ORIGINAL RESEARCH

Genomic Risk Profiling: Attitudes and Use in Personal and Clinical Care of Primary Care Physicians Who Offer Risk Profiling

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BACKGROUND: Genomic risk profiling involves the analysis of genetic variations linked through statistical associations to a range of disease states. There is considerable controversy as to how, and even whether, to incorporate these tests into routine medical care.

OBJECTIVE: To assess physician attitudes and uptake of genomic risk profiling among an 'early adopter' practice group.

DESIGN: We surveyed members of MDVIP, a national group of primary care physicians (PCPs), currently offering genomic risk profiling as part of their practice.

POPULATION: All physicians in the MDVIP network (N=356)

RESULTS: We obtained a 44% response rate. One third of respondents had ordered a test for themselves and 42% for a patient. The odds of having ordered personal testing were 10.51-fold higher for those who felt well-informed about genomic risk testing ($p<0.0001$). Of those who had not ordered a test for themselves, 60% expressed concerns for patients regarding discrimination by life and long-term/disability insurers, 61% about test cost, and 62% about clinical utility. The odds of ordering testing for their patients was 8.29-fold higher among respondents who had ordered testing for themselves ($p<0.0001$). Of those who had ordered testing for patients, concerns about insurance coverage ($p=0.014$) and uncertain clinical utility ($p=0.034$) were associated with a lower relative frequency of intention to order testing again in the future.

CONCLUSIONS: Our findings demonstrate that respondent familiarity was a key predictor of physician ordering behavior and clinical utility was a primary concern for genomic risk profiling. Educational and interpretive support may enhance uptake of genomic risk profiling.

KEY WORDS: primary care; genetic testing; risk; education.

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BACKGROUND

Unlike most genetic testing for Mendelian disorders that produce a relatively certain prediction of disease, genomic profiling for common, complex diseases generates risk information. Genome profiling typically involves analyzing genetic variants (single nucleotide polymorphisms or SNPs) associated with diseases through statistical associations. Whole genome risk profiles are commercially available and may be ordered directly by consumers (DTC) from private companies. The relative genomic risk of most conditions included in these testing panels ranges from 1.04 to 3.2¹).

Disease prevention is predicted to be one of the major benefits of genomic or personalized medicine. Although interventions based on individual genomic risk could potentially lead to adoption of risk reduction behaviors, screening and/or early diagnosis and improved morbidity and mortality, the validity of genomic risk information and likelihood of improving health outcomes is unclear^{2–4}. Recent data cast doubt on the utility and/or added value of genetic testing^{5–11}. Furthermore, many primary care physicians (PCPs) have limited knowledge of genetic testing or how to translate test results into clinically relevant information^{12–16}.

Given their long-term relationship with patients and their families, PCPs are in a unique position to offer personalized medicine¹⁷. In order to gain insight into the pros and cons of incorporating genomic risk profiling into PCP practices, we conducted a survey of a physician group, MDVIP, which recently incorporated genetic testing into their practices. Specifically, we assessed physicians' familiarity with genomic risk testing, intended use of results, likelihood of future testing, perceived benefits and risks, and their preferences for education/training in genetic testing. In order to determine underlying factors that may influence physician attitudes, we also assessed familiarity and experience with genetic testing, as well as perceived adequacy of genetics training. We anticipate that these data will help identify factors that may facilitate as well as challenge the

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adoption of genomic risk profiling in PCP practices and inform future efforts to understand utility of genomic risk testing.

METHODS

Survey Development. Based on a review of the literature, we developed a 27-item survey (using a Likert response and multiple choice responses). This survey addresses physician characteristics, their training, experience with/interest in genetic testing; and perceived benefit and risk of genomic risk profiling. The survey was reviewed by a small panel of PCPs affiliated with the Center for Genomic Medicine at the Duke Institute for Genome Sciences & Policy and revisions made accordingly. This study was approved by the Duke University Medical Center's Institutional Review Board.

Survey Population. The survey population was comprised of all physicians in the MDVIP network as of January 2010 (N=356). Founded in 2000, MDVIP is a national network of PCPs providing personalized care focused on prevention and wellness. [See online appendix for further description of survey population].

In December 2008, MDVIP and Navigenics announced a collaboration to integrate genomic-based preventive healthcare in physician offices. As part of this initiative, Navigenics offered complimentary genomic profiling to MDVIP physicians and discounted testing for MDVIP patients (\$399; retail price was \$999). The testing has not been used to market MDVIP services to patients. Testing is intended for patients interested in obtaining more information about their disease risk, those with an incomplete family history, and those interested in using genomic risk information to "personalize" preventive care. At the time, Navigenics' test analyzed SNPs associated with 28 conditions and diseases including obesity, heart attack, several cancers, dementia, and age-related macular degeneration. In 2009, pharmacogenetic testing was added to Navigenics' test. We did not distinguish between disease-risk and pharmacogenetic testing in this study. Testing is performed in a CLIA-certified lab on DNA extracted from a saliva sample.

Given physicians' limited knowledge of genetics and genetic testing¹²⁻¹⁶, prior to using the test physicians completed four online educational modules on genomic risk profiling developed by Navigenics. The modules provide an overview of the science underlying testing (genome-wide association studies), and the application of test results in preventive care¹⁸. In addition, Navigenics offers a free webinar overview of testing. Genetic counseling is a standard option offered to all Navigenics customers at no cost. Physicians were not encouraged to recommend the counseling service but to inform patients of its availability. Patient brochures were also made available, although it is unknown whether physicians distributed or displayed them.

Recruitment. The survey was administered January–March 2010. An advance letter from the MDVIP Medical Director informed physicians about the survey and encouraged

participation. An invitation was then e-mailed to the PCPs with the survey URL. A follow-up fax invitation was sent to non-responders two weeks later. Participants were presumed to have consented if they initiated the survey by clicking "Next" on the first page, which provided information about the purpose, risks, and benefits of the study. All responses were anonymous; no compensation was provided.

Data Analysis. Analyses were performed using SAS and SAS/STAT software (Version 9.2). Frequency counts and percentages were generated for each question. Write-in responses were either grouped into standing answer categories or placed into an "other" category. For tests of association between two categorical response variables, Fisher's exact tests were employed. Logistic and ordinal regression analyses were used to predict the likelihood of a particular response from a set of categorical and continuous covariates, including sex, time since medical school graduation, specialty, perceived adequacy of genetics training, perceived knowledge of traditional genetic testing and genomic risk testing, and use of traditional genetic testing. The effective sample size for analyses varied depending on the size of the subsample that completed the relevant section(s) of the survey.

RESULTS

Respondent Characteristics. A total of 171 physicians participated in the survey with 14 excluded due to incomplete data, yielding a 44% response rate. Respondents were predominantly male, white, and board-certified in internal medicine (Table 1). Respondents were similar to the overall MDVIP population with respect to sex and medical specialty; and were more likely to be recent graduates, male, and to be internists as compared to U.S. PCPs.

Knowledge of Traditional Genetic Testing & Genomic Risk Testing. Forty-five percent of respondents strongly or somewhat strongly agreed with the statement that they felt well-informed about genetic testing (defined as single-gene testing for disease susceptibility or diagnosis) and 52% strongly or somewhat strongly agreed with the statement that they would feel comfortable ordering genetic testing for disease susceptibility. However, 49% did not believe that their genetics training was adequate. Of those who felt well-informed, 80% believed their training to be adequate. In contrast, of those who didn't feel well-informed, 27% believed their training to be adequate. After adjusting for years since medical school graduation, sex, specialty, and frequency of ordering genetic testing in multiple logistic regression analysis, feeling well-informed about genetic testing lessened the odds of perceived inadequacy of genetics training (OR=0.10, $p<0.0001$, CI=0.05 to 0.23). The proportion of respondents who felt training was inadequate varied as a function of years since graduation [χ^2 (3, N=154)=9.4, $p=0.025$], such that 32% of those who graduated 11–20 years ago felt training was inadequate,

Table 1. Characteristics Of Survey Respondents (N/A=Not Available)

Characteristic	Total Respondents (%)	MDVIP Data (%)	National Data ^b (%)
Male	85.4%	87%	64.8%
Race ^a			
White	94.2	n/a	n/a
African-American	0.6	n/a	n/a
Asian	3.8	n/a	n/a
Other/Prefer Not to Answer	2.5	n/a	n/a
Hispanic	1.9	n/a	n/a
Year Since Medical School Graduation			
1–9 years	0	n/a	13.4
10–14 years	3.2	n/a	17.0
15–19 years	8.2	n/a	16.1
20–24 years	22.3	n/a	15.1
25–29 years	19.7	n/a	15.1
30–34 years	25.5	n/a	11.3
35–39 years	12.1	n/a	6.7
40+ years	8.9	n/a	5.2
Medical Specialty ^a			
Family Medicine	19.1	21%	47.5
Internal Medicine	79.0	79%	52.5
Other	1.9	n/a	–

^aRespondents could select more than one category; percentage based on total number of respondents (n=157)

^bNational data on board-certified physicians in family medicine and internal medicine (Direct Medical Data, 2010)

compared to 49%, 47%, and 90% of those who graduated 21–30 years, 31–40 years, and 41–50 years ago, respectively.

The majority of respondents (90%) had heard of genomic risk profiling offered by companies such as Navigenics, 23andMe and deCodeMe. Of those, 42% strongly or somewhat strongly agreed that they felt well-informed about it. Each additional year since graduation was associated with an 11% reduction in the odds of having heard of genomic risk profiling, all else held constant (OR=0.89, $p=0.015$, CI=0.81 to 0.98). Of those who felt well informed about genomic risk profiling, 86% also felt well informed about traditional genetic testing. Holding years since graduation, sex, specialty, and frequency

of ordering genetic testing constant, the odds of feeling well-informed about genomic risk profiling were 13.67 times greater for those who felt well-informed about genetic testing compared with those who did not ($p<0.001$, CI=4.91 to 38.04), but 3.34 times lower for those who believed their training to be inadequate ($p=0.02$, CI=0.11 to 0.82).

Factors Impacting Use of Traditional Genetic Testing & Personal Genomic Risk Profiling. The majority of respondents reported ordering traditional genetic testing or referring to a genetics specialist 1–10 times/year (Table 2). Of those who felt well-informed, 76% ordered 1–10 genetic tests per year compared to 69% who did not feel well-informed ($p=0.58$). Holding years since graduation, sex, and specialty constant, the odds of ordering at least one genetic test per year were higher for those who felt well-informed about genetic testing (OR=3.77, $p=0.01$, CI=1.30 to 10.87). There was a significant association between feeling well-informed about genetic testing and feeling “comfortable” ordering a genetic test for disease susceptibility, such that those who felt well-informed were more likely to feel comfortable (78.6%) than those who did not feel well-informed (29.8%; $p < 0.0001$).

Overall, 30% of respondents had ordered a genomic risk profile for themselves; 23% of those who had not yet ordered a test for themselves indicated that they intended to do so in the near future. Of those who felt well-informed about genomic risk testing, 59% ordered a genomic risk profile for themselves compared to 16% of those who did not feel well-informed ($p<0.0001$). Holding years since graduation, sex, specialty, perception that genetics training was inadequate, and frequency of ordering traditional genetic testing constant, the odds of a respondent having ordered testing for him/herself were 10.5 times higher for those who felt well-informed about genomic risk profiling (Table 3).

Forty-two percent of respondents indicated that they had ordered a genomic risk profile for a patient. Of those who had ordered a genomic risk profile for themselves, 77% also ordered a profile for a patient (OR=8.29, $p<0.0001$, CI=3.00 to 22.7). The odds of a respondent having ordered a genomic

Table 2. Overall Prevalence Of Traditional Genetic and Genomic Risk Profiling Test Ordering By Physician Characteristics

	Traditional Genetic Testing (n=154) (%)			Genomic Risk Profiling (n=154) (%)	
	Never	1–10 tests per year	>11 tests per year	For Self	For Patients
M (n=131)	16.8	71.0	9.9	30.5	39.7
F (n=23)	8.7	78.3	8.7	30.4	30.4
White (n=145)	16.6	71.0	9.7	29.7	37.2
Non-White or Not Specified (n=9)	0.0	88.9	11.1	44.4	55.6
Years since Graduation					
11–15 years (n=5)	20.0	80.0	0.0	20.0	40.0
16–20 years (n=17)	11.8	70.6	11.8	41.2	41.2
21–25 years (n=35)	5.7	80.0	11.4	28.6	40.0
26–30 years (n=34)	20.6	64.7	14.7	32.4	35.3
31–35 years (n=37)	16.2	67.6	10.8	27.0	43.2
36–40 years (n=16)	18.8	81.3	0.0	37.5	43.8
41–45 years (n=8)	25.0	75.0	0.0	25.0	12.5
46–50 years (n=2)	50.0	50.0	0.0	0.0	0.0
Specialty					
Family Medicine (n=30)	16.7	63.3	13.3	30.0	40.0
Internal Medicine (n=124)	15.3	74.2	8.9	30.7	37.9

*Total percentages may add up to less than 100% as some respondents selected “Don’t know/prefer not to respond”

Table 3. OR (95% CI) Comparing Factors Associated with Having Ordered Genomic Risk Profiling for Self, for Patients and Intention to Order Genomic Risk Tests for Patients in Future

	Ordered Test for Self			Ordered Test for Patient			Intends to Order Test for Patient		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Sex	2.3.8–29.259	0.65–10.2	0.18	0.68	0.21–2.2	.50	1.3	0.42–4.1	0.63
Years since graduation	1.03	0.96–1.1	0.41	1.0	0.95–1.1	0.52	1.0	0.94–1.1	0.94
Board Certification: Internal Medicine vs. Family Medicine	0.84	0.28–2.6	0.76	0.63	0.23–1.7	0.78	0.34	0.13–0.90	0.03
Genetics training perceived inadequate	1.04	0.38–2.8	0.76	1.1	0.46–2.7	0.82	0.92	0.38–2.2	0.85
Feel well-informed about genomic risk testing	10.5	3.8–29.2	<0.0001	4.6	1.9–11.3	0.0007	3.3	1.4–8.1	0.008
Does not order traditional genetic tests (vs. 1–10 test/yr)	0.48	0.12–1.9	0.30	0.13	0.03–0.63	0.01	0.71	0.23–2.2	0.56
Orders 11+ traditional genetic tests/yr (vs. 1–10 test/yr)	2.7	0.69–10.4	0.15	1.7	0.48–5.9	0.42	2.0	0.60–6.7	0.26

risk profile for a patient were 4.6 times higher for those who felt well informed about genomic risk profiling (Table 3). Moreover, compared with those who reported ordering 1–10 traditional genetic tests per year, respondents who never ordered traditional genetic tests were significantly less likely to have ordered a genomic risk profile for a patient. All else held constant; not having ordered for themselves likewise significantly reduced the probability of having ordered a genomic risk profile for a patient (Fig. 1). Factors considered by respondents who ordered genomic risk profiling for their patients included patient request or interest (80%), clinical utility (68%), motivating adoption of preventive behaviors (68%), family history (64%), and the cost of testing (58%). Thirty of 46 respondents who had indicated patient request as a driver of ordering a profile had also ordered one for themselves.

Respondents did not differ as to whether they did (35%) or did not (38%) intend to order genomic risk profiling for their patients in the next six months as part of an annual physical exam or personalized wellness plan. All else held constant, having ordered genomic risk profiling for patients was significantly associated with intention to order a profile for patients in the next six months (OR = 2.82, $p=0.03$, CI=1.12 to 7.12). The odds of ordering a profile for patients in the future were 66% lower for internists than family medicine practitioners, the only significant difference noted between the two groups (Table 3).

Concerns about Genomic Risk Profiling. When asked about factors considered in their decision *not* to order a genomic risk profile for themselves, 53% expressed concerns about life and long-term/disability insurance discrimination, 50% about health insurance discrimination, 43% about confidentiality, 41% about inadequate knowledge of testing, and 36% indicated they did not believe testing would provide useful information.

There were no statistical differences between the top four of five concerns for patients between those who had ordered genomic risk profiling for their patients and those who did not. The top four concerns were uncertain clinical utility, risk of long-term/disability or life insurance discrimination, confidentiality, and cost of test (Table 4). We assessed whether respondent characteristics were associated with the concerns of test cost, uncertain clinical utility, and potential for discrimination. The only association found was that respondents who ordered traditional genetic tests 11 or more times per year (vs. 1–3 times per year) were less likely to indicate concerns with cost (OR=0.29, $p=0.06$, CI=0.08–1.03). Of 32 respondents who had not ordered a profile for themselves, almost all (94%) also expressed concern about clinical utility for patients. Similarly, of 48 respondents who had not

Figure 1. Predicted probability of ordering a genomic risk test for a patient compared to ordering frequency of traditional genetic tests.

Table 4. Concerns Expressed Among Physicians Who Did and Did Not Order the Test for Themselves and for Their Patients (N=139)

Concern	Respondents who did not order testing for themselves (n=90)	Respondents who did order testing for themselves (n=47)	Respondents who did not order testing for their patients (n=79)	Respondents who did order testing for their patients (n=59)
Too costly	55 (61%)	25 (53%)	50 (63%)	31 (53%)
Uncertain clinical utility	56 (62%)	29 (62%)	53 (67%)	34 (58%)
Confidentiality issues	34 (38%)	18 (38%)	30 (38%)	22 (37%)
Physician unfamiliar with testing	24 (27%)	2 (4%)**	21 (27%)	5 (8%)**
Life/long-term disability insurance discrimination	54 (60%)	28 (60%)	49 (62%)	33 (56%)

** Between-group difference in frequency of concern is significant at $p < 0.01$

ordered a genomic risk profile for themselves at least partially due to concern about life and long-term/disability insurance discrimination, the majority (81%) also expressed concern about discrimination for patients; regardless, 29% had ordered genomic risk profiling for patients.

For respondents who had ordered a genomic risk profile for their patients, the following concerns were associated with a lower relative frequency of intention to order a profile in the next six months: insurance coverage ($p=0.014$), uncertain clinical utility ($p=0.034$), unfamiliarity with testing ($p=0.016$), and communicating genomic risks ($p=0.040$). If a respondent was unlikely to order a profile in the near future for a patient, the primary reason indicated was uncertain clinical utility (36%) followed by test cost (19%). Multiple concerns were compared between respondents who had already ordered genomic risk profiling for a patient and intended to order testing again in the near future ($n=32$) and those who had not already ordered genomic risk profiling for a patient and who did *not* intend to do so in the future ($n=62$). Membership in the latter group was associated with relatively more frequent endorsement of concerns about insurance coverage ($p=0.004$), potential negative impact of testing ($p=0.017$), uncertain clinical validity ($p=0.015$) or clinical utility ($p=0.025$), unfamiliarity with testing ($p<0.001$), and communicating genomic risks ($p=0.009$). The relative frequency of concerns about long-term/disability or life insurance discrimination did not vary significantly across the two groups ($p=0.37$).

Preferred Educational Resources. Respondents most frequently endorsed continuing medical education (CME) as a means of learning about genetics in general (57% had used this type of resource), preferably through meetings and in-person courses, followed by journal publications (55%) and coursework in medical school (44%). Respondents preferred similar methods to learn about genomic risk profiling: CME courses (69%), medical journals (57%), professional medical meetings (53%), and educational programs offered by testing companies (47%). When asked about the best way to educate physicians about genomic risk profiling, respondents most frequently endorsed in-person CME (38%) followed by long-distance CME (10%), grand rounds and other in-house seminars (10%), and educational materials from testing laboratories (8%). All else held constant, we found insufficient evidence to conclude that years since graduation had an impact on feeling well-informed about genomic risk profiling for respondents who had not

taken CME in genetics. However, for those who had taken CME in genetics, we found a lower probability of feeling well-informed about genomic risk profiling in respondents with a greater number of years since graduation.

DISCUSSION

The field of genomics is moving at a remarkable pace, giving rise to commercial applications before their clinical validity and/or utility is clearly demonstrated, appropriate educational resources are developed, and potential benefits or harms are considered. Given that one of the anticipated benefits of genomic risk profiling is disease prevention, PCPs are a logical group to offer such testing to their patients and integrate the results with other types of risk assessments. This is the first study to assess initial uptake, interest, and concerns of genomic risk profiling among an early adoption group of PCPs. The results suggest that PCPs who feel well-informed about genomic risk testing are willing to include this type of information in a patient's risk assessment, even while acknowledging the uncertain clinical utility.

Although this is a relatively small group of physicians with a unique practice model, our findings indicate that their attitudes to traditional genetic testing are similar to those of nationally representative samples of PCPs^{19,20}. For example, a national study of PCPs reported that 60% have ordered a genetic test and 74% have referred a patient for genetic testing¹⁹ compared to 82% and 62% in our study, respectively. In that survey, respondents who had received genetics training in medical school were almost twice as likely to have ever ordered a genetic test compared to those without such training (OR 1.80, 95% CI: 1.34–2.43; $p=0.001$). Several studies have reported limited physician knowledge of genetics, albeit higher in younger physicians and in disciplines more closely affiliated with genetics, namely pediatrics and obstetrics/gynecology^{12,15,16}. Similarly, we found that time since graduation is linked to perceived inadequacy of genetics training, and perceived knowledge is linked to test ordering behaviors²¹.

Although actual use of genomic risk profiling has not been ascertained until now, physicians have expressed strong interest in predictive genetic testing for complex conditions^{22,23}. In just over a year since the partnership was established between Navigenics and MDVIP, about a third of respondents had ordered a test for themselves and

more than 40% had ordered tests for their patients. The heavily discounted cost of the test (free for physicians and 60% off retail for patients) though, likely influenced the rate of uptake of the test. However, physicians' self-reported understanding of profiling was key given that those who accepted the offer of free testing were significantly more likely to report feeling well-informed about it.

Other studies have demonstrated that physicians' personal behavior influences practice behavior, with respect to exercise^{24,25} and preventive care²⁶. We found that personal experience with the test was also an important factor related to test ordering for patients, perhaps as a result of increased physicians' familiarity with the test and comfort in ordering it for patients. These data also validate companies' strategies to partner with physicians to increase uptake of genomic risk profiling by providing the test at no cost to physicians along with free education. We did not ascertain if the availability of free access to a genetic counselor encouraged physicians to order a profile who did not feel well-informed or confident in their personal knowledge.

We speculate that patient interest in profiling was also an important factor influencing physician behavior given that eight out of ten tests were ordered in response to patient requests. Patients' motivated to pay out-of-pocket to learn of their genetic predispositions may be more likely to adopt healthy lifestyles to reduce disease risk, potentially due to both interest and economic means to access healthy living initiatives²⁷. However, these patients may also require more time to discuss the results to ensure understanding of the limitations of testing and other factors that may influence overall disease risk as well as any follow-up testing^{28,29}. In addition, it is unknown if these patients experience any undue stress or anxiety after learning of their genomic risks. Receipt of genetic disease risks has not been reported to cause long-term psychological harms^{30,31}, suggesting that individuals interested in learning about their genomic risks are better able or prepared to manage the information. Physician involvement may be critical to ameliorating concerns about test results as another study reported nearly half of individuals surveyed who had undergone DTC testing had concerns about the testing process/experience³³. Although we were not able to assess characteristics of patients who underwent testing, prior studies have reported that individuals who are interested or have undergone genomic risk profiling tend to be White and have at least some college education³²⁻³⁴.

Low perceived clinical utility, as well as concerns about potential discrimination, have repeatedly been reported as primary barriers to uptake of both traditional genetic testing and newer applications³⁵⁻³⁹. Similarly, we found that uncertain clinical utility was among the top concerns of respondents for themselves and their patients. Interestingly, concerns about clinical utility did not significantly vary based on whether or not respondents had ordered a profile for a patient. Furthermore, we did not find that concerns of clinical utility was predictive of ordering behavior, unlike what was demonstrated for feeling well-informed about genomic risk profiling or ordering of test for self. Although, there was a significant difference between internists and family physicians in the likelihood of ordering a genomic risk profile in the future, there were no other identifiable differences between the two groups. It is possible that training experiences are responsible for this difference, but further study will be

necessary to discern the underlying factors. Graduate medical education requirements for family medicine include training in genetic counseling not required for internal medicine⁴⁰.

The rapid development of genomics over the last decade may quickly render physicians' education inadequate in this area, highlighting the need for CME courses, the preferred means of acquiring knowledge about genomic risk profiling. CME courses have been demonstrated to be an effective way to introduce new genetic tests and even increase personal interest⁴¹⁻⁴³. We did not anticipate the inverse relationship observed between feeling well-informed about genomic risk testing and years since graduation in respondents who had taken CME in genetics. We speculate that respondents could be learning about new scientific findings or applications through CME courses and are more aware of what they did not learn about in medical school and therefore, reporting that they are not well-informed. Given the interest in genomic risk profiling demonstrated by our study, development of more educational opportunities will help enhance physicians' understanding and enable informed decision-making about the appropriateness of testing.

Although these data provide insight into physician use of genomic risk profiling, several limitations should be noted. Although the respondents were representative of the MDVIP network, their differences with the national PCP population limits the generalizability of the findings. The diversity of patients undergoing testing was likely limited given that patients had to pay for the test and the reported make-up of other users of genomic risk profiles^{28,32}. The heavily discounted cost of the test may have swayed physician and patient use of the test. In addition, the relationship with and education provided by Navigenics is unique to this group. However, these data are of significant interest as they provide an initial report on use of genomic risk profiling in a clinical setting. Future studies should focus on the impact including benefits and harms of genomic risk profiling, particularly in terms of physician and patient behavioral changes in patient management, treatment, and adoption of healthy behaviors.

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Conflict of Interest: Duke University has no relationship with MDVIP. The Executive Health program at Duke University Medical Center offers genomic risk assessments to interested patients, including but not limited to tests provided by Navigenics.

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REFERENCES

1. Janssens AC, Gwinn M, Bradley LA, Oostra BA, van Duijn CM, Khoury MJ. A critical appraisal of the scientific basis of commercial genomic profiles used to assess health risks and personalize health interventions. *Am J Hum Genet.* 2008;82(3):593-599.

2. Mihaescu R, van Hoek M, Sijbrands EJ, Uitterlinden AG, Witteman JC, Hofman A, et al. Evaluation of risk prediction updates from commercial genome-wide scans. *Genet Med*. 2009;11(8):588–594.
3. Hunter DJ, Khoury MJ, Drazen JM. Letting the genome out of the bottle—will we get our wish? *N Engl J Med*. 2008;358(2):105–107.
4. Scheuner MT, Sieverding P, Shekelle PG. Delivery of genomic medicine for common chronic adult diseases: a systematic review. *JAMA*. 2008;299(11):1320–1334.
5. Paynter NP, Chasman DI, Pare G, Buring JE, Cook NR, Miletich JP, et al. Association between a literature-based genetic risk score and cardiovascular events in women. *JAMA*. 2010;303(7):631–637.
6. Talmud PJ, Hingorani AD, Cooper JA, Marmot MG, Brunner EJ, Kumari M, et al. Utility of genetic and non-genetic risk factors in prediction of type 2 diabetes: Whitehall II prospective cohort study. *BMJ*. 2010;340:b4838.
7. Bentley P, Peck G, Smeeth L, Whittaker J, Sharma P. Causal relationship of susceptibility genes to ischemic stroke: comparison to ischemic heart disease and biochemical determinants. *PLoS ONE*. 2010;5(2):e9136.
8. Meigs JB, Shrader P, Sullivan LM, McAteer JB, Fox CS, Dupuis J, et al. Genotype score in addition to common risk factors for prediction of type 2 diabetes. *N Engl J Med*. 2008;359(21):2208–2219.
9. Lyssenko V, Jonsson A, Almgren P, Pulizzi N, Isomaa B, Tuomi T, et al. Clinical risk factors, DNA variants, and the development of type 2 diabetes. *N Engl J Med*. 2008;359(21):2220–2232.
10. Lango H, Consortium UKTDG, Palmer CN, Morris AD, Zeggini E, Hattersley AT, et al. Assessing the combined impact of 18 common genetic variants of modest effect sizes on type 2 diabetes risk. *Diabetes*. 2008;57(11):3129–3135.
11. Marquinez GF, Pereira AC, Sousa AG, Mill JG, Hueb WA, Krieger JE. TCF7L2 variant genotypes and type 2 diabetes risk in Brazil: significant association, but not a significant tool for risk stratification in the general population. *BMC Med Genet*. 2008;9:106.
12. Hunter A, Wright P, Cappelli M, Kasaboski A, Surh L. Physician knowledge and attitudes towards molecular genetic (DNA) testing of their patients. *Clin Genet*. 1998;53(6):447–455.
13. Menasha JD, Schechter C, Willner J. Genetic testing: a physician's perspective. *Mt Sinai J Med*. 2000;67(2):144–151.
14. Metcalfe S, Hurworth R, Newstead J, Robins R. Needs assessment study of genetics education for general practitioners in Australia. *Genet Med*. 2002;4(2):71–77.
15. Baars MJ, Henneman L, Ten Kate LP. Deficiency of knowledge of genetics and genetic tests among general practitioners, gynecologists, and pediatricians: a global problem. *Genet Med*. 2005;7(9):605–610.
16. Wideroff L, Vadaparampil ST, Greene MH, Taplin S, Olson L, Freedman AN. Hereditary breast/ovarian and colorectal cancer genetics knowledge in a national sample of US physicians. *J Med Genet*. 2005;42(10):749–755.
17. Burke W, Psaty B. Personalized medicine in the era of genomics. *J Am Med Assoc*. 2007;298(14):1682–1684.
18. Navigenics. Navigenics MDVIP Physician and Staff Training. 2010 [accessed January 20, 2011]; Available from: http://www.navigenics.com/partners/mdvip_training.
19. Shields AE, Burke W, Levy DE. Differential use of available genetic tests among primary care physicians in the United States: results of a national survey. *Genet Med*. 2008;10(6):404–414.
20. Suchard MA, Yudkin P, Sinsheimer JS, Fowler GH. General practitioners' views on genetic screening for common diseases. *Br J Gen Pract*. 1999;49(438):45–46.
21. Wideroff L, Freedman AN, Olson L, Klabunde CN, Davis W, Srinath KP, et al. Physician use of genetic testing for cancer susceptibility: results of a national survey. *Cancer epidemiol biomark prev*. 2003;12(4):295–303.
22. Grant RW, Hivert M, Pandiscio JC, Florez JC, Nathan DM, Meigs JB. The clinical application of genetic testing in type 2 diabetes: a patient and physician survey. *Diabetologia*. 2009 Sep 2.
23. Shields AE, Blumenthal D, Weiss KB, Comstock CB, Currihan D, Lerman C. Barriers to translating emerging genetic research on smoking into clinical practice. Perspectives of primary care physicians. *J Gen Intern Med*. 2005;20(2):131–138.
24. Frank E, Tong E, Lobelo F, Carrera J, Duperly J. Physical activity levels and counseling practices of U.S. medical students. *Med Sci Sports Exerc*. 2008;40(3):413–421.
25. Lobelo F, Duperly J, Frank E. Physical activity habits of doctors and medical students influence their counselling practices. *Br J Sports Med*. 2009;43(2):89–92.
26. Frank E, Rothenberg R, Lewis C, Belodoff BF. Correlates of physicians' prevention-related practices. Findings from the Women Physicians' Health Study. *Arch Fam Med*. 2000;9(4):359–367.
27. Cherkas LF, Harris JM, Levinson E, Spector TD, Prainsack B. A survey of UK public interest in Internet-based personal genome testing. *PLoS ONE*. 2010;5(10):e13473.
28. McGuire AL, Diaz CM, Wang T, Hilsenbeck SG. Social networkers' attitudes toward direct-to-consumer personal genome testing. *Am J Bioeth*. 2009;9(6–7):3–10.
29. Kolor K, Liu T, St Pierre J, Khoury MJ. Health care provider and consumer awareness, perceptions, and use of direct-to-consumer personal genomic tests, United States, 2008. *Genet Med*. 2009;11(8):595.
30. O'Daniel JM, Haga SB, Willard HF. Considerations for the impact of personal genome information: a study of genomic profiling among genetics and genomics professionals. *J Genet Couns*. 2010;19(4):387–401.
31. Green RC, Roberts JS, Cupples LA, Relkin NR, Whitehouse PJ, Brown T, et al. Disclosure of APOE genotype for risk of Alzheimer's disease. *N Engl J Med*. 2009;361(3):245–254.
32. Bloss CS, Ornowski L, Silver E, Cargill M, Vanier V, Schork NJ, et al. Consumer perceptions of direct-to-consumer personalized genomic risk assessments. *Genet Med*. 2010;12(9):556–566.
33. Hensley Alford S, McBride CM, Reid RJ, Larson EB, Baxevasis AD, Brody LC. Participation in Genetic Testing Research Varies by Social Group. *Public Health Genomics*. 2010 Mar 18.
34. Goddard KA, Moore C, Ottman D, Szegda KL, Bradley L, Khoury MJ. Awareness and use of direct-to-consumer nutrigenomic tests, United States, 2006. *Genet Med*. 2007;9(8):510–517.
35. Escher M, Sappino AP. Primary care physicians' knowledge and attitudes towards genetic testing for breast-ovarian cancer predisposition. *Ann Oncol*. 2000;11(9):1131–1135.
36. Mountcastle-Shah E, Holtzman NA. Primary care physicians' perceptions of barriers to genetic testing and their willingness to participate in research. *Am J Med Genet*. 2000;94(5):409–416.
37. Freedman AN, Wideroff L, Olson L, Davis W, Klabunde C, Srinath KP, et al. US physicians' attitudes toward genetic testing for cancer susceptibility. *Am J Med Genet A*. 2003;120A(1):63–71.
38. Levy DE, Youatt EJ, Shields AE. Primary care physicians' concerns about offering a genetic test to tailor smoking cessation treatment. *Genet Med*. 2007;9(12):842–849.
39. Park ER, Kleimann S, Pelan JA, Shields AE. Anticipating clinical integration of genetically tailored tobacco dependence treatment: perspectives of primary care physicians. *Nicotine Tob Res*. 2007;9(2):271–279.
40. ACGME. ACGME Program Requirements for Graduate Medical Education in Family Medicine 2007. [accessed January 20, 2011]; Available from: http://www.acgme.org/acWebsite/downloads/RRC_progReq/120pr07012007.pdf.
41. Mrazek M, Koenig B, Skime M, Snyder K, Hook C, Black J 3rd, et al. Assessing attitudes about genetic testing as a component of continuing medical education. *Acad Psychiatry*. 2007;31(6):447–451.
42. Clyman JC, Nazir F, Tarolli S, Black E, Lombardi RQ, Higgins JJ. The impact of a genetics education program on physicians' knowledge and genetic counseling referral patterns. *Med Teach*. 2007;29(6):e143–e150.
43. Carroll JC, Rideout AL, Wilson BJ, Allanson JM, Blaine SM, Esplen MJ, et al. Genetic education for primary care providers: improving attitudes, knowledge, and confidence. *Can Fam Physician*. 2009;55(12):e92–e99.