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ORIGINAL ARTICLE ***Reproductive epidemiology***

The demographics of assisted reproductive technology births in a Nordic country

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STUDY QUESTION: What are the socio-demographic characteristics of families in Norway who have children after assisted reproductive technology (ART), and have these characteristics changed over time?

SUMMARY ANSWER: Parents who conceive through ART in Norway tend to be advantaged families, and their socio-demographic profile has not changed considerably over the period 1985–2014.

WHAT IS KNOWN ALREADY: A small number of studies show that couples who conceive through ART tend to be socio-economically advantaged.

STUDY DESIGN, SIZE, DURATION: Norwegian Population Register, the Medical Birth Register and the national data bases were linked to study all live births in Norway between 1985 and 2014.

PARTICIPANTS/MATERIALS, SETTING, METHODS: The sample consisted of 1 757 768 live births. Simple bivariate analyses were performed to describe the socio-demographic characteristics of parents who conceived through ART and changes in these characteristics over the time period 1985–2014. We used linear probability models to estimate the association between parental income and giving birth after ART from 2000 to 2014, before and after adjustment for maternal age at delivery, education and area of residence.

MAIN RESULTS AND THE ROLE OF CHANCE: Parents conceiving through ART were more likely to be older, with the highest levels of income and education, and married. Their socio-demographic profiles did not change considerably during the period 1985–2014. In the unadjusted model, parents belonging to the top income quartile were 4.2 percentage points more likely (95% CI: 4.1 to 4.3) to have conceived through ART than parents who belonged to the bottom income quartile. Adjustment for maternal age only partially reduced the income disparities (for the top income quartile by 35% ($\beta = 2.7$ with 95% CI: 2.5 to 2.8)). Additional adjustment for maternal education, marital status and area of residence did not further attenuate the associations.

LIMITATIONS, REASONS FOR CAUTION: The data does not enable us to tell whether the lower numbers of children conceived through ART amongst more disadvantaged individuals is caused by lower success rates with ART treatment, lower demand of ART services or barriers faced in access to ART. The study focuses on Norway, a context characterised by high subsidisation of ART services.

WIDER IMPLICATIONS OF THE FINDINGS: Even though in Norway access to ART services is highly subsidised, the results highlight important and persisting social inequities in use of ART. The results also indicate that children born after ART grow up in resourceful environments, which will benefit their development and well-being.

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Key words: assisted reproductive technologies / births / demographics / social inequalities / Norway

Introduction

The use of assisted reproductive technologies (ART) has increased rapidly in advanced societies since the 1980s. To date, more than 8 million children have been born after ART (Fauser, 2019). The rise in the use of ART has resulted in a wealth of research, motivated at least in part by concerns for the health and development of children born after ART (Hart and Norman, 2013a; Hart and Norman, 2013b). Most of the available evidence comes from the medical literature which has focused on analysing the consequences of ART for children's health and well-being by looking for example, at their cognitive, socio-emotional, physical and mental health outcomes (Zhan *et al.*, 2013; Spangmose *et al.*, 2017; Berntsen *et al.*, 2019).

Less attention has been given to social aspects around ART, which is partially explained by the fact that the demographic literature has, with a few exceptions (Sobotka *et al.*, 2008, Präg and Mills 2017a and Präg and Mills 2017b), given limited attention to this topic of research. A small number of studies show that individuals who conceive through ART tend to be socio-economically advantaged (Wilcox and Mosher, 1993, Stephen and Chandra, 2000, Klemetti *et al.*, 2007, Räisänen *et al.*, 2013, Barbuscia *et al.*, 2019), but apart from that, little is known about the socio-demographic composition of the group using ART to conceive. Studies exploring whether and how the characteristics of couples using ART might have changed over time are lacking. This is an important knowledge gap for two main reasons. First, knowing who accesses ART helps to identify potential social inequities in the utilisation, which would feed into policy discussions about whether steps should be taken to make ART services more broadly available and affordable. Moreover, systematic evidence on the link between ART and demographics, including whether it has changed over time, is relevant for clinicians and clinics offering ART services. Second, the socio-demographic characteristics of parents who conceive through ART determine the environment in which children born after ART grow up, which has long-lasting effects on their health and well-being later in life (McLanahan, 2004). Moreover, to the extent that socio-economically advantaged individuals are more likely to give birth after ART, their positively selected characteristics could compensate for the negative effects of ART on the children's health such as perinatal outcomes (Pandey *et al.*, 2012; Berntsen *et al.*, 2019).

This study, using population register data from Norway covering the full population during the period 1985–2014, presents a comprehensive analysis of the socio-demographic composition of parents who conceive through ART in Norway. We make three unique contributions to the existing literature. First, we describe the socio-demographic characteristics (parents' age, education, income and marital status at birth, and the child's birth order) of parents who conceive through ART. Second, we examine whether these characteristics have changed over time. Third, we advance our understanding of the drivers behind the marked social inequities we observe in the utilisation of ART services.

Materials and Methods

Study population

This study utilises data from the Norwegian Population Register, the Medical Birth Register and national databases with information on education and income. We studied all live births in Norway between 1985 and 2014, as the first registered ART delivery in Norway was in 1984. Personal identifiers of the child, the mother and the father were available based on unique national identification numbers. Information about whether the child was born after ART was taken from the Medical Birth Register. Our sample consisted of 1 757 768 live births, of which 32 580 were ART conceived.

Assisted reproductive technology in Norway

We identified all children in Norway who were registered as conceived through ART (*in vitro* fertilisation (IVF) or intracytoplasmic sperm injection (ICSI) or registered with unknown procedure) from the Medical Birth Register. The data does not provide information on intrauterine insemination (IUI) cycles, which are thus not included in the analyses. Norwegian ART clinics are either public or private and operate according to the Norwegian act relating to the application of biotechnology in human medicine. Under this act, infertile patients are required to be either married or to cohabit in a 'marriage like' relationship to be eligible for ART. To ensure the welfare of the child, couples must also be deemed by the infertility doctor to be fit to undergo treatment and to take care of a child, before starting treatment. There is no upper age limit for ART treatment set by law. Yet, public clinics follow national guidelines for prioritisation in the health-services, which discourage the treatment of women who are older than 38 years of age and/or have a body mass index of above 32 and/or already have children with their current partner. Single women are not eligible for ART treatment in Norway, whilst formalised same-sex couples have had access to ART treatments since 2010. Oocyte donation, embryo donation and surrogacy are prohibited in Norway, whilst sperm donation is allowed. Some women travel abroad to undergo ART treatments (such as oocyte donation) not permitted in Norway. These cases would still be registered as ART births provided that the mother informs the birth clinic that the child was conceived via ART. A small number of these cases could be misclassified and recorded as natural conceptions in the population register if the mother does not declare the mode of conception at the birth clinic.

In the public clinics in Norway, access to ART services is highly, but not fully, subsidised through the national health plan (Ory *et al.*, 2014) which covers up to three ART cycles and the transfer of all fresh and thawed embryos resulting from these cycles. Patients are required to contribute towards the cost of treatment and medication. The maximum expense for the three cycles is around 20 000 Norwegian kroner (NOK) (≈ 2000 euros), with the bulk of the expenses charged at the first cycle. In 2018, the median income in Norway for couples with the youngest child aged 0–6 was 787 700 NOK (www.ssb.no/en/inntekt-og-forbruk/statistikker/ifhus). Both public and private clinics are for the most part situated in the largest urban areas of Norway. Private clinics mainly provide ART treatments to couples who are not eligible for treatment in the public clinics or couples who did not conceive or who want more children after their three cycles in the public clinics. The private clinics charge about 40 000 NOK (data from 2019) for one fresh cycle, which the patient pays out of pocket. Patients pay the full cost of medication as well which typically is about 10 000 NOK (data from 2019) for one cycle, unless they have one or more of their three subsidised cycles, in which case medication cost is subsidised like it is in the public clinics.

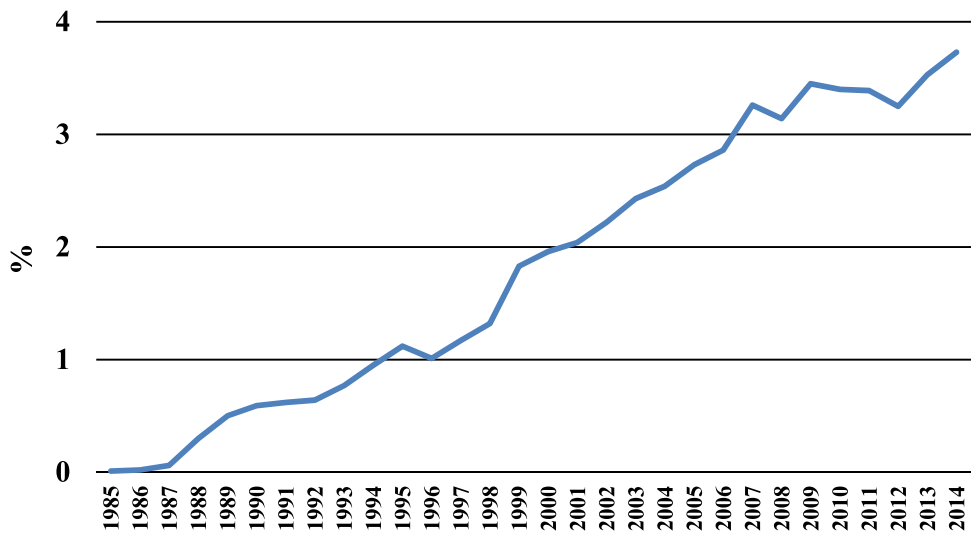

Figure 1 Percentage of ART births amongst all live birth in Norway 1985–2014.

This picture reflects the provision of ART services in Norway since the early 1990s and there have not been any major legislative changes since then. As shown in Fig. 1, between 1985 and 2014, the percentage of children born after ART increased remarkably, from 0.01 to 3.7%. The change is attributable to technological advancements which have resulted in the ART cumulative delivery rate improving over time (Pinborg *et al.*, 2009) and the increased availability of the ART treatments. Data from ESHRE shows that between 1997 and 2013, the number of clinics offering fertility treatments increased by 42% in Norway (European Ivf-monitoring programme, 2001; Kupka *et al.*, 2014; De Geyter *et al.*, 2018).

Demographic characteristics

We considered several socio-demographic characteristics of children born after ART: the mother's and father's age at birth (divided into five-year age categories), the mother's marital status, the child's birth order (defined as one plus the number of older maternal live born siblings), whether the child was part of a multiple birth and the parents' municipality of residence (grouped into a combination of main region and whether the municipality is reckoned as urban). All this information was extracted from the Population Register. In the case of a multiple birth, all the twins or triplets were included in the analyses and were assigned the same birth order (e.g. if the twins were the mother's first birth, they were both assigned birth order 1. If the mother had a subsequent child, s/he would be assigned birth order 2). Furthermore, we considered the highest educational level achieved by the parents (divided into primary/some secondary; full secondary; some tertiary; master/PhD) as recorded during the year of each child's birth (extracted from the Education Database through Statistics Norway) and their 'taxable income' 2 years before the year of birth of each child (extracted from the Tax Directorate through Statistics Norway). If both the mother and the father lived in the country at the beginning of that year as well as at the beginning of the next year, we defined 'total taxable income' as the sum of their 'taxable incomes'. The income variable was divided into a relative measure (first, second, third and fourth quartiles) by comparing with the corresponding parental-income variable for all children born in the same 5-year period (the period 1985–14 was divided into 5-year intervals). 'Taxable income' is the sum of labour income, capital income, transfers and pensions, minus various deductions. Some children were excluded from the analysis involving income (see details in the tables/figures). A few children had fathers who were not identified, and these were left out of the calculations involving paternal characteristics. Also, a few children were left out of some calculations because information about their mother's or father's education was missing, most commonly because the parent was born abroad (see details in tables/figures). From 2010, the analytical sample included about 100 cases per year of same-sex couples. Because of the small number of observations, we did not analyse this group separately. The data used in this study does not provide information on whether the ART treatments took place in private or public clinics.

Statistical analyses

First, a simple bivariate analysis was carried out to describe the socio-demographic characteristics of parents who conceived through ART and changes in these characteristics over time. For the period 1985–2014, we showed the percentage of ART births by parents' age, education and income quartiles, birth order and whether the child was part of a multiple birth. In the second step, we estimated a set of linear probability models to investigate the association between parental income and use of ART. In linear probability models, coefficients are interpretable as marginal effects which means that the coefficient indicates the percentage-point change in the probability of the birth being ART-conceived for one income quartile compared to the baseline (Wooldridge, 2012). In this analysis, we focused on the period 2000–14, as this period would assess potential social inequities in access to ART in more recent years and provide useful evidence to inform current policy discussions about whether steps should be taken to make ART services more broadly available. We estimated three different models: Model 1 was unadjusted; Model 2 was adjusted for

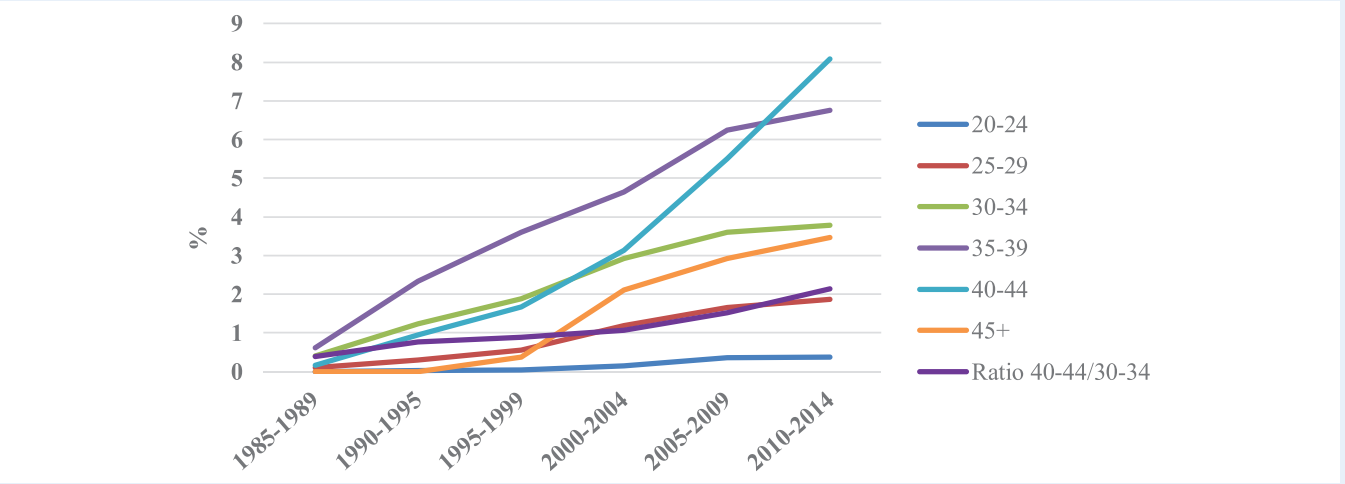

Figure 2 Percentage of ART births by maternal age categories (1985–2014). Note: No children had missing values on maternal age categories.

the mother's age at birth; and Model 3 was adjusted for mother's age at birth, maternal education, marital status around the time of birth and area of residence. We controlled for the mother's age at birth as a potential marker of 'need' for ART, since fecundity declines with age (Leridon, 2004), and maternal age also influences her income. Maternal education, marital status and area of residence were included in the model because they are associated with (and to a large extent determinants of) income levels as well as potentially the accessibility of ART treatments, since their provision could be higher in urban than rural areas in Norway and is contingent on partnership status, which is socially patterned (Perelli-Harris *et al.*, 2010). We first estimated models for all births and then separate models for first and higher-order births since childless couples are given priority in access to ART services.

Ethical approval

The national registry linkage was approved by the Regional Committee for Medical and Health Research Ethics for South/East Norway.

Results

ART births were more concentrated amongst older mothers (Fig. 2). For example, during the period 1985–1989, 0.62% of births to mothers aged 35–39 were ART, whilst only 0.1% of births to mothers aged 25–29 were ART. During the period 2010–14, 6.8% of births to mothers aged 35–39 were ART, whilst 1.9% to mothers aged 25–29. The prevalence of ART births increased over time across all maternal age groups. Yet, the increase in the use of ART has been more marked amongst older mothers (which can be seen in Fig. 2 'ratio 40–44/30–34' which shows the ratio of the proportions of ART births for the two age groups in each 5-year period). As a result, the maternal age profile of children born after ART has shifted upwards. Moreover, in the period 2010–14 the percentage of ART births to mothers aged 40–44 at the time of birth surpassed the percentage for mothers aged 35–39. The results for paternal age at birth are similar (Fig. 3).

Parents of children born after ART were more likely to belong to a higher than lower income quartile (Fig. 4). Amongst families belonging to the top income quartile in 1985–89, 0.5% of children were born after ART, compared to 0.06% for the bottom income quartile. In the period 2010–14, the corresponding proportions were 6.2% for the highest income quartile and 1.4% for the lowest quartile. Still, the prevalence of ART births has been increasing over time across all income quartiles. There is evidence that the social differences in the use of ART, although still existing, have slightly declined over time: the ratio of the proportion of parents who conceived after ART between the top and bottom income quartiles went from 7.8 in 1985–89, to 4.7 in 2000–04 and to 4.4 in 2010–14 (see Fig. 4 'ratio 4/1').

The relationship between maternal education and ART (Fig. 5) accords well with that observed between income and ART. Mothers of children born after ART were, at any point during the considered period, more likely to have a higher level of education (i.e. tertiary or master/PhD). The percentage of children born after ART increased over time for all educational groups, and there is evidence of a mild decline in educational difference in the use of ART. Yet, stark differences persisted at the end of the follow-up period. The same pattern appears when paternal instead of maternal education is considered (not shown in figures). Figure 6 shows that parents who conceived through ART were more likely to be married but also that the differences in marital status have declined over time.

Children born after ART were more likely to be firstborn than children who were conceived naturally (Table I). For example, in 1990–95, amongst all children who were born after ART 69% were first born (31% were second or higher order births); in contrast, amongst children who were naturally conceived, 42% were first born. There is no evidence of these patterns changing over time. Also, our results confirmed the well-known higher prevalence of multiple births amongst children born after ART and the difference in the proportion of multiple births declined over time due to a gradual shift to single embryo transfer.

Results from linear probability models including all births between 2000 and 2014 showed, in line with the observed frequencies, that

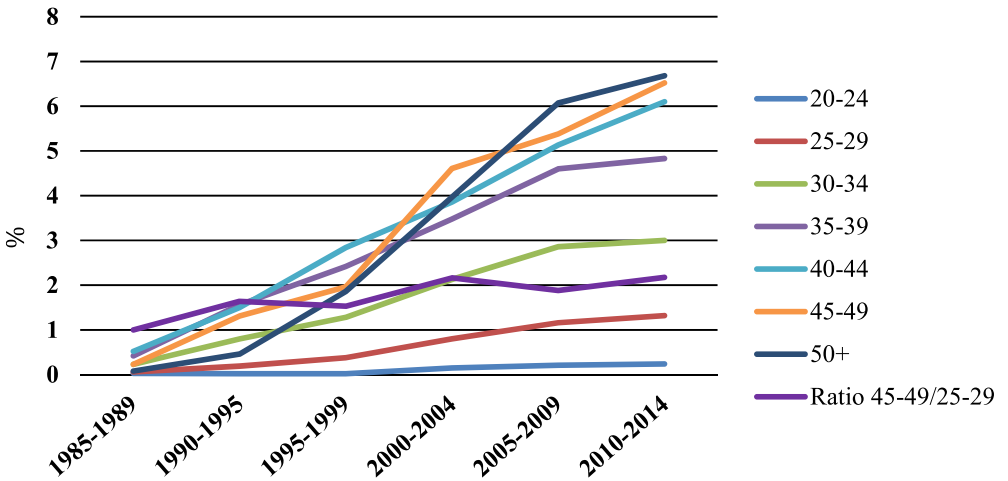

Figure 3 Percentage of ART births, by paternal age at birth (1985–2014). Note: 1.4% of children have missing values on paternal age at birth and have been excluded from this analysis.

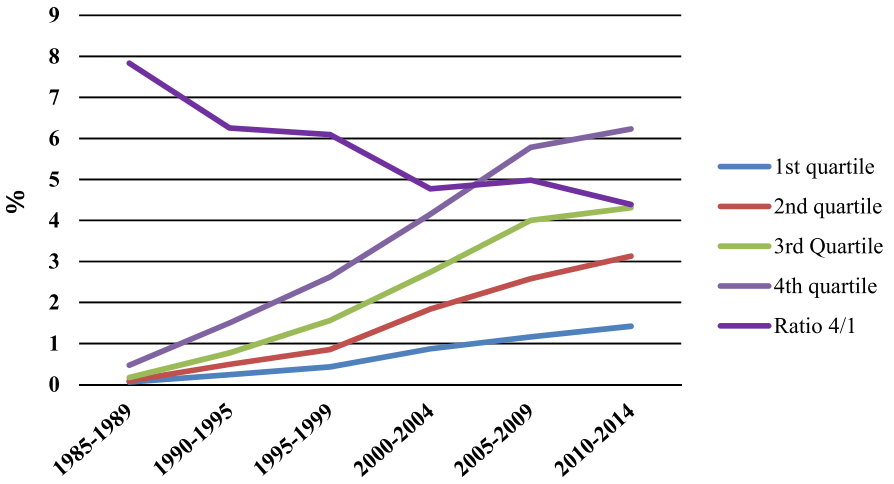

Figure 4 Percentage of ART births by income quartiles (births 1985–2014). Note: 8.5% of children have missing values on parental income and have been excluded from this analysis.

parents of children conceived by ART were more likely to belong to more economically advantaged families (Table II and Fig. 7, and Web Tables I–III). For example, in the unadjusted model (Model 1) parents who belonged to the top income quartile were 4.2 percentage points (95% CI: 4.1 to 4.3) more likely to have conceived via ART than parents who belonged to the bottom income quartile. The overall prevalence of ART in our data for the period 2000–2014 was 3.4% so 4.2 percentage points corresponds to a 124% increase in the proportion of ART. Adjustment for maternal age in Model 2 reduced the income disparities. For the top income quartile, adjustment for maternal age in Model 2 attenuated the estimate by 35% compared to Model 1 ($\beta = 2.7$ with 95% CI: 2.5 to 2.8). Additional adjustment for maternal education, marital status and place of residence in Model 3 did not further attenuate the coefficients.

The income difference in the use of ART was similar if we evaluated first or higher order births (Table II and Supplementary Tables SI–SIII). In the unadjusted model for first births, parents who belonged to the top income quartile were 7.1 (95% CI: 6.9 to 7.3) percentage points more likely to have conceived through ART than parents who belonged to the bottom income quartile. The overall prevalence of ART amongst all first births was 4.9%, so the increase corresponded to 145% increase in the proportion of ART. Adjustment for maternal age at birth attenuated the association by 70% (Table II). In the baseline model for higher order births, children were 2.2 (95% CI: 2.1 to 2.3) percentage points more likely to be born after ART if their parents belonged to the top than to the bottom income quartile and adjustment for maternal age (Model 2) attenuated the association by 40%.

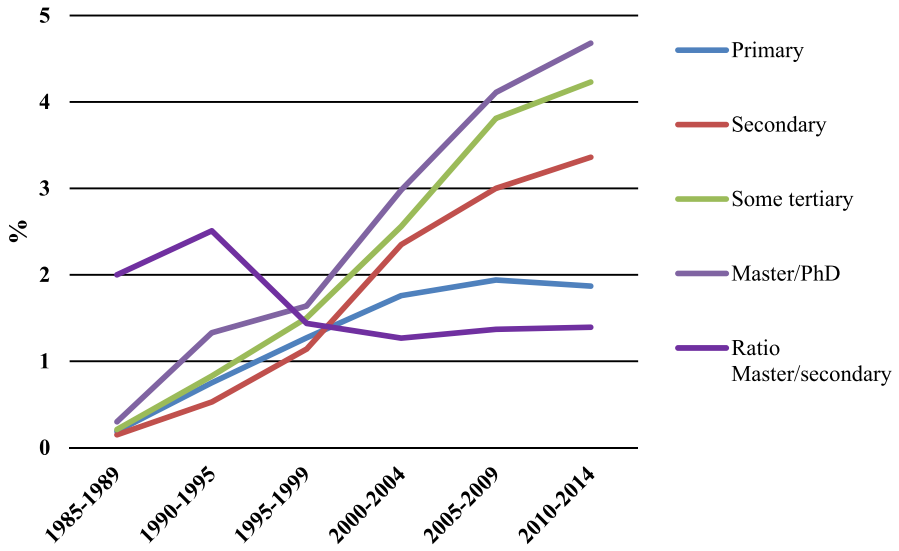

Figure 5 Percentage of ART births by maternal education (births 1985–2014). Note: 3.7% of children have missing values on maternal education and have been excluded from this analysis.

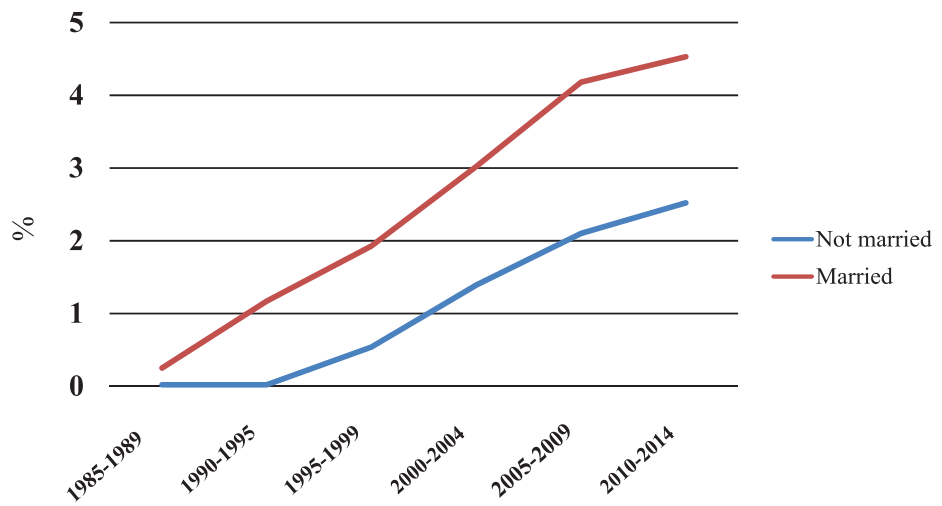

Figure 6 Percentage of ART births by marital status (births 1985–2014). Note: No children had missing values on marital status at birth.

Discussion

In this study, we provide a comprehensive description of the socio-demographics characteristics of parents who have conceived through ART based on nationwide Norwegian data from 1985 to 2014. We find that parents who conceive through ART tend to be more advantaged: they are more likely to be older, with the highest levels of income and education, and to be married. Children born after ART are also more likely to be firstborn. This is consistent with the existing literature (Klemetti *et al.*, 2007), although we have added considerably to the picture by considering a comprehensive set of socio-demographic differences. In addition, our results also show that the socio-demographic profile of ART parents has not changed over the considered period of time (1985–14). Two main implications follow from our results.

First, even though in Norway access to ART services is highly subsidised, the results highlight important and persisting social inequities in use of ART even when we adjust in the models for demographic factors that differ between more and less advantaged individuals such as maternal age at birth, a marker for the 'need' of ART treatment. The reasons for such disparities are likely to be multifactorial and potentially include differential access to resources, geographical barriers, and differences in demographic characteristics and sociocultural norms. The subsidisation of the ART services is partial in Norway, but individuals only need to contribute a small amount of money towards the cost of medication (a total of NOK20,000 for three cycles corresponds to less than 3% of the average annual gross income of NOK763,000 in relevant households). However, although Norway appears to offer ART services to a large majority of its citizens at an affordable price,

Table I Percentage of first births and multiple births for children conceived via natural conception (NC) and assisted reproductive technology (ART) (births 1985–2014).

	1985–89	1990–95	1995–99	2000–04	2005–09	2010–14
			First births			
NC	44.1	42.3	40.5	41.1	42.6	43.1
ART	73.2	69.4	70.1	68.8	64.8	62.9
			Multiple births			
NC	2.1	2.4	2.7	2.8	2.8	2.7
ART	43.7	45.4	42.5	40.2	25.0	18.6
Number of observations	274 867	301 704	298 705	284 822	296 731	300 939

Note: No children had missing values on birth order and whether they are part of a multiple birth respectively. Percentages are computed within each 5-year group, by mode of conception. For example, the results show that out of all children born after ART in 1985–89, 73.2% were first births (26.8% were higher order births).

more disadvantaged individuals could face some financial barriers in accessing treatments in the private sector should they need to undergo additional cycles beyond the three cycles covered by the public health system. Financial barriers could constitute an important reason, but would not be the only reason, behind the observed social disparities. There could be geographical barriers which might not be captured by the area of residence variable we adjusted for in the models as disadvantaged individuals may be more likely to live in isolated rural areas which could make it more difficult for them (or be a disincentive) to access ART services which require frequent and regular visits to the fertility clinics. This argument is supported by additional analyses (not presented in the paper) showing that the percentage of ART births is highest in Oslo and, outside of the capital, it is higher in urban than in rural areas. Disadvantaged individuals could also face more difficulties in satisfying the requirements for public provision of ART services. Indeed, they are less likely to be married, less likely to be in stable relationships and might find it more challenging to be considered able to undergo treatment and to take care of a child by the infertility doctor. There could also be normative reasons explaining the lower utilisation of ART services by less advantaged subgroups. For example, more disadvantaged individuals might be more likely to hold religious or cultural views which do not agree with the use of ART to treat subfertility. Indeed, Prag and Mills in a cross-national analysis show that normative cultural values measuring the acceptability of ART are the strongest predictor of ART usage (Präg and Mills, 2017b).

In summary, we observe persisting socio-economic inequalities in ART births despite the relatively high affordability of ART services in Norway (Chambers *et al.*, 2009), which raises the question of whether accessibility to ART treatments would be measured more effectively by accounting for a wider range of potential (geographical, cultural and normative) barriers which go beyond financial affordability. On the other hand, the data does not provide us with information about everyone who accesses ART, but only births after ART treatments (i.e. the successful cases). Therefore, we do not know whether the inequalities exist at the point of origin in the provision of ART services, or whether they emerge or widen throughout the ART process. Santaeulalia-Llopis *et al.*, (2017) show that, in Denmark, there is a large education gradient in IVF success: that is, amongst those who access ART services, the highly educated are the most likely to be successful. The evidence we have, therefore, does not enable us to assess to what extent the results reflect an 'unmet need' for ART. Future work using different data (with information on initiation, success/unsuccess of treatments and number of cycles, distance from the clinics as well as socio-demographic characteristics of the ART patients) will be instrumental in providing further answers to this key aspect around ART services in Norway, as well as in other contexts where the provision of ART services is less well subsidised.

Second, the results indicate that ART-conceived children grow up in resourceful environments which will benefit their development and well-being. A large amount of demographic and sociological research has shown the importance of family resources in predicting children's life-chances: being born to parents who are older, more educated, affluent and in stable relationships is positively associated with and a strong predictor of a range of important outcomes in early, as well as later, life (McLanahan, 2004). Boardman *et al.*, (2002) showed that the effect of low birth weight on developmental outcomes is small compared to the effect of the mother's education. Therefore, the advantaged social environments in which children born after ART are growing up might compensate for or partially offset the increased long-term health risks due to their increased risk of adverse pregnancy outcomes, such as low birth weight and preterm birth (Berntsen *et al.*, 2019). Being born to older parents can be seen as both an advantage in social terms and a disadvantage because it could be associated with increased risk of poorer birth outcomes (Goisis, 2015). Two prior studies (Tough *et al.*, 2000; Wennberg *et al.*, 2016) show that amongst children born after ART, an advanced maternal age at birth might not be as strongly associated with the risk of poorer birth outcomes as it is for naturally conceived children, but evidence is still limited. Moreover, the birth order profile of children born after ART could contribute to explain the combination of their higher risks of poorer birth outcomes and better cognitive and educational performances when looking at unadjusted associations (Barbuscia and Mills, 2017; Spangmose *et al.*, 2017). On the one hand, primiparity is associated with increased risk of adverse perinatal outcomes (Hinkle *et al.*, 2014) and thus birth order

Table II Linear probability models for ART births by income quartiles (births 2000–2014).

	All order births					
	Model 1 = baseline model		Model 2 = maternal age		Model 3 = maternal age + education + place of residence + marital status	
	β	95% CI	β	95% CI	β	95% CI
First quartile (*ref*)	0.00		0.00		0.00	
Second quartile	1.3	(1.2, 1.4)	0.8	(0.7, 1.0)	0.8	(0.7, 0.9)
Third quartile	2.5	(2.4, 2.6)	1.6	(1.5, 1.7)	1.6	(1.5, 1.7)
Fourth quartile	4.2	(4.1, 4.3)	2.7	(2.5, 2.8)	2.8	(2.7, 2.9)
Number of observations	755 797		755 797		755 797	
	First births					
	Model 1 = baseline model		Model 2 = maternal age		Model 3 = maternal age + education + place of residence + marital status	
	β	95% CI	β	95% CI	β	95% CI
First quartile (*ref*)	0.00		0.00		0.00	
Second quartile	2.6	(2.4, 2.8)	1.3	(1.1, 1.5)	1.2	(0.9, 1.4)
Third quartile	4.6	(4.3, 4.8)	1.8	(1.6, 2.1)	1.8	(1.6, 2.0)
Fourth quartile	7.1	(6.9, 7.3)	2.2	(1.9, 2.4)	2.6	(2.3, 2.8)
Number of observations	303 331		303 331		303 331	
	Second or higher-order births					
	Model 1 = baseline model		Model 2 = maternal age		Model 3 = maternal age + education + place of residence + marital status	
	β	95% CI	β	95% CI	β	95% CI
First quartile (*ref*)	0.00		0.00		0.00	
Second quartile	0.7	(0.6,0.8)	0.50	(0.4, 0.6)	0.46	(0.3, 0.6)
Third quartile	1.3	(1.1, 1.4)	0.79	(0.7, 0.9)	0.79	(0.7, 0.9)
Fourth quartile	2.2	(2.1, 2.3)	1.34	(1.2, 1.5)	1.42	(1.3, 1.5)
Number of obs.	452 466		452 466		452 466	

Coefficients show the percentage-point change in the probability of the birth being ART conceived.

could represent an important explanatory factor as to why children born after ART experience a disadvantage in birth outcomes (Goisis *et al.*, 2019). On the other, first-born children, on average, have better cognitive and educational outcomes than later-born children (Barclay, 2015), which has been attributed to the fact that first-borns have greater access to parental resources. Overall, our results support the idea that it is important to account for sociodemographic differences when investigating the long-term health outcomes and well-being of children born after ART. Indeed, researchers interested in the well-being of ART conceived children should recognise the importance of showing results both before (e.g. to illustrate how ART conceived children are actually doing compared to naturally conceived children) as well as after the careful adjustment for socio-demographic and health characteristics (e.g. to isolate the effect of the ART treatment from that of these variables).

This study has important strengths. It is based on population register data which covers the whole population in Norway. The data also enables us to explore whether the socio-demographic profiles of ART families have changed over time given the consistency in the recording of ART births in the medical birth register over the years. However, it also has limitations. First, the data does not enable us to tell whether more disadvantaged individuals are less likely to give birth to children born after ART because the treatment is less efficient for them, or because they access treatment to a lower extent as a

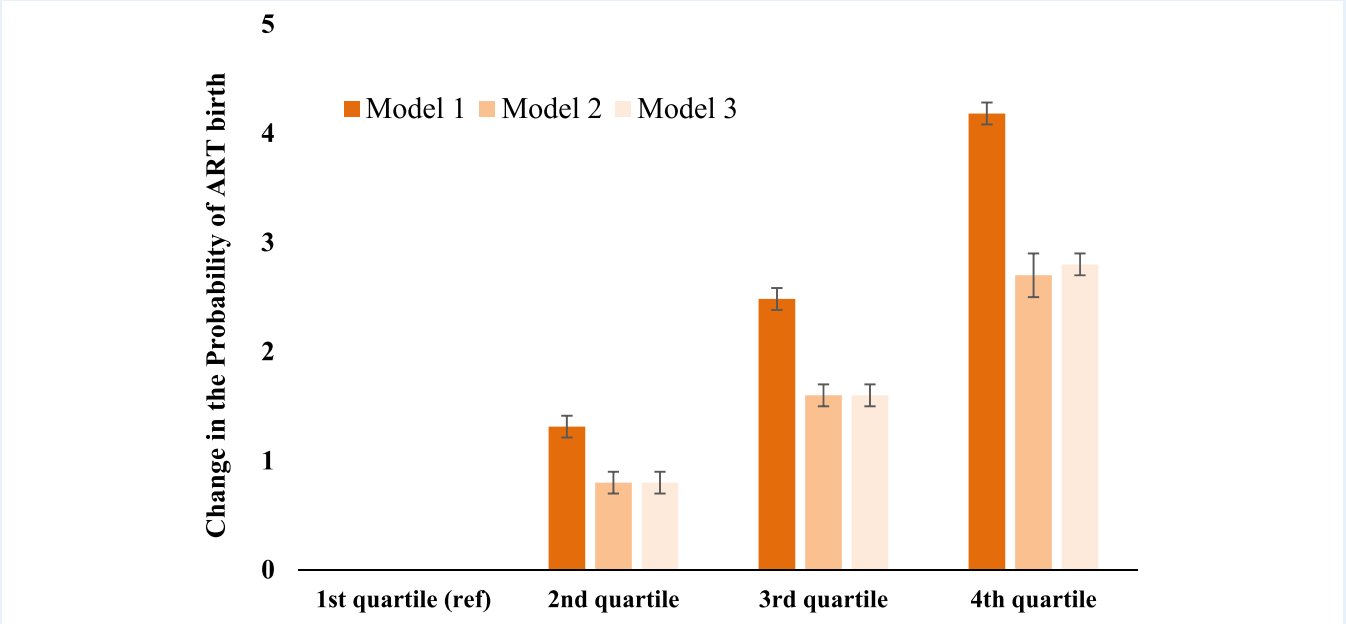

Figure 7 Percentage-point change in the probability of ART birth (with 95% confidence interval), by family income quartiles (births 2000–14), Model 1 Table II.

result of a lower demand or because they face (geographical, financial or cultural) barriers. Moreover, the data lack information on whether the ART treatments took place in public or private clinics. Second, the study focuses on Norway, a context characterised by high subsidisation of ART services and the results, therefore, may not well reflect the situation of other countries, where the social selection into ART may well be even more marked. Yet, the fact that we observe large and persisting social inequalities in Norway where the subsidisation of ART services is high makes the results even more striking and suggests that we would find even larger inequalities in contexts characterised by less subsidisation. Findings in the USA, UK and Finland (Wilcox and Mosher, 1993, Räisänen *et al.*, 2013, Barbuscia *et al.*, 2019) show a social gradient in ART births, but it is not possible to directly compare the results and test whether the social gradient is less marked in a context like Norway where the affordability of ART treatments is high (Chambers *et al.*, 2009). Performing the same analyses presented here in other contexts, both similar to (like Finland), and different from (like the USA), Norway in terms of ART accessibility and utilisation, will enrich our understanding of how ART accessibility and utilisation are linked to the social differentials seen in ART births.

Supplementary data

Supplementary data are available at *Human Reproduction* online.

Authors' roles

A.G. and Ø.K. conceived the idea and planned the analyses. Ø.K. performed the statistical analyses (data cleaning and calculations). All authors critically contributed to the interpretation of the results. A.G. wrote the first draft. All authors revised the manuscript and approved the final version for publication.

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Conflict of interest

The authors have no conflict of interest to declare.

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