Assessment of the contribution of assisted reproduction methods for the future development of the number of live births in Czechia

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Abstract

Background:
The key demographic trend concerns the postponement of parenthood to later ages. Moreover, the number of Czech women of reproductive age is decreasing, which will lead to a decrease in the number of live births even with higher fertility. The aims are to assess recent trends concerning using ART in Czechia and to estimate the impact of using ART on the future development of the number of live births.
**Methods:**
Based on data on the number of ART cycles involving the transfer of embryos in the period 2007–2012, the number of deliveries following ART was converted to the number of live births following ART by the maternal age at birth for the period 2008-2012. Subsequently, age-specific fertility rates following ART and models of the potential future development of live births following ART treatment were calculated. These models were based on a combination of two potential fertility development variants and four variants for the estimation of the future share of ART fertility of total fertility by age (V1-V4).

**Results:**
If the use of ART methods remains unchanged, there will be a decrease in the number of live births following ART in the period up to 2030 (V1 and V2) due to the declining reproductive potential of women. An increase in the number of live births following ART would occur only if there were an increase in the use of ART methods. Depending on the expected level of the increase in the use of ART, the number of live births following ART would increase by 2030 to 4.9 thousand (V3) and 6.5 thousand (V4). In relative terms, this would represent an increase from the initial 3.2% of the total number of live births to 5.0% and 6.8% respectively.

**Conclusions:**
We can expect an increase in the importance of ART for demographic trends in the future. The projection models assumed that the future development of the use of ART would be affected not only by the intensity of fertility postponement and different levels of fertility, but also by advances in reproductive medicine and the increasing availability of ART.

**Keywords:** assisted reproduction, fertility, postponement of childbearing, infertility, projection,

**Plain English Summary**
The number of couples who are unable to realise their wishes to have children is expected to increase due to the continuous postponement of parenthood to later ages. As a result, increasing numbers of women are opting for assisted reproductive technology (ART) treatment in most European countries and, in particular, in Czechia. Moreover, since ART is relatively easily accessible and cheap in Czechia, the country’s assisted reproduction centres
are attracting intensive reproductive tourism. The aims of the study are to assess recent demographic trends concerning the use of ART in Czechia and to estimate the impact of its use on the future development of the number of live births. If the use of ART methods remains unchanged, there will be a decrease in the number of live births following ART in the period up to 2030 due to the declining reproductive potential of women. An increase in the number of live births following ART will occur only if there is a corresponding increase in the use of ART methods. Depending on the expected level of the increase in the use of ART, the number of live births following ART will increase from an initial 3.5 thousand to a maximum of 6.5 thousand by 2030. In relative terms, this would represent an increase from an initial 3.2% of the total number of live births to 6.8%. Our results document an increase in the importance of ART in terms of future demographic trends.

**Background**

Recent decades have witnessed a large number of changes in terms of reproductive behaviour in all European countries. One of the most significant trends concerns the postponement of parenthood to later ages, in connection with which populations are being faced with a new problem, i.e. an increasing number of couples who are unable to realise their wishes to have children. A slow but steady decline in fecundity commences as early as women reach the age of 30, with a sharp decline from the age of 35 [1, 2]. According to estimates, an increase in the age at which women attempt their first pregnancy of 2.5 years leads to a decrease in fertility of around 5% from the age of 25 onwards [3]. The results consist not only of increasing rates of childlessness but also an increase in the proportion of multiple births [4]. Czechia is one of a number of countries that has seen the particularly intensive postponement of fertility by women to older ages over a relatively short period [5]. The most rapid increase in the mean age of women at first birth occurred from the early 1990s (22.5 years) to 2006 (27 years). Subsequently, the increase slowed and is currently approaching 29 years of age. At the same time, it has been determined that fertility postponement increased by 3% in Czechia [6]. Compared to other European countries, Czechia also recorded the greatest increase in multiple pregnancies [4].

The combination of the postponement of pregnancy and declining fecundity with age is leading to an increasing number of women opting for assisted reproductive technology (ART) treatment. According to the latest data, between 1% and 6% of all live births in Europe follow ART treatment and these proportions are increasing steadily [7]. Furthermore, over the last
two decades, Czechia has evinced one of the most rapid increases in Europe in this respect [8]. Assisted reproduction has been available in Czechia since 1997, at which time legislation was introduced allowing women under the age of 39 to undergo 3 ART cycles financed from the public health insurance system. Thus, it can be assumed that ART methods have become an important factor in terms of fertility trends in Czechia [9, 10, 11].

While assisted reproduction has often been assessed in terms of the inherent health risks and the various consequences for the health of both the mother and the child [12], demographic approaches are rare since it is difficult to access reliable data. The aim of the article is to assess recent trends concerning the use of ART in Czechia and, subsequently, to estimate the impact of ART on the future development of the number of live births, especially in connection with delayed fertility, the expected growth in infertility and the changing age structure of women of reproductive age. Unique data was accessed for the period 2008-2012, the definition of which was related to two significant legislative changes. In 2006, the obligation was introduced for all reproduction centres to submit data on ART treatment cycles to the Czech Institute of Health Information and Statistics (IHIS), which led to the creation of a national register in which complete data has been recorded since 2007. In Czechia the field of reproductive medicine is currently regulated by Act No 373/2011 of the Code relating to specific health services and Law No 48/1997 of the Code of public health insurance [13, 14]. The Act No. 373/2011 on specific health services, introduced the funding of a fourth ART cycle for women up to the age of 39 provided that only one embryo was transferred in each of the first two cycles. Our findings will contribute both to the refinement of the future estimation of the needs associated with newly-created population development forecasts and the estimation of future requirements concerning the capacity of reproduction centres in Czechia. At the application level, the results can be employed in the drafting of legislation on ART treatment, since the legislative availability of ART comprises a significant factor in terms of the demand for this type of treatment.

Data and Methods

Data

Data on ART in Czechia was obtained from the National Register of Assisted Reproduction (NRAR) which is administered by the Institute of Health Information and Statistics of the
The register records information on all women who have undergone ovarian stimulation or monitoring for the treatment of sterility by means of IVF [15].

The analysis is based on data on the number of ART cycles involving the transfer of embryos according to the number of transferred embryos and the completed age of women in the period 2007–2012 and the number of deliveries that resulted from these cycles (which took place from approximately 1 October 2007 to 30 September 2013). In order to determine the importance of ART methods in terms of births and to calculate the demographic fertility indicators of ART treatment, it was necessary to convert the number of deliveries following ART to the number of live births and to convert the ages of women and the date of embryo transfer to the maternal age and year of birth.

The transition from the age and year of embryo transfer to the age and year of childbirth is shown below in the form of a Lexis diagram (Fig. 1). The numbers of children born dated according to the time of embryo transfer (the grey shaded square) were shifted by 9 months in terms both of the mother’s completed age and the year (red square).

**Fig. 1: Conversion of births from the year/age at ART to the year/age at birth**

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1 Via the IVF, ICSI (intracytoplasmic sperm injection) or FET (frozen embryo transfer) methods.
This conversion method includes several assumptions:

1) births following ART exhibit the same rate of stillbirths as births conceived without the use of ART methods according to the age of the woman and to parity.

2) ART cycles, their rate of success and resulting births are distributed evenly throughout the calendar year.

3) all the pregnancies lasted for the standard period of 9 months (40 weeks).

The application of this input data transformation method resulted in the estimation of the number of children born in a given calendar year following the use of ART methods according to the age of the mother for the period 2018-2012.

It was important for the research that only data concerning women with Czech citizenship was used in the analytical and model calculations. Due to the fact that ART is relatively easily accessible and cheap in Czechia, the country’s assisted reproduction centres attract intensive reproductive tourism. In 2012, approximately 16.5% of all IVF cycles and 35.8% of FET cycles concerned foreign women, and 85.2% of the women registered for the acceptance of donated oocytes were of non-Czech citizenship [16]. According to a survey conducted by the European Society of Human Reproduction and Embryology [17], over 67% of women from Germany and over 50% of women from the United Kingdom of those who received ART treatment abroad in 2008 – 2009 chose services provided in Czechia.

A certain limiting factor of the data employed concerns the fact that the numbers of births entered in the assisted reproduction register are based solely on the data provided by assisted reproduction centres and are, therefore, likely to be underestimated. Since, following an amendment to legislation, the obligation to enter the woman’s identification number was abolished and data was collected in an anonymised form during the period 2010 – April 2012, it is, unfortunately, not possible to validate such data and thus to quantify the extent of underestimation.

Information on the age structure of women and live births according to the age of the mother was obtained from data provided by the Czech Statistical Office [18].

**Methods**

Standard demographic indicators were employed in order to assess the importance of the use of ART with respect to births in Czechia, i.e. the total fertility rate (TFR), age-specific fertility
rates and the mean age of women at birth, which were calculated only from births following ART treatment.

Age-specific fertility rate following ART ($f_x^{ART}$):

$$f_x^{ART} = \frac{B_x^{v,ART}}{P^w_x}$$

where $B_x^{v,ART}$ represents the number of live births to mothers at age $x$ following ART and $P^w_x$ represents the mid-year population of women at age $x$.

Total fertility rate following ART ($TFR^{ART}$):

$$TFR^{ART} = \sum_{x=x_{min}}^{x_{max}} f_x^{ART}$$

where $x_{min} = 15$ and $x_{max} = 49$.

Mean age of women at birth following ART ($MAB^{ART}$):

$$MAB^{ART} = \frac{\sum_{x=x_{min}}^{x_{max}} x \times f_x^{ART}}{\sum_{x=x_{min}}^{x_{max}} f_x^{ART}}$$

With respect to the assessment of the potential future impact of the use of ART methods on fertility in Czechia for the period 2013-2030, we employed the medium variant parameters of the expected development of fertility, mortality and migration as set out in an unpublished forecast of the development of the Czech population [19] based on the country’s population as at 31 December 2012.

The models of the potential future development of live births following ART treatment were based on a combination of two potential fertility development variants (a) the fixing of age-specific fertility rates at the 2012 level and (b) the medium fertility variant from the Burcin and Kučera forecast [19], and four variants for the estimation of the future share of ART fertility of total fertility by age.

The first variant (V1) of the estimate of ART live births works with a constant total fertility level (the age-specific fertility rates of women are fixed at the level of 2012) and the share of

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2 After a time period of several years, the medium variant of this fertility development forecast has proved to be very accurate; with respect to the period 2013-2019, it corresponds well to the actually observed development of fertility in Czechia.
ART fertility of total fertility (the share of ART fertility of total fertility at various ages remains at the level of the average for 2011–2012\(^3\)). Thus, this variant primarily illustrates the impact that the changing age structure of women of reproductive age would exert on the number of ART live births (and also, generally, on the use of ART) if the development of the overall fertility level and the use and success rate of ART were unchanged. It thus demonstrates the reproductive potential embedded in the age structure and the number of women in individual generations.

The other three model variants work with the medium variant of the total fertility development forecast for the Czech Republic for the period 2013-2030 rather than with the fixed 2012 value. This total fertility development variant is combined with three potential scenarios of the development of the use and success rate of ART treatment:

a) the share of ART fertility by age of overall fertility by age remains the same as the 2011–2012 average level. The future development of the number of ART births according to this variant is thus primarily influenced by the expected development of total fertility as well as the changing age structure of women of reproductive age.

b) a steadily increasing share of ART of total fertility of up to 1.5 times the average of 2011–2012 by 2030. In this case, the expected increase in the availability of ART methods (including the enhanced success of ART treatment) and increasing infertility due to the continuing trend of an increase in the mean age of women at childbirth were taken into account. Support for the assumption of an increasing share of ART births of total fertility is provided by the share of ART live births in countries with highly-developed ART treatment infrastructures and older mothers at childbirth - e.g. more than 6% of live births followed ART treatment in Denmark in 2012 [20].

c) a variant that considers the upper limit of the increase in the share of ART, i.e. up to twice the level of the reference period 2011 to 2012 assuming the broad availability of ART methods due to intensive technological development and significantly increasing infertility levels.

The variants concerning the potential development of the contribution of ART to the future development of the birth rate in the Czech Republic can thus be summarised as follows:

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\(^3\) We worked with the average for 2011 and 2012 in the model calculations of the potential future development of ART fertility so as to compensate for partial fluctuations caused by the lower absolute numbers of events in individual age categories. Moreover, this average was smoothed for the projection calculations since a partial fluctuation observed in one year could, over a time period of 17 years, lead to significant disparities in the projection model.
- **V1**: a constant share of smoothed age-specific fertility rates following ART based on the period 2011–2012 plus fertility rate values fixed at 2012 levels
- **V2**: a constant share of smoothed age-specific fertility rates following ART based on the period 2011–2012 plus the medium fertility forecast variant
- **V3**: an increasing share of smoothed age-specific fertility rates following ART (an increase of 50% by 2030 compared to the average of 2011–2012) plus the medium fertility forecast variant
- **V4**: an increasing share of smoothed age-specific fertility rates following ART (an increase of 100% by 2030 compared to the average of the 2011–2012 reference period) plus the medium fertility forecast variant.

**Results**

**Trends in the use of ART in Czechia in the period 2008-2012**

During the period 2008–2012, the number of ART cycles performed in Czechia ranged from 12,300 to 13,500 per year. The number of births following these cycles ranged between two and three thousand during the observed period and increased over time (Tab. 1).

In the same period, an increasing trend towards ART single-embryo transfer is evident, which was supported in 2011 by the introduction of a reimbursed 4th cycle provided that only 1 embryo had been transferred in the first two cycles. While in 2008 two or more embryos were transferred in 80% of ART cycles, by 2012 the proportion had decreased to just half of ART cycles (Tab. 1).

**Tab. 1: Trends in the use of ART in the period 2008-2012**

|                      | 2008  | 2009  | 2010  | 2011  | 2012  |
|----------------------|-------|-------|-------|-------|-------|
| Number of ART cycles*| 13,510| 12,775| 12,977| 12,277| 12,993|
| Number of ART deliveries | 2,339 | 2,241 | 2,343 | 2,977 | 2,757 |
| Proportion of ART cycles with 2 or more transferred embryos (in %) | 79.9  | 79.4  | 75.5  | 68.8  | 51.1  |
| Number of live births following ART | 2,920 | 2,835 | 2,895 | 3,634 | 3,272 |
| Share of live births following ART (in %) | 2.44  | 2.40  | 2.47  | 3.34  | 3.01  |

Note: *number of IVF, ICSI and FET embryo transfer cycles.
However, despite a significant decrease in multiple pregnancies, the number of live births conceived using ART increased from less than 3,000 from cycles performed in 2008 to 3,600 from cycles performed in 2011. In relative terms, there was an increase in live births following ART of the total number of live births from 2.4% to 3.3%. The slight decrease recorded in 2012 may have been related to an amendment to tissue and organ donation legislation, which abolished the obligation to register the woman’s identification number from mid-2010 to its re-introduction in 2012, and which may have led to a disruption in data continuity and the loss of information on the results of ART treatment [21].

**The use of ART in Czechia in the period 2008-2012 in the light of demographic indicators**

The age-specific fertility rates following ART (Fig. 2) reveal that in Czechia the highest values concern those aged between 30 and 34 years. A clear increase in the fertility rate following ART commences after the age of 26. A significant decrease is then observed at the age of 35; after the age of 40, fertility rates following ART decrease to negligible values, which is closely linked to the end of the payment of ART treatment by the public health insurance system.

Between 2008 and 2011, a slight decrease in, and stagnation of, fertility rates following ART is evident up to the age of 28. However, after the age of 29 a significant increase can be observed especially in 2010 and 2011, which was spread over a wide age range, and fertility rates increase every year up to the age of 40. This is also reflected in the increasing mean age of women at birth following ART, i.e. by almost one year in a period of just five years (from 32.5 in 2008 to 33.4 in 2012). This represented a significantly more dynamic increase than that of the total mean age of women at birth, which increased by 0.5 years over the same period. Moreover, mothers following ART were, on average, around 3.5 years older, i.e. the mean age of all mothers was 29.3 in 2008 and 29.8 in 2012 [22].

The total fertility rate following ART (TFR\textsuperscript{ART}) increased from 0.035 in 2008 to 0.045 in 2011 and subsequently decreased slightly to 0.041 in 2012. Due to the overall decrease in the TFR in the period under study, the relative importance of ART increased - while in 2008 the TFR\textsuperscript{ART} represented 2.3% of the TFR, it had risen to 3.2% by 2011 and stood at 2.8% in 2012.
Fig. 2: Fertility rates, mean age of women at birth and total fertility rate following ART in 2008–2012

Projections – reflection of the model assumptions concerning the demographic indicators of ART development

As follows from the description of the projection variants in the methodology section, the options regarding the future development of ART fertility suggest an increase in the age-specific fertility rate following ART compared to the period 2011-2012 due to both increasing levels of total fertility and the increasing importance of ART fertility in older age groups (Fig. 3). The exception in this respect concerns variant 1, which works with fixed total fertility rates and a fixed share of ART fertility of total fertility. It is clear from Fig. 3 that the difference between the initial state and the estimated state in 2030 assuming unchanged fertility intensities would be minimal; any partial differences would be the result merely of the changing structure of women according to age.

With respect to variant 2, which considers the constant distribution of the share of ART fertility rates of the total fertility by age over the whole of the studied period, the projected development is influenced by the expected increase in the total fertility level which, according
to this variant option, would lead to an increase in the absolute age-specific fertility rate following ART as well as the TFR\textsuperscript{ART} (increase from 0.043 in 2011-2012 to 0.055 in 2030, see Fig. 3).

According to variants 3 and 4, the share of fertility rates following ART of total fertility rates can be expected to increase by approximately 50% and 100% respectively by 2030 compared to the reference period of 2011-2012. If one considers the increasing share of ART fertility rates together with the medium total fertility forecast variant, the resulting fertility rates following ART and thus also the TFR\textsuperscript{ART} will be significantly higher, reaching 0.082 and 0.11 by 2030 according to variants 3 and 4 respectively. The projected fertility rates include the expected trend of a continuous increase in the age of mothers at childbirth, which is also reflected in a visible shift in fertility rates following ART to older ages in variants 2 to 4.

\textit{Fig. 3: Fertility rates following ART: average for 2011-2012 and expected development in 2020 and 2030}

The importance of a further shift in the mean age of women at childbirth is evident when one considers the share of ART fertility rates of overall fertility rates for selected age groups (Tab. 2). Not surprisingly, this proportion increases significantly with the age of the mother at childbirth. As already mentioned, not only does a woman’s ability to conceive decrease with
age, but it can also be expected that up to a certain age, most women try to conceive naturally and, therefore, are less interested in assisted reproductive treatment. With respect to the 35-39 age group, the share of fertility rates following ART of overall fertility exceeded 6% in the period 2011–2012. Assuming the constant share of ART fertility rates from the period 2011–2012 and the fixed fertility rate values of 2012 (variant 1), logically no significant changes should occur in this distribution throughout the observed period. However, conversely, with respect to variant 2 the combination of the fixing of the share of ART fertility rates and the projected increase in overall fertility according to the medium forecast variant will result in stabilisation at age 35-39 and a slight decrease in the oldest age group.

The remaining two variants that assume an increase in the proportion of ART fertility (V3 and V4) which is evenly distributed throughout the female reproductive period indicate, *inter alia,* that in this case the share of ART fertility rates of overall fertility rates after the age of 35 would be around 9% and 13% respectively in 2030 for variant 3 and more than 12% and 17% respectively in 2030 for variant 4.

**Table 2: Expected development of the share of ART fertility rates of overall fertility rates by age**

| Age group | Percentage of fertility rates following ART (in %) |
|-----------|--------------------------------------------------|
|           | 2011-2012 | V1  | V2 | V3 | V4 |
|           | 2013 | 2020 | 2030 | 2013 | 2020 | 2030 | 2013 | 2020 | 2030 |
| 20-29     | 1.43 | 1.43 | 1.44 | 1.47 | 1.47 | 1.48 | 1.80 | 2.21 | 1.52 | 2.13 | 2.94 |
| 30-34     | 3.77 | 3.77 | 3.75 | 3.79 | 3.81 | 3.85 | 4.63 | 5.71 | 3.96 | 5.47 | 7.61 |
| 35-39     | 6.20 | 6.20 | 6.16 | 6.18 | 6.21 | 6.34 | 7.55 | 9.32 | 6.51 | 8.92 | 12.42 |
| 40-49     | 9.23 | 9.44 | 8.95 | 8.86 | 8.74 | 9.20 | 10.82 | 13.08 | 9.44 | 12.75 | 17.39 |

In order to analyse the overall future significance of ART for childbirth, it is also necessary to consider the numbers of women who will enter the age at which ART is most often performed, i.e. the so-called reproductive potential of women. According to the population forecasts for Czechia used in this article [19], the number of women aged 20–39 will decrease in the period 2012–2030, with no significant numerical change in the 40–49 age group (Fig. 4). Compared to the projection threshold, there will be a significant decrease in the number of women especially in the 30–34 (by 32%) and the 35-39 (by 27%) age groups, whereas the 20–29 age group is expected to see a decrease of 14%. Since, clearly, this represents a significant reduction in the number of women who could, theoretically, receive ART treatment, these
developments should be taken into account when evaluating the total number and share of live births following ART.

**Fig. 4: Expected reproductive potential of women in the period 2012–2030 (selected age groups)**

![Graph showing expected reproductive potential of women](image)

**Results of the projection estimates - development of the number of live births following ART**

The results of the calculations for all the considered ART fertility development variants reveal two fundamental findings. Due to the declining reproductive potential of women (cf. Fig. 4), if the use of ART methods remains unchanged there will be a decrease in the number of live births following ART in the period up to 2030 (Fig. 5). This decrease would be most pronounced if neither the use of ART nor the total fertility level changed over the observed period (Fig. 6 - V1). Moreover, according to the medium variant of the fertility forecast, even the expected increase in the total fertility level would be insufficient to stabilise, let alone lead to an increase in the number of children born following ART at the end of the period under observation (Fig. 6 - V2). With concern to this decrease, it is necessary to bear in mind the
overall decrease in the number of live births that will, undoubtedly, occur during the period under study even with increasing total fertility levels (cf. Fig. 6 - V2-V4 “total” category) since it is deeply embedded in changes in the age structure and decline in the overall number of women of reproductive age.

An increase in the number of live births following ART would occur only if there were an increase in the use of ART methods (Fig. 6). Depending on the expected level of the increase in the use of ART, this development would be relatively significant and constant; by 2030, the number of live births following ART would increase from the initial 3.5 thousand to 4.9 thousand and 6.5 thousand according to variants 3 and 4 respectively (Fig. 5). In relative terms, this would represent an increase from the initial 3.2% of the total number of live births to 5.0% (V3) and 6.8% (V4) in 2030 (Fig. 6).

**Fig. 5: Expected development of the number of live births following ART in the period 2013–2030**
Fig. 6: Expected development of the number of live births and the share of ART live births, 2013–2030

Discussion

The main contribution of the article concerns the evaluation of trends in the use of ART aimed at estimating its impact on the future development of birth rates based on the example of Czechia. The prognostic approach to the analysis of ART has, to date, been applied only rarely in the expert literature. A major problem in this respect consists of the absence of data on age-specific fertility rates following ART, which is essential when attempting to assess the impact of the use of ART on birth rates. At present, the authors are not aware of any other study that has addressed the estimation of the expected development of ART over the longer term.
The only similar study published to date concerns the estimation of the development of the use of ART in Denmark [11]. The authors projected the complete cohort fertility following ART of Danish women born in the 1960s and 1970s. They assumed more fertility development variants and two scenarios of the development of the use of ART - a constant share of births following ART according to age and the extrapolation of the trend in ART use. The analysis concluded that the completed fertility of women from the 1960s and 1970s generations increased by an average of 0.05 children per woman as a consequence of ART use. While our data did not allow us to determine the cohort fertility level, it was possible to conclude that ART contributed to total fertility rate in Czechia by only a slightly lower value than in Denmark, i.e. 0.034–0.045 in the period 2008–2012 (Fig. 3). These results are consistent (considering developments over time) with the findings of other study [9], where it is argued that if the use of ART in the UK increased to the level of Denmark, total fertility rate would increase by approximately 0.04 children per woman. It can be expected in the future that total fertility rate following ART in Czechia will increase further and, assuming an increase in the share of fertility rates following ART and the medium fertility variant, it could reach approximately twice the value of 2008–2012, i.e. 0.08-0.11 by 2030 (depending on the development variant considered).

Variants 3 and 4 of our analysis assume ever-increasing demand for ART treatment. One of the starting points for this approach concerns the expected further increase in the mean age of women at childbirth and the inevitable increase in infertility with the age [2]. While the degree of compensation for declining fertility (due to the postponement of attempting a first pregnancy to later ages) via reproductive treatment methods is difficult to quantify, the results of models constructed for France and the Netherlands [23, 3, 24] suggest that despite the considerable benefits of ART, the overall decline in fecundity cannot be fully compensated for via this approach. Not only do the ability to conceive and the success rate of ART treatment decrease with age, but the risk of miscarriage increases significantly [25, 26]. Logically, therefore, the use of ART treatment has the potential to exert a greater impact on the birth rate if women are treated at younger ages [10].

In the European context, Czech women undergo ART treatment at relatively younger ages, a fact that is closely related to national legislation [27]. As can be seen from Tab. 2, the share of fertility rates following ART increases sharply with age, and Fig. 3 indicates that fertility intensity following ART is concentrated in the 30–34 age group. These trends stem not only from the unquestionable decline in ART success rates for women aged 35 and over [28], but
also from the fact that ART cycles are paid by the health insurance system, according to legislation (see above), only for women up to the age of 39. This distribution is unlikely to change significantly over time, and any major shift in the maximum fertility age following ART will most likely be linked to ground-breaking advances in terms of improving the effectiveness of infertility treatment for older women.

A further aspect that serves to support the assumption of a future increase in the proportion of live births from ART concerns male infertility. According to the results of a range of recent research studies, the quality of semen is declining dramatically throughout Europe, even among younger men [29]. According to the research, this trend may also result in a decline in birth rates. Although the effects on fecundity have not yet been reliably demonstrated, the increasing age of fathers is most likely to contribute to an overall increase in infertility. It has been reported that the age of the man exerts a significant effect on the ability to conceive, although this effect is not as significant as in the case of women [30]. Although ART has the potential to alleviate the effects of male infertility, it is important to note that views on the increase in male infertility are far from uniform. Some Czech doctors have claimed that, to date, it has proved difficult to compare the results of spermiograms and that rather than a decrease in the sperm concentration of healthy men, the concentration is, in fact, slightly increasing [31].

In connection with male infertility, recent research has also addressed the potential effect of ART on the semen quality of young men conceived via such methods [32]. The initial results indicate that the sperm concentration of men conceived via the ICSI method is significantly lower than that of their spontaneously conceived peers. Moreover, attention is increasingly being focused on the possible adverse effects of ART on the physical and mental development of children born following ART treatment. While a higher risk of pre-term birth and lower birth weight in infants conceived using ART has already been reliably demonstrated, it is still too early to be able to confirm potential longer-term risks employing a sufficiently large sample of the population [33].

The use of ART has also raised a number of ethical concerns [34], of which the number of embryos transferred is the most significant issue from the demographic point of view. As has been shown via data gathered in Czechia, the increase in the number of women using ART has contributed to a significant increase in the incidence of multiple births, a development that is linked to a range of health and economic risks [34] and which has also significantly contributed to the afore-mentioned concerns about the adverse consequences of ART [35].
However, due to the progress of reproductive medicine, the transfer of just one embryo has become increasingly common in recent years in developed countries [20], including in Czechia (Tab. 1) encouraged by an amendment to national legislation. Since 2011, four cycles of ART have been funded by the health insurance system conditional on the transfer of a single embryo during the first two cycles [14].

Future changes in legislation will undoubtedly affect the use of ART. Recently, proposals have been submitted in Czechia concerning expanding the availability of ART to a wider range of women, e.g. raising the age limit to 43 and increasing the number of cycles covered by the health insurance system have been discussed as part of the compilation of a new family policy concept. It is not unreasonable to assume that such changes will be reflected in an increase in the demand for ART and, subsequently, an increase in the number of live births.

It is possible that the consequences of the extension of ART methods for birth rates in Czechia as presented herein is limited by the quality of the data provided. Although the IHIS asserts that it registers practically all ART cycles performed in the country, the data on births may be underestimated since reporting a ART cycle birth is not a mandatory requirement. In addition, the IHIS covers only those ART cycles performed in Czechia and, thus, does not include cases where Czech women undergo ART treatment abroad.

Moreover, it is not possible to determine whether women were able to conceive spontaneously despite having undergone ART treatment. Some women who use ART can decide to treat their perceived infertility sooner than is necessary (9). Indeed, some authors have estimated that between 15% and 35% of women who undergo ART treatment are able to conceive naturally [11]. However, since more detailed longitudinal analysis (including with respect to the Czech data) would be needed in order to verify these claims, we have not considered this issue in our projection assumptions.

Conclusions

ART treatment is becoming an increasingly important factor in Czechia and is already influencing various birth rate characteristics; moreover, its importance can only be expected to grow in the future. Our projection calculations considered four potential future development scenarios, all of which predicted increases in the share of live births following ART by 2030 - from 3.2%, assuming a constant share of ART smoothed fertility rate values taken from 2011–2012 and fixed fertility rate values from 2012, and up to 6.8%, assuming an increasing share of ART smoothed fertility rate values (twice the average for 2011–2012 by
The enhanced potential of ART is limited by the reproductive potential of women at the age at which such treatment is most frequently performed.

Future trends concerning the use of ART will be influenced not only by the development of the age of women and men at childbirth and the related prevalence of infertility in the population, but also by advances in reproductive medicine and changes in legislation. The projections presented herein should, therefore, be understood as merely an outline of potential future development trajectories in the overall context of the complicated links between the use of ART treatment and the various factors that influence birth rates.

**Declarations:**

*Ethics approval and consent to participate*
Not applicable

*Consent for publication*
Not applicable

*Availability of data and materials*
The datasets used and analysed during this study are available from the corresponding author on reasonable request

*Competing interests*
Not applicable

*Funding*
This research was supported by the Czech Science Foundation (Project 18-08013S: ‘Transition towards the late childbearing pattern: individual prospects versus societal costs’) and Charles University Research Centre programme UNCE/HUM/018.

*Authors contributions*
BB analyzed all data and calculated projections. TP was a major contributor in writing the manuscript. AŠ performed data conversion and contributed to data analysis and interpretation. JK prepared the concept of the manuscript, specified research aims contributed to writing the manuscript. All authors read and approved the final manuscript.
Acknowledgements

Not applicable

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