of virtual mentoring and their implementation procedures for medical physicists could be of relevance to many other professional groups as well, especially in the context of healthcare and L&MICs.

Acknowledgements:

The authors wish to thank Dr Danielle Rodin, Department of Radiation Oncology, University of Toronto, and Princess Margaret Cancer Centre, and Dr Chris Watling, Centre for Education Research and Innovation, Western University, London, Canada, both for sharing their time and advice at the outset of this project. We thank Tomas Kron and Monique van Prooijen for their review of the draft manuscript. We also acknowledge the contributions of those individuals involved in the focus group discussions.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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