High school Tay–Sachs disease carrier screening: 5 to 11-year follow-up

Helen Curd · Sharon Lewis · Ivan Macciocca · Margaret Sahhar · Vicki Petrou · Agnes Bankier · Sari Lieberman · Ephrat Levy-Lahad · Martin B. Delatycki

Received: 3 June 2013 / Accepted: 16 July 2013 / Published online: 27 July 2013
© Springer-Verlag Berlin Heidelberg 2013

Abstract The Melbourne high school Tay–Sachs disease (TSD) carrier screening program began in 1997. The aim of this study was to assess the outcomes of this screening program among those who had testing more than 5 years ago, to evaluate the long-term impact of screening. A questionnaire was used for data collection and consisted of validated scales and purposively designed questions. Questionnaires were sent to all carriers and two non-carriers for each carrier who were screened in the program between 1999 and 2005. Twenty-four out of 69 (34.8 %) carriers and 30/138 (21.7 %) non-carriers completed the questionnaire. Most participants (82 %) retained good knowledge of TSD and there was no evidence of a difference in knowledge between carriers and non-carriers. Most participants (83 %) were happy with the timing and setting of screening and thought that education and screening for TSD should be offered during high school. There was no difference between carriers and non-carriers in mean scores for the State Trait Anxiety Inventory and Decision Regret Scale.

This evaluation indicated that 5–11 years post high school screening, those who were screened are supportive of the program and that negative consequences are rare.

Keywords High school · Adolescent · Psychological impact · Carrier screening

Introduction

Population carrier screening refers to testing for carrier status in individuals who are not at increased risk of being a carrier as a result of a family history of carrier status or of the condition. The primary aim of population carrier screening is to identify couples at high risk of having children affected by genetic conditions and thus to enable them choices in relation to reproductive options (Gason et al. 2003).

Human Genetics Societies have developed policies and guidelines for the effective implementation of genetic screening programs within communities (Aymc et al. 2000). These guidelines emphasize the need for appropriate and effective education and counseling to promote individual autonomy in informed decision making through awareness of benefits, harms, and alternatives.

Tay–Sachs disease (TSD) is the prototype condition for population carrier screening as it was the first recessive disease for which carrier screening was offered (Kaback et al. 1974). TSD is a severe, life shortening, autosomal recessive disease for which there is currently no treatment that has been shown to prolong survival (Desnick and Kaback 2001). It is rare in the general population, but most common among Ashkenazi Jewish people, with a carrier frequency of approximately 1 in 28 and a disease incidence of 1 in 3,100 live births. TSD is caused by mutations in *HEXA*, which disrupt the production of hexosaminidase α -chain isoenzyme. Three common mutations account for more than 99 % of all mutations in the Ashkenazi Jewish community (Bach et al. 2001).

H. Curd · S. Lewis · I. Macciocca · M. Sahhar ·
M. B. Delatycki (✉)

Murdoch Childrens Research Institute, Flemington Road, Parkville,
Melbourne, VIC 3052, Australia
e-mail: martin.delatycki@ghsv.org.au

H. Curd · M. B. Delatycki
Department of Paediatrics, University of Melbourne, Parkville, VIC,
Australia

H. Curd · I. Macciocca · M. Sahhar · V. Petrou
Genetic Health Services Victoria, Parkville, VIC, Australia

V. Petrou
Royal Australian and New Zealand College of Obstetricians and
Gynaecologists, Melbourne, VIC, Australia

A. Bankier · M. B. Delatycki
Clinical Genetics, Austin Health, Heidelberg, VIC, Australia

S. Lieberman · E. Levy-Lahad
Clinical Genetics, Shaare Zedek Medical Centre, Jerusalem, Israel

TSD screening was first introduced in the United States in 1971 and similar programs have been implemented in other countries where there are large Ashkenazi Jewish populations. TSD carrier screening programs have been associated with relatively high uptake and have resulted in a greater than 90 % reduction in the incidence of the disease in communities where screening is offered (Kaback 2000).

Evaluations of population carrier screening programs are important to assess their impact and identify areas for improvement. Uptake rates are important for a program's continuation and are also of practical use to determine the cost-effectiveness of programs. Decline in incidence of the disease is another common measure of a successful program (Marteau et al. 1992). However, because of the value of ensuring informed choice, other factors need to be considered, including knowledge, reasons for accepting or declining testing, attitude toward testing, and acceptability of the program (Ayme et al. 2000).

TSD carrier screening programs have been implemented in Jewish high schools in Canada and Australia. The screening program offered in Montreal high schools demonstrated high uptake, high knowledge levels, and positive attitudes towards screening, and a 20-year follow-up study showed that most carriers remembered their status, were not stigmatized, and used the genetic information for reproductive purposes (Mitchell et al. 1996).

Screening in high school allows access to a large numbers of students, promotes informed choice through education, and provides timely results for reproductive planning. High school carrier screening carried out in the Jewish community is associated with higher uptake than state-funded screening programs targeted towards adults (Ross 2006). However, some have questioned the appropriateness of offering screening in high schools. Concerns relate to autonomy, potential harm to minors, and the impact of peer pressure (Frumkin and Zlotogora 2008).

High school screening for TSD in Australia began in Sydney in 1995 (Barlow-Stewart et al. 2003) and in Melbourne, in 1997. An evaluation of the Melbourne program was conducted from 1998 to 2000, during which time, testing was performed using a blood sample. The average uptake of testing was 67 % and the main reason for students to have TSD carrier screening was to use carrier status for future reproductive decision making (Gason et al. 2003). This study reported high knowledge levels and positive attitude towards screening. From 2003, screening was by cheek scrape and testing for the three *HEXA* mutations that are most common in the Ashkenazi Jewish community.

In 2008, the program was extended to screen for other genetic conditions with carrier frequencies that range from 1 in 25 to 1 in 100 in the Ashkenazi Jewish community. These conditions are as follows: Canavan disease, Niemann–Pick Disease type A, Fanconi anemia, Bloom syndrome, familial dysautonomia, and cystic fibrosis (Delatycki 2008). Ioannou et al. (2010) evaluated the current program and compared the results with an evaluation of the program when screening was only offered for TSD

(Gason et al. 2003). Notably, knowledge level decreased and predicted negative feelings about being a carrier increased in the expanded screening program compared to when screening was offered for TSD alone. Despite this, the authors concluded that the expanded screening program is effective with high uptake, low predicted negative feelings, and high knowledge levels as compared to adult screening programs.

Several studies have demonstrated the acceptability of TSD carrier screening in many settings, indicating a favorable attitude towards screening (Childs et al. 1976; Clow and Scriver 1977). However, further research is needed, with specific focus on the long-term outcomes of school-based screening such as that reported for the Montreal TSD school-based carrier screening program (Mitchell et al. 1996).

The aim of the current study was to assess the outcomes of the Melbourne TSD school carrier screening program among those who had testing more than 5 years ago (and therefore, only had testing for TSD). The outcomes assessed were as follows: the long-term psychological impact of TSD carrier testing in high school (anxiety, regret about the decision to have testing, and the impact of finding out positive carrier status); long-term knowledge of TSD and memory of carrier status; and use of the test result and retrospective opinion and satisfaction about the timing and setting of screening. The study also aimed to identify areas in which the high school screening program could improve.

Materials and methods

Participants

The TSD carrier screening program is offered to students in the second last year of high school at six Jewish high schools in Victoria, Australia, where most students are 16 years of age at the time of screening. The target population for this study was individuals who had carrier screening for TSD alone at high school between 1999 and 2005. All carriers identified through the program were invited to participate, and for each carrier, two non-carriers from the same school who were also screened in the program were sent a letter of invitation to participate.

Questionnaire

The questionnaire, which can be viewed at www.mcri.edu.au/TS, was purposely designed to examine the following areas: demographics, knowledge of TSD and its genetics, experience of carrier screening, attitudes towards the school screening program, memory and utilization of test results, and knowledge and attitudes about screening for other recessive genetic conditions. The knowledge questions were adapted from a validated survey evaluating the school-based TSD genetic screening program in 2003, for the purpose of comparison (Gason et al. 2003). Participants were asked to answer five questions regarding

their knowledge of TSD and genetics. The questions were in multiple choice formats with four options, and questions were scored as correct or incorrect. The total knowledge score out of five was calculated for each student. The anxiety scale used was the short version of the State Trait Anxiety Inventory (STAI) (Marteau and Bekker 1992). Scores range from 20 to 80 and a higher score indicates greater anxiety. The Decision Regret Scale was included in the questionnaire to measure “distress or remorse” after making the decision to have carrier testing for TSD (Brehaut et al. 2003). The Impact of Event Scale assesses current subjective distress, in this instance, regarding being a carrier for TSD. Scores range from 0 to 35, with higher scores indicating more impact. The questionnaires were returned anonymously by mail and coded for carrier status, year of screening, and school.

Data analysis

Data analysis was conducted using SPSS (Windows, version 10.0; SPSS Inc., Chicago, IL, USA). Preliminary descriptive analysis generated frequency data. Statistical significance of between-group comparisons was assessed using chi-square tests of association for categorical variables. Where variables had more than two categories, degrees of freedom are given with the chi-square statistic. To assess statistical significance between groups (carriers and non carriers) of continuous data such as those produced by scales, independent *t* tests were employed. A *p* value of <0.05 was considered statistically significant.

Ethics committee approval

This study was approved by the Royal Children's Hospital Human Research Ethics Committee (CA29176).

Results

Response

Questionnaires were distributed to 69 carriers and 138 non-carriers who had TSD screening in high school between 1999 and 2005. Nineteen were returned addressee unknown and four other individuals were identified as being unavailable to complete the questionnaire. Of the remaining 184 questionnaires (62 carriers and 122 non carriers), 54 were completed and returned, giving a response of 24/62 (38.7 %) for carriers, 30/122 (24.6 %) for non-carriers, and an overall response of 54/184 (29.3 %).

Demographic variables

The demographics of respondents are presented in Table 1. The mean age of participants was 24.0 (SD=2.0) years. For the majority of the participants (89 %), both parents were

Table 1 Demographic characteristics of participants

Variable	Responses (<i>n</i>)	Percent (%)
Carrier Status		
Carrier	24	44.4
Non-carrier	30	55.6
Gender		
Male	21	38.9
Female	33	61.1
Highest level of education		
Completed secondary school	8	14.8
College diploma/apprenticeship/trade	7	12.9
University graduate degree	35	64.8
University postgraduate degree	2	3.7
Parents' ancestry		
Both Ashkenazi	48	88.9
One Ashkenazi, one Sephardi	3	5.6
Both Sephardi	1	1.8
One Ashkenazi, one non-Jewish	2	3.7
Marital status		
Partnered, living together	13	24.1
Partnered, not living together	10	18.5
Separated/divorced	1	1.9
Single	30	55.6

Ashkenazi Jewish. More than half (56 %) of the participants were single, and the rest were either living with their partner or in a relationship but not living together. Four participants reported having children.

Knowledge

Most respondents still had good knowledge of TSD, with 81.5 % of participants answering at least four out of five questions about TSD correctly (Fig. 1). A comparison of knowledge scores showed no difference between carriers and non-carriers ($\chi^2=2.90$, $p=0.7$). Overall participant responses for each question are shown in Fig. 2.

Memory of test result

The majority of participants correctly recalled their carrier status. Most carriers reported being carriers (22/24, 92 %) and most non-carriers reported being non-carriers (26/29, 90 %). One participant (a non-carrier) reported being unsure if she had carrier screening for TSD, so did not answer this question. One carrier reported being a non-carrier (tested in 2000); and one carrier (tested in 2001) and three non-carriers (tested from 1999–2001) could not remember their test result.

Fig. 1 Knowledge scores of carriers and non-carriers

Impact of event scale

Of the 24 carriers, the 22 who remembered their result completed this scale. The minimum score was zero and the maximum score was 17, with a mean score of 1.95 (SD=4.24). A score of 9 or above is considered clinically significant (Smith et al. 2004) and two participants scored in this range (10 and 17).

State Trait Anxiety Inventory: 6-item short form

Of the 54 participants, 52 completed the STAI (Table 2). The mean score for all participants who completed the STAI was 28.0 (SD=8.4) and the median score was 26.7. There was no difference between carriers (M=29.7, SE=2.0) and non-carriers (M=26.7, SE=1.4) for STAI scores ($t(50)=1.2$, $p=0.2$). Of the 52 participants who completed the scale, one carrier (63.3) and one non-carrier (43.3), scored above the clinically significant cut off of 42 (Michie et al. 1996).

Fig. 2 Overall participant responses for each knowledge question. The questions Q8–Q12 represent the questions as presented in the questionnaire which can be seen at www.mcrci.edu.au/TS

Decision regret scale

Of the 54 participants, 51 completed the Decision Regret Scale (Table 3). The mean score for all participants was 5.9 (SD=9.7). The mean score of carriers (M=7.6, SE=2.3) was not significantly different to the mean score of non-carriers (M=4.5, SE=1.6), ($t(49)=0.3$, $p=0.3$). Overall, 33/51 (65 %) scored zero (no regret), 16/51 (31 %) scored between 1 and 25 (mild regret), and 2/51 (4 %), one carrier and one non-carrier, scored above 25 (moderate to strong regret).

Opinion regarding timing and setting of TSD carrier screening

Eighty-eight percent of carriers and 79 % of non-carriers reported that they were happy with the timing and setting of screening. One carrier was not happy with the time of testing; however, the main issue raised was that the result was conveyed the evening prior to an examination and the participant was otherwise satisfied with the program. Two (4 %) carriers and six (11 %) non-carriers could not remember if they were happy with the timing and setting of screening.

Opinion about TSD screening in high school

Forty-seven (87 %) participants remembered being given information about TSD and screening before they had the

Table 2 STAI scores for carriers and non-carriers

	Number of observations	Mean	Standard deviation	Range
Carriers	23	29.7	9.4	20–63.3
Non carriers	29	26.7	7.3	20–43.3

Table 3 Decision Regret Scale scores for carriers and non-carriers

	Number of observations	Mean	Standard deviation	Range
Carriers	23	7.6	10.9	0–35
Non carriers	28	4.5	8.5	0–30

carrier test. Most participants think that it is best to educate about TSD in high school (96.3 %). All non-carriers and 96 % of carriers thought that carrier screening should be offered in high school (overall 98.1 %). One carrier did not believe that carrier screening should be offered to students at high school, but instead, before being in a relationship. Interestingly, this carrier also reported being happy with the timing and setting of screening.

Use of result: partner carrier testing

Of the 54 participants, 28 reported that they had a partner. Participants were asked if their partner had had carrier screening for TSD (Fig. 3). Partners of 6/14 carriers and 3/14 non-carriers had screening ($\chi^2=1.47$, $p=0.22$). All partners who had had testing were not carriers. Four participants (two carriers) reported having children. The two carriers reported that their partners had been tested and were non-carriers.

Discussion

In this study, the outcome 5–11 years after high school TSD carrier screening was assessed. Those tested retained good knowledge levels, there was no significant difference in anxiety levels between carriers and non-carriers and most remembered their test results.

Fig. 3 Comparison of carriers and non-carriers responses to the question “Has your partner had carrier testing?”

Knowledge

The questionnaire assessed the level of knowledge that has been retained since the time of testing, as evaluations of population carrier screening programs have found that education plays a critical role in allowing informed decisions and minimizing the possible harms (Frumkin and Zlotogora 2008).

The knowledge scores in this follow-up study suggest that students who had carrier testing for TSD retain high levels of knowledge about the disease years after having the test. These results are comparable to those of a similar follow-up study in Sydney high schools which found that 74 % of participants retained “good” knowledge of the conditions for which they had genetic carrier testing (Barlow-Stewart et al. 2003). Interestingly, over one third of participants do not know how many “affected” genes a carrier has, yet most participants understand that both parents need to be carriers to be at risk of having a child affected with TSD and that this risk does not change with each pregnancy.

It has been suggested that carriers probably give more meaning to their positive result and are presumably more motivated to seek additional information on TSD after they have received their result (Zeesman et al. 1984). In the Barlow-Stewart et al. (2003) Sydney follow-up study, 3 to 6 years after testing, carriers were found to have significantly greater knowledge than non-carriers ($p=0.013$). The current study did not identify a difference in knowledge scores between carriers and non-carriers. It is possible that increased education and awareness in the Jewish school communities as a result of the program's long-term operation has made this topic more relevant and students and their families are more aware of the disease. It is also possible that the participants in this study accessed information about TSD when completing the questionnaire.

Timing and setting of screening

The majority (83 %) of participants in this study reported that they were happy with the timing and setting of screening. In addition, almost all participants thought that it is best to educate about TSD in high school *and* also offer carrier screening in high school, which provides strength to the case that the high school setting is acceptable for carrier screening programs.

Psychological impact of screening

Carriers were asked to complete the Impact of Event scale to evaluate the impact that finding out they were a carrier for TSD through the screening program has had on their lives (Horowitz et al. 1979). The carriers have a mean score of 1.95, which is below the cut off of 9, which is considered clinically significant (Smith et al. 2004) and similar to the mean score observed in a non-clinical population (male, $M=2.5$, $SD=3.0$; female: $M=6.1$, $SD=5.3$).

All participants completed the Spielberger STAI and the Decision Regret Scale. The mean score of the STAI was 28, which is below the clinically significant cut off of 42. One carrier and one non-carrier scored above this cut off. Students are expected to experience some anxiety upon being found to be a carrier (Gason, et al. 2003); however, no difference in anxiety levels between carriers and non-carriers was observed in this study. This is comparable to observations from the Montreal program which found that carriers were more worried than non-carriers about the initial report of their test but their concern dissipated with time (Zeesman et al. 1984). The Decision Regret Scale asked participants to reflect on their decision to have carrier testing for TSD, and the mean decision regret score was 5.9 out of a possible 100 (higher scores indicate greater regret) (Brehaut et al. 2003). These results indicate that students who decide to have carrier testing for TSD during high school do not regret their decision and there was no difference in regret scores between carriers and non-carriers. The low levels of regret and anxiety experienced by these participants suggests that high school students are able to make autonomous informed decisions about TSD carrier screening and that concerns about the potential harms of offering genetic tests during high school are unwarranted.

Memory of test result

The majority of participants (88 %) in this study correctly remembered their test result; however, one individual who was found to be a carrier incorrectly reported being a non-carrier. These results are comparable to the 8-year follow-up study of students from Montreal in which 90.0 % of respondents correctly remembered their result, and one carrier also reported being a non-carrier (Zeesman et al. 1984). Other follow-up studies have observed that all participants correctly reported their test result (Barlow-Stewart et al. 2003; Mitchell et al. 1996). While the high percentage of carriers remembering their result is pleasing, the fact that two carriers did not remember their result when considerable effort to reinforce the result with telephone genetic counseling and a letter is some cause for concern. These two individuals were tested in 2000 and 2001 (9 and 10 years, respectively, before this study) and so the considerable length of time may account for this. The non-carriers who could not remember their result were tested between 1999 and 2001. Individuals who have been tested are able to contact the screening program coordinator at any time to be reminded of their carrier status. As a result of this issue arising from this study, we now offer carriers the option of their result being sent to their general practitioner.

Partner testing

A common reason for deciding to have carrier testing is for a person to know their carrier status to use for future reproductive

decision making (Gason et al. 2003; Ioannou et al. 2010). About half of the participants in the current study had partners, and half of those with partners were TSD carriers. Although not statistically significant, more carriers ($n=6/14$) reported that their partner had had testing for carrier status than non-carriers ($n=3/14$), which may suggest that partners of carriers are informed about the partner's carrier status and have made the decision to have testing. It is possible that some partners were also tested through the high school screening program. Of the four participants who had children, two were carriers and reported that their partners had been tested and were non-carriers, indicating that they were informed about their reproductive risk for TSD as a couple prior to having children. There were no “carrier couples”—that is, couples in which both are carriers of a mutation for TSD—so it is not possible to comment on how carrier couples use the information for reproductive purposes. However, more non-carriers than carriers reported being “unsure” whether their partner had had carrier testing. These responses suggest that carriers are aware of their status and are more likely to discuss TSD and carrier status with their partners than non-carriers, who are at very low risk of having a child with TSD based on their negative result in the screening program.

In a 20-year follow-up study of the Montreal high school TSD screening program, Mitchell et al. (1996) reported that the information gained from the program was used by carriers later in their lives. Since the introduction of the program, there has been a transition in the rationale for seeking prenatal diagnosis, from those with an affected individual in the family, to those who discovered their carrier status in the screening program.

Study limitations

The main limitation of this study was the low response (29.4 %), which is likely due to the length of time since testing and potential for students to have moved from their family home. As a result of the response rate, the findings may not be representative and hence not generalizable to all of the students screened in the Melbourne high school screening program between 1999 and 2005. It is possible that those who returned the questionnaire were more likely to correctly remember their carrier status, have better knowledge of TSD, and experience less regret and anxiety in relation to the testing than those whose questionnaires were not returned.

Practice implications

Genetic counselors and trainee genetic counselors play an important role in the ongoing development and management of the TSD high school screening program. The program is organized and facilitated by genetic counselors. In addition to a group education session, all students receive individual genetic

counseling before they have testing as an essential part of the current population screening program. Genetic counselors are trained to provide genetic information, assist in the decision making process about whether to have genetic testing, and offer support (Resta et al. 2006). The provision of genetic counseling offers each student the opportunity to ask questions, raise concerns, and further promotes informed decision making.

A small number of parents have expressed concerns about the potential psychological impacts of genetic testing on their adolescent children. This study provides evidence that genetic carrier testing for TSD in adolescence through the Melbourne high school screening program does not result in long-term harmful psychological impacts or high levels of anxiety. This evidence can be used by genetic counselors to inform and reassure concerned parents about the likely outcome of genetic testing for TSD, and it supports the continued offering of TSD screening in Melbourne high schools.

Research recommendations

As education plays a critical role in allowing informed decisions and minimizing the possible harms of genetic testing, it would be valuable to perform a long-term assessment of students' knowledge after having screening through the current multi-disease screening program in Melbourne high schools. It would also be valuable to conduct a long-term study exploring people's experiences of the multi-disease screening program currently being offered to students attending Jewish high schools in Melbourne.

Conclusions

In conclusion, the majority of participants correctly remembered their carrier status, most participants still had good knowledge of TSD and there was no evidence of a difference in knowledge levels between carriers and non-carriers. There was no evidence of any long-term negative psychological impact of the screening program and the majority of participants did not regret their decision to have carrier screening for TSD in high school. Most participants were happy with the timing and setting of screening and most participants thought that education and screening for TSD should be offered during high school. We did not identify major changes to improve the program other than offering to inform the carrier's general practitioner of their status. The results of this long-term evaluation study support the offering of TSD screening in high schools and may be useful in the implementation of high school carrier screening programs for other autosomal and X-linked recessive conditions.

Acknowledgments The authors thank the participants for completing the questionnaire. We thank the teachers and coordinators at the schools

in which the program runs, and the Pratt Foundation for supporting the program.

Conflict of interest MBD is a NHMRC Practitioner Fellow; SL is funded by a NHMRC Capacity Building Grant. There is no conflict of interest for any of the authors on this paper.

Ethics committee approval This study was approved by the Royal Children's Hospital Human Research Ethics Committee (CA29176) and thus complies with the requirements for research conduct in Australia.

References

- Ayme S, Bobrow M, Coviello D, Evers-Kiebooms G, Farndon P, Kaariainen H, Tranebjaerg L (2000) Population genetic screening programmes: proposed recommendations of the European Society of Human Genetics. *Eur J Hum Genet* 8:998–1000
- Bach G, Tomczak J, Risch N, Ekstein J (2001) Tay–Sachs screening in the Jewish Ashkenazi population: DNA testing is the preferred procedure. *Am J Med Genet* 99:70–75
- Barlow-Stewart K, Brunett L, Proos A, Howell V, Huq F, Lazarus R, Aizenberg H (2003) A genetic screening programme for Tay–Sachs disease and cystic fibrosis for Australian Jewish high school students. *J Med Genet* 40:e45
- Brehaut JC, O'Connor AM, Wood TJ, Hack TF, Siminoff L, Gordon E, Feldman-Stewart D (2003) Validation of a decision regret scale. *Med Decis Making* 23:281–292
- Childs B, Gordis L, Kaback M, Kazazian HH (1976) Tay–Sachs screening—motives for participating and knowledge of genetics and probability. *Am J Hum Genet* 28:537–549
- Clow CL, Scriver CR (1977) Knowledge about and attitudes toward genetic screening among high school students—Tay–Sachs experience. *Pediatr* 59:86–91
- Delatycki MB (2008) Population screening for reproductive risk for single gene disorders in Australia: now and the future. *Twin Res Hum Genet* 11:422–430
- Desnick RJ, Kaback MM (2001) Future perspectives for Tay–Sachs disease. *Adv Genet* 44:349–356
- Frumkin A, Zlotogora J (2008) Genetic screening for reproductive purposes at school: is it a good strategy? *Am J Med Genet A* 146A:264–269
- Gason AA, Sheffield E, Bankier A, Aiken MA, Metcalfe S, Stewart KB, Delatycki MB (2003) Evaluation of a Tay–Sachs disease screening program. *Clin Genet* 63:386–392
- Horowitz M, Wilner N, Alvarez W (1979) Impact of Event Scale—measure of subjective stress. *Psychosom Med* 41:209–218
- Ioannou L, Massie J, Lewis S, Petrou V, Gason A, Metcalfe S, Delatycki MB (2010) Evaluation of a multi-disease carrier screening programme in Ashkenazi Jewish high schools. *Clin Genet* 78:21–31
- Kaback MM (2000) Population-based genetic screening for reproductive counseling: the Tay–Sachs disease model. *Eur J Pediatr* 159:S192–S195
- Kaback MM, Zeiger RS, Reynolds LW, Sonnebor M (1974) Approaches to control and prevention of Tay–Sachs disease. *Prog Med Genet* 10:103–134
- Marteau T, Bekker H (1992) The development of a six-item short-form of the state scale of the Spielberger State-Trait Anxiety Inventory (STAI). *Br J Clin Psychol* 31:301–306
- Marteau TM, Vanduijn M, Ellis I (1992) Effects of genetic screening on perceptions of health—a pilot study. *J Med Genet* 29:24–26
- Michie S, McDonald V, Bobrow M, McKeown C, Marteau T (1996) Parents' responses to predictive genetic testing in their children: report of a single case study. *J Med Genetics* 33:313–318
- Mitchell JJ, Capua A, Clow CL, Scriver CR (1996) Twenty-year outcome analysis of genetic screening programs for Tay–Sachs and beta-

- thalassemia disease carriers in high schools. *Am J Hum Genet* 59:793–798
- Ross LF (2006) Heterozygote carrier testing in high schools abroad: what are the lessons for the US? *J Law Med Ethics* 34:753–764
- Resta R, Biesecker B, Bennett R, Blum S, Hahn S, Strecker M, Williams J (2006) A new definition of genetic counseling: National Society of Genetic Counselors' Task Force report. *J Genet Couns* 15:77–88
- Smith CO, Lipe HP, Bird TD (2004) Impact of presymptomatic genetic testing for hereditary ataxia and neuromuscular disorders. *Arch Neurol* 61:875–880
- Zeesman S, Clow CL, Cartier L, Scriver CR (1984) A private view of heterozygosity—8-year follow-up-study on carriers of the Tay–Sachs gene detected by high-school screening in Montreal. *Am J Med Genet* 18:769–778