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A systematic analysis of online marketing materials used by providers of expanded carrier screening

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Purpose: Expanded carrier screening (ECS) for a large number of recessive disorders is available to prospective parents through commercial providers. This study aimed to analyze the content of marketing materials on ECS providers' websites.

Methods: To identify providers of ECS tests, we undertook a comprehensive online search, reviewed recent academic literature on commercial carrier screening, and consulted with colleagues familiar with the current ECS landscape. The identified websites were archived in April 2017, and inductive content analysis was performed on website text, brochures and educational materials, and video transcripts.

Results: We identified 18 ECS providers, including 16 commercial genetic testing companies. Providers typically described ECS as an important family planning tool. The content differed in both the tone used to promote ECS and the accuracy and completeness of the test information provided. We found that most providers offered complimentary genetic counseling to their consumers, although this was often optional, limited to the posttest context, and, in some cases, appeared to be available only to test-positive individuals.

Conclusion: The quality of ECS providers' websites could be improved by offering more complete and accurate information about ECS and their tests. Providers should also ensure that all carrier couples receive posttest genetic counseling to inform their subsequent reproductive decision making.

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Key Words: direct-to-consumer; ELSI genetics; expanded carrier screening; reproductive genetics; website content analysis

INTRODUCTION

Carrier screening aims to identify prospective parents at risk of having a child with a monogenic disorder. Carrier screening is primarily performed for recessive genetic disorders, for which carriers are said to be individuals who have (or carry) one mutated copy of the gene associated with a recessive disorder and one normal copy.[1] Carriers of recessive disorders are typically healthy and do not develop symptoms associated with the disease.[2] However, they may be at risk of giving birth to a child affected by the recessive disease. There is a 25% chance that a couple in which both members are carriers of the same autosomal recessive disorder will conceive an affected child in each pregnancy, and female carriers of an X-linked disorder have a 25% risk of conceiving an affected (male) child in each pregnancy. Due to the recessive pattern of inheritance, most at-risk individuals and couples are unaware of their reproductive risks.[3] Thus, carrier screening is beneficial for such prospective parents, as it identifies the risks of having an affected child, providing potentially actionable information to prospective parents before conception, such as choosing to undergo in vitro fertilization through preimplantation genetic diagnosis to select unaffected embryos, or deciding against having children. In situations where the risk is identified in an ongoing pregnancy, expectant parents' options are more limited in that they can either opt for prenatal diagnosis and decide on pregnancy termination if the fetus is found to be affected,[4] or choose to carry an affected pregnancy to term and, where possible, initiate early treatment in the newborn to limit disease-associated mortality and morbidity.[5]

Traditionally, carrier screening has been limited to a small number of relatively common recessive disorders, such as cystic fibrosis, or was provided to specific ethnic groups, such as Ashkenazi Jewish and Middle Eastern communities, for recessive disorders predominantly affecting individuals of these ethnic backgrounds.[6] Improvements in the characterization of heritable disorders and decreasing costs of genetic testing have led to the development of expanded carrier screening (ECS) tests that screen for a large number of recessive disorders and are not ethnicity-specific.[7] The first clinical ECS test was described in 2009,[8] with ECS gradually emerging as the dominant paradigm in carrier screening in subsequent years. Currently, more than 200,000 ECS tests are performed each year in the United States alone, and the number is growing rapidly.[9]

The growing availability of ECS creates a need to educate prospective parents about ECS and for genetic counseling to be provided. Professional medical societies recommend that all individuals and couples undergoing ECS be made aware of the purpose of carrier screening, the potential significance of carrier screening results in reproductive decision making, and the main clinical characteristics of the test, including its limitations.[10,11] An important challenge to ensuring high-quality pretest information lies in the fact that many ECS tests are currently

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advertised on the Internet by commercial genetic testing companies.[12] Furthermore, a recent review of online news articles about ECS identified commercial entities as the main source of information about ECS in the news articles.[13] This suggests that Internet users who are interested in ECS are highly likely to access the websites of commercial ECS providers for information. While past studies have assessed the information on the websites of commercial genetic testing companies,[14,15] none have focused on websites of carrier screening providers. Professional medical organizations also recommend that nondirective genetic counseling be made available before testing, stressing the importance of posttest counseling in at-risk couples.[10,11] However, little is known about these practices.

We aimed to analyze the content of online marketing materials of ECS providers to investigate the quality and accuracy of the information they convey to potential consumers, and the availability of pre- and posttest genetic counseling.

MATERIALS AND METHODS

To identify providers of ECS worldwide, we employed multiple complementary search strategies from August to December, 2016. First, a comprehensive online search was performed independently by two researchers (D.C. and D.V.) utilizing an identical search string in depersonalized Google search mode and reviewing the first 30 pages (or 300 entries) of the results. Second, we surveyed the recent academic literature on carrier screening and commercial genetic testing to find providers mentioned as employers of authors, or cited by unaffiliated authors. Third, we consulted with colleagues who had recently conducted a global review of carrier screening offers for cystic fibrosis and were familiar with various carrier screening initiatives. A more detailed description of the search methodology has been published elsewhere.[16]

Our search strategy identified 34 providers. We excluded two providers whose websites were in a language other than English and 14 whose offers were aimed at specific groups of patients rather than advertised to the general public (assisted-reproduction clinics catering to patients pursuing fertility treatment, ethnicity-specific carrier screening initiatives, such as Ashkenazi Jewish or Mediterranean, and research-based carrier screening projects). Websites of the remaining providers were archived on 13 April 2017. The data set included three forms of marketing

Table 1 Overview of ECS providers

ECS provider	Country	Type of provider	Details relating to the ECS test
23andMe	USA	Genetic testing company	"Health+Ancestry" is a combined testing service, including 41 autosomal recessive disease genes
Baby Genes	USA	Genetic testing company	The Carrier Screening test includes 92 genes. It is based on the newborn screening panel developed by the company
Baylor Genetics	USA	Genetic testing company	The "GeneAware" carrier test includes 159 genes
Counsyl	USA	Genetic testing company	The "Family Prep Screen" includes 111 genes
DNA Testing Centres Canada	Canada	Genetic testing company	Intermediary company, providing Pathway Genomics' "Carrier DNA Insight" to patients in Canada
GenPath Diagnostics	USA	Genetic testing company	"InheriGen" is an ECS test screening for 169 genes
Good Start Genetics	USA	Genetic testing company	Offers multiple options. The "GeneVu" ComprehensivePlus panel includes 281 genes
Igenomix	Spain	Genetic testing company	"CGT" Igenomix includes 549 genes
Insight Medical Genetics	USA	Medical clinic specialized in genetic testing	Carrier screening is part of the broader preconception assessment. The test includes 164 genes
Integrated Genetics	USA	Genetic testing company	The "Inheritest Carrier Screen NGS" Comprehensive Panel option includes 136 genes
LifeLabs Genetics	Canada	Genetic testing company	An intermediary provider of the "Family Prep Screen" (developed by Counsyl) to patients in Canada
Mount Sinai Hospital	USA	Medical Hospital	"NextStep Carrier Screening" offers multiple screening options, with the most comprehensive panel consisting of 281 genes
Natera	USA	Genetic testing company	Offers multiple ECS panels. The most comprehensive panel, "Horizon 274", includes 273 genes
Pathway Genomics	USA	Genetic testing company	"Carrier DNA Insight" screens for 74 genes
Progenity	USA	Genetic testing company	Offers multiple ECS panels. The "Preparent Global" option screens for 226 genes
Recombine	USA	Genetic testing company	"CarrierMap" screens for 301 genes
Sequenom	USA	Genetic testing company	"HerediT Universal" has been developed in collaboration with Recombine and has the same characteristics as "CarrierMap"
Viafet	UAE	Genetic testing company	Based in Dubai, Viafet offers a carrier screening test including more than 600 genes

materials: website text, information brochures, and videos/infomercials, which were transcribed verbatim and analyzed as transcripts. We excluded legal documents, such as informed consent and user agreement forms, as these are not commonly used for marketing purposes.

Data analysis was performed on the text obtained from the three sources of marketing materials and did not include other types of content, such as images, animation, or music. Data were analyzed using inductive content analysis, for which common content categories are derived from the data, rather than predefined.[17] Data from the three sources were coded iteratively and compared across the data set. Codes were aggregated to form broad content categories.

RESULTS

Our final sample consisted of 18 providers offering ECS to the general population. The list and characteristics of these providers are described in **Table 1**. The majority of ECS providers were based in the United States (14/18) and can be best described as commercial genetic testing companies (16/18). Fourteen providers offered their own ECS tests, with two Canadian providers distributing ECS tests of other providers to Canadian residents, and one US provider offering an externally developed test to their consumers. One provider (Insight Medical Genetics) did not specify whether they used an in-house ECS test.

Our analysis focused on the content of the websites relating to four main categories: (i) the benefits of undergoing carrier screening, (ii) the limitations of carrier screening, (iii) details relating to the test, and (iv) the availability of genetic counseling.

Benefits of undergoing carrier screening

All providers discussed the benefits of taking a carrier screening test, with the importance of carrier status information for family planning being the most commonly mentioned benefit (**Table 2**). However, the tone when discussing the significance of carrier status varied considerably: while in some cases, carrier screening was presented using relatively neutral phrasing, at times it was also advertised as "one of the most important things" prospective parents can do, and as "the most responsible way" to plan a family. Some providers (6/18) also emphasized that for most couples, the recessive nature of the disorders screened means that carrier screening is the only way to learn about their reproductive risks. Other potential benefits discussed included: to provide reassurance or gain peace of mind through negative test results (3/18), the potential for therapeutic benefits for the future affected child

Table 2 Benefits of ECS advertised by providers

Benefit (no. and percentage of providers that mentioned it; $n = 18$)	Illustrative quotes (provider, medium)
Importance in family planning (17; 94%)	"Knowing your carrier status is important when having children. If you and your partner are both carriers, you may have a child with the condition." (23andMe, website text)
	"Learning about which genetic disease you are a carrier for before pregnancy allows you to take steps to plan for your future family." (Viafet, website text)
	"If you find out you both carry irregularities in the same gene before you get pregnant, or early in your pregnancy, you'll have the time to work with your healthcare provider to consider your options and make choices that feel right for you." (Counsyl, website text)
	"Knowing your genetic carrier status is one of the most important things you can do to prepare for parenthood." (Progenity, information video voiceover)
	"CGT Igenomix—the most responsible way to plan your family." (Igenomix, information video voiceover)
Identifying "hidden" risks (6; 33%)	"[Genetic] disorders can stay hidden in a family for generations. The only way to find out if you are a carrier is to have genetic carrier screening." (Progenity, information video voiceover)
	"Even healthy individuals with no family history of a specific condition and previous healthy children may be a carrier of a genetic disease that can be passed on to their baby." (Sequenom, website text)"We all carry something – which is why we need carrier screening." (Sequenom, information brochure)
Reassurance of a healthy child (3; 17%)	"We want to emphasize that for many people, indeed the majority, the results of preconception testing will provide reassurance as well as potentially important information. Most couples will learn that a potential pregnancy would have a reduced risk for the abnormalities being screened." (Insight Medical Genetics, website text)
Therapeutic benefits for the affected child (3; 17%)	"[InheriGen] Identifies babies at risk, and provides necessary preparation for delivery management and the ability to optimize postnatal care of the newborn." (GenPath Diagnostics, website text)
Improving prenatal care (3; 17%)	"[InheriGen] Provides you with information to help optimize pregnancy outcomes." (GenPath Diagnostics, website text)
Personal health benefits (2; 11%)	"Knowing if you are a carrier of a specific genetic disease can help you, whether with family planning or your own medical care, or both." (Natera, video voiceover)

through early medical interventions (3/18), and the possibility of using carrier status information for one's own medical care (2/18). Finally, some providers (3/18) mentioned that the results of carrier screening tests can be used to improve prenatal care, often without clearly indicating how ECS test results could be utilized during pregnancy. For example, one provider mentioned helping to "optimize pregnancy outcomes" as an additional potential benefit, albeit without explaining what was meant by this.

Providers also discussed the specific options available to prospective parents found to be at risk of having an affected child. However, both the amount of detail and the accuracy of this information varied considerably among providers (**Table 3**). Some providers (e.g., Baylor Genetics) briefly mentioned the main reproductive options available to carrier couples, stating that these would need to be discussed with a healthcare provider following a positive test result. Others (e.g., GenPath Diagnostics) offered more detailed information about the reproductive options available to screen-positive couples. Some providers emphasized a particular reproductive option when discussing the actionability of carrier screening results, which often corresponded with the context in which the test was offered. For example, Igenomix, which collaborates closely with fertility clinics, emphasized preimplantation genetic diagnosis as the main option following the identification of an at-risk carrier couple. In contrast, Baby Genes, which offers ECS for the same panel of disorders that it uses in the newborn screening context, focused on the therapeutic benefits of their test for the future affected child, disregarding other reproductive options at-risk couples may choose to pursue.

Limitations of carrier screening tests

The majority of providers (11/18) mentioned one or more statements that we categorized as limitations of carrier screening. The most commonly mentioned limitation was residual risk, referring to the possibility that an individual is a carrier of a recessive disorder, despite a negative screening result for that disorder. In general, they used cautious language when discussing the meaning of negative carrier screening results, as is illustrated by the quotes in **Table 4**. Yet, more definitive language was used to discuss positive carrier screening results, implying that a positive test result has perfect predictive value.

> *A positive test result means that a mutation was found, which means that you are a carrier and you are at increased risk to have a child with a genetic disorder. … If both you and your partner are carriers of the same disorder, there is a 1 in 4 (or 25%) chance your baby will inherit the disorder.* (Good Start Genetics, website text)

Similarly, another provider described the probability of having an affected child in a test-positive couple to be 25%, while acknowledging the imperfect predictive value of a negative test result.

> *If you and your partner are both identified as carriers for the same autosomal recessive disease, your risk of having a child with that disease is one in four, or 25%. If only one of you is identified as a carrier for an autosomal recessive genetic disease, your risk of having an affected child is less than 1%.* (Recombine, information video)

Besides residual risk, some providers mentioned other limitations of carrier screening, such as the inability to screen

Table 3 Options available to carrier couples, according to ECS providers

Provider	Illustrative quotes (medium)
Baylor Genetics	"If you and your partner are found to be at a significantly increased risk of having a child affected with one of these disorders, there are many family planning options you can discuss with your health care provider (including, but not limited to, using an egg or sperm donor, adoption, prenatal testing, or preimplantation genetic diagnosis)." (website text)
	"If both parents are found to be carriers for the same disease, then you may want to discuss your family planning options with your physician or a genetic counselor." (Information video voiceover)
GenPath Diagnostics	"If both you and your partner are carriers for the same autosomal recessive disorder, or if the female is a carrier for an X-linked disorder, there are many options available to you. If InheriGen is performed prior to conception, preimplantation genetic diagnosis, or PGD is available, which can test embryos for a particular disease prior to implantation. During pregnancy, prenatal diagnostic testing by chorionic villus sampling or amniocentesis can be performed to determine if the fetus is affected with certain genetic diseases. It is your decision whether or not to undergo prenatal testing. A genetic counselor can review the risks, benefits and limitations of prenatal diagnostic testing, as well as the spectrum of disease manifestations so you can make a decision that is right for you. Some couples at risk of having a child with a genetic disease may not wish to conceive a pregnancy using their own egg or sperm. These couples may wish to pursue pregnancy using egg or sperm donation, or they may consider adoption." (Information video voiceover)
Igenomix	"In the event of a couple's match being positive, Igenomix will assist them in carrying out the PGD treatment necessary to prevent the transmission of the disease to their baby." (Information video voiceover)
Baby Genes	"Baby Genes Carrier Screening targets 105 genes that are clinically linked to 71 newborn metabolic conditions. Nearly all of these conditions have successful treatment options to enable the child to develop normally if detected early. As a parent, it is important to understand the inheritance risks involved with your pregnancy and prepare appropriately in the event that your child is affected. If detected early, the child can be appropriately diagnosed and treated. Carrier screening provides proactive information that may potentially save your child's life." (website text)

Table 4 Limitations of carrier screening

Limitation (no. and percentage of providers that mentioned it; $n = 18$)	Illustrative quotes (provider, medium)
Residual risk (11; 61%)	"[No] test can detect all possible mutations that could cause a disorder, so there is always a small chance (called a residual risk) of being a carrier even after a negative test result." (Good Start Genetics, website text)
	"[It is] important to keep in mind that carrier screening is risk-reducing, not risk-eliminating. That means that even if you undergo testing for the most extensive panel, a full negative result does not completely guarantee that you are not a carrier for one of those conditions." (Mount Sinai Hospital, information video voiceover)
	"[A negative result] means that we did not detect any disease causing variants for which you were screened. While your risk for having a child with one of these conditions is significantly decreased, Horizon, like other carrier screens, does not screen for all possible variants." (Natera, website text)
Does not test for all possible genetic disabilities (4; 22%)	"This analysis does not detect germline mosaicism, and does not rule out the presence of large chromosomal aberrations including deletions, insertions, and rearrangements, or mutations in regions or genes not included in this test, and possible inter/intragenic interactions between sequence variants." (Integrated Genetics, website text)
Limitations to analytic validity (3; 17%)	"[Discordant] results may occur due to bone marrow transplantation, blood transfusions, or other causes. In some cases, genetic variations other than those being tested may interfere with mutation detection, resulting in false negative or false positive results." (Sequenom, website text)

for all possible genetic disorders, including chromosomal aneuploidies (4/11), and false-positive or false-negative results arising due to the imperfect analytic validity of the test (3/11).

Details relating to the test

Most providers (16/18) listed both the genes and the disorders included on their ECS panels. One company, Viafet, listed only disorders, without specifying the genes. Insight Medical Genetics listed neither the genes nor the disorders screened for. Most providers (14/18) included detailed, written information about all the disorders on their ECS panels, referencing sources such as the National Center for Biotechnology Information, Online Mendelian Inheritance in Man and/or peer-reviewed publications. This information included the main clinical symptoms, prognosis, and any possible treatment options. One provider (GenPath Diagnostics) had produced a large video library containing a brief educational video on every condition included on their ECS panel. However, there were significant differences across providers in the amount and quality of information regarding the clinical and analytical characteristics of the tests. Most providers utilizing targeted genotyping techniques disclosed the complete list of disease-specific mutations included on their panels. While in some cases this information was presented next to the list of diseases and recessive genes (e.g., Igenomix and Recombine), in other cases it was more difficult to find on the website (e.g., Progenity). Others employing nontargeted sequencing (e.g., Baby Genes and Good Start Genetics) did not offer detailed information regarding their methodologies for identifying pathogenic mutations.

All 18 providers discussed the ability of their ECS tests to identify carrier individuals and couples. However, only four ECS providers indicated a specific numerical estimate of the probability that individuals or couples taking their ECS test would be identified as carriers. This number varied depending on the size and characteristics of the ECS panel offered by a given provider. For example, Igenomix, which screens for more than 600 recessive disorders, stated that "5% of couples have genetic mutations in the same gene and therefore have 25% chance of having a child affected by these diseases" (Igenomix, information video). Counsyl, whose ECS panel included 108 disorders, estimated that "[less] than 1% of men and women who undergo carrier screening end up being positive for the same disease as their partners" (Counsyl, information video). Notably, this information was discrepant with an estimate provided by LifeLabs Genetics—a company offering Counsyl's test to consumers in Canada: "3% of all couples screened test positive for the same condition on the Counsyl Family Prep Screen 2.0 test" (LifeLabs Genetics, website text). This discrepancy may be because the numerical estimates in Counsyl's information video referred to an earlier version of the Family Prep Screen. Finally, GenPath Diagnostics provided an estimate for individuals, as opposed to couples: "It's estimated that approximately 20 to 25% of patients tested will be a carrier for at least one disorder on the InheriGen panel" (GenPath Diagnostics, information video).

Providers often referred to recommendations by professional medical organizations to show the medical community's support for carrier screening. However, a minority (3/18) used wording implying that their own ECS tests had either been endorsed by a professional organization or that they were developed in compliance with these recommendations.

> *Professional medical societies recommend that all women planning a family be offered genetic carrier screening such as CarrierMap.* (Recombine, website text)

Carrier DNA Insight® follows the American College of Obstetricians and Gynecologists (ACOG) recommendations, and screens patients for more than 120 recessive genetic diseases. (Pathway Genomics, website text)

The [CGT] test covers a wide range of mutations that result in serious genetic illnesses. It includes screening of all the mutations recommended by professional gynecology and genetic associations. (Igenomix, information brochure)

Availability of genetic counseling

Almost all providers (17/18) of ECS operated through healthcare channels, accepting orders and reporting test results through medical professionals, as opposed to the consumer. A notable exception was 23andMe, which sells genetic tests and reports the results directly to consumers, without the intermediation of a medical professional.

The majority (15/18) indicated that they employ a team of board-certified genetic counselors who are available to support their consumers (**Table 5**). However, complimentary genetic counseling did not always constitute an integral part of the carrier screening process, with some providers making genetic counseling accessible solely upon request. Viafet, a genetic testing company based in Dubai, included the following:

Viafet has a team of Genetic Counsellors available to assist you through phone or email in the case of any questions or concerns related to your genetic testing. (Viafet, website text)

Table 5 Accessibility of genetic counseling among the providers

Provider	Availability of complimentary genetic counseling[a]	Pretest counseling	Posttest counseling	Mode of counseling
23andMe	Not available	NA	NA	NA
Baby Genes	Not available	NA	NA	NA
Baylor Genetics	Available	Upon request	Routinely offered to all carrier and noncarrier individuals	Via phone. 30 min posttest session
Counsyl	Available	Upon request	Routinely offered to all carrier and noncarrier individuals	Via phone
DNA Testing Centres Canada	Not available	NA	NA	NA
GenPath Diagnostics	Available	Upon request	Routinely offered to all carrier and noncarrier individuals	Via phone
Good Start Genetics	Available	Routinely offered to all individuals	Routinely offered to all carrier and noncarrier individuals	Via phone
Igenomix	Available	Upon request	Upon request	Unclear
Insight Medical Genetics	Available	Mandatory	Mandatory	On-site, face-to-face. Up to 60 min pre- and posttest sessions[b]
Integrated Genetics	Available	Upon request	Routinely offered to all carrier individuals	Via phone
LifeLabs Genetics	Available (via Counsyl)	See Counsyl above	See Counsyl above	See Counsyl above
Mount Sinai Hospital	Available	Routinely offered to all individuals[c]	Routinely offered to all carrier individuals.	Pretest: 30 min on-site group sessions; posttest: via phone
Natera	Available	Routinely offered to all individuals	Routinely offered to all carrier and noncarrier individuals	Via phone. 15 min pre- and posttest sessions
Pathway Genomics	Available	Upon request	Upon request	Via phone
Progenity	Available	Upon request	Routinely offered to all carrier and noncarrier individuals	Via phone
Recombine	Available	Upon request	Routinely offered to all carrier and noncarrier individuals	Via phone
Sequenom	Available	Upon request (following a referral from an ordering physician)	Routinely offered to all carrier individuals	Via phone. 15 min pretest session; 30 min posttest session
Viafet	Available	Upon request	Upon request	Via phone or email

[a]By a board-certified genetic counselor. [b]Pretest preconception counseling is not limited to carrier screening and also includes other aspects, such as discussing personal and family health histories. [c]Group genetic counseling sessions organized on a weekly basis.

Of the providers that systematically integrated complimentary genetic counseling into their services, most limited the provision of complimentary genetic counseling to after consumers had undergone the test. Nine offered complimentary posttest genetic counseling to all consumers, regardless of their test results, while three limited routine posttest genetic counseling to carriers. With the exception of Insight Medical Genetics, posttest genetic counseling was optional: patients could choose to receive their test results through their ordering physician and decide against complimentary genetic counseling offered by the provider. In most cases, pretest genetic counseling was not a standard part of the screening process and consumers wishing to speak to a genetic counselor before testing typically had to submit their request to the provider. Exceptions were Natera and Good Start Genetics, which offered pretest genetic counseling to all potential consumers interested in ECS; Mount Sinai Hospital, which organized weekly group genetic counseling sessions; and Insight Medical Genetics, which provided an in-depth preconception risk assessment consultation.

DISCUSSION

Our study found that although most of the providers we identified advertised ECS as a useful tool for family planning, they differed substantially in their tone when discussing the importance of ECS. While some presented ECS as an option prospective parents may find valuable, others used more persuasive language, describing testing as one of the most important steps in preparing for parenthood. Given the commercial nature of these test offers, it is understandable that providers employ marketing strategies aimed at increasing the appeal of ECS to potential consumers, as observed previously among commercial providers of genetic testing services.[15,18] However, in the context of reproductive genetic testing, it is important that the information presented when marketing a test to potential consumers is balanced and nondirective.[19] As prospective parents tend to be highly concerned about the health of their future child, they may be particularly susceptible to persuasion by commercial providers of genetic testing services. The use of overly emotive language or appealing to parental responsibility may undermine informed decision making and, as such, should be avoided by providers.[20] Some providers emphasized that ECS can help future parents prepare for the birth of an affected child and initiate a potentially lifesaving treatment during the newborn period. Several also mentioned improved prenatal care as a potential benefit of ECS, at times without clearly indicating how test results can be utilized in an ongoing pregnancy. Such statements are problematic, as they may mislead some consumers into believing that ECS tests are primarily performed for therapeutic purposes. However, in practice, many couples use their carrier status information to prevent the birth of an affected child, often through prenatal diagnosis and selective termination of an affected pregnancy.[21,22] To ensure that potential consumers understand the purpose of ECS, it is important that providers offer a more complete overview of the main reproductive options available.

Most websites we analyzed mentioned the limitations of ECS tests—predominantly, the residual risk in a test-negative individual.[10] Remarkably, none of the providers explicitly stated that ECS tests may also overestimate the number of at-risk couples due to incomplete penetrance of most pathogenic variants in recessive genes and/or the possibility that the provider may misreport a benign polymorphism as a disease-causing variant. A close look at the ECS tests offered reveals that some disorders (e.g., hereditary hemochromatosis) are characterized by a penetrance of as low as 10%, meaning that only a minority of prospective parents identified as carriers will be at risk of having an affected child.[16] It is important for ECS providers to explicitly acknowledge the possibility that some individuals with positive carrier screening results may not be true biologic carriers of the disorder, as this impacts on their potential to make informed decisions about taking the test.

The majority of providers displayed complete lists of both the genes and the disorders included on their ECS panels. In addition, most providers that utilized targeted genotyping also listed all the pathogenic variants screened for. However, only four mentioned an estimated carrier yield of their ECS tests, with three of these listing the percentage of future pregnancies their test would identify as being at-risk. It would be desirable if more providers shared this information on their websites for two reasons. First, some prospective parents may find it helpful to incorporate the likelihood of obtaining a positive test result into their frame of reference when making decisions regarding screening.[23] Second, the estimated yield of at-risk couples offers valuable insight into the clinical validity of an ECS test. If the rate of at-risk couples identified through the test considerably exceeds the estimated prevalence of at-risk couples in the population, this may indicate a high proportion of false-positive results.[24]

We observed that some websites used wording implying that their own ECS tests were developed in line with professional recommendations from organizations such as the American College of Obstetricians and Gynecologists and the American College of Medical Genetics and Genomics, presumably to highlight the clinical value of their tests. Empirical evidence suggests that linking medical information to an authoritative professional organization increases its credibility among Internet users.[25,26] However, detailed examination of these providers' ECS tests reveals that they do not conform to professional recommendations due to the inclusion of disorders for which screening is not recommended.[16] These providers could improve the accuracy of their claims by clearly indicating that while ECS is generally supported by many professional organizations, their ECS tests may not meet all the specific recommendations laid out by the professional organizations.

Finally, we looked at whether providers offered genetic counseling services to their consumers, both pre- and posttest. In the pretest context, most providers did not integrate

genetic counseling into their services, and potential consumers willing to access pretest genetic counseling through the provider had to explicitly request this. However, a minority of ECS providers offered complimentary genetic counseling to all potential consumers. This practice is line with the recommendations from professional organizations, which state that pretest genetic counseling should be made available to those who request it.[10,11] In the posttest context, the vast majority of ECS providers routinely offered genetic counseling to help consumers interpret their test results and, where relevant, discuss the available reproductive options. However, in some cases, it appeared that complimentary posttest genetic counseling was only available for those identified as carriers through the test. It is important that posttest genetic counseling is equally accessible to test-negative individuals to ensure that they understand the results and are adequately informed about the residual risk of being a carrier despite negative results.[10,11] Posttest genetic counseling was mostly discretionary, where consumers could choose to opt out of the service. While this strategy may be acceptable for most individual consumers, it also raises concerns that some carrier couples may not access posttest genetic counseling, despite its critical role in reproductive decision making. Encouragingly, a recent follow-up study by Counsyl found that the vast majority of carrier couples identified in their patient population utilized posttest genetic counseling, either via Counsyl, or through an external genetic counselor.[22] However, the ECS tests of the providers analyzed in our study can also be accessed by individuals, making it challenging to ensure that all carrier couples receive posttest genetic counseling. This is particularly concerning where the couple is screened as individuals at different time points, or by different providers.

Limitations

This study has several limitations. First, we deliberately excluded legal documents, such as informed consent and user agreement forms, as these are unlikely to be used as marketing materials by providers. However, we acknowledge that legal documents may include more complete and accurate information compared with marketing materials. Second, our analysis was limited to the content presented in the form of written text and video voiceover, and excluded other media, such as images and animations. Therefore, the findings of our study may not offer a complete picture of ECS providers' online advertising practices. Finally, our study was limited to analyzing English-language websites, excluding some providers, particularly those offering ECS to consumers in a specific geographical region. Consequently, our sample may not be completely representative of the current ECS landscape worldwide.

Conclusion

We found that providers differed in the tone used to describe the benefits of ECS, with some using noticeably emotive or directive language. In some cases, the presented information about the relevance of carrier screening test results was incomplete, such as stressing that the identification of at-risk couples could lead to therapeutic benefits in the future affected child. Such incomplete statements are problematic, as they may mislead consumers into believing that ECS tests are primarily performed for therapeutic purposes. Furthermore, while several providers used wording suggesting that their ECS tests were developed in line with recommendations from authoritative medical societies, the accuracy of such statements is questionable, as ECS panels of these providers do not meet all the recommendations made by the societies they cite. Healthcare professionals ordering ECS tests should be mindful of the limitations of information presented on providers' websites and consult more neutral sources of information, including guidelines from professional organizations and the recent academic literature.

While the majority of providers offered complimentary genetic counseling services to their consumers, this was mostly optional and primarily designed to meet the needs of individuals, rather than couples. Providers should ensure that all carrier couples receive posttest genetic counseling to inform their subsequent reproductive decision making.

DISCLOSURE

The authors declare no conflict of interest.

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