


Characteristics, utilization of reproductive health services and AI prediction among Taiwanese adolescent mothers during the COVID-19 pandemic

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Abstract

Background: Although adolescent birth rates have declined globally, the sexual and reproductive health of adolescent mothers remains an area of specific concern, and these were impacted by the COVID-19 pandemic. This study investigates characteristics, utilization of reproductive health services (RHS) and artificial intelligence (AI) prediction during the pandemic.

Methods: We conducted an exploratory study using data for 2020–2022 from the Taipei City Government Health Bureau. Adolescent mothers under the age of 20 received post-birth telephone-based RHS, covering contraception, abortion, post-partum care, and social welfare support. The data analysis included descriptive statistics, and various machine learning techniques were employed, including random forest, SVM, KNN, logistic regression, and Bayesian network analysis.

Results: Of 112 participants, most were aged 17 to 19 (80.4%) and married (58.0%). The majority had full-term deliveries (86.6%) with healthy infants. A high percentage had not used contraception before conception (60.7%), and some had had earlier abortion or termination experiences (13.4%). In the examination of eight influential factors, the machine learning models, specifically the random forest and Bayesian network analyses, exhibited the highest accuracy, achieving 90.91% and 89%, respectively, in predicting service acceptance. The key determinants identified were abortion experience and marital status, directly influencing the acceptance of services.

Conclusion: The COVID-19 pandemic reduced hospital visits for adolescent mothers, but the RHS provided timely guidance. Telemedicine consultations and internet-based psychological consultations may play a crucial role in facilitating such services in the future.

Keywords

Adolescent birth, reproductive health services, COVID-19, AI prediction

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Introduction

Adolescent pregnancy is a worldwide occurrence.¹ Despite a global decline in adolescent birth rates,^{1,2} they remain a specific area of concern in public health, and the COVID-19 pandemic has placed added stress on the sexual and reproductive health of adolescents.^{3–6} Adolescent pregnancy not only presents physical and psychological challenges, but also places significant burdens on the adolescents, their families, and society, from the pregnancy itself through to childbirth.^{4,6–9} Further, adolescent pregnancy is linked to an elevated risk of adverse birth outcomes.^{10–13} After giving birth, adolescent mothers face an increased susceptibility to postpartum depression (PPD) due to the demands of transitioning into their new role.^{14,15} This depression not only affects a substantial proportion (10–57%) of adolescent mothers but also has consequences for their infants.¹⁶ A systematic review that aimed to identify risk factors associated with adolescent PPD revealed several contributing factors, including prior depression, insufficient familial social support, and socio-economic hardship.¹⁷

The utilization of reproductive health services (RHS) plays a crucial role in mitigating mortality and morbidity linked to adolescent pregnancy and childbirth.¹⁸ Notably, however, the ongoing impact of COVID-19 has affected the availability and use of both routine and emergency healthcare services. A systematic review that examined the impact of the COVID-19 pandemic on maternal and child health services in Africa identified three key themes: delays and reduced care, disruptions in service delivery and utilization, and mitigation strategies or recommendations.¹⁹ Another systematic review assessed the effectiveness of various interventions designed to prevent PPD in adolescent mothers. These interventions encompassed home-visiting programs, prenatal and postnatal educational initiatives, psycho-educational support, interpersonal therapy, and infant massage training. The review showed that these interventions successfully reduced the prevalence of PPD symptoms among adolescent mothers in the intervention groups compared to those in control groups.¹⁶

In Taiwan, the legal age for marriage is 18 years for both men and women; however, individuals aged 17 may legally marry parental consent. Such marriages are officially recognized only upon registration with the government.²⁰ Additionally, Taiwan's National Health Insurance (NHI), introduced in 1995, provides comprehensive coverage to 99.9% of the country's 23 million residents.²¹ Under the NHI, pregnant women have access to 14 rounds of prenatal examinations, ensuring that maternal health services are widely available and accessible to all, including those within the adolescent population.²² Over the past decade (2010–2020), the birth rate among women aged under 20 decreased from 14 per 1000 in 2000 to 4 per 1000 in 2020.²³ On average, approximately 2000–3000 babies

were born to adolescent mothers annually during this period. In 2017, there were 2477 such births, constituting 1.35 per 1000 of the total births. In 2021, in line with Taiwan's overall declining birth rate, this number decreased to 1904, representing 1.18 per 1000.²⁴ However, in that year, the stillbirth rate among mothers aged under 20 was 4.20 per 1000, substantially higher than the overall stillbirth rate of 1.25 per 1000.²⁵

Taiwan's experience with the SARS outbreak in 2004 enabled the government to swiftly implement a series of effective COVID-19 prevention measures, including stringent border controls, comprehensive case monitoring, proactive quarantine protocols, and efficient resource allocation.²⁶ Despite initial concerns due to Taiwan's geographical proximity to China, the country successfully maintained a low number of COVID-19 cases—reporting only 429 cases and 6 deaths as of May 1, 2020—without resorting to a full lockdown.²⁶ Additionally, as of May 1, 2020, Taiwan had experienced no new local infections for over 2 weeks.²⁷ Notably, there were no reported cases among pregnant or postnatal women, a success attributed in part to the establishment of specialized maternity units within hospitals.^{27,28} In May 2020, the Taipei City Government Health Bureau (TCGHB) in Taiwan's capital launched the “Taipei City Special Population Health Care Program” to address the needs of vulnerable populations, including individuals with mental and intellectual disabilities, as well as adolescents. Given the unique challenges associated with adolescent pregnancy and childbirth, specialized maternal care is essential for this population.

Globally, multiple studies have indicated that the COVID-19 pandemic exacerbated adolescent pregnancy and birth rates.^{29–31} However, there is limited information regarding the utilization of RHS and predicting the RHS during the pandemic. Therefore, the study aimed to investigate the characteristics and utilization of RHS among adolescent mothers in Taiwan during the COVID-19 pandemic. Additionally, the study explored the application of artificial intelligence (AI) in predicting RHS utilization during the pandemic. Through examining these aspects, the research aimed to provide insights into the impact of the pandemic on adolescent mothers' access to and use of RHS, and how AI could be leveraged to enhance service delivery and outcomes for this vulnerable population. These insights were intended to inform public health strategies and strengthen support systems for adolescent mothers, particularly in the context of ongoing and future public health crises.

Methods

Study design

This study utilized an exploratory research design to investigate the utilization of RHS among adolescent mothers during the COVID-19 pandemic.

Table 1. Participants' demographic characteristics ($n = 112$).

Characteristics	n (%)
Nationality/ethnicity	
Taiwanese	100 (89.3)
Indigenous	10 (8.9)
Expatriate	2 (1.8)
Age group (years)	
≤13	1 (0.9)
14–16	9 (8.0)
17–19	90 (80.4)
20	12 (10.7)
Marital status	
Married	65 (58.0)
Single	39 (34.8)
Cohabiting	2 (1.8)
Data missing	6 (5.4)
Education	
Primary school	1 (0.9)
Junior high school	14 (12.5)
Senior high school/vocational high school	52 (46.4)
College	11 (9.8)
University	11 (9.8)
Data missing	23 (20.5)
School status	
Currently schooling	11 (9.8)
Graduated	33 (29.5)
Dropped out of school	55 (49.1)
Dropped out before pregnancy	23 (20.5)
Dropped out because of pregnancy	32 (28.6)
Taking leave from school	2 (1.8)

(continued)

Table 1. Continued.

Characteristics	n (%)
Data missing	11 (9.8)
Employment status	
Unemployed	82 (73.2)
Employed	16 (14.3)
Data missing	14 (12.5)
Living habits	
Smoker	18 (81.8)
Drinks alcohol	3 (13.6)
Other	1 (4.5)

Data source and participants

Purposive sampling was employed to select participants for the study. The primary data source was an encrypted database provided by TCGHB. Eligible participants were identified based on the following inclusion criteria: (a) adolescents who had given birth under the age of 20 during the COVID-19 pandemic (2020–2022); (b) willingness to participate in a telephone interview; (c) approximately three months postpartum; (d) residency in Taipei City during the study period; and (e) proficiency in either Mandarin or Taiwanese. The exclusion criterion was a miscarriage occurring before 20 weeks of gestation. The dataset comprised basic demographic information (e.g. age, nationality/ethnicity, marital status, education level, and lifestyle), obstetric details (e.g. parity, history of abortion or termination, and mode of birth), and infant-related data (e.g. gender, birthweight, gestational age, and health status).

Reproductive health services

The RHS program, launched in July 2020 by TCGHB, was designed to support adolescent mothers during the COVID-19 pandemic. The program was executed through the following steps: (a) identifying eligible participants using the TCGHB's encrypted database; (b) recruiting and training healthcare providers in reproductive and postpartum care; (c) conducting initial outreach via telephone to explain the program and obtain consent; (d) delivering services through both telephone and in-person visits, including contraception education, postpartum care, and infant care guidance; and (e) making referrals for additional support, such as economic assistance and mental health services, to relevant city departments. Implemented citywide in

Table 2. Participants' obstetric information ($n = 112$).

Characteristics	n (%)
Gravida	
1	81 (72.3)
2	21 (18.8)
3	5 (4.5)
Data missing	5 (4.5)
Para	
Stillbirth	3 (2.7)
One	96 (85.7)
Two	8 (7.1)
Data missing	5 (4.5)
Contraception	
No	68 (60.7)
Yes	27 (24.1)
Oral pill	8 (7.1)
Condom	19 (17.0)
Intrauterine device	1 (0.9)
Extracorporeal ejaculation	1 (0.9)
Safety period	2 (1.8)
Data missing	17 (15.2)
Abortion history	
Yes	15 (13.4)
No	76 (67.9)
Data missing	21 (18.8)
Termination	
Yes	15 (13.4)
No	76 (67.9)
Data missing	21 (18.8)
Prenatal examination	

(continued)

Table 2. Continued.

Characteristics	n (%)
Regular	93 (83)
Irregular	6 (5.4)
None	2 (1.8)
Data missing	11 (9.8)
Birthplace	
Medical hospital	48 (42.9)
Reginal hospital	41 (36.6)
Clinic	22 (19.6)
Data missing	1 (0.9)
Mode of birth	
Vaginal	88 (78.6)
Cesarean	10 (8.9)
Data missing	14 (12.5)
Postpartum depression	
No depression	86 (76.8)
Possible depression	5 (4.5)
Depressed but medical help not sought	7 (6.3)
Data missing	14 (12.5)
Postpartum depression score	
≤ 9	81 (89)
10–12	3 (2.7)
≥ 13	7 (5.4)
Data missing	21 (18.8)

Taipei, the program is continuously evaluated to enhance its effectiveness in improving the well-being and social integration of these vulnerable groups.

Data collection and procedures

Eligible adolescent mothers were identified using the TCGHB encrypted database. Case management teams

conducted telephone visits based on participant lists provided by the TCGHB, during which case managers explained the study protocol and obtained verbal consent from participants. RHS were subsequently offered to those who accepted. In cases where the case manager identified significant needs, such as severe PPD, challenges in role transition, or a high-risk family environment, the case was promptly referred to appropriate mental health or social welfare services. Additional cases requiring services such as economic assistance, employment support, mental health services, social welfare, adoption, or legal services were directed to the relevant city departments and the Social Affairs Bureau for continued case management. In instances where participants declined services, were unreachable, or had relocated outside the jurisdiction, the TCGHB was notified within 2 days. Follow-up consultations were typically conducted approximately three months postpartum, with sessions lasting 15 to 20 minutes. In 2023, the fertility rate for adolescent women aged 15–19 years in Taipei City was recorded at 1 per 1000 women.²⁴ Despite Taiwan's notably low fertility rate, all 112 eligible participants contacted for the study consented to participate. Additionally, all participants who reported being married had their marital status officially recognized.

Data analysis

Data analysis was performed using IBM SPSS Modeler version 18.2 and IBM SPSS Statistics software version 25.0. Descriptive statistics (frequencies, percentages, and means) were used to analyze the demographic variables. Correlation analysis, logistic regression analysis, and machine learning techniques (including random forest, SVM, KNN, logistic regression, and specifically conditional Bayesian network analysis) were used to explore the relationships in the data. Given the limited data available, we explored factors influencing the participants' decision to utilize RHS. Key factors identified through correlation analysis and logistic regression were integrated into a decision-support system for RHS utilization. Bayesian networks as probabilistic graphical models facilitated Bayesian classification through a statistical analysis of probability involving calculating the posterior probability ($P(H/X)$) and prior probability ($P(H)$), where X represents the data tuple and H denotes the hypothesis: $P(H/X) = P(X/H)P(H)/P(X)$.

Ethical considerations

Prior to the commencement of the study, ethics approval was obtained from the Research Ethics Committee of Taipei City Hospital (TCHIRB-11102002-E-F). To ensure participant privacy, each participant was assigned a number identity code and all data were encrypted and

Table 3. Newborn information ($n=112$).

Characteristics	<i>n</i> (%)
Gender	
Male	51 (45.5)
Female	61 (54.5)
Gestation week	
≤19	1 (0.9)
20–28	5 (4.5)
29–36	9 (8.0)
37–40	93 (83.0)
≥41	4 (3.6)
Body weight (g; mean (SD))	
Stillborn	6 (5.4)
≤2500 g	9 (8.0)
2501–3000 g	45 (40.2)
3003–3500 g	45 (40.2)
3501–4000 g	7 (6.3)
Birth conditions	
Normal	108 (96.4)
Respiratory distress syndrome	1 (0.9)
Hypoxia	2 (1.8)
Airway problems	1 (0.9)
Health condition	
Normal	101 (90.2)
Premature	4 (3.6)
Congenital heart disease	1 (0.9)
Congenital appearance defect	2 (1.8)
Other	4 (3.6)

securely stored on the principal researcher's password-protected computer in a locked office. Access to the dataset was restricted to the study investigator.

Results

Demographic information

Data for 112 participants were extracted from the TCGHB database (Table 1). The majority were Taiwanese (89.3%; $n = 100$), aged 17–19 years (80.4%; $n = 90$), and legally married (58.0%; $n = 65$). Nearly half of the participants had dropped out of school (49.1%; $n = 55$) and 73.2% were unemployed ($n = 82$). More than two-thirds of the participants were primigravida (72.3%; $n = 81$) and primipara (85.7%; $n = 96$) (Table 2). Notably, two of them had mild intellectual disabilities. The majority had not used contraception before conception (60.7%; $n = 68$). A small proportion had previously undergone an abortion (13.4%; $n = 15$) or termination (13.4%; $n = 15$). Most of the participants had regular prenatal examinations (83%; $n = 93$) and opted to give birth at either a medical central (42.9%; $n = 48$) or a regional hospital (36.6%; $n = 41$). Vaginal birth was the most common mode of birth, accounting for 78.6% of participants ($n = 88$), while 10 participants gave birth via cesarean section, this detail was missing for the remaining 14 participants. After birth, the majority did not experience depression (76.8%; $n = 86$), and most PPD scores were <9 (89%; $n = 81$). Most births were full-term (86.6%; $n =$

97), and most infants were healthy, with an average body weight of 2860 g (Table 3).

Descriptive analysis of RHS utilization

The most common form of RHS used by the participants was postpartum maternal–infant care consultations (Table 4). A considerable proportion sought postpartum healthcare consultations (24.4%, $n = 59$), baby care services (62.4%; $n = 68$), and breastfeeding support (11.2%; $n = 27$). In terms of fertility consultations, 42% of participants ($n = 17.4%$) received birth-planning guidance, while only one participant (0.4%) sought abortion and termination services. Additionally, nearly two-thirds of the participants opted for joint custody (67.9%; $n = 76$), with a similar proportion applying for maternal grants (51.8%; $n = 58$).

Prediction of RHS utilization

This analysis was conducted concurrently with a comprehensive review of pertinent literature.^{32–34} The examination identified eight pivotal discriminant factors through correlation analysis and logistic regression results. These factors encompassed abortion experience 1 (abortion) and experience 2 (termination), education, smoking status, drinking status, disability, contraception, and marital status, collectively serving as predictors for the utilization of RHS. A dataset of 101 training instances underwent testing through 5-fold cross-validation, employing various machine learning methods such as random forest, SVM, KNN, and logistic regression to assess their predictive capabilities. Notably, the random forest model demonstrated the highest accuracy on the test set, achieving 90.91%. Applying the shape algorithm to scrutinize the ranking of key features predicted by the random forest model revealed abortion as the most influential factor, followed by marital status (Figure 1). This observation aligns with the Bayesian calculus analysis results, affirming the consistency of factors influencing RHS utilization prediction.

Bayesian network analysis shows an overall predictive rate of 70%. Notably, two significant factors affecting adolescents' acceptance of RHS during the COVID-19 pandemic were identified: the presence of abortion experience and the odds ratio of indigenous ethnicity ($P < 0.05$). The relative risk ratio associated with abortion experience revealed that participants without abortion experience were 0.25 times more likely to accept RHS than those with abortion experience. Furthermore, those of indigenous ethnicity were 9.05 times more likely to accept RHS than those of other ethnicities. The Bayesian network analysis further revealed that the combination of these eight factors provided 89% predictive accuracy in terms of the acceptance of RHS. Of these factors, abortion experience and marital status emerged as the most influential determinants. These findings are presented in Figure 2,

Table 4. Utilization of RHS.

Item	n (%)
Postpartum healthcare	59 (24.4)
Baby care	61 (25.2)
Breastfeeding	27 (11.2)
Birth planning	42 (17.4)
Abortion and termination	1 (0.4)
Medical information	14 (5.8)
Medical and social welfare	38 (15.7)
Maternal grant	58 (51.8)
Data missing	21 (18.8)
Newborn placement	
Raised by couple	76 (67.9)
Raised by female	19 (17.0)
Adoption	1 (0.9)
Other	4 (3.6)

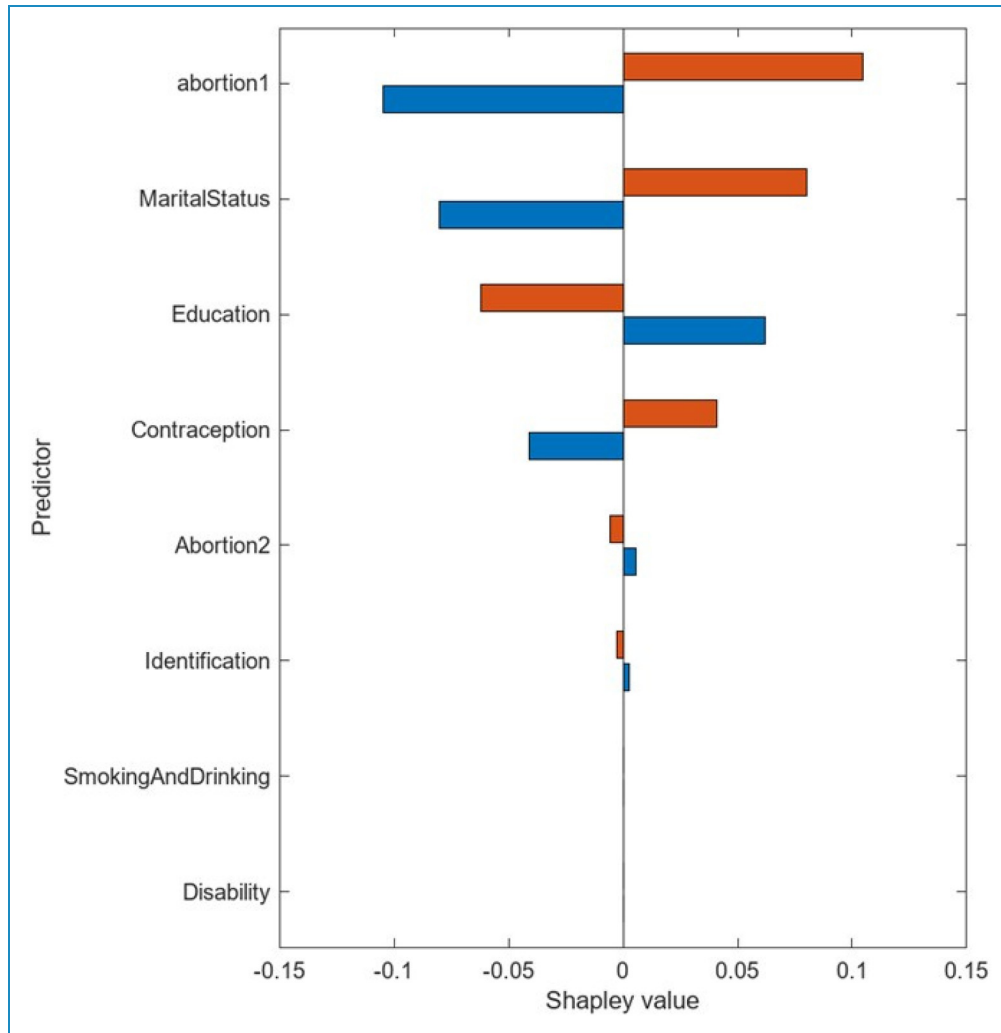


Figure 1. SHAP feature importance in RHS usage prediction model.

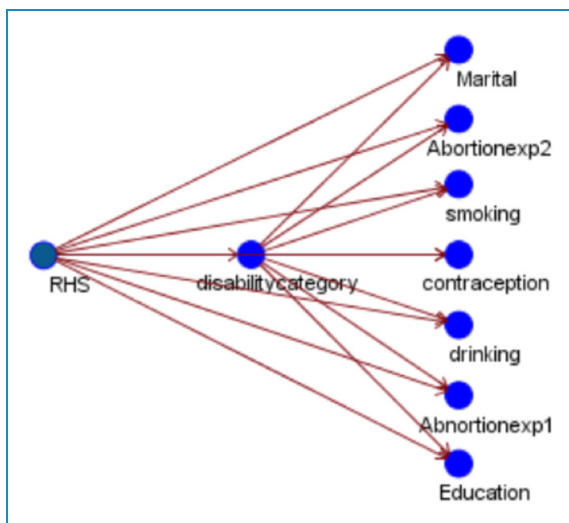


Figure 2. RHS predictive model with Bayesian network analysis.

where nodes connected by a single arrow signify a cause-and-effect relationship, with one node acting as the “cause (parent)” and the other as the “effect (offspring or child),” resulting in a conditional probability value. For instance, abortion experience was directly linked to the acceptance of RHS, whereas smoking and drinking had indirect effects on the outcome.

Discussion

Taiwan’s effective COVID-19 measures have maintained normal adolescent birth rates, particularly in Taipei City, which exhibits one of Taiwan’s lowest rates.²⁴ This trend may be attributable to the TCGHB’s RHS program and Taiwan’s overall low fertility rates.^{24,26,35} These findings contrast with those from developing countries during COVID-19. For example, in Kenya, there were significant increases in the use of family-planning services by young people, uptake of injectable contraception, cesarean

section rates, adolescent maternal deaths, and fresh stillbirths, along with a reduction in contraceptive implant uptake during COVID-19 pandemic.³⁶ In sub-Saharan Africa, a systematic review revealed that a significant number of adolescents did not access and use maternity services during pregnancy.¹⁸ Several factors across levels from the individual to the systemic contributed to this low access and utilization.¹⁸ A comparative study revealed that 75% of 760 Australian adolescents aged 12 to 18 experienced worsening mental health during the COVID-19 pandemic, particularly those with a prior diagnosis of depression or anxiety. The pandemic also negatively impacted their learning, relationships, and psychological well-being.³⁷ Similarly, an online survey in a high-deprivation region of New Zealand among 500 respondents aged 15 to 24 found that 22.2% reported sexual health needs during lockdown, but less than half received assistance due to perceived delays, service access barriers, and lack of information.³⁸ In Italy, a survey of 2064 adolescents found that COVID-19 significantly affected emotions, lifestyle, and relationships, with regional variations noted.³⁹

Taiwan's NHI system reimburses healthcare providers on a fee-for-service basis, ensuring that most participants in our study received at least five regular prenatal visits and delivered healthy babies during the pandemic. However, it is concerning that the stillbirth rate in our study was 5.4%, and 8.0% of infants were born with low birth weight (<2500 g).²⁵ A study analyzing infant mortality risk from 2015 to 2017 found that maternal age under 20 increased the risk of infant death by 1.62 times, having fewer than six prenatal visits raised it by 8.25 times, and premature birth elevated the risk by 7.44 times.⁴⁰ Our findings are consistent with three systematic reviews showing that, compared to adults, adolescent mothers have higher rates of low birth weight, premature birth, and stillbirth in developed countries such as Canada and Turkey.^{10,11,41} Despite Taiwan's comprehensive NHI, the stillbirth rate observed in our study exceeds the national average, pointing to potential care quality issues that are less prevalent in other developed nations. Taiwan's lower prevalence of PPD, supported by strong Chinese familial networks, contrasts with higher PPD rates in developed countries with less robust social support systems.

In our study, most pregnancies (80.4%) occurred among senior high-school students and were probably due to insufficient availability of contraceptive measures during the pandemic. A nationwide survey in Taiwan conducted in 2012 to 2016 examined condom usage among sexually active adolescents.⁴² Although the rate of sexual activity found was low (4.95%), condom use was lower during subsequent sexual encounters than in initial encounters.⁴² This was particularly true for junior high-school students, and it was attributed to inconsistent safe-sex practices, forgetting to use contraception, or choosing the wrong method.⁴² Students were potentially influenced by misinformation,

peer pressure, and boyfriend pressure.⁴² A review study also emphasized that Taiwanese adolescent pregnancies are linked to limited knowledge but open attitudes and behaviors regarding sexuality, inadequate access to contraceptives, risk-taking behaviors, family issues, and low socioeconomic status.⁴³ Due to the lack of emphasis on education evaluation in the Chinese school system, the effects of school-based sex-education programs are often unclear. To improve the evaluation of reproductive health information in the Chinese school system, a comprehensive, culturally sensitive program should be integrated into the junior high curriculum, focusing on accurate information on contraception and safe-sex practices. Prioritizing teacher training will ensure effective content delivery and counter misinformation. AI-based tools can personalize learning and identify gaps, allowing for targeted interventions. Regular assessments of student knowledge should be conducted to refine the program. Expanding access to internet-based counseling and telehealth services will provide crucial support to adolescent mothers, especially during public health crises.

Abortion history and marital status emerge as pivotal factors shaping adolescent births and impacting service acceptance, according to AI predictions. The unique social and cultural context in China plays a substantial role in influencing adolescent pregnancy. A noteworthy revelation from our study indicates that over half of the participants were married. These adolescents continued their pregnancies and gave birth, with parental support, which is consistent with the findings of a previous study in Hong Kong.⁴⁴ Participants without abortion experience showed a greater willingness to accept RHS in the current study. Another study in Taiwan indicated that several factors influence adolescents' decisions to terminate their pregnancies, including uncompleted studies, lack of financial support, peers and boyfriends providing relevant information about abortion, public opinion, and being abandoned by boyfriends.⁴⁵ Particularly for high-school students who are not financially independent, influence from their peers and boyfriends is a factor that leads to the choice of abortion. Designing and implementing more comprehensive internet-based psychological counseling and telehealth services is important, as these services can facilitate better communication, support, and care for adolescent mothers, even in times of crisis.

Study limitations and recommendations

The study's relevance extends beyond the pandemic, addressing critical issues in adolescent reproductive health, including contraception access, socio-cultural influences, and familial support in PPD. While pandemic-related disruptions in RHS are less urgent now, the AI application for predicting service acceptance and enhancing personalized care remains valuable, offering insights applicable in

both routine and crisis scenarios. The findings provide essential guidance for improving RHS.

Despite the study's significant findings, several limitations must be acknowledged. Firstly, the pandemic influenced the participation of adolescent mothers in postnatal check-ups, and the insufficient sample size may have affected the generalizability of the findings. Secondly, the data collection was confined to Taipei City, raising concerns about the representativeness of the sample due to its limited geographical scope. Lastly, we found that our participants frequently exhibited reluctance to fully express themselves, resulting in incomplete and missing data. Further research is needed to understand the long-term impacts of the COVID-19 pandemic on adolescent pregnancy and reproductive health outcomes. Policy and practice should prioritize ongoing monitoring and evaluation of RHS programs to identify gaps, measure effectiveness, and inform evidence-based interventions. This will facilitate continuous improvement and adaptation of services to meet the evolving needs of adolescents.

Conclusion

The COVID-19 pandemic led to a decline in hospital visits for adolescent births, but the RHS program proved instrumental in offering timely guidance. Notable factors influencing adolescent births, and the acceptance of related services included abortion history and ethnicity. These findings emphasize the importance of addressing multifaceted issues through holistic sex education, enhancements in healthcare provision, and the reinforcement of social support systems. These measures are essential for safeguarding the well-being of adolescent mothers and their children. The provision of telemedicine consultations and internet-based psychological counseling is poised to assume a pivotal role in facilitating these essential services in the future.

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Gurantor: SWC.

Informed consent: Prior to commencement, as this was retrospective medical records data, the requirement for obtaining written informed consent from all participants was waived by the ethics committee of Taipei City Hospital.

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