Received: 14 January 2018 | Revised: 8 March 2018 | Accepted: 20 March 2018

DOI: 10.1111/cge.13253

WILEY CLINICAL GENETICS

REVIEW

Children and young people's understanding of inherited conditions and their attitudes towards genetic testing: A systematic review

B.C. McGill[1,2] | C.E. Wakefield[1,2] | J. Vetsch[1,2] | K. Barlow-Stewart[3] | N.A. Kasparian[1,4] | A.F. Patenaude[5,6] | M.-A. Young[7] | R.J. Cohn[1,2] | K.M. Tucker[8,9]

[1]Discipline of Paediatrics, School of Women's and Children's Health, UNSW Sydney, Kensington, Australia

[2]Behavioral Sciences Unit Proudly Supported by the Kids with Cancer Foundation, Kids Cancer Centre, Sydney Children's Hospital, Randwick, Australia

[3]Discipline of Genetic Medicine, Sydney Medical School, University of Sydney at the Northern Clinical School, Royal North Shore Hospital, St Leonards, Australia

[4]Heart Centre for Children, The Sydney Children's Hospitals Network (Westmead and Randwick), Sydney, Australia

[5]Department of Psychosocial Oncology and Palliative Care, Dana-Farber Cancer Institute, Boston, Massachusetts, USA

[6]Department of Psychiatry, Harvard Medical School, Boston, Massachusetts, USA

[7]Garvan Institute of Medical Research, Darlinghurst, Sydney, Australia

[8]Hereditary Cancer Clinic, Department of Medical Oncology, Prince of Wales Hospital, Randwick, Australia

[9]Prince of Wales Clinical School, UNSW Sydney, Sydney, Australia

Correspondence
Brittany C. McGill, Kids Cancer Centre, Level 1 South, Sydney Children's Hospital, High Street, Randwick, NSW 2031, Australia.
Email: b.mcgill@unsw.edu.au

Funding information
National Health and Medical Research Council, Grant/Award Number: APP1143767; Cancer Institute NSW, Grant/Award Number: ID: 11/ECF/3-43

Children and young people are increasingly likely to receive information regarding inherited health risks relevant to their genetic relatives and themselves. We reviewed the literature to determine what children and young people (21 years and younger) understand about inherited conditions and their attitudes towards genetic testing. We screened 1815 abstracts to identify 20 studies representing the perspectives of 1811 children and young people between the ages of 6 and 21 years (1498 children or young people at general population-level risk from 9 studies, 313 affected/at risk from 15 studies). Children and young people at general population-level risk demonstrated a basic understanding that disease predisposition can be inherited within families. Those affected by or at risk of genetic conditions inferred their genetic status from observable, relational characteristics within their family and the results of personal genetic testing if it had occurred, but some misunderstandings of important genetic concepts were evident. Children and young people expressed interest in and a willingness to undertake personal genetic testing, but also articulated concerns about the limitations and risks of testing. Paediatric patients require developmentally-sensitive genetic counselling and support in navigating the unique landscape of their condition.

KEYWORDS

adolescent, attitude, child, genetic counselling, genetic testing, paediatrics

1 | INTRODUCTION

With increasing availability of genetic testing due to reductions in cost and turn-around-time, children and young people have unprecedented exposure to genetic information regarding hereditary health risks for their genetic relatives and themselves. Children and young people may learn of the results of genetic testing undertaken by other genetic relatives,[1] or may undergo testing themselves for predictive or diagnostic purposes.[2] Despite clinical benefits of the genetic information generated in terms of prevention and management of inherited conditions, there are complex developmental, ethical and, psychosocial factors requiring careful consideration in the paediatric setting.[3]

The extent to which children and young people can understand and use genetic information about their health risks is dependent on their cognitive and emotional maturity. Studies investigating health knowledge within this group indicate that even children as young as 5 years old can actively theorise about biological aspects of the world,[4,5] including disease processes such as contagion.[6,7] Although there is evidence that pre-school children have an understanding of kinship relationships and the concept that physical characteristics can be inherited within families,[8,9] the developmental trajectory that leads to a more advanced theory of biological inheritance is less well defined.[10,11]

The results obtained from genetic—and increasingly genomic—testing are complex and may have lifelong consequences. Genetic health information requires an ability to think about one's health at both an individual and family-level.[12] As children enter adolescence additional psychosocial considerations arise, such as the meaning of the genetic test result for the identity of the young person and potential impact on peer and intimate relationships.[13] As children and young people enter adulthood they may be required to think generationally; for example, considering the impact on the health of future offspring in the context of family planning as well as on that of their parent/s and other genetic relatives. The ability to interpret concepts of risk, susceptibility and predisposition requires an understanding of probability that even adults may struggle to grasp.[14] Genetic test results may also require an ability to understand and tolerate uncertainty.[15,16] Taken together, the complexity of genetic testing opens up the potential for misinterpretation and misunderstandings in children and young people.

In the context of children and young peoples' understanding and knowledge it is important to consider the role of family communication. Recent reviews indicate that although parents hold largely positive attitudes towards childhood genetic testing,[17] miscommunication and misinformation are common in families affected by genetic conditions.[18] Parents may find it difficult to communicate openly with their children about the potential impact of a genetic condition, due in part to feelings of guilt.[1] In children and young peoples' broader social context, information about disease, genetics and risk is increasingly present in the media and can influence personal knowledge and misinformation.[19] Several authors have suggested an important role for the school curriculum in ensuring that children receive accurate and developmentally appropriate information about genetics and the associated ethical and legal issues.[20–22] Knowledge and understanding of genetics may also differ across cultures.[23] Strong scientific literacy and, more specifically, genetic literacy is essential for young people born in the "genomic era."

Children's involvement in decision-making about their health is a perennially contentious issue.[24] Although the legal perspective that children below a jurisdiction-specified age are unable to provide informed consent is rarely challenged, it would be wrong to assume that children, especially adolescents, do not have the cognitive capacity to actively engage in discussions about their health.[25] In some cases, a child below the age of 16 may be able to make decisions about their healthcare without parental involvement, if they are determined through legal processes to have sufficient maturity and intellectual capacity (referred to as "Gillick competence").[25] In the context of childhood pre-symptomatic and predictive testing, clinical guidelines commonly recommend that children and young people should participate at some level in discussions about the implications of genetic testing.[3,26,27] However, if the nature of these discussions is to be judged on a case-by-case basis "…in a manner that is appropriate for their age and understanding",[27] developmentally informed guidance is required. A deeper appreciation of children and young peoples' understanding of genetic concepts and genetic testing will act to scaffold parents' and healthcare providers' communication with children about their genetic health risks.

We conducted this review as impetus for further "bottom-up" child-focused health research in which children and young people are given the space to articulate what they understand and think about issues related to hereditary illness predisposition that may impact them.[28,29] As an extension of previous reviews in this area[30] and in the context of the "unstoppable train"[31] of genetic technologies, we aimed to provide an up-to-date summary of children and young peoples' perspectives on clinical genetic testing.

1.1 | Objectives

This review asked the following questions:

1. What do children and young people of different ages understand about the genetics of disease, risk, and inheritance?
2. What are children and young peoples' attitudes towards clinical genetic testing? Specifically, do they perceive benefits and/or disadvantages to testing?

2 | MATERIALS AND METHODS

2.1 | Database search procedure

Our systematic review procedure followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[32] We searched Medline, Embase, PsycINFO and CINAHL using the following search terms: ([child$ OR minor OR adolescen$ OR paediatric OR paediatric OR teen] AND [genom$ OR genetic OR genetic testing OR genetic screening] AND [hereditary OR inherit$ OR risk] AND [understanding OR knowledge OR attitude$ OR belief $ OR health literacy] AND [disease OR illness]). We also searched GreyLit, OpenGrey, Google scholar, and the reference lists of eligible studies; all increasingly commonly adjuncts to standard database search strategies.[33] We exported the search results to EndNote X7 (Thomas Reuters). Our final search was conducted in September 2017.

2.2 | Inclusion/exclusion criteria

Articles were included if they:

1. Investigated children and young peoples' (21 years or younger; as per the American Academy of Paediatrics guidelines[34]) understanding of concepts of genetics, risk, and/or inheritance as they

pertain to disease, and/or their perspectives on genetic testing for disease predisposition;
2. Assessed the understanding and perspectives of children and young people with a genetic diagnosis (both symptomatic and pre-symptomatic), at risk, carriers, and/or those who are not at increased risk (ie, general population-level risk); and
3. Were published in English in a peer-reviewed journal between 1990 (the commencement of the Human Genome Project) and 2017.

Articles were excluded if they:

1. Investigated children and young people's understanding of genetic concepts not related to inherited conditions (eg, eye colour inheritance) and/or attitudes not related to genetic testing;
2. Only investigated the perspectives of parents or healthcare professionals, or where results were averaged across groups and the perspectives of children and young people 21 years or younger could not be distinguished;
3. Were systematic reviews, narrative reviews, case studies, commentaries, editorials or opinion pieces.

2.3 | Quality analysis

We used the QualSyst tool[35] to determine the risk of bias of included studies. One author (B.M.) carried out the analysis and a second author (J.V.) independently rated 20% of the included studies, with any discrepancies resolved through discussion. Studies were rated according to either qualitative or quantitative criteria, with mixed-method designs subjected to both scoring systems. To ensure fairness in ratings, if the studies included both qualitative and quantitative elements but were not explicitly stated to be mixed methods then only the primary research design was evaluated. As per the QualSyst scoring system, the total possible score for quantitative studies varies according to the number of items "not applicable" to the study (eg, random allocation of participants in observational analytic studies). Quality scores were defined as limited (<50%), adequate (50%-70%), good (71%-80%) or strong (>80%; see Table 1).[18,36]

2.4 | Data extraction

We identified 1815 articles after screening for English-only, human studies and de-duplicating (Figure 1). Two authors (B.M. and J.V.) independently screened the titles and abstracts (with an inter-rater agreement of 89%), and any disagreements were resolved through discussion. Full-texts were reviewed for any abstracts that did not yield sufficient information to determine eligibility. Of the 41 reviewed full-texts, 11 studies met our inclusion criteria. An additional nine eligible studies were found through study reference lists and Google scholar.

One author (B.M.) extracted data from all 20 studies and another author (J.V.) independently extracted data for 20% of studies (randomly selected) to monitor accuracy of the process. In addition to information regarding study design and sample(s), where possible we also extracted information about predictors of children and young peoples' understanding and attitudes, and differences in understanding and/or attitudes between groups (eg, general population-level risk vs from families with a history of breast cancer).

Similar to a recent psychosocial review examining parents' attitudes towards genetic testing,[17] we divided results according to current clinical guidelines concerning genetic testing in children and young people.[3,26,27] We distinguished between studies which focused on conditions for which genetic testing (either predictive testing or diagnostic testing) is clinically indicated in childhood, and conditions for which genetic testing is only recommended in adulthood or "emerging adulthood."

3 | RESULTS

3.1 | Study characteristics

Twenty studies representing the views of 1811 children and young people aged between 6 and 21 years were identified (1498 children or young people at general population-level risk from 9 studies, 313 affected/at risk from 15 studies). A minority of studies[37–41] (n = 5) investigated the perspectives of children 10 years or younger. Eleven studies[38,41–50] exclusively investigated the perspectives of children and/or young people while the remainder of studies also included the perspectives of other groups, predominately parents.[37,39,40,51–55] Thirteen studies[38–43,46,47,51–55] described children and young peoples' understanding or knowledge of clinical genetics and genetic testing, and 12 studies[37,40,42,44,45,48–51,53,54,56] described their attitudes towards clinical genetic testing.

3.2 | Methodological rigour

Eleven studies were qualitative and nine were quantitative using a cross-sectional, descriptive design. QualSyst scores ranged from 75% to 100%, with the majority of articles scored as strong (>80%), indicating a low risk of bias. As all studies were of at least "good" quality, the results did not need to be qualified by a discussion of the studies' methodological rigour.

3.3 | Children and young peoples' understanding of clinical genetics (n = 13 studies)

3.3.1 | Conditions for which genetic testing in childhood is clinically indicated

Studies indicated that adolescents and young people affected by or at risk for autosomal dominant and recessive conditions generally understand that disease predisposition can be inherited within families and, where testing had occurred, hold mostly accurate knowledge of their personal genetic status (n = 5).[39,42,47,52,54] Only one study investigated young peoples' understanding of X-linked conditions.[54]

When asked directly about their knowledge of the heritability of familial adenomatous polyposis (FAP), adolescents who had parents diagnosed with FAP indicated they knew that FAP was heritable and associated with cancer risk.[39] Similarly, adolescents with cystic fibrosis (CF) demonstrated good "general knowledge" (measured by the percentage of objectively correct answers) of patterns of inheritance within families.[52] Young people who had genetic testing for acute

TABLE 1 Overview of included articles

Author (year), country	Quality score[a]	Sample[b,c]	Study setting/ recruitment	Study design/ methods	Disease/mutation of focus[d]	Mode of inheritance	Understanding	Attitudes towards testing
Andersen et al (2011),[42] Norway	18/20 (90%)	16 to 21-year olds who had genetic testing (*n* = 10; 6 females, 4 males).	Norwegian porphyria Centre.	Qualitative/semi-structured interviews.	Active or latent acute intermittent porphyria (AIP).	Autosomal dominant.	Knowledge of genetic status.	Risk information useful. Some concern about young age of testing, and worry for the future.
Bernhardt et al (2003),[37] USA	18/20 (90%)	10 to 17-year olds of parents at high risk for breast cancer/heart disease (*n* = 37; 28 females, 9 males) (with parent dyads).	Breast cancer clinic, cardiology clinic.	Qualitative/semi-structured interviews.	Breast cancer, heart disease.	N/A.		Initial positive attitudes. Both benefits and risks noted. Some children would not want testing if prevention was not possible, or if the test indicated probability not certainty of developing a disease.
Bradbury et al (2012),[43] USA	17/20 (85%)	11 to 19-year olds with and without a family history of breast cancer (*n* = 54; all female).	Cancer risk clinic, community paediatric practice.	Quantitative /semi-structured interviews.	Breast cancer/BRCA1/2.	Autosomal dominant.	Understanding that breast cancer can be hereditary, but few aware of BRCA1/2 genes. High-risk girls accurately perceived themselves to be at increased risk of breast cancer.	
Cappelli et al (2005),[51] USA	22/22 (100%)	11 to 19-year olds of mothers treated for breast cancer or from the general population (*n* = 110; all female) (with mother dyads).	Hospital (via medical records).	Quantitative case-comparison design/ questionnaire.	Breast cancer/BRCA1/2.	Autosomal dominant.	High-risk daughters reported elevated perceived risk of developing breast cancer and having the BRCA mutation compared to controls.	Positive attitudes towards BRCA testing, and high-risk girls reported more benefits.
De Braekeleer et al (2001),[52] Canada	19/22 (86%)	Adolescents with cystic fibrosis (CF; *n* = 16) (with family members, healthcare professionals)	CF clinic, paediatric clinic.	Quantitative/ questionnaire.	Cystic fibrosis CF.	Autosomal recessive.	The majority of adolescents understand patterns of inheritance in CF. gaps in knowledge include: Incidence and carrier rates, and the risk of having a "normal" child if both parents are carriers.	

TABLE 1 (Continued)

Author (year), country	Quality score[a]	Sample[b,c]	Study setting/ recruitment	Study design/ methods	Disease/mutation of focus[d]	Mode of inheritance	Understanding	Attitudes towards testing
Decruyenaere et al (1995),[44] Belgium	15/18 (83%)	16-20-year-old high-school students (*n* = 166; 55% female)	Recruited from high schools, data collected in a medical clinic setting.	Quantitative/ questionnaire.	Hypothetical genetic disease.	N/A.		Positive attitudes towards majority would at least "probably" seek genetic information regarding disease risk prior to pregnancy; benefits noted.
Driessnack and Gallo (2013),[38] USA	19/20 (95%)	7 to 10-year olds (*n* = 27; 14 females. 13 males)	Community Centre.	Qualitative/face-to-face "draw and tell" interviews.	Genetic disease generally.	N/A.	Early understanding of genetics evident. The term "genetic" linked to concepts of inheritance and disease. Deterministic beliefs about genetics evident.	
Duncan et al (2008),[56] Australia	17/20 (85%)	14 to 26-year olds who had genetic testing (*n* = 8/18 eligible age; 5 females, 3 males)	Children's hospital, in-home.	Qualitative/semi-structured interviews.	Huntington's disease (HD)/ familial adenomatous polyposis (FAP).	Autosomal dominant.		Reported various benefits/ concerns, across test results (but no HD-positive participants <21 years old).
Gason et al (2005),[53] Australia	19/22 (86%)	15 to 18-year olds, community school sample (*n* = 748; 54% female) (with parents, school staff)	Secondary school.	Quantitative /questionnaire.	Hereditary haemochromatosis.	Autosomal recessive.	High mean knowledge scores following the education session. Female students know more than males.	Positive attitude towards genetic susceptibility screening in schools, both before and after an education session. If offered the test, the majority would take it up.
Gjone et al (2011),[39] Norway	20/22 (91%)	10-20-year-old children of parents with FAP (*n* = 22; 12 males, 10 females), children with Hirschprung disease (*n* = 19; 13 males, 6 females) and general population (*n* = 35; 19 females, 18 males) (with parents)	Hospital (medical records).	Quantitative/ questionnaire and semi-structured interview.	FAP.	Autosomal dominant.	Majority demonstrated understanding that FAP is heritable and indicates cancer risk. Risk explained via reference to familial experiences rather than reference to specific genes.	
Harel et al (2003),[45] USA	19/22 (86%)	16 to 18-year olds, school community sample, but some had a family history (*n* = 361; 50% girls)	Secondary school.	Quantitative descriptive/ questionnaire.	Breast cancer, Tay-Sachs disease, hypercholesterolemia.	Autosomal dominant/ recessive.		Positive attitudes towards testing for breast cancer risk and other diseases, especially if have family history.

TABLE 1 (Continued)

Author (year), country	Quality score[a]	Sample[b,c]	Study setting/ recruitment	Study design/ methods	Disease/mutation of focus[d]	Mode of inheritance	Understanding	Attitudes towards testing
Housten et al (2015),[46] USA	15/20 (75%)	13 to 19-year olds with sickle-cell disease (SCD; *n* = 20; 50% females)	Outpatient haematology clinic setting or hospital inpatient.	Qualitative/semi-structured interview.	Sickle-cell disease (SCD).	Autosomal recessive.	Limited knowledge of SCD. Seeking information on transmission, pattern of inheritance and family planning.	Expressed interest in SCD education program
James et al (2003),[54] USA	18/20 (90%)	12-15-year-old sisters of males with chronic granulomatous disease (CGD; *n* = 9; all female) (with parents)	Institute/national registry.	Qualitative/semi-structured telephone interviews.	CGD.	X-linked recessive.	Awareness and correct basic understanding of inheritance of CGD. Assessment of personal reproductive risks based on family experience, "gut feelings", and in some cases, results of carrier testing.	All indicated that access to carrier testing is important, but older age at testing preferred. Concerns included psychological risks and stigma, especially if tested too young.
Mand et al (2013),[50] Australia	16/20 (80%)	17 to 21-year olds who had genetic testing (*n* = 9; 7 females, 2 males)	Hospital, recruited by clinical staff.	Qualitative/ interviews.	HD, autosomal-dominant cerebellar ataxia (ADCA), BRCA1, CDH1, hereditary nonpolyposis colorectal cancer (HNPCC).	Autosomal dominant.		Desire for testing motivated by uncertainty. Some felt disempowered when testing was discouraged. None regretted testing, but psychological impact evident.
Rew et al (2010),[55] USA	17/20 (85%)	14 to 21-year olds from the general population (*n* = 22; 12 male, 10 female) (with parents)	Community, convenience sampling.	Qualitative descriptive/ interviews.	Cancer, Alzheimer's disease.	N/A.	Older adolescents demonstrated greater knowledge of genetics than the younger adolescents. Most had "heard of" genetic testing, although the younger adolescents demonstrated limited knowledge.	A wide range of benefits/ concerns influenced attitudes towards testing.

TABLE 1 (Continued)

Author (year), country	Quality score[a]	Sample[b,c]	Study setting/ recruitment	Study design/ methods	Disease/mutation of focus[d]	Mode of inheritance	Understanding	Attitudes towards testing
Rowland et al (2016),[40] UK	18/20 (90%)	10 to 21-year olds affected or at risk of a BRCA gene mutation (n = 13) (with parents)	Genetics clinic.	Qualitative/semi-structured interviews.	Breast cancer/BRCA.	Autosomal dominant.	Parental anxiety and desire to protect their children can inhibit young peoples' understanding of their BRCA risk and influence their perceptions of prophylactic surgery. Mothers disclosed less to their sons, leading to poor understanding of their BRCA risk.	Selective communication can influence genetic testing decision-making (ie, wanting testing to be able to obtain a free breast augmentation). Some young people wanted testing to be able to make informed reproductive decisions.
Sparbel et al (2008),[49] USA	18/20 (90%)	14 to 18-year olds from HD families (n = 32)	Five HD clinics in US and Canada.	Qualitative/focus groups.	HD.	Autosomal dominant.		Mixed perspectives on the best timing for HD predictive testing. Described both benefits (eg, reducing uncertainty, family planning) and concerns (eg, negative psychological impact).
Szybowska et al (2007),[47] Canada	13/16 (81%)	12 to 19-year olds with a diagnosis of phenylketonuria (PKU; n = 11) or congenital adrenal hyperplasia (CAH; n = 6) (total n = 17; 9 female, 8 male); no previous genetic counselling	Hospital genetics database or through staff.	Quantitative descriptive/ questionnaire.	PKU, CAH.	Autosomal recessive.	Knowledge of genetic condition. Understanding of the inheritance of their condition. Aware of reproductive risks.	

TABLE 1 (Continued)

Author (year), country	Quality score[a]	Sample[b,c]	Study setting/ recruitment	Study design/ methods	Disease/mutation of focus[d]	Mode of inheritance	Understanding	Attitudes towards testing
Tercyak et al (2001),[48] USA	15/16 (93%)	11 to 17-year olds of mothers affected by or at risk for breast/ ovarian cancer (*n* = 20; 14 girls, 6 boys)	Mothers enrolled in a cancer assessment and risk evaluation program.	Quantitative/ questionnaire.	Breast cancer/BRCA1/2.	Autosomal dominant.		Most interested in having cancer predisposition genetic testing as adults. Positive attitudes towards testing in adulthood, with a number of benefits cited (eg, monitor health, inform family planning).
Vatne et al (2015),[41] Norway	18/20 (90%)	6 to 17-year old unaffected siblings of children with a rare disorder (*n* = 56; 37 females, 19 males)	Centre for rare disorders.	Qualitative/coded support group sessions.	Various rare genetic disorders.	Mixed.	Misconceptions and uncertainty about siblings' disorder evident, across disorders. Misconceptions based on "common sense" beliefs (eg, brother's growth excessive because he has "eaten too much") and misunderstanding more complex medical concepts (eg, chromosomes).	

[a] The total possible quality score for the quantitative studies varied according to which scoring items were relevant to the study.

[b] Other participant groups other than children and young people also noted.

[c] Age refers to age at study participation unless otherwise stated. Participant gender specified where possible.

[d] Some presented to participants in a hypothetical scenario.

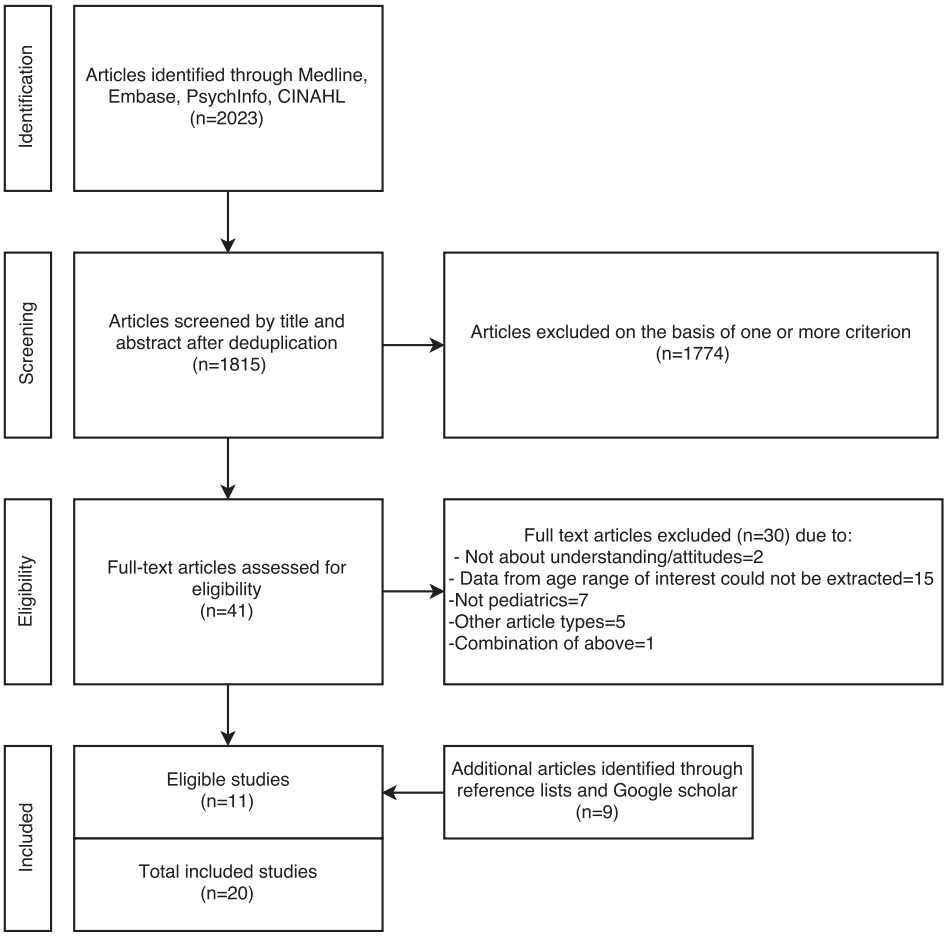

FIGURE 1 PRISMA flow diagram: Search and selection process

intermittent porphyria (AIP) as minors demonstrated knowledge of their genetic status,[42] as did adolescents with phenylketonuria (PKU) or congenital adrenal hyperplasia (CAH).[47] Studies also showed that adolescents tend to know their future reproductive risks, demonstrated in the case of PKU/CAH[47] and in sisters of males with X-linked chronic granulomatous disease (CGD).[54]

Some gaps in understanding were also identified. Generally, studies (n = 4)[39,41,46,52] indicated that children and young peoples' understanding of heritability was grounded in observable family experience rather than knowledge of specific genes or carrier rates. For example, youth with sickle cell disease (SCD) demonstrated limited understanding of the inheritance of SCD and did not know the probability of passing SCD to their offspring.[46] In addition, adolescents with CF did not know the incidence and carrier rates of CF.[52] Misconceptions may be related to misunderstanding of more complex medical concepts (eg, chromosomes), as was demonstrated in the case of siblings of children with rare disorders.[41] Further, although AIP-mutation carriers generally knew their genetic status, some demonstrated confusion about the symptoms of clinically manifest AIP.[42]

3.3.2 | Conditions for which genetic testing in emerging adulthood/adulthood is clinically indicated

Three studies investigated children and young peoples' understanding of breast cancer genetics (BRCA1/2; autosomal dominant).[40,43,51] Two studies reported that children as young as 11 years of age from families with a strong history of breast cancer understood they were at increased risk of breast cancer due to familial/genetic risk.[43,51] The majority of adolescent girls at general population-level risk for breast cancer did not indicate they were at elevated risk of breast cancer.[43] Adolescent girls at general population-risk for breast cancer did not demonstrate specific knowledge of *BRCA1/2* genes,[43] nor did females with a strong family history.[43,51] From a small qualitative study there is some evidence that young people in families with a history of breast cancer may have limited understanding of their own health risks due to inhibited risk disclosure by parents, especially to male children in the family.[40]

A basic understanding of hereditary conditions and genetic concepts (eg, DNA) was also evident in a community sample of school-aged adolescents,[53] as well as children 7 to 10 years old.[38] One study indicated that although a community sample of adolescents had "heard of" genetic testing and were familiar with some genetic concepts related to the Human Genome Project, younger adolescents (14-17 years old) demonstrated very little in-depth knowledge of either genetics or genetic testing for disease susceptibility.[55]

3.3.3 | Factors that may influence children and young peoples' understanding of clinical genetics

Five studies provided insight into the factors that may influence children and young peoples' understanding.[40,43,51,53,55] Studies suggest that "younger" adolescents (11 to 13-year olds in one study,[43] and 14 to 17-year olds in another[55]) may know less about concepts related to genetics and genetic testing than "older" adolescents (older than 13 years,[43] and 18 to 21-year olds[55]). Two studies suggest that

TABLE 2 Children and young peoples' attitudes towards clinical genetic testing: Summary of reported concerns and benefits

	Concerns	Benefits
Conditions for which genetic testing in childhood is clinically indicated.	Negative psychological impact (eg, worry, low mood, regret).[37,42,54,56] Stigma.[54] Poor understanding of implications if tested too young.[42] Privacy and misuse of results.[37] Disease prevention may not be possible.[37]	Informed future reproductive decision-making.[54] Knowledge of risk status.[37,42] Early lifestyle modification for management of the condition.[37,42]
Conditions for which genetic testing in emerging adulthood/adulthood is clinically indicated.	Negative psychological impact (eg, nervousness, stress).[37,45,49–51] Regret knowledge of genetic status.[56] Privacy concerns and misuse of results.[45] Impact on relationships/stigma.[37,56] Interference with other important aspects of life (eg, schooling).[56]	Prompt lifestyle changes (eg, increased screening, prophylactic procedures).[37,40,45,48,51] Desire for cosmetic breast augmentation (in the context of a BRCA gene mutation).[40] Informed future reproductive decision-making.[40,44,48,49] Positive psychological impact (eg, relief from uncertainty).[48–50,56] Sense of control/mastery in managing the condition.[56] Strengthening of relationships through the testing experience.[56]

females, compared to males,[40,53] may have a more developed understanding of inheritance and genetic risk. Females from families with a history of breast cancer, compared to females at general population-risk, may also demonstrate a more developed understanding of the heritability of breast cancer.[43,51]

3.4 | Children and young peoples' attitudes towards clinical genetic testing (*n* = 12 studies)

3.4.1 | Conditions for which genetic testing in childhood is clinically indicated

Five studies indicated that children and young people were generally receptive to the idea of childhood genetic testing for disease predisposition.[37,42,53,54,56] The majority of secondary school students in one study indicated positive attitudes and a willingness to take up genetic testing for hereditary haemochromatosis (autosomal recessive).[53] Those who had genetic testing for AIP (autosomal dominant) indicated that knowledge of their risk status was useful,[42], and others at-risk or affected by other autosomal dominant[56] or recessive conditions[54] also indicated benefits to accessing testing. Nevertheless, participants' attitudes were commonly tempered by an appreciation of some of the possible risks associated with testing (*n* = 4/5 studies; see Table 2); for example, when describing their personal experiences of predictive testing (eg, Andersen et al[42]) or when reflecting on hypothetical genetic testing scenarios in childhood (eg, Bernhardt et al[37]).

3.4.2 | Conditions for which genetic testing in emerging adulthood/adulthood is clinically indicated

Eight studies investigated children and young peoples' attitudes towards clinical genetic testing recommended for emerging adulthood/adulthood.[37,40,44,45,49–51,56] Most young women with[37,51] or without[45,51] a family history of breast cancer expressed at least some interest in or positive attitudes towards genetic testing for breast cancer risk. One study indicated that young women's interest in undertaking genetic testing for breast cancer risk may sometimes be driven by a desire for breast augmentation as part of prophylactic treatment.[40] In many cases, positive attitudes were tempered by concerns, namely the potential for a negative psychological impact as a result of knowing one's genetic risk (*n* = 5/8 studies; see Table 2).

Young people who had undergone predictive testing for other adult-onset autosomal-dominant conditions held a variety of attitudes towards testing across both positive and negative test results.[50,56] A small number of young people in one study felt disempowered when testing was discouraged or delayed, but this did not include the perspectives of young people with a Huntington's disease (HD) gene-positive test result.[50] Young people from HD families in another study demonstrated mixed perspectives about the appropriate timing of HD predictive testing, and described various concerns and benefits.[49] When presented with a hypothetical scenario involving genetic testing for disease susceptibility, children and young people at risk of coronary artery disease initially held favourable attitudes towards testing, although this was tempered by concerns about negative psychological impact.[37] A community sample of adolescents also held positive attitudes towards genetic testing in the context of future reproductive planning.[44] Overall, concerns about the potential risks or limitations of testing were noted by participants in the majority of studies (*n* = 6/8; Table 2).

3.4.3 | Factors that may influence children and young peoples' attitudes towards clinical genetic testing

Three studies provided insight into the factors that may influence children and young peoples' attitudes.[45,51,53] Children and young people with a family history[45,51] or who are in ethnic groups at high risk for hereditary disease predisposition[45] appear more willing to undergo genetic testing than those from lower-risk groups. Those

with higher perceived knowledge regarding genetic conditions[53] and who perceive benefits to genetic testing in terms of condition management[45] may also be more willing to undergo testing.

4 | DISCUSSION

Children and young people today are increasingly likely to receive information about genetic risks within their family. This systematic review provides a timely overview of 20 studies on children and young peoples' understanding of genetics and health and their attitudes towards clinical genetic testing. The review revealed an eclectic range of studies with varying methodologies, participant groups and study settings. Results indicated that although children and adolescents in the general community may have a basic understanding of inheritance, they may lack deeper knowledge of concepts related to genetics and genetic testing. Of the smaller overall proportion of children and young people in the studies affected by or at-risk of specific genetic conditions, they generally demonstrated an understanding of the heritability of their/their family's condition; however, this understanding tended to be grounded in a subjective family narrative rather than specific genetic knowledge. Although there is evidence that children and young people from both community and clinical samples are generally willing and interested in clinical genetic testing in both childhood and adulthood, this was not unanimous and concerns were expressed about the implications of testing and its potential risks.

There is evidence that children and young people demonstrate a basic understanding of inheritance that is mainly grounded in observable, relational information such as family history. Although studies with younger children were sparse, one small qualitative study provided a preliminary indication that this level of understanding may be evident in 7 to 10 year-olds.[38] However, young adolescents in the general community may have very little knowledge of more complex genetic concepts or genetic testing.[55] Importantly, children and young people in families with a strong history of a condition (eg, breast cancer and/or *BRCA1/2* mutations) typically understand they are at increased risk of the condition.[43,51] We also found that young patients who had had genetic testing were generally able to accurately report their genetic status.[42,47] However, these results are balanced with evidence that children and young people may not understand patterns of inheritance or misunderstand specific genetic concepts; for example, the name of the gene involved, carrier or penetrance rates, or what it means to be a carrier of a genetic mutation.

Although we may not expect a high level of genetic knowledge in children and young people who are not at-risk, an understanding of these concepts may be more critical for children and young people affected by or at-risk of genetic conditions. Although from a small number of studies, the results also point to specific groups of young people who may require more in-depth counselling and/or information provision to ensure they accurately understand their personal risks; for example, adolescent and young adult males with a strong family history of breast cancer or where a predisposing mutation has been identified,[57] and young people with SCD.[46] Family-based communication interventions may be particularly crucial in families where parents' ability to effectively communicate with their children about genetic risks and potentially life-saving prophylactic procedures may be compromised by anxiety or guilt.[40]

Children and young peoples' attitudes towards clinical genetic testing in both childhood and emerging adulthood/adulthood appeared open and interested. The finding that some young people from families affected by Huntington disease and other adult-onset conditions felt disempowered and frustrated when predictive genetic testing was delayed until adulthood[49,56] speaks to the tension between clinical judgement and children and young peoples' desire for information, and the ongoing debate as to whether uncertainty or knowing one's genetic status presents the greatest emotional burden.[58] However, it is crucial to note that the Duncan et al[56] study did not represent the perspectives of young people with a HD gene-positive result who were 21 years old or younger, indicating a need for further research with HD gene-positive adolescents and young adults. Further, children and young people commonly expressed concerns about testing which mirror those reported by parents.[17] Concern about the possible psychological impact of testing was commonly reported. Studies seem to indicate that children and young people, whether they are at general population-level risk or affected by/at-risk of genetic conditions, understand that genetic testing is a complex process that can have both positive and negative consequences and psychosocial sequelae. In the context of the possible gaps in knowledge and misunderstandings evident in some studies, it is possible that views about testing may be grounded in misinformation. Nevertheless, these conclusions are based on a relatively small number of studies and further research is required.

4.1 | Limitations

Only a small proportion of the abstracts identified by our search terms were eligible for inclusion, primarily as a result of the age-range criteria. Although our decision to specify 21 years or younger was pragmatic and intended to maximise the relevance of this review to the paediatric setting, we acknowledge our narrow definition of "young people." In addition, our search was limited to papers published in English, potentially eliminating other relevant articles. Although the reviewed studies were all of at least "good" quality, we note the absence of mixed methods, longitudinal and intervention studies in this area. Several deficiencies in study design, or the reporting of study design, were commonly observed. For example, in the qualitative studies, sampling methods and researcher reflexivity were rarely discussed thoroughly, if at all. Finally, our interpretation of what children and young people understand about clinical genetics may be complicated by the varied settings and methodologies used. The included studies with the largest sample sizes were recruited from "healthy" community or school populations, while the experiences of at-risk or affected children and young people were generally explored through smaller, qualitative studies. Further evidence from at-risk or affected children and young people is needed to draw conclusions to inform clinical practice. Further, some studies sought to understand children and young peoples' subjective knowledge of and experience with genetics via open-ended qualitative approaches, while others used closed general knowledge-type questions with a

clear "correct/incorrect" answer. Differences in the assessment methods used may influence or bias responses.[59]

4.2 | Future directions

As genetic technologies continue to evolve and children and young people are increasingly faced with information concerning their current and future health, several important lines of research are indicated to inform best-practice counselling and interventions. From a developmental perspective, longitudinal studies are required to answer questions of how and when children and young peoples' understanding and knowledge of genetics changes with age. From a clinical perspective, further studies investigating young peoples' experience with specific conditions are required, as they will have different information and support needs depending on the mode of inheritance and clinical trajectory of the condition. Although outside the scope of this review, we also acknowledge the need to further investigate young people and their families' perspectives on and experiences with whole genome and exome sequencing, which again entails unique ethical and clinical issues.[60]

4.3 | Conclusions

Children and young people may demonstrate a basic understanding of genetic conditions, often inferred from observable patterns within families. Those at-risk of or affected-by genetic conditions may sometimes misunderstand or lack important knowledge about their/their family's condition. Although children and young people demonstrate an appreciation of the potential benefits of genetic testing in both childhood and adulthood, they also express significant concerns, especially the potential for negative psychological impact. Young patients require developmentally sensitive genetics support and guidance to navigate the unique landscape of their condition and understand the implications of testing.

ACKNOWLEDGEMENTS

B.C.M. is supported by an Australian Government Research Training Program Scholarship. C.E.W is supported by a Career Development Fellowship from the National Health and Medical Research Council of Australia (APP1143767) and an Early Career Development Fellowship from the Cancer Institute of New South Wales (ID: 11/ECF/3-43). The Behavioural Sciences Unit is proudly supported by the Kids with Cancer Foundation.

Conflict of interest

Nothing to declare.

ORCID

B.C. McGill https://orcid.org/0000-0002-2134-2988

REFERENCES

1. Metcalfe A, Coad J, Plumridge GM, Gill P, Farndon P. Family communication between children and their parents about inherited genetic conditions: a meta-synthesis of the research. *Eur J Hum Genet*. 2008;16(10):1193-1200.
2. Tercyak KP, Streisand R, Peshkin BN, Lerman C. Psychosocial impact of predictive testing for illness on children and families: challenges for a new millennium. *J Clin Psychol Med Settings*. 2000;7(1):55-68.
3. Botkin JR, Belmont JW, Berg JS, et al. Points to consider: ethical, legal, and psychosocial implications of genetic testing in children and adolescents. *Am J Hum Genet*. 2015;97(1):6-21.
4. Gopnik A. Scientific thinking in young children: theoretical advances, empirical research, and policy implications. *Science*. 2012;337(6102):1623-1627.
5. Inagaki K, Hatano G. Young children's conception of the biological world. *Curr Dir Psychol Sci*. 2006;15(4):177-181.
6. Toyama N. Adults' explanations and children's understanding of contagious illnesses, non-contagious illnesses, and injuries. *Early Child Dev Care*. 2016;186(4):526-543.
7. Raman L, Gelman SA. Children's understanding of the transmission of genetic disorders and contagious illnesses. *Dev Psychol*. 2005;41(1):171-182.
8. Ergazaki M, Alexaki A, Papadopoulou C, Kalpakiori M. Young children's reasoning about physical & behavioural family resemblance: is there a place for a precursor model of inheritance? *Sci Educ*. 2014;23(2):303-323.
9. Solomon GE, Johnson SC, Zaitchik D, Carey S. Like father, like son: young children's understanding of how and why offspring resemble their parents. *Child Dev*. 1996;67(1):151-171.
10. Smith LA, Williams JM. "It's the X and Y thing": cross-sectional and longitudinal changes in children's understanding of genes. *Res Sci Educ*. 2007;37(4):407-422.
11. Venville G, Gribble SJ, Donovan J. An exploration of young children's understandings of genetics concepts from ontological and epistemological perspectives. *Sci Educ*. 2005;89(4):614-633.
12. Tsui CY, Treagust DF. Understanding genetics: analysis of secondary students' conceptual status. *J Res Sci Teach*. 2007;44(2):205-235.
13. Fanos JH. Developmental tasks of childhood and adolescence: implications for genetic testing. *Am J Hum Genet A*. 1997;71(1):22-28.
14. Fuller R, Dudley N, Blacktop J. How informed is consent? Understanding of pictorial and verbal probability information by medical inpatients. *Postgrad Med J*. 2002;78(923):543-544.
15. Newson AJ, Leonard SJ, Hall A, Gaff CL. Known unknowns: building an ethics of uncertainty into genomic medicine. *BMC Med Genet*. 2016;9(1):57.
16. Rolland JS, Williams JK. Toward a biopsychosocial model for 21st-century genetics. *Fam Process*. 2005;44(1):3-24.
17. Lim Q, McGill BC, Quinn VF, et al. Parents' attitudes toward genetic testing of children for health conditions: a systematic review. *Clin Genet*. 2017;92:569-578.
18. Young AL, Butow PN, Vetsch J, et al. Family communication, risk perception and cancer knowledge of young adults from BRCA1/2 families: a systematic review. *J Genet Couns*. 2017;26(6):1179-1196.
19. Haran J, O'Riordan K. Public knowledge-making and the media: Genes, genetics, cloning and Mass Observation. *European Journal of Cultural Studies*. 2017:1–20. https://doi.org/10.1177/1367549416682971
20. Kung JT, Gelbart ME. Getting a head start: the importance of personal genetics education in high schools. *Yale J Biol Med*. 2012;85(1):87-92.
21. McElhinny TL, Dougherty MJ, Bowling BV, Libarkin JC. The status of genetics curriculum in higher education in the United States: goals and assessment. *Sci Educ*. 2014;23(2):445-464.
22. Elmesky R. Building capacity in understanding foundational biology concepts: a K-12 learning progression in genetics informed by research on children's thinking and learning. *Res Sci Educ*. 2013;43(3):1155-1175.
23. Ramorogo G, Wood-Robinson C. Botswana children's understanding of biological inheritance. *J Biol Educ*. 1995;29(1):60-71.
24. Mand C, Gillam L, Delatycki MB, Duncan RE. Predictive genetic testing in minors for late-onset conditions: a chronological and analytical review of the ethical arguments. *J Med Ethics*. 2012;38:519-524.
25. Griffith R. What is Gillick competence? *Hum Vaccin Immunother*. 2016;12(1):244-247.

26. Human Genetics Society of Australasia. *Guideline: Pre-symptomatic and Predictive Testing for Children and Young Adults*. Sydney, Australia. Human Genetics Society of Australasia; 2014.
27. Druker H, Zelley K, McGee RB, et al. Genetic counselor recommendations for cancer predisposition evaluation and surveillance in the pediatric oncology patient. *Clin Cancer Res*. 2017;23(13):e91-e97.
28. Smyth R. Research with children. *BMJ*. 2001;322:1377-1378.
29. Melton GB. Treating children like people: a framework for research and advocacy. *J Clin Child Adolesc Psychol*. 2005;34(4):646-657.
30. Rew L, Mackert M, Bonevac D. A systematic review of literature about the genetic testing of adolescents. *J Spec Pediatr Nurs*. 2009;14(4):284-294.
31. Maher B. Genomes on prescription. *Nature*. 2011;478(7367):22.
32. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7):e1000097.
33. Arora RS, Eden TO. Assessing the impact of paediatric oncology publications using three citation databases. *Pediatr Blood Cancer*. 2011;56(1):152-153.
34. Hardin AP, Hackell JM, Simon GR, et al. Age limit of pediatrics. Pediatrics. 2017;140:e20172151.
35. Kmet LM, Lee RC, Cook LS. Standard quality assessment criteria for evaluating primary research papers from a variety of fields. Alberta Heritage Foundation for Medical Research; 2004.
36. Laidsaar-Powell R, Butow P, Bu S, et al. Physician–patient–companion communication and decision-making: a systematic review of triadic medical consultations. *Patient Educ Couns*. 2013;91(1):3-13.
37. Bernhardt BA, Tambor ES, Fraser G, Wissow LS, Geller G. Parents' and children's attitudes toward the enrollment of minors in genetic susceptibility research: implications for informed consent. *Am J Med Genet A*. 2003;116(4):315-323.
38. Driessnack M, Gallo AM. Children 'draw-and-tell' their knowledge of genetics. *Pediatr Nurs*. 2013;39(4):173-180.
39. Gjone H, Diseth T, Fausa O, Nøvik T, Heiberg A. Familial adenomatous polyposis: mental health, psychosocial functioning and reactions to genetic risk in adolescents. *Clin Genet*. 2011;79(1):35-43.
40. Rowland E, Plumridge G, Considine A-M, Metcalfe A. Preparing young people for future decision-making about cancer risk in families affected or at risk from hereditary breast cancer: a qualitative interview study. *Eur J Oncol Nurs*. 2016;25:9-15.
41. Vatne TM, Helmen IØ, Bahr D, Kanavin Ø, Nyhus L. "She came out of mum's tummy the wrong way"(Mis) conceptions among siblings of children with rare disorders. *J Genet Couns*. 2015;24(2):247-258.
42. Andersen J, Sandberg S, Raaheim M, Gjengedal E. Psychosocial aspects of predictive genetic testing for acute intermittent porphyria in Norwegian minors. *JIMD Rep*. 2011;1:1-7.
43. Bradbury AR, Patrick-Miller L, Egleston BL, et al. Knowledge and perceptions of familial and genetic risks for breast cancer risk in adolescent girls. *Breast Cancer Res Treat*. 2012;136(3):749-757.
44. Decruyenaere M, Evers-Kiebooms G, Welkenhuysen M, Bande-Knops J, Van Gerven V, Van den Berghe H. Adolescents 9 opinions about genetic risk information, prenatal diagnosis, and pregnancy termination. *J Med Genet*. 1995;32(10):799-804.
45. Harel A, Abuelo D, Kazura A. Adolescents and genetic testing: what do they think about it? *J Adolesc Health*. 2003;33(6):489-494.
46. Housten AJ, Abel RA, Dadekian J, Schwieterman K, Jason D, King AA. Youth with sickle cell disease: genetic and sexual health education needs. *Am J Health Behav*. 2015;39(6):856-865.
47. Szybowska M, Hewson S, Antle BJ, Babul-Hirji R. Assessing the informational needs of adolescents with a genetic condition: what do they want to know? *J Genet Couns*. 2007;16(2):201-210.
48. Tercyak KP, Peshkin BN, Streisand R, Lerman C. Psychological issues among children of hereditary breast cancer gene (BRCA1/2) testing participants. *Psychooncology*. 2001;10(4):336-346.
49. Sparbel KJ, Driessnack M, Williams JK, et al. Experiences of teens living in the shadow of Huntington disease. *J Genet Couns*. 2008;17(4):327-335.
50. Mand C, Gillam L, Duncan RE, Delatycki MB. It was the missing piece: adolescent experiences of predictive genetic testing for adult-onset conditions. *Genet Med*. 2013;15(8):643-649.
51. Cappelli M, Verma S, Korneluk Y, et al. Psychological and genetic counseling implications for adolescent daughters of mothers with breast cancer. *Clin Genet*. 2005;67(6):481-491.
52. De Braekeleer M, Bellis G, Rault G, Allard C, Milot M, Simard F. Disease knowledge in a high-risk population for cystic fibrosis. *Patient Educ Couns*. 2001;43(3):265-270.
53. Gason A, Aitken M, Metcalfe S, Allen KJ, Delatycki M. Genetic susceptibility screening in schools: attitudes of the school community towards hereditary haemochromatosis. *Clin Genet*. 2005;67(2):166-174.
54. James CA, Holtzman NA, Hadley DW. Perceptions of reproductive risk and carrier testing among adolescent sisters of males with chronic granulomatous disease. *Am J Med Genet C*. 2003;119(1):60-69.
55. Rew L, Mackert M, Bonevac D. Cool, but is it credible? Adolescents' and parents' approaches to genetic testing. *West J Nurs Res*. 2010;32(5):610-627.
56. Duncan RE, Gillam L, Savulescu J, Williamson R, Rogers JG, Delatycki MB. "You're one of us now": young people describe their experiences of predictive genetic testing for Huntington disease (HD) and familial adenomatous polyposis (FAP). *Am J Med Genet C*. 2008;148(1):47-55.
57. Rauscher EA, Dean M. "I've just never gotten around to doing it": men's approaches to managing BRCA-related cancer risks. *Patient Educ Couns*. 2017;101(2):340-345.
58. Godino L, Turchetti D, Jackson L, Hennessy C, Skirton H. Impact of presymptomatic genetic testing on young adults: a systematic review. *Eur J Hum Genet*. 2016;24(4):496-503.
59. Creswell JW. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Thousand Oaks, California. Sage Publications; 2013.
60. Wade CH, Tarini BA, Wilfond BS. Growing up in the genomic era: implications of whole-genome sequencing for children, families, and pediatric practice. *Annu Rev Genomics Hum Genet*. 2013;14:535-555.

How to cite this article: McGill BC, Wakefield CE, Vetsch J, et al. Children and young people's understanding of inherited conditions and their attitudes towards genetic testing: A systematic review. *Clin Genet*. 2019;95:10–22. https://doi.org/10.1111/cge.13253