



Teaching clinicians practical genomic medicine: 7 years' experience in a tertiary care center

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Purpose: Increased implementation of complex genetic technologies in clinical practice emphasizes the urgency of genomic literacy and proficiency for medical professionals. We evaluated our genomic education model.

Methods: We assessed the 5-day, extended format program, encompassing lectures, videos, interactive tests, practice cases, and clinical exercises. Pre- and post questionnaires assessed knowledge change, using *t*-tests to compare groups. Satisfaction on program completion and after 3 years were evaluated. Implementation in other centers determined acceptability.

Results: During 2012–2018, 774 clinicians from multiple disciplines and career stages attended 35 programs; 334 (43%) attended the 5-day extended format. Evaluations showed significant improvement of genomic literacy (mean 15.05/100 points, $p < 0.001$). Residents initially had higher scores than specialists (pre: 66.3 ± 17.3 vs. 58.7 ± 16.6 , respectively, $p = 0.002$); both significantly improved, with specialists “catching up” (post: 79.1 ± 17.2 vs.

75.7 ± 15.9 , nonsignificant (NS)); there was a similar trend between fellows and subspecialists (pre: 70 ± 18 vs. 59.4 ± 16.4 , respectively, $p = 0.007$; post: 78.6 ± 16.4 vs. 73.2 ± 17.7 , respectively, NS). Younger specialists (≤ 10 years residency) had significantly higher pre- and post scores. Absolute improvement in scores did not depend on medical specialties.

Conclusion: Our program is effective in improving genomics literacy for clinicians, irrespective of career length or expertise, and could be a model for improving skills in practical genomics for all medical professionals.

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INTRODUCTION

Over the past decade, there has been a dramatic rise in the use of genetic counseling and testing in clinical practice. This is probably due to a combination of factors, such as the inclusion of new genomic technologies in national health insurance programs, and a growing number of physicians subspecializing in medical genetics.

In Israel, we witnessed this rise as well. In 2013, chromosomal microarray (CMA) was included in the national health basket, followed by single-gene sequencing (Sanger) in 2015, next-generation sequencing (NGS) sequencing in 2017, exome “trios” in 2018, and recently NGS panels in 2019. The number of newly board-certified specialists in medical geneticists has increased nearly fourfold during since 2013.

In accordance with Israel regulations, referrals to genetic testing must be carried out by medical geneticists or specialists in their respective fields (for example, referral to prenatal genetic testing by obstetricians). Due to the shortage of genetic professionals, proficiency of physicians in genetic testing is of utmost importance, as it is for physicians practicing in the United States and most centers in Europe.

New genomic technologies are constantly emerging. In current medicine, knowledge of genetics and genomics is imperative for medical professionals.

The need for providing nurses with genomic education for managing their patients was previously described.¹ A recent study² demonstrates the need for continuing education for genetic counselors due to the continuous rapid expansion of

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genetic technologies. The authors conclude that “indeed fundamental changes may be warranted” regarding genetic counselors’ knowledge, skills, and attitudes.

With the increasing implementation of genomic technologies into the clinic, physicians are also expected to be proficient in this field. A systematic literature review on primary care providers’ barriers against provision of genetic testing found that knowledge about genomics was one of the most common.³

A recent survey assessing the need for genomic education and training in England’s National Health Service (NHS) emphasized the importance of ongoing awareness about genomics, as some health-care professionals are unaware how genomics can be applied to health care. The conclusion was that general information should be targeted to professional groups, in addition to cross-professional resources in specific clinical areas.⁴

Genetic training of physicians is offered in various programs across Europe and the United States. Despite evidence of progress in training nongenetic health professionals in genetics, there is a need for a standardized model and effective programs for practicing physicians. Such a model would potentially enable high quality training of a growing number of health-care providers.

A recent systematic review summarized different aspects of programs described in the literature.⁵ Although 44 articles about genetic training programs were included, most studies had few participants (less than 100). In addition, less than half were based on theoretical frameworks, or included information about participants’ years of practice.

A 2015–2018 review of genomic medicine education and training articles describes various genomic education initiatives. The authors conclude these programs should be assessed systematically to create an optimal evidence-based program, and that utilizing genetics specialists to teach physicians is an effective approach that enables interdisciplinary collaboration.⁶

Our mission is to teach physicians principles of genomic medicine, and proficiency in various aspects of genetic testing such as indications, advantages, test results interpretation along with their clinical implications, and limitations of various novel technologies. This would enable clinicians to guide their patients through the genetic evaluation process, to the benefit of all parties.

We present our genomic medicine education program and analyze its quality with regard to knowledge change, teaching techniques, participants’ satisfaction, and acceptability.

The study objective was to evaluate the strength of our genomic education model in improving genomic knowledge among practicing physicians.

MATERIALS AND METHODS

Program description

In 2012, we established a genomic medical education program for physicians at the Recanati Genetic Institute, Rabin Medical Center, in Israel.

Participants

The program was designed for practicing physicians in multiple disciplines of medicine, working in hospitals or outpatient clinics. The courses were offered to physicians from all stages of training/practice, from residency to retired physicians. To ensure effective learning, we required participants be completely engaged in the course, and dedicate their undivided attention to learning.

Lecturers and teaching

The course director was present at all lectures. The 23 lecturers were highly motivated and scientifically updated certified medical geneticists. They were encouraged to attend their colleagues’ lectures to develop continuity between lectures and avoid gaps in the learning process. Participants evaluated the lecturers at the end of each course to guide improvements in subsequent courses. We used social media (e.g., email or WhatsApp groups) for effective communication between participants and lecturers (questions and answers, referrals to recommended reading materials, etc.).

Topics

The opening lectures were dedicated to basic knowledge in genetics and terminology and principal genomic tests used in medicine and research to provide the fundamental tools that would serve participants from varied backgrounds. These were followed by various topics in clinical genetics such as oncogenetics, reproductive genetics, and pediatric genetics. Application of different genomic technologies was presented in each field, using actual cases that had presented at our clinic. State of the art topics such as epigenetics and genetic treatments were addressed, as well as lectures on complexities, ethics, and legal regulations related to genetic counseling and testing. The courses included guided visits to the medical genetic laboratories.

Format and learning tools

The workshop schedule varied among the program’s formats, from one day (8 hours) to the most extended format consisting of 5 consecutive 8-hour days. The workshops combined frontal lectures, interactive multiple-choice tests (smart phone based), exercises involving clinical cases (interpreting pedigrees and laboratory results), as well as other methods. Participants received preparatory learning materials ahead of the course, including printed booklets with lectures slides, as well as computer access to all course files. Teaching videos were sent as an additional learning tool, to further strengthen skills acquired during lectures. Participants were allowed time for questions at the beginning and end of each day. In the extended format, the participants received daily homework assignments consisting of 10 multiple-choice questions, which were reviewed in the following class.

Following the courses, we maintained contact with our graduates and continuously updated them with key articles in the field and invitations to genomic conferences. We encouraged

communications through social media, to facilitate consultation and cooperation for both clinical and research purposes.

To enable more participants to attend our courses, we created four additional program formats. These included weekly afternoon classes, courses designed for physicians in specific subspecialties, bioinformatics for geneticists, and continued education courses for graduates. Several participants attended more than one course, sometimes in different formats. The different course formats are detailed in Table 1.

Program evaluation

We used several methods to analyze the quality of our program:

1. Effectiveness: improvement of test scores between the first and last day of the course (post-test minus pretest).
2. Satisfaction of participants: questionnaires were filled out immediately upon course completion and at follow-up 3 years later.

3. Uptake: implementation of course programs in other centers in Israel and abroad.

Statistical analysis

Analyses were performed with SAS version 9.4 software package (SAS, Cary, NC, USA), and *t* tests were used to compare pre- and post-test scores overall, and between different groups of participants (according to medical discipline and years of medical practice). Wilcoxon nonparametric tests yielded the same results, and normal distribution was also demonstrated visually. Comparison of score improvement between various medical fields was performed by Tukey–Kramer post hoc analysis.

RESULTS

Description of courses

During our 7-year educational experience, we held 35 courses overall; 19 were 5-day courses and 16 had other formats.

Table 1 Course formats.

Course format	Hours per day	Frequency of classes, length of course	Audience, special adjustments
Extended	8	5 consecutive days (40 hours in total)	Physicians from multiple disciplines and stages of training/practice (described in text).
Afternoon	3	Twice a month, 2 semesters (42 hours in total)	Same as extended, catered to physicians that are unable to take a full week leave from other commitments.
Subspecialists	8	1–4 consecutive days	Physicians in specific subspecialties, planned carefully in consultation with a representative from within the specific department. The representative first attended the extended course and then helped plan the specialized course optimally for the departments' needs. Case examples and exercises were specific for subspecialty.
Bioinformatics	8	1 day	Genetics professionals from different fields in genetics and at various levels of training/practicing, a highly specialized course for a group of motivated physicians with prior knowledge, interested in improving their bioinformatics skills in analysis of genetic variants.
Continuation	8	1 day (4 years after extended course)	Graduates of extended course, for refreshing knowledge and skills, and getting updated with new genomic techniques.

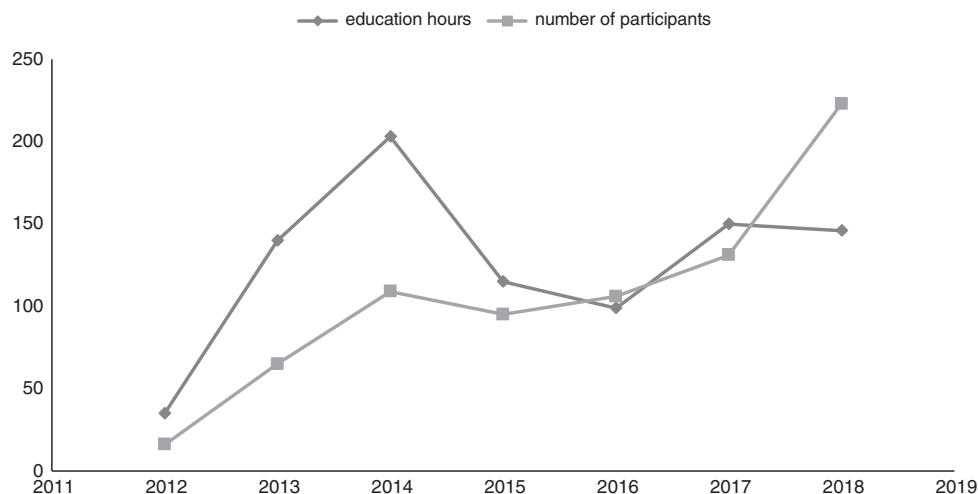


Fig. 1 Change in number of hours and participants by years.

Growth in education volume is presented in Fig. 1, both by number of participants and hours of education. Table 2 summarizes the days and hours of all courses provided.

Description of participants

The 774 medical personnel (691 physicians; 83 genetic counselors and laboratory workers) who participated in the programs included mostly clinicians from various disciplines and career stages, but also researchers, lab personnel, and health-care managers from different positions in hospitals, health maintenance organizations (HMOs), and the Ministry of Health (e.g., clinic directors, department chairs).

As presented in Table 2, among the physicians participating, 137/691 (20%) were residents and 554/691 (80%) board-certified specialists, among whom 123/554 (22%) were department chairs. Most worked in 1 of 24 different tertiary medical centers throughout Israel, 8% (46) in outpatient centers, and a few were lab workers.

The physicians were from 33 different medical disciplines (see Fig. 2). Of those with known fields of practice, 332 (52%) were from internal medicine, 200 (31%) pediatricians, and 112 (17%) from surgical fields (including gynecologists).

Program evaluation

Score improvement

Pretest and post-test results are reported in Table 3. Test scores improved significantly for all groups (mean 15.05, $p < 0.001$). Residents initially had higher scores than specialists (pretest score 66.3 ± 17.3 vs. 58.7 ± 16.6 , respectively, $p = 0.002$). Scores of both groups improved significantly, by similar magnitude, with specialists “catching up” (post-test 79.1 ± 17.2 vs. 75.7 ± 15.9 , nonsignificant (NS)). The trend was similar when comparing physicians training in a subspecialty (fellows) and physicians who had completed their subspecialty (pretest 70 ± 18 vs. 59.4 ± 16.4 , $p = 0.007$, post-test 78.6 ± 16.4 vs. 73.2 ± 17.7 , NS). Specialists who had completed medical training within the past 10 years had significantly higher scores than those practicing >10 years, both before and after the program, but all participants improved dramatically. Scores did not depend on the specialty field, and degree of improvement in knowledge due to the course was equivalent, regardless of practice years. However, in post hoc analysis of specialty fields adjusted for

Table 2 Summary of courses.

Course characteristic	N (%)
Number of courses	35
Single-day courses	8
One-week courses	19
Other	8
Total education days	154
Total hours	924
Number of participants (%)	774 (100%)
Nonphysicians	83 (11%)
Physicians	691 (89%)
Residents within physicians	137 (20%)
Specialists within physicians	554 (80%)
Managers within specialists	123 (22%)

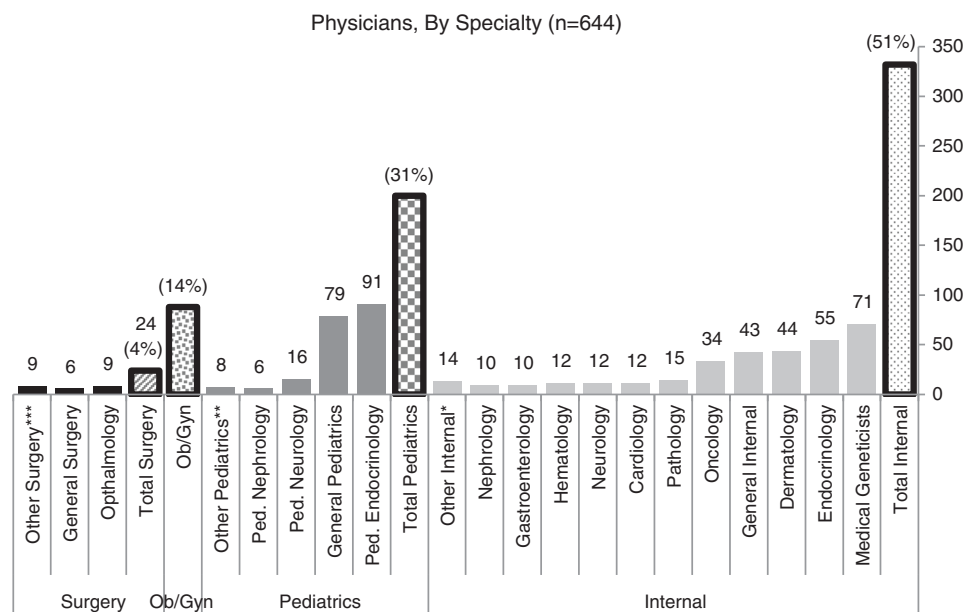


Fig. 2 Physicians according to specialty, classified according to the latest qualification. Five percent of participants were classified as other. *Other internal includes pulmonology, psychiatry, radiology, anesthesiology, immunology, rheumatology. **Other pediatrics includes pediatric pulmonology, pediatric gastroenterology, pediatric cardiology, pediatric hematology, pediatric rheumatology. ***Other surgery includes orthopedics, plastic, ENT, urology.

Table 3 Pretests and post-tests results^a.

Level of profession	Pretest		Post-test		Delta	
	Mean ± SD	P value	Mean ± SD	P value	P value	P value
Residents (n = 62) vs. Specialists (n = 222)	66.3±17.3 vs. 58.7±16.6	0.002	79.1±17.2 vs. 75.7±15.9	0.156	0.129	0.129
Residents 1st (n = 37) vs. Specialists 1st (n = 136)	63.7±16.5 vs. 58.3±16.7	0.085	79.4±17.9 vs. 77.4±14.4	0.536	0.45	0.45
Residents 2nd (n = 25) vs. Specialists 2nd (n = 86)	70±18 vs. 59.4±16.4	0.007	78.6±16.4 vs. 73.2±17.7	0.179	0.147	0.147
Residents 1st (n = 37) vs. Residents 2nd (n = 25)	63.7±16.5 vs. 70±18	0.167	79.4±17.9 vs. 78.6±16.4	0.856	0.085	0.085
Specialists 1st (n = 136) vs. Specialists 2nd (n = 86)	58.3±16.7 vs. 59.4±16.4	0.637	77.4±14.4 vs. 73.2±17.7	0.075	0.074	0.074
Young professionals (n = 114) vs. Senior professionals (n = 146)	65.72±16.5 vs. 55.8±16.1	<0.001	80.1±15.2 vs. 73.1±16.8	<0.001	0.298	0.298
Internal (n = 133) vs. Surgery (n = 75)	56.9±17.1 vs. 61.6±16.4	0.06	74.1±17.8 vs. 79.5±13.1	0.016	0.613	0.613
Internal (n = 133) vs. Pediatrics (n = 78)	56.9±17.1 vs. 64.7±16.3	0.001	74.1±17.8 vs. 77.3±15.8	0.19	0.105	0.105
Physicians (n = 284) vs. Others (n = 41)	60.4±17 vs. 72.6±13.1	<0.001	76.5±16.2 vs. 79.9±17.4	0.219	0.043	0.043
Total	61.78±16.94		76.82±16.35			<0.0001

Residents 1st = first residency, Specialist 1st = primary specialty only, Residents 2nd = during subspecialty residency, Specialist 2nd = completed subspecialty residency, Young professionals ≤10 years of medical practice, Senior Specialists ≥10 years of medical practice. "Others" include lab workers, researchers, and external commercial companies.
^aSome of our participants attended more than one course, in which case we analyzed their scores separately for each course.

years of practice, there was a tendency toward greater improvement for surgeons (mostly obstetricians) compared with pediatricians (delta 17.4 points vs. 11.7 points, respectively, $p = 0.09$ (NS)).

Satisfaction of participants

Participants were extremely satisfied with the program in general, and particularly with the clinical approach. They reported satisfaction on all levels, including content, lecturers, organization, exercises, and learning tools, and supported the 5-day intensive learning format without interruptions, due to demanding work schedules that would not have enabled learning in parallel. Most physicians had finished their medical training at least 10 years before the course, therefore were impressed by the great advancements in the field. They expressed their satisfaction with a course that covered a huge gap in their knowledge, which would not have been covered otherwise. Some compared this new genomic language with "learning any other language" or "learning how to swim." They enjoyed the use of example clinical cases from their practices rather than textbook cases, which naturally included cases with mistakes and negative results. Actual laboratory results from their own patients were presented and helped them better appreciate the clinical context, rather than hypothetical results from literature. Availability of the lecturers for questions contributed to their satisfaction, as well as the variety of fields among the participants, which enabled case examples from multiple disciplines of medicine.

Participants remembered the course fondly after 3 years and had made good use of skills acquired during the workshops. Perhaps the best indicator of satisfaction was that many expressed interests in attending additional courses to refresh their memory and learning new updates on genetic technologies.

Uptake and acceptability

This parameter was more difficult to quantify than knowledge, quality, and satisfaction. However, five other medical centers throughout Israel have adopted our teaching format, and the extended format course was held a couple of times for participants overseas (Moscow and Yekaterinburg, Russia).

In addition, in recent years we have seen a rise in the number of referrals for genetic testing, and more willingness of HMO regulators in Israel to accept these referrals, despite high costs. We believe that the increase in genetic testing may be partially due to changes in attitude of many physicians after participating in our workshop. Therefore, they are more comfortable incorporating genetics into their practices. We expect this trend to continue as more physicians learn about genomics.

DISCUSSION

We describe our program that encompassed nearly 800 participants in a 7-year period (2012–2018). Analysis demonstrated effectiveness in improving genetics knowledge among all physicians, from all backgrounds, years of practice,

medicine disciplines, and positions. Although we observed similar improvements in score, the younger physicians scored higher than their senior colleagues, both in pretests and post-tests. Residents and fellows had higher pretest scores than specialists and subspecialists, respectively, but post-test scores were not significantly different.

Our findings are in line with previous reports from the literature, which show that knowledge in genetics is linked to a younger age, since recently graduated clinicians are better trained in this field.^{7–9}

The more senior physicians, many of whom are chairmen, department heads, regulators, etc., showed less knowledge at both stages. This may be because the junior physicians completed their medical training more recently, and have more baseline knowledge in genetics, compared with their older colleagues who attended medical school prior to the era of genomic medicine. Medical training in later years may also have provided more “genomic familiarity” and facilitated acquisition of genomic approach and knowledge. One must also take into consideration that younger age is an advantage for learning new fields both in general, and specifically in terms of ability to dedicate time to learning, as more senior physicians usually have more work commitments.

Based on our experience, physicians at any level of practice would likely benefit from the workshop. However, the optimal timing for genomic training is probably shortly after completing residency programs, as this is the point in the physician’s career with the greatest potential for utilization of genetic tests. However, it may be important to include department heads in genomic courses to facilitate implementation of new genetic tests into the health-care system. We did not evaluate optimal timing for training, and plan to do so in future studies.

We have observed a dramatic increase in genomic testing in all fields of medicine over recent years, for many reasons, including their inclusion in Israel’s health basket of services. It is possible that improvement in physicians’ attitudes, skills, and confidence in their own abilities after obtaining knowledge in genetics has also contributed to this process. Examining the association between participation in genomic workshops and increased use of genomic testing is another goal for future studies.

Since we only had 1–3 courses in other formats, these were not assessed formally. However, from our experience, afternoon classes were less successful than the 5-day course, probably due to long intervals between lectures (2 weeks), which disrupted continuity. Long intervals are detrimental to the learning process, especially when new and technically difficult materials are being presented. In addition, afternoon courses involved less commitment of the participants in attendance and assignment completion. The extended courses enabled physicians to completely focus on and be devoted to the course, as they freed their schedules from work routines and clinical commitments.

Workshops catering to physicians according to subspecialties had excellent results, both in improvement in knowledge and skills, and participant satisfaction. This may largely be explained by participants’ similar baseline level of knowledge with more targeted teaching to the participants’ knowledge, topics of interest, and expected goals. Due the high success rate, this may be the most beneficial format, which we plan to repeat in future courses.

A recent review that summarized different aspects of training programs described in the literature⁵ had significantly fewer participants (less than 100) compared with our study, and most lacked information about participants’ years of practices or were based on theoretical frameworks. Another paper⁶ on genomic medicine education and training that reviewed articles published in 2015–2017 concluded these programs should be assessed systematically. Our study systematically evaluated a curriculum-based program that, thus far, has included almost 800 participants, with data regarding their medical disciplines and years of practice.

Further research is needed to validate results of our program on a larger scale and in other centers. We aim to continue our educational program in its current formats, and our future direction will also involve online courses (e-learning tool). We plan to continue to evaluate our program using the methods described here as well as others.

To conclude, in the genomic era, physicians need to be knowledgeable in genetics. Training physicians from all fields will potentially increase the use of clinical genetic testing.³ We described an example of a program that may be beneficial for improving the genomic skills and competence of health providers in additional centers.

DISCLOSURE

The authors declare no conflicts of interest.

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