Published in final edited form as:

Clin Genet. 2015 December ; 88(6): 565–572. doi:10.1111/cge.12555.

Genetic counselors' (GC) knowledge, awareness, and understanding of clinical next-generation sequencing (NGS) genomic testing

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Abstract

Genomic tests are increasingly complex, less expensive, and more widely available with the advent of next-generation sequencing (NGS). We assessed knowledge and perceptions among genetic counselors pertaining to NGS genomic testing via an online survey. Associations between selected characteristics and perceptions were examined. Recent education on NGS testing was common, but practical experience limited. Perceived understanding of clinical NGS was modest, specifically concerning tumor testing. Greater perceived understanding of clinical NGS testing correlated with more time spent in cancer-related counseling, exposure to NGS testing, and NGS-focused education. Substantial disagreement about the role of counseling for tumor-based testing was seen. Finally, a majority of counselors agreed with the need for more education about clinical NGS testing, supporting this approach to optimizing implementation.

Keywords

genetic counseling; next generation sequencing; preparedness

INTRODUCTION

Recent advances in sequencing technology, including next generation sequencing (NGS), have made the integration of clinical genomics into patient care a rapidly foreseeable reality. Due to the low cost, rapid turnaround, and broad potential application of NGS sequencing, its role in clinical care is expected to continue to grow (1). Research has yet to investigate how the medical community will respond to incorporation of genomics into practice. Studies of genomic technologies like pharmacogenomic testing have highlighted provider reluctance coupled with perceived lack of expertise towards genomics-based medicine as well as high patient expectations (2, 3). Additional apprehensions relate to provider lack of experience with genomic medicine, as well as unclear utility (4). Existing knowledge gaps raise doubt whether providers are adequately prepared to bridge the emerging clinical genomics gap (5–

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The authors report no conflicts of interest.

7). Moreover, barriers to adequate informed consent for genomic tests are many, stemming from the information complexity and variability of patient needs (8–10). Clinical implementation is further complicated by uncertainty related to the optimal management of ancillary genomic information.

Informed consent prior to genetic testing is the standard of care in the United States (11, 12). In recent years, the profession of genetic counseling has grown substantially in response to the increasing role of genetic testing in patient care. Nonetheless, GCs remain a scarce resource (13, 14). As genetic/genomic tests become more widely available, greater demands will be placed on all segments of health care to provide counseling and result interpretation. It is thus imperative to understand the perceived preparedness of healthcare professionals, particularly the GC community, to address emerging clinical demands. Here, we report the results of a survey developed to broadly examine knowledge and perceptions of NGS genomic tests within a large professional GC society.

MATERIALS AND METHODS

Survey development

A 90-item web-based survey was developed by a multidisciplinary team of GCs, oncologists, and scientists conducting genomic research. Items relevant to NGS genomic testing were drafted after extensive literature search including review of publically available materials and informed consent documents for available genomic tests. Items were beta-tested and refined among health professionals at our center including: members of the Department of Clinical Genetics, oncologists, local GCs, and several counseling students (n=16). Results were reviewed to identify items of limited utility or ambiguous meaning. The final survey included assessments of awareness and perceived understanding of NGS genomic testing, preparedness to implement genomic testing, items eliciting knowledge of clinical NGS genomic tests, and participant characteristics.

Participant characteristics—Age, sex, and race/ethnicity were queried. Items assessed whether GCs had a professional degree, years in practice, and time spent in cancer-related counseling.

Knowledge scale—24 items developed by the study team examined knowledge of NGS clinical testing (Table 2). 'Unsure' or 'do not wish to answer' responses were combined.

Understanding of genomic testing—Nine Likert-type items examined GCs' perceived understanding of NGS genomic testing, including: 1) advantages/disadvantages of germ-line or tumor-based tests (n=4 items, $\alpha=0.76$), and GCs' perceived understanding of the practical aspects of NGS genomic testing including costs, wait times, privacy, and informatics demands (n=5, $\alpha=0.78$). Response options were Poor, Fair, Good, Very Good, and Excellent. Mean responses and standard deviations were calculated for each item, and a mean participant rating was used in univariate analyses.

Awareness of NGS clinical genomic testing—Four items assessed awareness of availability of NGS genomic testing in the clinical setting [same Likert-type scale used

previously ($\alpha=0.79$)). Response frequencies are reported for germ-line and tumor-testing items. For univariate associations with demographics and understanding, we examined the proportion with high awareness, characterized as either “Very Good” or “Excellent” responses for both items.

Perceived role of genetic counseling in clinical genomic testing—Four items assessed perceived role for genetic/genomic counseling to accompany germ-line and tumor whole genome and gene panel testing ($n=4$, $\alpha=0.75$). Responses were Strongly disagree, Disagree, Neutral, Agree, or Strongly agree.

Clinical experience and professional needs for NGS genomic testing—Total patients counseled, participation in education, perceived need for education, and perceived relevance of NGS genomic testing to current practice were queried.

Recruitment

Recruitment occurred through the National Society of Genetic Counseling (NSGC) and was incentivized (\$25 gift card). Between April-June 2013, 340 GCs were recruited by a list-serv posting from ~ 800 regular users (personal communication, NSGC). Additional subjects were recruited via email invitation to all NSGC members ($n=2589$) — 353/690 (51%) who opened the invitation completed the survey. Overall response rate was 26.7% (693/2589). Survey was administered via Research Electronic Data Capture (REDCap). All participants completed IRB-approved electronic informed consent(15).

Statistical analyses

Data were analyzed using SAS (v.9.3). We examined univariate associations between counselor characteristics and perceptions as 1) differences in perceptions by characteristic category, using analysis of variance (ANOVA) or Chi-square test, and as 2) trend association using linear regression or Cochran-Armitage trend tests. Significance level $p<0.05$ was used.

RESULTS

Participants

Similar to the NSGC membership (16–18), participants were predominantly female (95.9%) and white (92.0%). Majority (74.6%) were 22–39 years old. Over half (52.3%) had been in practice over 5 years. While nearly half (45.9%) practiced mainly cancer-related counseling, a significant minority (41.6%) did not (Table 1).

Exposures to NGS genomic testing

Majority (75.4%) reported recent education about NGS genomic testing. However, almost half (46.6%) had never counseled a patient for an NGS test result, and <25% reported counseling >5 patients for a germ-line NGS test. Further, the vast majority (87%) had never counseled a patient for a tumor-based NGS test, and only 13% had counseled >1 patient. Nevertheless, >50% saw NGS testing as already or becoming routine within 1 year.

Knowledge of NGS-based testing

Mean number knowledge items correct was 11.7 (SD 4.1), and mean number “unsure” was 8.3 (SD 4.8) (Table 2). Older age was associated with lower score ($p = 0.001$) and older age/more years in practice were associated with more frequent “unsure” responses ($p < 0.001$). More time in cancer-related counseling was associated with fewer “unsure” responses ($p = 0.015$), and a trend toward higher knowledge ($p = 0.004$).

Perceived understanding of NGS-based testing

GCs reported modest perceived understanding of the advantages/disadvantages of NGS germ-line and tumor-based testing (mean 3.1, good/very good), but poorer understanding of clinical aspects of NGS (mean 2.5) ($p < 0.0001$). Notably, perceived understanding of the advantages/disadvantages of genome vs gene panel testing was greater in germ-line (3.0 = Good) than tumor testing (2.3 = Fair-Good). Respondents with prior NGS testing experience, education, and higher knowledge scores had overall higher confidence in their level of understanding of clinical NGS (Table 3).

Modest awareness of the clinical availability of NGS testing for germ-line and tumor testing was seen. For germ-line, 34% noted “good” awareness, whereas for tumor tests, 80% reported “poor” or “fair” awareness of availability. Awareness of germ-line tests was significantly higher with greater practical exposure to NGS testing, education, and higher perceived relevance of NGS to current practice (Table 3). Similar trends were seen with tumor-based testing.

Perceived role and needs

Interestingly, GCs viewed professional roles in germ-line versus tumor NGS testing differently. Nearly all “agreed” or “strongly agreed” that GCs are critical for germ-line whole genome (99%) or gene panel (97%) testing. However, for tumor NGS testing, less than half (46%) felt counseling was routinely needed for panel testing. Increasing age ($p < 0.0001$) and years in practice ($p < 0.0001$) were associated with a lower perceived importance of counseling for tumor NGS (Table 4). Those who practiced more cancer-related counseling ($p < 0.0001$), and who had participated in NGS-related education ($p = 0.0068$), also felt counseling was less important for tumor testing. Finally, GCs overwhelmingly agreed with the need for more education regarding NGS testing.

DISCUSSION

This survey is one of the first to query knowledge and perceptions among GCs of clinical NGS genomic testing. Our study examined a diverse sample with variable exposure to and clinical experience with NGS testing (16–18). We hypothesized that GCs, with limited time for preparation for the rapidly changing clinical incorporation of NGS, would demonstrate low levels of awareness and preparedness. In line with our hypothesis, the data suggest many GCs perceive deficiencies in their understanding of NGS testing, notably in many of the clinically relevant aspects of this new technology (e.g. support resources, privacy limitations, costs). Both overall modest familiarity with the technical, practical, and information-based aspects of NGS testing as well as perceived understanding of advantages/

disadvantages of NGS testing, were associated with knowledge scores ($p<0.0001$). This suggests that counselors' were generally accurate in their self-assessment of perceived understanding as measured by objective knowledge, and thus, that these results report true deficits among practicing counselors.

Interestingly, age or years in practice were not associated with greater knowledge, awareness, or positive perceptions. However, several factors were consistently associated with knowledge and greater perceived understanding of the clinical factors related to and the advantages/disadvantages of NGS testing. These were: more time spent in cancer-related counseling, greater exposure to NGS testing in the clinic, more NGS-related education, and higher perceived relevance of NGS testing in the future ($p<0.0001$ for all). Our findings suggest that practical exposure to NGS testing and education are effective routes to increase understanding and knowledge in the counseling community.

At the time of survey, GCs were relatively inexperienced in counseling patients on NGS results. However, those who had experience and those who viewed NGS tests as becoming routine within a year were more confident in their understanding and awareness of NGS-based testing, attributes which correlated with greater knowledge. Further, NGS education also correlated with perceived understanding and awareness, and higher knowledge (more correct and fewer 'unsure'), highlighting the importance of practical experience coupled with education for disseminating new technologies. Yet at this early juncture, confidence towards NGS was tepid at best, and GCs reported broad needs for further education.

Somewhat unexpected were the counselors' perceptions of NGS tumor testing. Only half supported a role for counseling in tumor testing. Examined by subgroup, older, more experienced (with NGS), cancer-oriented, and more knowledgeable counselors viewed counseling as less important for tumor testing. Tumor-based testing is not undertaken to examine the germ-line and thus may not have immediate hereditary implications. Nonetheless, somatic mutations, if found in the context of a family history, may be highly suspicious for a germ-line mutation, and thus could warrant counseling. Whether counseling should be offered before somatic testing or after, and whether patients should be able to opt-out of germ-line information from tumor testing, remains undefined.

The emerging standard in genetic medicine is that there are particular test results related to hereditary risk that must be communicated to patients if detected (19). On this point, the opinions of the counselors surveyed here are intriguing. It is possible they reflect lack of awareness of the potential germ-line implications of tumor testing among counselors with less knowledge and experience--nearly half provided minimal or no cancer counseling, and 87% had never provided counseling for NGS tumor testing. However, these results could also reflect their belief that somatic testing should be kept distinct from the more complex decision to pursue germ-line testing. In either case, as the demand for genetic testing increases, we need to better delineate which patients will require pre-test counseling. More detailed annotation of somatic test results may help prevent important findings from being missed by oncology providers, but will not substitute for the clinical contribution of a medical genetics professional.

Strengths of our study include our large sample, as well as multi-disciplinary development of a clinical NGS knowledge measure and perception items. Nonetheless, with no standard measures to benchmark validity, the conclusions drawn here must be considered hypothesis-generating. In addition, NGS genomic testing is rapidly evolving—thus the correct responses to some knowledge items could change. Thus, we presented response frequencies rather than scoring only correct items. Finally, the modest response rate limits generalizability (16).

Few studies addressing preparedness and perceptions regarding NGS testing exist. Our findings merit further investigation, especially as experience with tumor testing continues to increase. For example, it would be interesting to re-evaluate changes in counselors' perceptions over time after greater exposure to practical training and formal education. Determining optimal means of provider and patient education, optimal delivery of results, and optimal integration of genetic testing into patient care will be necessary for our molecular genetic advances to fully transform into clinical gains.

Acknowledgements

This research was supported in part by funding received through the Fox Chase Cancer Center core grant from the National Cancer Institute (P30 006927-45). Additionally supported by grant #IRG-92-027-18 from the American Cancer Society.

REFERENCES

1. Drmanac R, Sparks AB, Callow MJ, et al. Human genome sequencing using unchained base reads on self-assembling DNA nanoarrays. *Science*. 2010; 327(5961):78–81. [PubMed: 19892942]
2. Haga SB, Burke W, Ginsburg GS, et al. Primary care physicians' knowledge of and experience with pharmacogenetic testing. *Clinical genetics*. 2012; 82(4):388–394. Epub 2012/06/16. [PubMed: 22698141]
3. Haga SB, Tindall G, O'Daniel JM. Public perspectives about pharmacogenetic testing and managing ancillary findings. *Genetic testing and molecular biomarkers*. 2012; 16(3):193–197. Epub 2011/11/04. [PubMed: 22047505]
4. Fargher EA, Eddy C, Newman W, et al. Patients' and healthcare professionals' views on pharmacogenetic testing and its future delivery in the NHS. *Pharmacogenomics*. 2007; 8(11):1511–1519. [PubMed: 18034616]
5. Gurwitz D, Lunshof JE, Dedoussis G, et al. Pharmacogenomics education: International Society of Pharmacogenomics recommendations for medical, pharmaceutical, and health schools deans of education. *The pharmacogenomics journal*. 2005; 5(4):221–225. [PubMed: 15852053]
6. Frueh FW, Gurwitz D. From pharmacogenetics to personalized medicine: a vital need for educating health professionals and the community. *Pharmacogenomics*. 2004; 5(5):571–579. [PubMed: 15212593]
7. Latif DA. Pharmacogenetics and pharmacogenomics instruction in schools of pharmacy in the USA: is it adequate? *Pharmacogenomics*. 2005; 6(4):317–319. [PubMed: 16004550]
8. Feld AD. Informed consent: not just for procedures anymore. *Am J Gastroenterol*. 2004; 99(6):977–980. [PubMed: 15180712]
9. Ormond KE, Banuvar S, Daly A, et al. Information preferences of high literacy pregnant women regarding informed consent models for genetic carrier screening. *Patient education and counseling*. 2009; 75(2):244–250. [PubMed: 19013744]
10. Robertson JA. Consent and privacy in pharmacogenetic testing. *Nat Genet*. 2001; 28(3):207–209. [PubMed: 11431685]
11. Robson ME, Storm CD, Weitzel J, et al. American Society of Clinical Oncology policy statement update: genetic and genomic testing for cancer susceptibility. *J Clin Oncol*. 2010; 28(5):893–901. [PubMed: 20065170]

12. Committee on Ethics ACoO, Gynecologists, Committee on Genetics ACoO. ACOG Committee Opinion No: 410: Ethical issues in genetic testing. *Obstetrics and gynecology*. 2008; 111(6):1495–1502. [PubMed: 18515541]
13. Sutphen R, Davila B, Shappell H, et al. Real world experience with cancer genetic counseling via telephone. *Familial cancer*. 2010; 9(4):681–689. Epub 2010/08/28. [PubMed: 20799063]
14. American Board of Medical Genetics, Inc. Number of Certified Specialists in Genetics. [10/10/2014]; Available from: http://www.abmgg.org/pdf/Statistics_allyears_1.pdf.
15. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *Journal of biomedical informatics*. 2009; 42(2):377–381. Epub 2008/10/22. [PubMed: 18929686]
16. Bradbury AR, Patrick-Miller L, Fetzter D, et al. Genetic counselor opinions of, and experiences with telephone communication of BRCA1/2 test results. *Clinical genetics*. 2011; 79(2):125–131. [PubMed: 21039431]
17. Nardini MD, Matthews AL, McCandless SE, et al. Genomic Counseling in the Newborn Period: Experiences and Views of Genetic Counselors. *Journal of genetic counseling*. 2014 Epub 2014/03/25.
18. National Society of Genetic Counselors. 2012 Professional status survey: Executive summary. 2012. Available from: <http://nsgc.org/p/cm/ld/fid=68>.
19. Green RC, Berg JS, Grody WW, et al. ACMG recommendations for reporting of incidental findings in clinical exome and genome sequencing. *Genetics in medicine : official journal of the American College of Medical Genetics*. 2013; 15(7):565–574. Epub 2013/06/22. [PubMed: 23788249]

Table 1

Demographic and professional characteristics of participants (n=639)

Baseline characteristics	N (%)
Demographic characteristics	
Age (mean=34.7 (std dev=9.7), median=32, range=22 to 72)	
22–29	241 (37.7)
30–39	236 (36.9)
40–49	95 (14.9)
50+	67 (10.5)
Sex	
Female	613 (95.9)
Male	26 (4.1)
Race	
Non-White	51 (8.0)
White	588 (92.0)
Ethnicity	
Hispanic	9 (1.4)
Non-Hispanic	630 (98.6)
Professional exposures	
<i>Do you have a genetic counseling degree?</i>	
Yes	612 (95.8)
No	27 (4.2)
<i>How many years have you been counseling?</i>	
Currently in training	24 (3.8)
< 2 years	135 (21.1)
2–5 years	146 (22.9)
5+ years	334 (52.3)
<i>Cancer-related counseling represents what percentage of your total counseling activity?</i>	
<25%	266 (41.6)
25–50%	46 (7.2)
50–75%	34 (5.3)
75+%	223 (45.9)
NA	70 (11.0)
<i>Have you participated in any education in the last 2 years regarding the role of genomic testing using NGS technology in clinical practice?</i>	
Yes	482 (75.4)
No	157 (24.6)
<i>How many patients have you participated in counseling on the results of germ-line genome or gene panel test that uses NGS?</i>	
None or not sure	298 (46.6)
1–5 patients	184 (28.8)

Baseline characteristics	N (%)
6–20 patients	110 (17.2)
20+ patients	47 (7.4)
<i>How many patients have you participated in counseling on the results of tumor genome or tumor gene panel test that uses NGS?</i>	
None or not sure	556 (87.0)
1–5 patients	64 (10.0)
6–20 patients	15 (2.4)
20+ patients	4 (0.6)
<i>I believe genetic counseling for NGS-based gene panels will become a routine part of patient practice</i>	
Already is routine	138 (21.6)
Within 1 year	189 (29.6)
Within 2–5 years	226 (35.4)
At least 5 years in the future	30 (4.7)
Unsure	56 (8.8)

Table 2

Knowledge of NGS testing (n=639). For each item, the percent in boldface indicates the response considered correct at the time of the survey.

	Participant Response (percent)		
	True	False	Unsure or do not wish to answer**
In the clinical setting, traditional (also known as Sanger) sequencing has nearly been replaced by sequencing using NGS technology.	24.6	57.3	18.1
NGS testing is more accurate than traditional sequencing.	10.6	63.1	26.3
An actionable item discovered by NGS testing is one in which further research must be performed to determine the significance.	22.7	56.0	21.3
The definition of clinically relevant target for NGS testing depends on the laboratory being used.	56.2	13.9	29.9
Commercial laboratories are required to contact a patient or their treating physician if a variant of uncertain significance is later discovered to be of clinical significance.	25.7	43.3	31.0
Excessive coverage of sequenced gene regions by NGS leads to high error rates.	7.7	50.2	42.1
Commercial laboratories are required to make the sensitivities and specificities for NGS sequencing tests available to the public.	42.7	17.4	39.9
dbSNP is a free public archive run by the National Center for Biotechnology Information (NCBI) with extensive data including polymorphism occurrence frequency.	65.7	0.0	34.3
Incidental findings are rare for tumor genome sequencing.	5.5	44.9	49.6
Current electronic medical record capabilities are insufficient to manage the output of data from tumor genome sequencing.	61.0	7.2	31.8
If no actionable mutation is detected by tumor genome sequencing, my patient could still have a genetic change driving their cancer.	88.6	0.8	10.6
A patient found to have a <i>BRCA1</i> mutation by tumor panel sequencing is very likely to have a germ-line <i>BRCA1</i> mutation.	20.5	44.8	34.7
Genes selected for testing as part of new commercial tumor sequencing panels are reviewed by the Food and Drug Administration (FDA) before approval of the new panel test.	5.0	62.8	32.2
The Genetic Information Non-discrimination Act does not protect individuals who choose to undergo tumor genome or tumor panel sequencing using NGS.	19.6	34.9	45.5
Both tumor tissue and normal tissue (or blood) are required for NGS analysis of a patient's tumor by tumor genome or tumor panel sequencing.	41.9	9.7	48.4
NGS is a powerful way to sequence cancer-related genes in GC repeat regions of the genome.	23.3	23.3	53.4
Unlike other online resources, dbSNP was specifically designed for easy clinical use by medical providers and genetic counselors who perform tumor genome and tumor panel sequencing.	18.5	18.6	62.9
All abnormal variants detected during my patient's germ-line panel sequencing are reported to me.	28.6	45.7	25.7
Germ-line panel sequencing tests are prohibited from examining breast cancer risk genes and colorectal cancer risk genes on the same panel.	2.2	64.8	33.0
NGS technology reduces germ-line genome sequencing processing time from 6 months to around 3 weeks.	35.5	27.9	36.6
Copy number variants (CNV) are reliably detected by germ-line genome sequencing.	16.3	50.2	33.5
Sample de-identification is sufficient to ensure patient privacy in germ-line whole genome sequencing.	16.0	45.5	38.5
Germ-line whole genome sequencing tests will sequence patented genes like <i>BRCA1</i> and <i>BRCA2</i> but results may not be reported.*	56.3	13.3	30.4
Commercial germ-line genome sequencing and tumor genome sequencing tests must be CLIA certified.	69.8	10.0	20.2

* Patents on the *BRCA1* and *BRCA2* genes held by Myriad Genetics were in place at the time of survey. This item had 19 responses of "Do not wish to answer".

**
Number of "Do not wish to answer" varied from 2 to 10, except as noted above.

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Table 3

Associations of counselor characteristics with understanding and awareness of NGS testing

Characteristic	Understanding of Advantages/Disadvantages, mean (std dev) ¹	Understanding clinical elements, mean (std dev) ¹	High awareness of clinical germ-line (percent) ²	High awareness of clinical tumor-based (percent) ²
Age (years)				
22–29	3.2 (0.7)	2.5 (0.8)	26.3	4.3
30–39	3.0 (0.8)	2.5 (0.8)	23.0	6.6
40–49	3.1 (0.8)	2.5 (0.8)	20.2	4.6
50+	2.9 (0.9)	2.4 (0.8)	17.9	3.1
Trend test p-value	0.024	0.370	0.099	0.764
Years counseling				
<i>In training</i>	3.0 (0.5)	2.3 (0.6)	4.2	0.0
< 2 years	3.2 (0.8)	2.4 (0.8)	22.2	3.8
2–5 years	3.1 (0.8)	2.5 (0.8)	29.7	6.3
5+ years	3.0 (0.8)	2.5 (0.8)	22.3	5.4
Trend test p-value	0.113	0.355	0.451	0.313
Cancer-related counseling				
N/A	2.7 (0.7)	2.2 (0.8)	14.3	0.0
<25%	2.9 (0.8)	2.3 (0.8)	20.5	3.9
25–50%	3.2 (0.7)	2.6 (0.8)	30.4	6.8
50–75%	3.2 (0.7)	2.6 (0.8)	32.4	0.0
75+%	3.3 (0.7)	2.7 (0.7)	26.5	8.4
Trend test p-value, excl N/A	<0.001	<0.001	0.122	0.093
# of pts counseled for NGS germ-line				
<i>None or not sure</i>	2.8 (0.8)	2.2 (0.7)	11.8	2.5
1 or more	3.3 (0.7)	2.7 (0.8)	33.2	7.3
t-test or Chi-square test p-value	<0.001	<0.001	<0.001	0.006
# of pts counseled for NGS tumor				
<i>None or not sure</i>	3.0 (0.8)	2.4 (0.8)	20.1	3.2
1 or more	3.5 (0.7)	2.9 (0.7)	44.6	17.1
t-test or Chi-square test p-value	<0.001	<0.001	<0.001	<0.001
Previous participation in education				
<i>Yes</i>	3.2 (0.8)	2.6 (0.8)	28.3	6.0
<i>No</i>	2.7 (0.8)	2.2 (0.7)	7.7	2.1
t-test or Chi-square test p-value	<0.001	<0.001	<0.001	0.061
Perceived relevance of NGS clin tstng				
<1 year	3.3 (0.8)	2.7 (0.8)	30.5	7.1
Over 1 year	2.9 (0.7)	2.3 (0.7)	15.3	3.2

Characteristic	Understanding of Advantages/Disadvantages, mean (std dev) ¹	Understanding clinical elements, mean (std dev) ¹	High awareness of clinical germline (percent) ²	High awareness of clinical tumor-based (percent) ²
<i>Uncertain</i>	2.6 (0.8)	2.2 (0.7)	17.9	1.9
ANOVA or Chi-square test p-value	<0.001	<0.001	<0.001	0.065
Knowledge Score, number correct				
0–6	2.4 (0.8)	1.9 (0.7)	1.5	1.6
7–12	3.0 (0.7)	2.3 (0.7)	16.7	3.3
13–18	3.3 (0.7)	2.7 (0.8)	33.9	7.2
19–24	3.8 (0.7)	3.1 (0.9)	44.4	11.5
Trend test p-value	<0.001	<0.001	<0.001	0.005

¹ Results represent an assessment of understanding via 5-point Likert-type Scale (1= Poor, 5=Excellent), expressed as the mean result of the relevant survey items (4 items each for the understanding scores; 2 items each for the awareness scores).

² Represents the percentage of GCs who rated their awareness of the availability of testing as Very Good or Excellent (4 or 5)

Table 4

Associations of counselor characteristics with knowledge score and perceived counselor role

Characteristic	Clinical role of GC tumor based (percent) ^I	NGS testing Knowledge Score, based on 24 items mean (std dev)	
		Correct	Unsure
Age (years)			
22–29	56.6	12.1 (3.7)	7.4 (4.3)
30–39	42.1	11.9 (4.4)	8.4 (5.0)
40–49	34.4	11.1 (3.9)	8.9 (4.2)
50+	28.4	9.8 (4.5)	10.3 (5.6)
Trend test p-value	<0.001	<0.001	<0.001
Years counseling			
<i>In training</i>	75.0	10.5 (4.2)	8.0 (4.7)
< 2 years	55.6	12.4 (3.5)	6.8 (4.0)
2–5 years	49.7	11.9 (3.9)	8.2 (4.6)
5+ years	36.3	11.3 (4.4)	9.0 (5.1)
Trend test p-value	<0.001	0.078	<0.001
Cancer-related counseling			
N/A	68.1	10.1 (4.2)	10.4 (5.0)
<25%	63.0	11.5 (4.3)	8.6 (5.1)
25–50%	40.0	11.6 (4.1)	8.1 (4.5)
50–75%	21.2	12.0 (4.2)	7.6 (4.8)
75+%	23.3	12.3 (3.8)	7.4 (4.2)
Trend test p-value, excl N/A	<0.001	0.105	0.015
# of pts counseled for NGS germ-line			
<i>None or not sure</i>	54.3	10.5 (4.1)	9.5 (5.2)
1 or more	36.8	12.7 (3.8)	7.3 (4.2)
T-test or Chi-square test p-value	<0.001	<0.001	<0.001
# of pts counseled for NGS tumor			
<i>None or not sure</i>	46.2	11.5 (4.2)	8.6 (4.9)
1 or more	36.6	12.8 (3.7)	6.4 (3.9)
t-test or Chi-square test p-value	0.103	0.005	<0.001
Previous participation in education			
<i>Yes</i>	41.6	12.3 (3.9)	7.7 (4.5)
<i>No</i>	55.3	9.7 (4.1)	10.2 (5.2)
t-test or Chi-square test p-value	0.003	<0.001	<0.001
Perceived relevance of NGS clinical testing			
<1 year	38.7	12.5 (3.8)	7.4 (4.3)

Characteristic	Clinical role of GC tumor based (percent) ^I	NGS testing Knowledge Score, based on 24 items mean (std dev)	
		Correct	Unsure
<i>Over 1 year</i>	50.6	10.9 (4.1)	8.9 (5.0)
<i>Uncertain</i>	55.6	9.7 (4.5)	11.2 (5.2)
ANOVA or Chi-square test p-value	<i>0.005</i>	<i><0.001</i>	<i><0.001</i>

^I Represents the percentage of GCs who Agreed or Strongly Agreed that all patients undergoing NGS-based testing should be provided profession genetic counseling services (2 items)