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Original Research

Pregnancy and Urban Environment (PRUNE) Cohort Profile and Built Environment in Infertile Couples

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Abstract

Background: Addressing the association between the perceived physical environment and human fertility is necessary to understand the impact of the built environment on reproductive health and develop effective interventions to improve human fertility. We assessed the association between perceived built environment and pregnancy in infertility patients. **Methods**: We constructed a prospective cohort study (Pregnancy and Urban Environment, PRUNE) recruiting 778 eligible infertility patients who visited one of the two university-affiliated infertility centers for infertility treatment between 2019 and 2022. Using a mobile survey, we collected the information of demographic, clinical characteristics, residential address, perceived proximity to neighborhood green and blue space, and environmental noise. Adjusted risk ratios (aRR) were calculated for the achievement of pregnancy within three months of survey participation. **Results**: In the 728 infertility patients, 445 completed the second round of survey. Median age of women and men was 39 and 40 years, respectively. Most reported they have green (91%) and blue space (67%) within a 10-min walking distance. A fourth of patients (26%) had an annoying environmental noise. Probability of pregnancy within three months was higher for those who had green space within walking distance (aRR = 1.18, 95% confidence interval: 1.06, 1.32). The association with pregnancy was close null for blue space and annoying environmental noise. The aRR for women and for men was comparable (p for interaction = 0.875). **Conclusions**: We observed a positive association between living close to green space and pregnancy. This finding would provide evidence of the potential impact of built environment on human fecundity in infertility couples. **Clinical Trial Registration**: This study is registered in the Clinical Research Information Service (https://cris.nih.go.kr, CRIS number: KCT0003560).

Keywords: infertility; noise; green space; blue space; environment

1. Introduction

Infertility constitutes a medical condition affecting either the male or female, characterized by the inability to achieve a pregnancy even after engaging in regular unprotected sexual intercourse for a duration of 12 months or more [1]. Approximately one in every six individuals of reproductive age worldwide is estimated to encounter infertility in their lifetime [2]. The prevalence of infertility diagnosis was 15% in South Korean women who participated in a community survey [3]. Identifying contributing factors of infertility is challenging given the complexity of human conception process. A growing body of evidence indicates the potential impact of the physical environment on human fertility. Physical environment encompasses exposure to air pollution, noise, and other environmental stressors. Some studies have suggested that exposure to certain environmental factors may increase the risk of infertility and prolong time to spontaneous conception. For example, exposure to air pollution has been linked to decreased probability of *in vitro* fertilization (IVF) pregnancy [4–6], diminished ovarian reserve [7], and worse semen quality [8]. Longer distances to fresh water and nighttime environmental noise were associated with reduced semen quality [9,10].

Physical environment contributes to health and well-being by determining physical activity and psychological functioning of the residents [11]. In most prior studies on the environmental determinants of reproductive health, built environment exposure have been estimated by recorded home address linked to geospatial information [9,10,12]. Since the perception of the built environment has the potential to significantly influence the health and overall well-being of individuals [13], it becomes imperative to investigate the connection between the perceived physical environment and human fertility. This exploration is essential for comprehending the intricate relationship between the built environment and reproductive health. Such insights will aid in the formulation of targeted interventions aimed at enhancing human fertility. We were to explore the

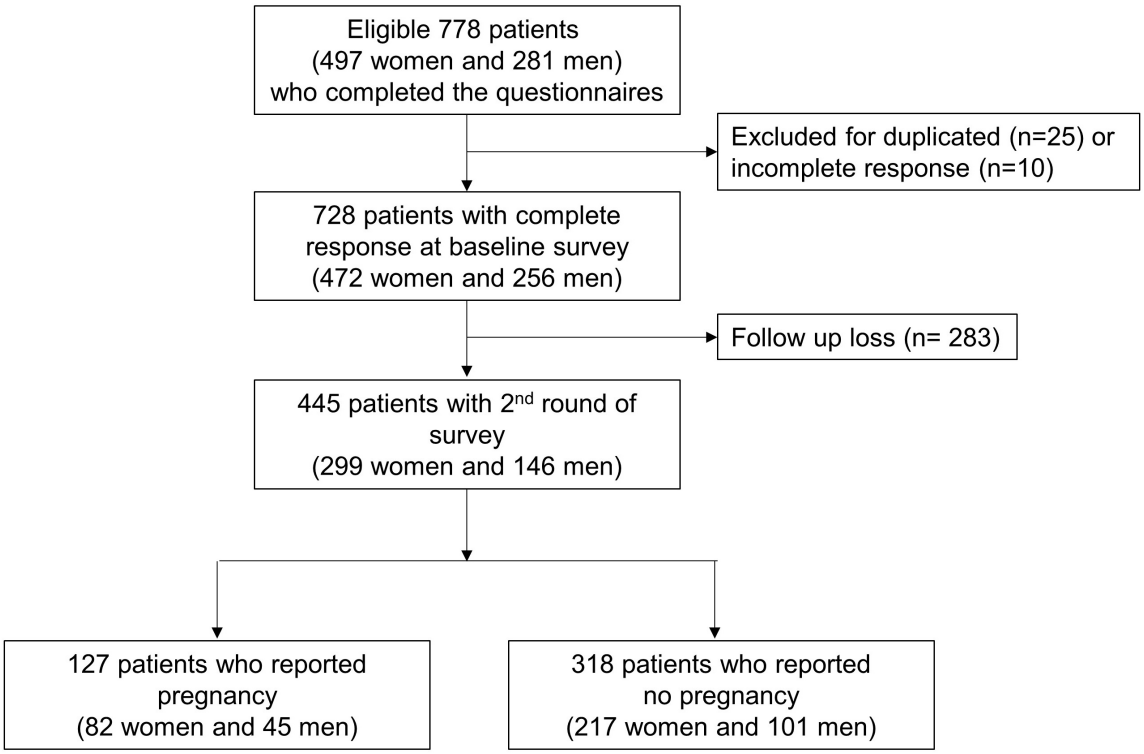

Fig. 1. Participants and their pregnancy of the Pregnancy and Urban Environment (PRUNE) study.

Table 1. List of variables available in the Pregnancy and Urban Environment (PRUNE) study data.

Round	Domain	Questionnaires
Baseline survey	Demographic and clinical variables	Age, education, presence of siblings, birthweight, occupation, income, underlying disease (malignancy, hypertension, diabetes, etc.), history of gynecologic surgery, vaccination, current medication, parity and gravidity
	Environmental exposures	Residential address, occupational exposure, presence of neighborhood green/blue space, environmental noise, duration of daily use of electronic device such as cell phone, tablet, and laptop computer, use of sanitary products
	Behavioral characteristics	Smoking, alcohol drinking, quality of sleep, physical activity
	Psychological status	Depression, self-rated health
Follow-up survey	Clinical variables	Infertility treatment, treatment outcome (clinical pregnancy)
	Environmental exposures	Residential address (when relocated)
	Behavioral characteristics	Smoking, alcohol drinking, quality of sleep, physical activity
	Psychological status	Depression, self-rated health

association between perceived built environment and pregnancy within three months in couples who visited two infertility centers.

2. Materials and Methods

2.1 Study Population

The Pregnancy and Urban Environment (PRUNE) study was a prospective cohort study of infertility patients who visited one of the two university-affiliated infertility centers in Seoul and Gyeonggi, South Korea for infertility treatment between October 2019 and July 2022. This study included women and men aged 20 and older, heterosexual couples living together, and provided informed consent to participate in baseline and follow-up surveys. Those with known genetic disorders or other severe chronic conditions affecting reproductive function, visited for gamete donation cycle, surrogate, and an *in vitro* fertilization (IVF) cycle using frozen oocytes or sperm were excluded. We planned to conduct two rounds of mobile survey for all women and men participants. First round was the baseline survey. With online survey questionnaires, we collected information of residential address and perceived built environment as well as demographic characteristics, medical history, smoking, and alcohol drinking at the baseline (Table 1). In the second round (follow-up) of survey, every participant was sent a text message with a link to the sets of follow-up questionnaires within three months of the baseline survey. The par-

ticipants were recruited at the time of their first visit to the facility by resident nurses and their physicians. This study is registered in the Clinical Research Information Service (CRIS number: KCT0003560).

2.2 Perceived Built Environment

We estimated the perceived built environment by asking the participants whether they have green space, blue space, and environmental noise. The questionnaires on the perceived built environment were developed by the authors. Our questions about perceived proximity to green and blue space were "Is there a green space (park or woods) in 10-min walking distance?" and "Is there a water (lake, creek, stream and river) in 10-min walking distance?", respectively. Environmental noise was examined by asking "Do you feel annoyed by environmental noise (traffic, construction, flight, neighborhood, and others)?". Response options were 'yes', 'no', and 'don't know' for the question of green and blue spaces. For environmental noise, participants were asked to respond with one of the 'very much', 'pretty much', 'not much', 'almost never', 'not at all', and 'don't know'. We coded the presence of annoying environmental noise when the response to the question was more than 'pretty much'.

2.3 Outcome of Pregnancy

We collected the information of infertility treatment received, treatment outcome (clinical pregnancy), residential address (when relocated), body weight, smoking, alcohol drinking, quality of sleep, physical activity, depression, and self-rated health since the baseline survey. Because the responses of other options were less frequent, infertility treatment was coded as received IVF or not. Those who achieved clinical pregnancy were identified based on the response to the question "Are you in pregnancy (your partner for men participants)?" which had response options of yes, no, and don't know.

2.4 Statistical Analysis

Descriptive statistics were calculated for women and men participants. Age, body mass index (BMI), current smoking and alcohol drinking, gonadotoxic treatment, level of education, and *in vitro* fertilization cycle since first survey were used as covariates. Adjusted risk ratios (aRR) were calculated for achievement of pregnancy within three months of survey participation. The risk estimates were stratified by sex, and multiplicative interaction in the association between perception of built environment and pregnancy by sex was assessed. Due to the high missing rate of follow-up survey (39.3%), we conducted analysis with inverse probability-of-censoring weighted techniques [14]. All analyses were done with R version 4.0.5 (The R Foundation for Statistical Computing, Vienna, Austria).

Table 2. Baseline characteristics of women and men participants of the follow-up survey, the Pregnancy and Urban Environment (PRUNE) study.

Variables	Women (n = 299)	Men (n = 146)
	Frequency (%)	Frequency (%)
Age (years)		
25–34	53 (18)	16 (11)
35–36	132 (44)	56 (39)
37–39	86 (29)	51 (35)
≥40	28 (9)	21 (14)
Missing	0 (0)	2 (1)
Education		
High school or lower	23 (8)	9 (6)
College or university	224 (75)	103 (71)
Graduate school	51 (17)	31 (21)
Missing	1 (0)	3 (2)
Current smoking	6 (2)	26 (18)
Current alcohol drinking	215 (72)	127 (87)
History of treatment that can reduce gonadal function[a]	6 (2)	5 (3)
BMI (kg/m^2)		
<18.5	21 (7)	0 (0)
18.5–25	222 (74)	56 (38)
>25	55 (18)	87 (60)
Missing	1 (<1)	3 (2)
IVF after the baseline survey	133 (44)	68 (47)

BMI, body mass index; IVF, *in vitro* fertilization. [a]Includes total or partial gonadectomy, cytotoxic chemotherapy, and radiotherapy involving pelvic region.

3. Results

During the study period, a total of 778 responses from eligible infertility patients were collected from the two infertility clinics (Fig. 1). Excluding duplication and incomplete responses, responses from 728 patients were collected at the baseline survey. The type of treatment and its outcome (clinical pregnancy) were prospectively examined using the online survey within three months of the first survey. In the follow-up survey, 442 (follow-up rate of 60.7%) patients participated.

For the 445 participants of follow-up of survey, median age of women and men was 39 and 40 years, respectively. Most participants were aged 35 years or older and were college graduates (Table 2). While 74% of women showed normal bodyweight, 60% of men were overweight. Current smokers were 2% of women and 18% of men participants. Alcohol drinking was prevalent in both women (72%) and men (87%). Prevalence of past treatment that can reduce gonadal function were similar between women (2%) and men (3%). Almost half of participants received IVF treatment between the baseline and follow-up surveys.

Majority of participants (90% for women and 91% of men) reported they have green space in 10-min walking distance at the baseline survey (Table 3). Having blue space

Table 3. Perceived built environment in 445 women and men participants of the Pregnancy and Urban Environment (PRUNE) study.

Component of built environment	Total	Women	Men
	Frequency (%)	Frequency (%)	Frequency (%)
Green space in 10-min walking distance	394 (91)	263 (90)	131 (91)
Blue space in 10-min walking distance	289 (67)	193 (66)	96 (67)
Annoying noise - neighborhood	112 (26)	70 (23)	42 (29)

was reported in 66% of women and 67% of men. Almost one in four participants responded they have annoying environmental noise at the living place. At the follow-up survey, 29% (127/445) of participants reported they achieved pregnancy after the baseline survey. When adjusted for individual demographic and clinical variables, probability of pregnancy within three months was higher for those who had green space within walking distance (aRR = 1.18, 95% confidence interval (CI): 1.06, 1.32; Fig. 2). The association with pregnancy was close null for blue space and annoying environmental noise. The aRR for women and for men was not statistically different (p for interaction = 0.875).

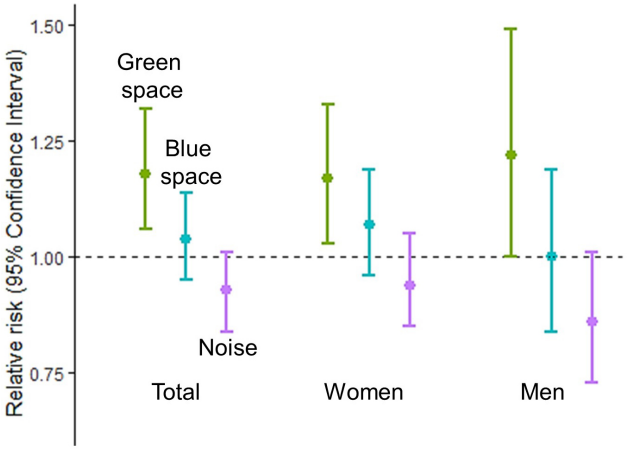

Fig. 2. Adjusted risk ratio of pregnancy within 3 months for the exposure to three built environments features among total, women, and men participants of the Pregnancy and Urban Environment (PRUNE) study.

4. Discussion

This study assessed the association between perceived physical components of environment and achievement of pregnancy in a sample of infertility patients mostly living in an urban area. We observed a positive association between perceived proximity to green space and probability of pregnancy. This association was not different between women and men patients. We present the profile of our prospective cohort of infertility patients and add empirical evidence of the potential impact of perceived built environment on the reproductive health.

The mechanism of this positive association between perceived built environment features such as proximity to green and blue space, and noise around home on the human fecundity is not clear. The benefit of living in restorative environment can be postulated to be both physiological and psychological. Physiologically, the reduction of harms of air pollution by green space might have improved fertility. Although there is no universal definition of "green spaces" due to cultural and disciplinary differences [15], most types of neighborhood green space are known to reduce the impact of air pollution [16,17] which is associated with decreased fertility and reduced probability of successful conception [18,19]. For psychological aspect, prior studies indicated mental health was positively associated with more perceived access to greenspaces and negatively associated with noise annoyance [13,20]. Given the close association between psychological well-being and success of conception, satisfaction with neighboring built environment might have led to better result of infertility treatment [21]. Our null finding of the association between environmental noise and pregnancy may be due to the generally lower exposure to annoying environmental noise.

Our study needs to be interpreted with caution due to several limitations. The study population may not be representative for general population. Given infertility patients represent a vulnerable population, the potential impact of perceived built environment on fertility would have been stronger than general population. In addition, given the infertility patients are more likely to be older than general couples, our finding may not reflect the association in younger people. The finding of this study can be valid for the infertile patients living in urban area of South Korea and would need to be confirmed with future research on the general population. Second, potential bias could arise from remaining confounding factors, encompassing lifestyle habits, mental health, and workplace environment, wherein a subset of participants may have predominantly spent their daytime. Because we did not assess the perception of workplace environment, our analysis was restricted to the perception of living place. Third, there can be misclassification when we assess the perceived proximity to green or blue space and environmental noise based on three simple questions. Since the exposure to environmental noise is intermittent, a singular assessment of the bothersome noise would require an evaluation of its reliability. The positive response to these questions might have

reflected the positive attitude in general of the participants. However, given the different result across the exposures, we believe the responses can detect their perception of specific environmental features.

5. Conclusion

Perception of living close to green space was associated with higher probability of conception in a sample of infertile patients. This highlights the need for more research to confirm a positive impact of restorative built environment on human fertility.

Availability of Data and Materials

The anonymous data used in this study are available from the corresponding author on a reasonable request.

Author Contributions

EG conducted primary analysis and drafted manuscript. TK and EB contributed to data acquisition, interpretation, and critical review and revision. HTP contributed to the conceptualization of the study and revised the manuscript critically for important intellectual content. SAC designed the study and revised manuscript critically for important intellectual content. JHK designed the research and revised the manuscript critically for important intellectual content. All the authors approved the final version to be published and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Gangnam CHA Hospital (approval number: GCI-18-48).

Acknowledgment

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Conflict of Interest

The authors declare no conflict of interest.

References

[1] Mascarenhas MN, Flaxman SR, Boerma T, Vanderpoel S, Stevens GA. National, regional, and global trends in infertility prevalence since 1990: a systematic analysis of 277 health surveys. PLoS Medicine. 2012; 9: e1001356.

[2] WHO. Infertility Geneva: World Health Organization; 2023. Available at: https://www.who.int/news-room/fact-sheets/detail/infertility (Accessed: 23 August 2023).

[3] Lee HJ, Han JY, Choi HZ, Na BJ. Infertility Prevalence and Associated Factors among Women in Seoul, South Korea: A Cross-Sectional Study. Clinical and Experimental Obstetrics & Gynecology. 2023; 50: 54.

[4] Choe SA, Jun YB, Lee WS, Yoon TK, Kim SY. Association between ambient air pollution and pregnancy rate in women who underwent IVF. Human Reproduction. 2018; 33: 1071–1078.

[5] Tartaglia M, Chansel-Debordeaux L, Rondeau V, Hulin A, Levy A, Jimenez C, *et al*. Effects of air pollution on clinical pregnancy rates after *in vitro* fertilisation (IVF): a retrospective cohort study. BMJ Open. 2022; 12: e062280.

[6] Liu J, Zhao M, Zhang H, Zhao J, Kong H, Zhou M, *et al*. Associations between ambient air pollution and IVF outcomes in a heavily polluted city in China. Reproductive Biomedicine Online. 2022; 44: 49–62.

[7] Kim H, Choe SA, Kim OJ, Kim SY, Kim S, Im C, *et al*. Outdoor air pollution and diminished ovarian reserve among infertile Korean women. Environmental Health and Preventive Medicine. 2021; 26: 20.

[8] Zhang HT, Zhang Z, Cao J, Tang WH, Zhang HL, Hong K, *et al*. Ambient ozone pollution is associated with decreased semen quality: longitudinal analysis of 8945 semen samples from 2015 to 2018 and during pollution-control period in Beijing, China. Asian Journal of Andrology. 2019; 21: 501–507.

[9] Choe SA, Kim S, Im C, Kim SY, Wellenius G, Kim YS, *et al*. Land use and semen quality: A fertility center cohort study. PLoS ONE. 2021; 16: e0255985.

[10] Choe SA, Kim S, Im C, Kim SY, Kim YS, Yoon TK, *et al*. Nighttime environmental noise and semen quality: A single fertility center cohort study. PLoS ONE. 2020; 15: e0240689.

[11] Guite HF, Clark C, Ackrill G. The impact of the physical and urban environment on mental well-being. Public Health. 2006; 120: 1117–1126.

[12] Choe SA, Kauderer S, Eliot MN, Glazer KB, Kingsley SL, Carlson L, *et al*. Air pollution, land use, and complications of pregnancy. The Science of the Total Environment. 2018; 645: 1057–1064.

[13] Cerletti P, Eze IC, Keidel D, Schaffner E, Stolz D, Gasche-Soccal PM, *et al*. Perceived built environment, health-related quality of life and health care utilization. PLoS ONE. 2021; 16: e0251251.

[14] Howe CJ, Cole SR, Lau B, Napravnik S, Eron JJ, Jr. Selection Bias Due to Loss to Follow Up in Cohort Studies. Epidemiology. 2016; 27: 91–97.

[15] Diener A, Mudu P. How can vegetation protect us from air pollution? A critical review on green spaces' mitigation abilities for air-borne particles from a public health perspective - with implications for urban planning. The Science of the Total Environment. 2021; 796: 148605.

[16] Junior DPM, Bueno C, da Silva CM. The Effect of Urban Green Spaces on Reduction of Particulate Matter Concentration. Bulletin of Environmental Contamination and Toxicology. 2022; 108: 1104–1110.

[17] Meo SA, Almutairi FJ, Abukhalaf AA, Usmani AM. Effect of Green Space Environment on Air Pollutants PM2.5, PM10, CO, O_3, and Incidence and Mortality of SARS-CoV-2 in Highly Green and Less-Green Countries. International Journal of Envi-

ronmental Research and Public Health. 2021; 18: 13151.
[18] Gregoire AM, Upson K, Niehoff NM, Chin HB, Kaufman JD, Weinberg CR, *et al*. Outdoor air pollution and anti-Müllerian hormone concentrations in the Sister Study. Environmental Epidemiology. 2021; 5: e163.
[19] Conforti A, Mascia M, Cioffi G, De Angelis C, Coppola G, De Rosa P, *et al*. Air pollution and female fertility: a systematic review of literature. Reproductive Biology and Endocrinology. 2018; 16: 117.
[20] Bloemsma LD, Wijga AH, Klompmaker JO, Hoek G, Janssen NAH, Lebret E, *et al*. Green space, air pollution, traffic noise and mental wellbeing throughout adolescence: Findings from the PIAMA study. Environment International. 2022; 163: 107197.
[21] Holter H, Anderheim L, Bergh C, Möller A. First IVF treatment–short-term impact on psychological well-being and the marital relationship. Human Reproduction. 2006; 21: 3295–3302.