RBM ONLINE

ELSEVIER

Article

Health outcomes of school-aged children conceived using donor sperm

David J Amor [a,b,c,*], Sharon Lewis [a,b], Joanne Kennedy [a], Emily Habgood [b], John McBain [d,e], Robert I McLachlan [f,g,h], Luk J Rombauts [f,g,h], Katrina Williams [a,b,c], Jane Halliday [a,b]

[a] Murdoch Childrens Research Institute, Royal Children's Hospital, Parkville, Victoria, Australia
[b] Department of Paediatrics, The University of Melbourne, Victoria, Australia
[c] Royal Children's Hospital, Parkville, Victoria, Australia
[d] Royal Women's Hospital, Parkville, Victoria, Australia
[e] Reproductive Services, Royal Women's Hospital, Victoria, Australia
[f] Hudson Institute of Medical Research, Victoria, Australia
[g] Department of Obstetrics and Gynaecology, Monash University, Victoria, Australia
[h] Monash IVF Group, Richmond, Victoria, Australia

David Amor is clinical geneticist and Professor of Developmental Medicine at The University of Melbourne. He has a PhD in chromosome biology and a research interest in genetic causes of disability and health outcomes in children conceived using assisted reproduction.

KEY MESSAGE
In school-aged children conceived using donor sperm, most aspects of child health and wellbeing are similar to the general population.

A B S T R A C T

The use of donor sperm is increasing, yet limited information is available about the health and development of children conceived from donor sperm. This retrospective descriptive study aimed to assess health and development in a cohort of school-aged children who were conceived using donor sperm. Participants included 224 children, aged 5–11 years, who were conceived using donor sperm. Participants' mothers completed a questionnaire comprising validated scales examining their child's current and past physical, psychosocial and mental health, healthcare needs and child development, as well as the mothers' health and wellbeing. At the conclusion of the study, the response rate was 296 out of 407 (72.7%), with a participation rate of 224 out o 407 (55.0%). Compared with the normative Australian population, sperm donor-conceived children had similar physical, psychosocial and mental health and development. A modest increase in healthcare needs was evident. The study concludes that in school-aged children conceived using donor sperm, most aspects of child health and wellbeing are similar to the general population.

* Corresponding author.
E-mail address: david.amor@mcri.edu.au (DJ Amor).
http://dx.doi.org/10.1016/j.rbmo.2017.06.012

Introduction

Donor sperm has been used in reproductive medicine for more than 100 years, originally in heterosexual couples as a treatment of severe male infertility. In the 1990s, the introduction of intracytoplasmic sperm injection (ICSI) enabled most infertile men to father their own children, and as a result the need for donor sperm declined (Devroey and Van Steirteghem, 2004). More recently, however, use of donor sperm has risen, driven in part by its increased use by single women and same-sex couples (De Wert et al., 2014; Human Fertilization and Embryology Authority, 2014). In Victoria, Australia, the number of births after donor sperm conception more than doubled between 2010 and 2015, and, in 2015, 50% of women accessing donor sperm were single and 35% were in same-sex relationships (Victorian Assisted Reproductive Treatment Authority, 2016). Yet, information about the health, healthcare needs and development of children conceived from donor sperm is still limited (Kovacs et al., 2013). Although studies to date have produced reassuring results (Brewaeys et al., 1997; Golombok et al., 2002a, 2002b; Kovacs et al., 1993; Murray and Golombok, 2005), most are relatively small and have focused on psychosocial factors and family functioning rather than physical and mental health outcomes. Where health outcomes have been studied, only birth data are available, such as birth weight and the presence or absence of birth defects (Adams et al., 2016).

Child health and development are influenced by a broad range of genetic and non-genetic factors, and we hypothesized that some of these factors will differ between children conceived using donor sperm and the general population. The aim of this study was to describe, in the setting of a changing profile of women accessing donor sperm, the physical, psychosocial and mental health, healthcare needs and child development in a cohort of school-aged children who were conceived using donor sperm. We were also interested in examining the family functioning and the quality of life for the mothers of the donor sperm conceived children.

Materials and methods

Study design

This was a descriptive study of a cohort of children conceived using donor sperm, using a self-completed maternal questionnaire comprising a range of validated scales.

Participants

Participants were singleton children conceived using donor sperm and born between January 2003 and December 2009, and who were at least 5 years of age at the time of questionnaire completion. Potential study participants were sourced from the two clinics that provided the most donor sperm treatment cycles in Victoria, Australia, during the study time period: Melbourne IVF and Monash IVF. All fresh and frozen treatment procedures, including IVF, ICSI, and intrauterine insemination were included. Children who had one or more full siblings conceived using donor sperm during this time period were also included in the study. The study included some children who were half siblings, having been conceived by different mothers using the same sperm donor; however, the number of these cases is not presented to preserve confidentiality. Children were excluded if their mother did not have adequate English reading skills, had used preimplantation genetic diagnosis (PGD), used donor eggs in conjunction with donor sperm or had a fetal, infant, child or maternal death.

Recruitment

The mothers of all potential participants were sent a study pack by 'Registered Post' from the director of the relevant IVF clinic, which included documents such as a detailed letter about the study, a consent form, the questionnaire and a reply paid envelope. If no reply was received, a reminder letter was sent 3 weeks after the initial invitation, with a second reminder letter sent 2 months after the initial invitation. Mothers willing to participate were asked to complete the questionnaire and return it with the signed consent form to the study team in the envelope provided.

The questionnaire asked about current and past health and wellbeing of school-aged children conceived using donor sperm, as well as the mothers' health and wellbeing. The seven measures included in the questionnaire have all been shown to have good psychometric properties (Bethell et al., 2002; Chandler et al., 2007; Coghlan et al., 2003; Hawthorne and Osborne, 2005; Hayes, 2007; Kabacoff et al., 1990; Waters et al., 2000). Particular aspects of the treatment cycle were verified by the relevant fertility clinic, such as type of treatment undertaken.

Measures

The questionnaire comprised a number of reliable and well-validated scales.

Health and wellbeing

Health and wellbeing was assessed using the Child Health Questionnaire (CHQ), Australian adaption, short form (Waters et al., 2000). This version of the CHQ comprises 28 items and measures functional health and wellbeing in children aged between 5 and 18 years. It provides summary data in 13 domains: physical functioning, social limitations resulting from emotional, behavioural difficulties, and physical difficulties, bodily pain or discomfort, behaviour, mental health, self-esteem, general health, emotional impact on parent, time impact on parent, family activities, family cohesion and change in health (not used for this study). Australian normative data were from Waters et al. (2000), based on 1033–1044 Australian school-children aged 5–7 years.

Mental health

Mental health was assessed using the Strengths and Difficulties Questionnaire (SDQ), a validated 25-item parent reported measure (Goodman, 1997) that produces five subscale scores (range: 0–10) and a total difficulties score (range: 0–40). The subscales are emotional symptoms, conduct problems, hyperactivity, peer problems and prosocial behaviour. Higher scores indicate more difficulties except for the prosocial subscore (Goodman, 1997). Australian normative data from Hayes (2007) were based on 1899 Australian school children aged 5–10 years.

Child development

Child development was assessed using the Parents' Evaluation of Development Status (PEDS) (Glascoe, 1999), a 10-item parent completed

standardized questionnaire that elicits parental concerns about child development in children from birth up to the age of 8 years. The PEDS open-ended questions cover expressive and receptive language, fine motor, gross motor, behaviour, socialisation, self-care, and learning and also provide opportunity for parents to raise other concerns. Australian normative data from Coghlan et al. (2003) were based on 262 Australian preschool children aged 18 months to 5 years 9 months.

Autism spectrum disorder

Autism spectrum disorder (ASD) status was assessed using the Social Communication Questionnaire (SCQ) (Rutter et al., 2003), a screening tool for ASD that is widely used in clinical research and practice. The main domains of the questionnaire are reciprocal social interaction, communication, and restricted, repetitive and stereotyped patterns of behaviour. The SCQ uses a 40-point yes-no scale, and total scores can range from 0–39. Any scores of 15 or over indicate an increased risk for ASD. The SCQ shows strong discrimination between ASD and non-ASD cases (Chandler et al., 2007). Australian population data were not available for comparison; therefore, British general population data were used from Chandler et al. (2007), who studied 658 English children with mean age of 11.5–12 years. Parents were not asked specifically about a diagnosis of ASD in their child, but could provide this information in response to open-ended questions about their child's health in the Special Health Care Needs Screener. Parental report of a diagnosis of ASD was compared with general population data from the Longitudinal Study of Australian Children 'B cohort' with birth years 2003–2004 (Randall et al., 2016).

Healthcare needs

Healthcare needs were assessed using the Children with Special Health Care Needs Screener (CSHCNS) (Bethell et al., 2002). The CSHCNS asks a series of questions classified into three subgroups: children who are considered to be dependent on medication; reported to require or use more medical services than usual for their age; and regarded as having functional limitations. Comparison was with Australian normative data from 2006 for 5000 children aged younger than 13 years (Victorian Government Department of Human Services, 2006) and from the Longitudinal Study of Australian Children 'K' cohort, comprising 4460 children born between 1999 and 2000 who were screened using the CSHCNS at age 6–7 years (Quach et al., 2014).

Family functioning

Family functioning was assessed using the McMaster Family Assessment Device (FAD) (Kabacoff et al., 1990), which comprises seven subscales that evaluate different aspects of family life. The study used the 12-item general functioning subscale, which has a range of scores between 1 and 2.75, to evaluate overall family functioning; a cut-off of 2.00 is used to decide if families are classified into the clinical or non-clinical category (Miller et al., 1985). Normative data from Boterhoven de Haan et al. (2015) were based on 3225 Australian parents.

Mothers' wellbeing

Mother's wellbeing was assessed using the Assessment of Quality of Life (AQoL) (Hawthorne and Osborne, 2005), which uses 20 questions to measure six aspects of life: independent living, mental health, coping, relationships, pain and senses. Normative data from Hawthorne and Osborne (2005) were based on 3010 Australian adults.

Data management and analysis

The questionnaire data were entered into the database program EpiData 3.1 (The EpiData Association, Odense, Denmark) and STATA 14 (StataCorp Texas, USA) was used for analysis. Descriptive statistics for comparisons were undertaken for each scale; T-tests and chi-square tests were carried out for continuous and categorical data, respectively, with 95% confidence intervals and *P*-values presented. Because of multiple analyses, $P < 0.01$ was considered statistically significant. Difference in group means were examined using one-way analysis of variance testing.

Ethics approval

All documents were approved by the Monash Surgical Private Hospital Human Research Ethics Committee (ID number 12095, now Monash Health 15149M) on 2 May 2012 and the Melbourne IVF Human Research Ethics Committee (ID number 09/12) on 22 May 2012.

Results

Response rate

At the conclusion of the study, the response rate was 296 out of 407 (72.7%), with a participation rate of 224 out of 407 (55.0%). The mothers of seventy-two participants declined participation, and reasons for declining were not collected. Thirty-one sibling pairs were included in the study; therefore, the number of mothers included in the analyses was 193. All birth mothers were also the biological mothers of their children. Characteristics of the 224 participants, their mothers and mode of conception are shown in **Table 1**. In our clinic population, the high use of IVF–ICSI (81.7%), rather than intrauterine insemination, is to maximise the use of donated sperm, the availability of which is limited, rather than reflecting poor sperm quality.

Health and wellbeing

Child Health Questionnaire results are summarized in **Table 2**, and compared with Australian population data (Waters et al., 2000). For both male and female children conceived using donor sperm, the mean score for general health perceptions was markedly higher (mean difference >8.5; $P < 0.001$) compared with Australian population data. For female children, the mean scores for mental health and self-esteem were also much higher ($P < 0.001$) than the Australian population. There were no measures for which donor conceived children scored significantly lower than Australian population data.

Mental health

Results of the Strengths and Difficulties Questionnaire are presented in **Table 3** and **Supplementary Table S1**. Male donor-conceived children had lower hyperactivity scores and higher pro-social behaviour scores compared with the Australian population (Hayes, 2007). In female donor-conceived children, conduct problems were higher

Table 1 – Descriptive characteristics of sperm donor-conceived children and their mothers.

Child characteristics	n (%)[a]
Gender	
Male	112 (50.0)
Female	112 (50.0)
Age (years)	
5	100 (44.6)
6	50 (22.3)
7	32 (14.3)
8	29 (12.9)
9–10	13 (5.8)
Age: mean (SD)	6.54 (1.38)
Birth order	
First	150 (67.3)
Second	62 (27.8)
Third and over	11 (4.9)
School year	
Yet to start	61 (27.5)
Prep	58 (26.1)
One	46 (20.7)
Two/three/four	50 (22.5)
Special school	7 (3.2)
Mode of conception (n = 223)	
IVF	67 (30.0)
ICSI	116 (52.0)
Intrauterine insemination	40 (17.9)
Maternal characteristics (n = 193)[a]	**n (%)**
Country of birth	
Australia	171 (88.6)
Perceived financial position	
Prosperous	7 (3.6)
Very comfortable	48 (24.9)
Comfortable	100 (51.8)
Just getting along/poor/no answer	38 (19.7)
Education	
< Year 12	12 (6.2)
Year 12, TAFE, Diploma	73 (37.8)
University	102 (52.8)
Other	6 (3.1)
Work	
Full time	54 (28.0)
Part time	90 (46.6)
Home duties	30 (15.5)
Other	19 (9.8)
Living situation	
Heterosexual couple	98 (50.8)
Same sex couple	37 (19.2)
Single	39 (20.2)
Divorced/widowed/other	19 (9.8)

[a] Thirty-one mothers had two children included in the study; therefore, data are presented for a total of 224 children and 193 mothers.

compared with the Australian population (mean difference 0.64, 95% CI 0.35 to 0.93; $P < 0.001$).

Child development

The Parents' Evaluation of Developmental Status scores are categorized into subclasses depending on the number of concerns that are reported. Results for the 211 children who were 8 years old or younger at the time of assessment are shown in **Supplementary Table S2**. When comparing the donor-conceived children with the Australian population, there was no difference in the proportion of children at moderate risk (one significant concern) or high risk (two or more significant concerns) of disability.

Autism spectrum disorders

Mothers reported that nine of the 224 children (4.0%; 95% CI 1.8 to 7.4%) had previously been diagnosed with an ASD.

Using the 40-question Social Communication Questionnaire, 11 children (4.9%) obtained a score of 15 or over, indicating a high risk of having an ASD. The 11 children in our study included eight of the nine children who had previously received a clinical diagnosis of ASD, and one child who had a pre-existing diagnosis of Prader–Willi syndrome. One child scored 11 on the SCQ who had previously received a clinical diagnosis of ASD (Asperger syndrome). Excluding the child with Prader–Willi syndrome, the 11 children with known or suspected ASD (i.e. who had a previous clinical diagnosis of ASD, scored 15 or over on the SCQ, or both) comprised 10 males and one female, with a mean age of 6.5 years (range 5–9 years). All were the offspring of different sperm donors, five were conceived by ICSI, five by standard IVF and one by intrauterine insemination. All 11 were born at term (mean gestational age 39.4 weeks). Eight had been diagnosed with high-functioning autism or Asperger syndrome. The indication for use of donor sperm was male factor infertility in six; two recipients were single women and three recipients were in same-sex relationships.

Healthcare needs

Results of the Special Health Care Need Screener are shown in **Table 4**. Overall, 23.2% of donor conceived children had one or more special health care needs, which is significantly above the Australian norms of 15.7% from 2006 for children aged younger than 13 years (Services, 2006) (chi-square 9.00; $P = 0.003$) and 15.0% for children aged between 6 and 7 years from the Longitudinal Study of Australian Children (Quach et al., 2014). In the sperm donor-conceived children, the increase in healthcare needs was mostly in the domain of special service needs, and was particularly apparent in male children, 28.6% of whom had one or more special healthcare needs. When the 11 children with a known or suspected diagnosis of ASD were excluded from the analysis, the percentage of children with one or more special health care needs reduced to 19.2% overall and 21.6% for males, results that are not statistically different from the Australian population.

Family functioning: General Functioning subscale of McMaster Family Assessment Device

In the General Functioning subscale of the McMaster Family Assessment Device, higher scores indicate worse levels of family functioning, and a score above 2.00 is used to identify families experiencing problems (Miller et al., 1985). In families with a sperm donor-conceived child, the mean score was 1.45 (SD 0.41), compared with the general population mean of 1.84 (SD 0.43) (Kabacoff et al., 1990) and Australian normative mean of 1.68 (Boterhoven de Haan et al., 2015) indicating better family functioning in families with a sperm donor-conceived child. Fifteen families (7.8%) in this study sample scored in the clinical category of above 2.00, compared with Australian normative data of 14.8% (Boterhoven de Haan et al., 2015).

Table 2 – Health and wellbeing of sperm donor-conceived children as measured by the Child Health Questionnaire (CHQ).

	Males			Females		
	Donor sperm sample; mean (SD) (n = 109–111)	Australian population data (5–7 years[a]) (Waters et al., 2000); mean (SD) (n = 521–527)	Mean difference (95% CI)	Donor sperm sample; mean (SD) (n = 111–112)	Australian population data (5–7 years[a]) (Waters et al., 2000) Mean (SD) (n = 512–517)	Mean difference (95% CI)
Physical functioning	97.80 (10.36)	94.53 (16.74)	3.36 (0.85 to 5.67)[b]	97.02 (11.55)	96.57 (10.81)	0.97 (1.38 to 3.32)
Social limitations: emotional behavioural	93.88 (18.79)	93.85 (17.07)	0.30 (–3.82 to 3.89)	96.43 (15.73)	95.62 (13.87)	0.81 (–2.36 to 3.98)
Social limitations: physical	95.76 (15.05)	95.27 (15.37)	0.48 (–2.65 to 3.61)	96.43 (15.73)	96.24 (13.33)	0.19 (–2.97 to 3.35)
Bodily pain or discomfort	89.81 (16.20)	86.51 (16.45)	3.31 (–0.05 to 6.67)	87.50 (17.01)	85.18 (16.82)	2.32 (–1.17 to 5.81)
Behaviour	72.21 (17.52)	72.83 (15.42)	–0.62 (–4.19 to 2.95)	77.60 (15.35)	77.68 (13.96)	0.08 (–3.19 to 3.03)
Mental health	83.79 (15.50)	79.68 (11.06)	4.11 (1.02 to 7.20)[b]	84.30 (11.36)	79.76 (11.47)	4.54 (2.16 to 6.92)[c]
Self esteem	83.83 (21.81)	84.91 (15.01)	–1.08 (–5.41 to 3.25)	90.03 (14.41)	85.09 (14.96)	4.94 (1.95 to 7.93)[c]
General health perceptions	85.30 (16.99)	76.41 (15.48)	8.89 (5.41 to 12.37)[c]	84.99 (17.89)	76.55 (16.58)	8.44 (4.80 to 12.08)[c]
Parental impact: emotional	83.92 (17.47)	80.82 (18.71)	3.11 (–0.52 to 6.74)	84.38 (19.53)	83.62 (18.51)	0.76 (–3.22 to 4.74))
Parental impact: time	92.56 (15.15)	90.01 (18.56)	2.55 (–0.69, 5.79)	92.41 (16.87)	92.09 (14.81)	0.32 (–3.08 to 3.72)
Family activities	84.26 (18.96)	83.52 (17.13)	1.12 (–2.71, 4.95)	85.81 (18.88)	86.87 (15.87)	–1.06 (–4.86 to 2.74)
Family cohesion	83.39 (19.59)	78.72 (19.09)	4.67 (0.67, 8.67)	84.64 (15.62)	79.86 (18.86)	4.78 (1.44 to 8.12)[b]

[a] Australian normative data for ages 5–7 years used because this age range matches the mean age of sperm donor-conceived children in the study.
[b] $P < 0.01$.
[c] $P < 0.001$.

Table 3 – Mental health of sperm donor-conceived children as measured by the Strengths and Difficulties Questionnaire (SDQ).

	Males, mean (SD)			Females, Mean (SD)		
	Donor sperm sample (n = 112)	Australian population data (Hayes, 2007) (n = 1006)	Mean difference (95% CI)	Donor sperm sample (n = 110[a])	Australian population data (Hayes, 2007) (n = 893)	Mean difference (95% CI)
Total difficulties	7.44 (5.19)	8.33 (7.12)	–0.89 (–1.95 to 0.18)	5.82 (4.30)	5.25 (5.71)	0.57 (–0.32 to 1.46)
Emotional symptoms	1.44 (1.70)	1.45 (2.02)	–0.01 (–0.35 to 0.33)	1.44 (1.57)	1.49 (2.09)	–0.05 (–0.38 to 0.28)
Conduct problems	1.36 (1.39)	1.43 (2.14)	–0.06 (–0.35 to 0.23)	1.35 (1.43)	0.69 (1.47)	0.66 (0.37 to 0.95)[c]
Hyperactivity	3.29 (2.18)	3.95 (3.32)	–0.66 (–1.16 to –0.16)[b]	2.18 (1.88)	1.97 (2.64)	0.21 (–0.19 to 0.60)
Peer problems	1.35 (1.85)	1.53 (1.91)	–0.18 (–0.55 to 0.19)	0.85 (1.34)	1.15 (1.66)	–0.30 (–0.73 to 0.13)
Prosocial behaviour	7.95 (1.93)	7.36 (2.54)	0.59 (0.20 to 0.98)[b]	8.46 (1.85)	8.47 (2.04)	0.01 (–0.38 to 0.36)

[a] SDQ data was incomplete for two donor sperm-conceived female children.
[b] $P < 0.01$.
[c] $P < 0.001$.

Mothers' physical and mental wellbeing

Assessment of Quality of Life (AQoL) data are shown in **Supplementary Table S3**. In each sub-scale of this assessment, the means for mothers of a sperm donor-conceived child were higher than the Australian population, indicating that the mothers of the donor conceived children have a better physical and mental wellbeing. Compared with the Australian population, the mothers scored significantly higher in

Table 4 – Health care needs of sperm donor-conceived children as measured by the Children with Special Health Care Need Screener (CSHCNS).

	Donor sperm sample (n = 224;112 males, 112 females)		Australian population data (Victorian Government Department of Human Services, 2006) (n = 5000: 2500 males, 2500 females)		Relative risk ratio (95% CI)
	n	%	n	%	
Dependency on medication	23	10.3	465	9.3	1.11 (0.73 to 1.69)
Special service needs	38	17.0	475	9.5	1.88 (1.34 to 2.63)[b]
Functional limitations	17	7.6	205	4.1	1.85 (1.15 to 2.98)
At least one special health care need	52	23.2	785	15.7	1.58 (1.17 to 2.14)
Males	32	28.6	415	16.6	1.93 (1.30 to 2.88)[a]
Females	20	17.9	370	14.8	1.24 (0.77 to 1.98)

[a] $P < 0.01$.
[b] $P < 0.001$.

relationships and mental health and also in the composite utility score.

Secondary analysis of outcomes according to family structure

Results of the Child Health Questionnaire and the Strengths and Difficulties Questionnaire were also analysed according to the relationship status of the mother (**Supplementary Table S1**). No statistically significant differences were found between the results for children living with different sex parents, same sex parents or single parents.

Discussion

The health and welfare of children conceived using donor sperm is an important topic for IVF clinics and for society in general, particularly given the recent rise in the use of donor sperm, by single women and same-sex couples (Human Fertilization and Embryology Authority, 2014; De Wert et al., 2014; Victorian Assisted Reproductive Treatment Authority, 2016). This is the largest study to date to examine psychosocial development in school-aged children conceived using donor sperm, and the first study to describe health outcomes in these children. Overall, the results are reassuring, and consistent with previous studies of perinatal outcomes in sperm donor-conceived babies, which have shown no increase in the frequency of obstetric complications or congenital abnormalities (Adams et al., 2016; Hoy et al., 1999; Lansac and Royere, 2001), and with studies that have examined psychosocial development in children conceived using donor sperm (Kovacs et al., 1993, Golombok et al., 2002a, Golombok et al., 2002b]. These similarities are despite the indications for the use of donor sperm having shifted over the last two decades (Victorian Assisted Reproductive Treatment Authority, 2016).

Results from the Child Health Questionnaire, which measures health and wellbeing, found that children conceived using donor sperm, when compared with the Australian normative population data, scored equal to or higher on all subscales, particularly in General Health Perceptions. Sperm donor-conceived females also scored higher on Mental Health, Self Esteem and Family Cohesion, indicating high levels of psychosocial and functioning in families with a sperm donor-conceived daughter. Similarly, the development of sperm donor-conceived children, as assessed using Parents' Evaluation of Developmental Status (PEDS), was the same as the general population. The mental health of sperm donor-conceived children was assessed using the Strengths and Difficulties Questionnaire (SDQ). Although the score for conduct problems in females was higher than expected, the overall scores in both males and females were not significantly different from the Australian general population. Family functioning, as assessed by the McMaster Family Assessment device, and maternal quality of life, as assessed by the AQoL, were better in the families of sperm donor-conceived children that in the general population. This is consistent with previous studies which have shown high levels of family functioning in families created using new reproductive technologies (Bos and van Balen, 2010; Brewaeys, 2001; Chan et al., 1998; Kovacs et al., 2013).

We undertook a secondary analysis to determine if there were differences in child health and mental health outcomes according to family structure and did not detect any statistically significant differences between the results for children living with different sex parents, same sex parents or single mothers. These results are similar to previous research that show that children living with same sex parents have comparable general health and mental health outcomes to children living with different sex parents (Bos et al., 2016; Chan et al., 1998; Crouch et al., 2014; Reczek et al., 2016).

One area in which the sperm donor-conceived children differed from Australian norms was the Children with Special Health Care Needs Screener (CSHCNS). The CSHCNS is used to assess whether there is an elevated need for, or use of health care services, and if there are limitations in activity, both caused by a chronic health condition. Results from the CSHCNS demonstrated that sperm donor-conceived children, particularly boys, were relying on health services more than the normative Australian population. This difference was seen in the domains of Special Service Needs and Functional Limitations but not Dependence on Medication. This increase in health care needs is an interesting finding, particularly as we did not detect evidence of impairment to the health of sperm donor-conceived children in the CHQ, PEDS and SDQ. One possibility is that the increase in special healthcare needs among sperm donor-conceived children reflects an increased tendency for parents of sperm-donor conceived children to access health care for their child, rather than a true difference in health. We and others have suggested previously that elevated parental vigilance may be a factor in the increased health care usage of young children conceived using IVF (Halliday et al., 2014; Koivurova et al., 2007).

By conducting a sensitivity analysis, we explored one possible explanation for the increase in healthcare needs in sperm donor-conceived children, specifically the 4% of sperm donor-conceived

children reported as being diagnosed with an ASD. The increase in healthcare needs was no longer significant when these children were removed from the analysis. The 4% (95% CI 1.8 to 7.4%) prevalence of ASD diagnosis is higher than published international figures for ASD, which in most countries is less than 1% (Elsabbagh et al., 2012); however, it is relevant that our study took place in the context of a secular trend towards increased diagnosis and reporting of ASD. In the latest data from the Longitudinal Study of Australian Children 'B cohort' (Randall et al., 2016), a cohort that parallels our sperm donor-conceived children in age and year of birth, the prevalence of parent-reported diagnosis of autism at age 6–7 years was 2.5% (95% CI 2.0 to 3.0%). The difference in prevalence of ASD diagnosis between the Longitudinal Study of Australian Children cohort and our donor conceived children was not statistically significant. As a second line of evidence, the Social Communication Questionnaire (SCQ), a screening tool for ASD, was used to evaluate the likelihood that each sperm donor-conceived child had an ASD, independent of whether a clinical diagnosis of ASD had been made. On the basis of the results of the SCQ, 4.4% of sperm donor-conceived children were assessed as being at high risk of ASD. No normative Australian SCQ data were available for comparison, but a British study found that the proportion of children in the general population who screened as high risk for ASD was 4.4% in a school-based sample and 5.3% in a population based sample (Chandler et al., 2007).

When evaluating the results from this study, three important limitations must be considered. First, the study used Australian population normative values for comparison rather than a study-specific control group, precluding adjustment for potential confounders. Second, incomplete ascertainment means that there may be a bias in the mothers who responded to the survey; mothers of sperm donor-conceived children with more health or developmental problems may have been either more (or less) likely to respond than mothers of children without these problems. Third, the questionnaire design of this project means that the data are dependent on the mother's report rather than validated clinical data.

In conclusion, this large descriptive study of school-aged children conceived using donor sperm showed that general health, child physical health, mental health and development are similar to, or even better than, the general population. On the other hand a modest increase in healthcare needs was evident, in part due to the 4% of offspring with an ASD. The importance of conducting prospective cohort studies in this changing field of assisted reproduction techniques is emphasised by findings in our questionnaire-based follow up.

Acknowledgement

The authors thank Ms Marianne Tome, Dr Vivien McLachlan and Ms Sue Breheny for assistance with data collection. This study was supported by the National Health and Medical Research Council Senior Research Fellowship (ID: 436904). This work was funded in part by Melbourne IVF and Monash IVF. This work was made possible through the Victorian State Government Operational Infrastructure Support and Australian Government NHMRC IRIISS.

Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.rbmo.2017.06.012.

ARTICLE INFO

Article history:
Received 24 January 2017
Received in revised form 15 June 2017
Accepted 15 June 2017
Declaration: This work was funded in part by Melbourne IVF and Monash IVF. This work was made possible through the Victorian State Government Operational Infrastructure Support and Australian Government NHMRC IRIISS.

Keywords:
Assisted reproduction
Child health
Donor sperm

REFERENCES

Adams, D.H., Clark, R.A., Davies, M.J., De Lacey, S., 2016. A meta-analysis of sperm donation offspring health outcomes. J. Dev. Orig. Health Dis. 1–12.

Bethell, C.D., Read, D., Stein, R.E., Blumberg, S.J., Wells, N., Newacheck, P.W., 2002. Identifying children with special health care needs: Development and evaluation of a short screening instrument. Ambul. Pediatr. 2, 38–48.

Bos, H., van Balen, F., 2010. Children of the new reproductive technologies: Social and genetic parenthood. Patient Educ. Couns. 81, 429–435.

Bos, H.M., Knox, J.R., Van Rijn-Van Gelderen, L., Gartrell, N.K., 2016. Same-sex and different-sex parent households and child health outcomes: Findings from the national survey of children's health. J. Dev. Behav. Pediatr. 37, 179–187.

Boterhoven de Haan, K.L., Hafekost, J., Lawrence, D., Sawyer, M.G., Zubrick, S.R., 2015. Reliability and validity of a short version of the general functioning subscale of the mcmaster family assessment device. Fam. Process 54, 116–123.

Brewaeys, A., 2001. Review: Parent-child relationships and child development in donor insemination families. Hum. Reprod. Update 7, 38–46.

Brewaeys, A., Ponjaert, I., Van Hall, E.V., Golombok, S., 1997. Donor insemination: Child development and family functioning in lesbian mother families. Hum. Reprod. 12, 1349–1359.

Chan, R.W., Raboy, B., Patterson, C.J., 1998. Psychosocial adjustment among children conceived via donor insemination by lesbian and heterosexual mothers. Child Dev. 69, 443–457.

Chandler, S., Charman, T., Baird, G., Simonoff, E., Loucas, T., Meldrum, D., Scott, M., Pickles, A., 2007. Validation of the social communication questionnaire in a population cohort of children with autism spectrum disorders. J. Am. Acad. Child Adolesc. Psychiatry 46, 1324–1332.

Coghlan, D., Kiing, J.S., Wake, M., 2003. Parents' evaluation of developmental status in the australian day-care setting: Developmental concerns of parents and carers. J. Paediatr. Child Health 39, 49–54.

Crouch, S.R., Waters, E., McNair, R., Power, J., Davis, E., 2014. Parent-reported measures of child health and wellbeing in same-sex parent families: A cross-sectional survey. BMC Public Health 14, 635.

De Wert, G., Dondorp, W., Shenfield, F., Barri, P., Devroey, P., Diedrich, K., Tarlatzis, B., Provoost, V., Pennings, G., 2014. Eshre task force on ethics and law 23: Medically assisted reproduction in singles, lesbian and gay couples, and transsexual peopledagger. Hum. Reprod. 29, 1859–1865.

Devroey, P., Van Steirteghem, A., 2004. A review of ten years experience of icsi. Hum. Reprod. Update 10, 19–28.
Elsabbagh, M., Divan, G., Koh, Y.J., Kim, Y.S., Kauchali, S., Marcin, C., Montiel-Nava, C., Patel, V., Paula, C.S., Wang, C., Yasamy, M.T., Fombonne, E., 2012. Global prevalence of autism and other pervasive developmental disorders. Autism Res. 5, 160–179.
Glascoe, F.P., 1999. Using parents' concerns to detect and address developmental and behavioral problems. J. Soc. Pediatr. Nurs. 4, 24–35.
Golombok, S., Brewaeys, A., Giavazzi, M.T., Guerra, D., Maccallum, F., Rust, J., 2002a. The european study of assisted reproduction families: The transition to adolescence. Hum. Reprod. 17, 830–840.
Golombok, S., Maccallum, F., Goodman, E., Rutter, M., 2002b. Families with children conceived by donor insemination: A follow-up at age twelve. Child Dev. 73, 952–968.
Goodman, R., 1997. The strengths and difficulties questionnaire: A research note. J. Child Psychol. Psychiatry 38, 581–586.
Halliday, J., Wilson, C., Hammarberg, K., Doyle, L.W., Bruinsma, F., McLachlan, R., McBain, J., Berg, T., Fisher, J.R., Amor, D., 2014. Comparing indicators of health and development of singleton young adults conceived with and without assisted reproductive technology. Fertil. Steril. 101, 1055–1063.
Hawthorne, G., Osborne, R., 2005. Population norms and meaningful differences for the assessment of quality of life (aqol) measure. Aust. N. Z. J. Public Health 29, 136–142.
Hayes, L., 2007. Problem behaviours in early primary school children: Australian normative data using the strengths and difficulties questionnaire. Aust. N. Z. J. Psychiatry 41, 231–238.
Hoy, J., Venn, A., Halliday, J., Kovacs, G., Waalwyk, K., 1999. Perinatal and obstetric outcomes of donor insemination using cryopreserved semen in victoria, australia. Hum. Reprod. 14, 1760–1764.
Human Fertilization and Embryology Authority, 2014. Egg and sperm donation in the UK: 2012–2013. http://www.hfea.gov.uk/docs/Egg_and_sperm_donation_in_the_UK_2012-2013.pdf. (Accessed 1 December 2016).
Kabacoff, R.I., Miller, I.W., Bishop, D.S., Epstein, N.B., Keitner, G.I., 1990. A psychometric study of the mcmaster family assessment device in psychiatric, medical, and nonclinical samples. J. Fam. Psychol. 3, 431–439.
Koivurova, S., Hartikainen, A.L., Gissler, M., Hemminki, E., Jarvelin, M.R., 2007. Post-neonatal hospitalization and health care costs among ivf children: A 7-year follow-up study. Hum. Reprod. 22, 2136–2141.
Kovacs, G.T., Mushin, D., Kane, H., Baker, H.W., 1993. A controlled study of the psycho-social development of children conceived following insemination with donor semen. Hum. Reprod. 8, 788–790.
Kovacs, G.T., Wise, S., Finch, S., 2013. Functioning of families with primary school-age children conceived using anonymous donor sperm. Hum. Reprod. 28, 375–384.
Lansac, J., Royere, D., 2001. Follow-up studies of children born after frozen sperm donation. Hum. Reprod. Update 7, 33–37.
Miller, I.W., Epstein, N.B., Bishop, D.S., Keitner, G.I., 1985. The mcmaster family assessment device: Reliability and validity. J. Marital Fam. Ther. 11, 345–356.
Murray, C., Golombok, S., 2005. Solo mothers and their donor insemination infants: Follow-up at age 2 years. Hum. Reprod. 20, 1655–1660.
Quach, J., Oberklaid, F., Gold, L., Lucas, N., Mensah, F.K., Wake, M., 2014. Primary health-care costs associated with special health care needs up to age 7 years: Australian population-based study. J. Paediatr. Child Health 50, 768–774.
Randall, M., Sciberras, E., Brignell, A., Ihsen, E., Efron, D., Dissanayake, C., Williams, K., 2016. Autism spectrum disorder: Presentation and prevalence in a nationally representative australian sample. Aust. N. Z. J. Psychiatry 50, 243–253.
Reczek, C., Spiker, R., Liu, H., Crosnoe, R., 2016. Family structure and child health: Does the sex composition of parents matter? Demography 53, 1605–1630.
Rutter, M., Bailey, A., Lord, C., 2003. Social Communication Questionnaire (scq). Western Psychological Services, Los Angeles.
Victorian Assisted Reproductive Treatment Authority, 2016. Annual report. https://www.varta.org.au/sites/varta/files/public/VARTA%202016%20Annual%20Report.pdf. (Accessed 1 December 2016).
Victorian Government Department of Human Services, 2006. The state of victoria's children report 2006. http://www.education.vic.gov.au/Documents/about/research/sovcreport06.pdf. (Accessed 10 August 2016).
Waters, E., Salmon, L., Wake, M., Hesketh, K., Wright, M., 2000. The child health questionnaire in australia: Reliability, validity and population means. Aust. N. Z. J. Public Health 24, 207–210.