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ORIGINAL ARTICLE

Semen Quality and Fertility Rates in Taipei City

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Background: Although female factors are the major focus of attention for infertility, male factors are responsible for approximately 40% of infertility problems. **Aims:** The aim of this study is to investigate male infertility in Taiwan, establish a database of semen quality, and explore associations between semen quality and infertility. **Methods:** Results of semen tests of males who were examined at Zhongxiao Branch, Taipei City Hospital, between January 2008 and July 2015 were collected and analyzed retrospectively. All examination procedures and processing of human semen were performed according to the World Health Organization laboratory manual. Total semen volume and the concentration, motility, and morphology of sperm were evaluated and recorded. Pearson's correlation was used to explore associations between age and all semen parameters. **Results:** Significant differences were found in sperm concentration between the examined years ($P = 0.011$). Bonferroni post hoc analysis showed that the sperm concentration in 2012 decreased significantly ($P = 0.026$) compared to data of 2014. Age was significantly associated with sperm motility and morphology ($P < 0.01$). Normal test rates for semen in the study period were between 68.33% (2008) and 77.47% (2014). Total fertility rates were not associated with normal semen test rates in Taipei City, and no significant correlations were identified in any semen analysis parameters. **Conclusions:** No significant associations are found between normal semen test rates and total fertility rates from 2008 to 2015 in Taipei City. This study determined the baseline semen parameters of the general male population in Taipei City, but due to the multifactorial nature of fertility, more socioeconomic and biological factors need to be analyzed to investigate and solve the problem of low fertility rates.

Key words: Male infertility, semen parameters, semen quality

INTRODUCTION

Infertility has become a global health problem in recent years and is estimated to affect 30% of reproductive-aged couples worldwide to different degrees;[1] about 15% of couples are infertile and more than 10% are subfertile. Although the attention for infertility is often focused on female factors, male factors are responsible for infertility and subfertility in approximately 40%–50% of cases, respectively.[2-4] In Taiwan, the male factor infertility rate is 18.3%, as reported by the Health Promotion Administration, Ministry of Health and Welfare.[5] Inadequate production of motile and functional sperm may contribute up to 70% of these infertility cases.[6] Thus, semen analysis is still the most important diagnostic tool for the assessment of male fertility. The assessed semen parameters may include the number, motility, and viability of sperm. According to the World Health Organization (WHO) definition, male infertility is described as several different types, including oligozoospermia, asthenozoospermia, teratozoospermia, and combinations of these factors.[7]

Male infertility problems are worsening globally and the trend of rapid decline in semen quality is not slowing down. For example, sperm concentrations have decreased by 52.4%

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in the past 40 years from 1973 to 2011, with a slope of about 1.4% per year.[8] Furthermore, across several geographic regions of the world, a remarkable proportion of young men between the ages of 18 and 21 years have a subfertile range of sperm concentrations.[9] Because of the significant public health implications, performing studies of male infertility is needed urgently. The precise reasons for this continuing decline in semen quality are still unknown but appear to be related to environmental rather than genetic factors.[10] The many environmental factors reported to be associated with male infertility include stress, environmental toxins and hormones, smoking, alcohol consumption, dietary factors, and sequential obesity problems.[9,11]

Environmental factors include common ones found worldwide and specific ones regionally. In addition, as a reference for future investigations in reproductive physiology and pathophysiology, baseline characteristics of semen quality must be established first. Therefore, in the present study, we aimed to establish a database of semen quality in Taipei, Taiwan. The Childbirth Promotion Program of Taipei City supports birth and parental subsidies and prepregnancy health examinations aiming to increase the total fertility rate. Semen analysis, one test provided by the fertility workup, is an important item in this program. Semen analysis data were collected and analyzed in this study with the purpose of identifying associations between semen quality and fertility rates in Taipei.

METHODS

Materials

For the present study, total fertility rates of Taipei City for years 2008–2015 were accessed from household registration statistics data of the Department of Household Registration, Ministry of the Interior, Taiwan. In the Childbirth Promotion Program of Taipei City, males who are residents of Taipei City, married and without children, can attend any branches of Taipei City Hospital for free infertility examination. Between January 2008 and July 2015, a total of 823 male residents attended infertility examinations at the Zhongxiao Branch, Taipei City Hospital.

Ethical considerations

The protocol of this study was approved by the Institutional Review Board Committee of Taipei City Hospital (TCHIRB-10402105-E). All participant data were deidentified before retrospective review and therefore, signed informed consent was waived for the present study.

Semen sampling and preparation

After at least 3–5 days of complete sexual abstinence, the participants reported to the laboratory on sampling days. All procedures were performed according to the WHO laboratory manual for the examination and processing of human semen. Between 2008 and 2011, the fourth edition of the manual was used and after 2012, the fifth edition was followed.[7,12] Semen specimens were obtained by masturbation and collected in a plastic, nontoxic container. Before semen examination, the specimen containers are placed at room temperature for liquefaction, which usually occurs within 15–30 min.

Measurements

Semen analysis was conducted soon after liquefaction. The total semen volume, concentration, motility, and morphology of sperm were evaluated and recorded. The definitions of abnormal for each parameter followed the cutoff values of the WHO laboratory manual for the examination and processing of human semen, as follows: cutoff values of the fourth edition specify that semen volume lower than 2 mL is abnormal; and for spermatozoa evaluation, concentration lower than 20×10^6; motility, progressive motility (PR) plus nonprogressive motility (NP) below 50% or PR <25% are abnormal; and the percentage of normal morphology under 30% are defined as abnormal. Cutoff values of the fifth edition specify that semen volume lower than 1.5 mL is abnormal; and for spermatozoa evaluation, concentration lower than 15×10^6; motility, PR plus NP <40% or the percentage of normal morphology under 4% were defined as abnormal.[7,12]

Statistical analysis

Comparisons were made by one-way analysis of variance with Bonferroni *post hoc* analysis. Pearson's correlation was used to explore the associations between age and each semen parameter. All statistical assessments were two-sided, and $P < 0.05$ was considered statistically significant. Statistical analyses were performed using SPSS version 23 statistics software for Windows (IBM Corp., Armonk, New York, NY, USA).

RESULTS

Table 1 presents the characteristics of semen quality. Significant differences were found in sperm concentration between the examined years ($P = 0.011$), with the highest concentration ($82.12 \pm 52.42 \times 10^6$/mL) shown in 2014, and the lowest concentration ($62.15 \pm 42.01 \times 10^6$/mL) shown in 2015. Results of Bonferroni *post hoc* analysis showed that sperm concentration in 2012 was significantly lower than that in 2014 ($P = 0.026$). Participants' age, semen volume, sperm

motility, and morphology were not significantly different between the examined years (all, $P > 0.05$).

Analysis of patients' age and parameters of semen quality revealed that age was significantly associated with sperm motility and morphology ($P < 0.01$). Semen volume was significantly associated with both the concentration and motility of the sperm ($P < 0.01$). Sperm motility and morphology also were significantly correlated with sperm concentration ($P < 0.01$), and sperm motility and morphology also correlated significantly ($P < 0.01$) [Table 2].

Table 3 displays data from 2008 to 2011, showing the trend of abnormality from 2008 to 2015. No significant changes were found in trends by years of these parameters; normal test rates for semen were between 68.33% (2008) and 77.47% (2014); abnormal test rates for semen volume were between 0.83% (2008) and 11.57% (2013); abnormal test

Table 1: Characteristics of semen of male residents of Taipei City, 2012-2015

Examine year	2012	2013	2014	2015[a]	*P*
Participants numbers	101	121	142	57	
Age (year)	33.33±4.43	33.27±5.35	33.8±4.17	34.93±4.84	0.133
Semen volume (mL)	3.06±1.51	3.12±1.58	3.39±1.77	3.14±1.97	0.354
Sperm concentration (10^6/mL)	64.16±52.46	70.85±42.44	82.12±52.42	62.15±42.01	0.011*
Sperm motility (PR/total number)	56.92±17.53	56.07±17.45	57.59±18.86	56.75±19.99	0.928
Sperm morphology (normal form/total numbers)	52.97±12.49	51.32±10.58	50.95±10.93	49.74±11.00	0.312

Data are presented as mean±SD. [a]Data of 2015 were collected from January to July. *A significat difference among examine years, $P<0.05$. SD=Standard deviation; PR=Progressive motility

Table 2: Correlations between patients' age and the parameters of semen quality. Age was correlated with the motility and the morphology of sperm significantly; semen volume was correlated with both the concentration and the motility, and sperm concentration, motility and morphology were associated with each other

Parameter	Statistics parameter	Age	Semen volume	Sperm concentration	Sperm motility	Sperm morphology
Age	*r*		−0.63	−0.61	−0.163*	−0.227*
	P		0.194	0.215	0.001	0.000
	n		421	421	421	421
Semen volume	*r*			−0.141*	0.130*	0.073
	P			0.004	0.007	0.135
	n			421	421	421
Sperm concentration	*r*				0.359*	0.492*
	P				0.000	0.000
	n				421	421
Sperm motility	*r*					0.787*
	P					0.000
	n					421

*A significat correlation, $P<0.01$

Table 3: Normal test rate of semen analysis and the abnormal test rate in each parameter, 2008-2015

Examine year	2008	2009	2010	2011	2012	2013	2014	2015[a]
Participants numbers	120	135	155	112	101	121	142	57
Normal test rate[b] (%)	68.33	72.59	74.19	69.60	70.30	75.21	77.47	71.93
Abnormal semen volume test rate (%)	0.83	2.22	1.29	9.80	5.94	11.57	7.75	8.77
Abnormal sperm concentration test rate (%)	8.33	5.18	5.16	4.50	17.82	5.79	5.63	12.28
Abnormal sperm motility test rate (%)	15.00	16.29	14.83	19.60	13.86	14.88	16.20	21.05
Abnormal sperm morphology test rate (%)	0	0	0.64	0	0.99	0.83	2.11	1.76
Not accessed	7.50	3.70	8.38	4.50	0	0	0	0

[a]Data of 2015 were collected from January to July, [b]Normal test was defined as all four parameters should be normal

rates for sperm concentration were between 4.50% (2011) and 17.82% (2012); abnormal test rates for sperm motility were between 13.86% (2012) and 21.05% (2015); and abnormal test rates for spermatozoa morphology were between 0% (2008, 2009, and 2011) and 2.11% (2014) [Table 3].

In Taiwan, 2012 was the Chinese "Year of the Dragon," which conventionally means to Taiwanese people that being born in a Dragon year will bring luck and a better life. For this reason, the total fertility rate of that year may be increased. Furthermore, since the pregnancy period of 9 months is close to 1 year, the effects of semen quality on total fertility may appear in the next year; thus, the analyzed year of fertility should be transited by 1 year. For example, if the correlation analysis uses semen quality data of 2008, then total fertility data are predicted for the following year, 2009. To diminish the potential effects of a Dragon year, correlation of the total fertility rate and the semen normal rate were analyzed by different approaches: all 7 years were included, excluding the data of 2012, transitioned by 1 year later and combined exclusion data of 2012 and the transition year. These results are shown in Table 4. No significant correlations were identified in any sperm parameters, and the total fertility rates were not associated with normal semen test rates in Taipei City.

DISCUSSION

The total fertility rate is defined as the average number of live births per woman within a given period. All over the world, both mature and newly industrialized countries have experienced a decline in total fertility rates for the past several decades. Among total fertility rates, 2.1 is the rate that is considered necessary to sustain the population size. However, the current total fertility rates reported by many countries are far <2.1. In the European Union, the United States, Japan, Hong Kong, and Singapore, all total fertility rates range from 1.0 to 1.5 at present, which is regarded as a very low fertility rate.[10] Less than 1.3 is considered the lowest-low fertility rate.[13] As we have shown [Supplementary Table 1], the total fertility rate of Taipei City during the 7 years from 2008 to 2014, the total fertility rates were <1.3, which indicates the severity of the infertility problem. Reproductive health affects the fundamental factors of a population, the economy, and social structures and hence that the public health status may become problematic when the fertility rate is not appropriate.

Table 4: Correlation between total fertility rates and semen normal rates in Taipei City

y	x	Number of involved years	*r* of correlation	*P*
Total fertility rates	Normal test rate	7	0.176	0.707
Total fertility rates	Normal test rate, without data of "Dragon" year (2012)	6	0.449	0.372
Total fertility rates	Normal test rate, transition by 1 year later	6	0.240	0.647
Total fertility rates	Normal test rate, transition and without "Dragon" year	5	0.595	0.289

Studies about the factors associated with low fertility rates have indicated the complexity of this issue. Not only do the medical factors, including physiological and pathological factors in both partners of the couples, play an impressive role, but the social, economic and psychological factors are also involved and are changing over time. The complex interaction between these factors makes the research difficult. In the present study, we aimed to focus on the male factors, the semen quality, in particular, attempting to simplify the research process by establishing a database of semen quality over a period of years. However, the factors that may affect the semen quality parameters are still too numerous. We did not find any obviously similar trends between the annual abnormal rates of each semen parameter and smoking rates, consumer price indexes, particulate matter concentrations, and sulfur dioxide concentrations, which are shown in Supplementary Table 1. For example, the sperm concentration in 2014 was significantly higher than the concentrations of other years, but no significant differences were found in smoking rates, consumer price indexes, and air pollution factors of the same year when compared with the other years, although these factors have been known to be associated with semen quality. Environmental chemicals and lifestyle factors, including stress, sleep, smoking, and nutrition, can affect sperm production.[14-16] The study results may reflect that these factors have an impact on sperm production throughout the lifetime; thus, longer observation periods are essential.[17]

In the present study, age was significantly associated with all semen quality parameters that we evaluated. The effect of aging on male fertility has been recognized in several reports and reviews,[18] documented through decreases in sperm cell counts, motility and the deterioration of testicular histological architecture,[19] and probably due to decreases in testosterone levels. The decline in testosterone as a response to luteinizing hormone stimulation is a natural phenomenon in the physical course of aging.[20,21] In addition, changes in body composition during aging leads to obesity and metabolic disorders such as Type 2 diabetes and metabolic syndrome, which are all associated with decreased levels of free testosterone.[22,23] The impact of these factors is very obvious, since our population is restricted to Taipei City male residents who are married and without children, and within a limited age range of about

30s, the correlation between age and semen quality is still significant.

The results of correlation analysis revealed no significant findings between the normal semen test rate and the total fertility rate, which were both crude and adjusted by removing data of the "Dragon" year and/or the transition year. Because of the multifactorial nature of infertility, it is not unusual to find that semen quality correlated poorly with the total fertility rate. Usually, a medical classification system is expected to correlate with clinical outcomes, suggesting that the relevance between the WHO classification and the probability of conception considering male infertility, as well as the spontaneous pregnancy rate or the pregnancy rate after artificial reproduction is poor.[24] Both socioeconomic and biological factors contribute to the low fertility phenomenon.

Investigating the effects of the availability of efficient contraceptive methods, delayed family initiation, less desire or less opportunity to raise children and other socioeconomic causes, is especially difficult.[10] Clearly, we must include more variables of socioeconomic factors to adjust our results appropriately in future studies. Furthermore, the present study did not include the female status and related factors, which may also be an important limitation. Approximately half of infertility is attributed to female factors with clear reasons, including the abnormalities of the endocrine system and hormones, as well as uterine, cervical, and oocyte abnormalities. The Childbirth Promotion Program of Taipei City also supports female infertility examination, and these data might be useful for further analysis. Other end points, for example, total pregnancy rate, which includes both live births and induced abortions, might reflect more precisely the fecundity of the population than the total fertility rate.[25] Time to pregnancy may be considered as well, since this may be more highly associated with semen quality, especially the subfertility status of semen.[26] Studies of assisted reproductive technology have indicated that the WHO classification might not be the best tool by which to evaluate semen quality, and the total motile sperm count has been reported to have a greater predictive value than WHO cutoff values for pregnancy outcomes in couples undergoing intracytoplasmic sperm injection,[27] intrauterine insemination.[28] Conventional *in vitro* fertilization[29] and spontaneous pregnancy in infertile couples.[30]

CONCLUSIONS

This study has provided baseline semen parameters of the general male population in Taipei City. No significant associations are found between normal semen test rates and total fertility rates from 2008 to 2015. Because of the multifactorial nature of fertility, more socioeconomic and biological factors need to be analyzed to investigate and solve the problem of low fertility rates. Further collection and analysis of appropriate data may help to modify the policy of childbirth promotion with the goal of increasing the fertility rate in Taiwan in a reasonable and productive way.

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Conflicts of interest

There are no conflicts of interest.

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Supplementary Table 1: Statistics of Taipei City during 2008 and 2014

Year	2008	2009	2010	2011	2012	2013	2014
Total fertility rates (%)	0.98	0.94	0.90	1.20	1.41	1.21	1.35
Smoking rate, male (%)	35.09	27.13	24.27	29.70	25.54	35.17	-
Consumer price index	99.07	98.10	98.59	100.00	101.63	102.46	104.18
Consumer price index, annual growth rate (%)	3.40	−0.98	0.05	1.43	1.63	0.82	1.68
Air quality, particulate matter ($\mu g/m^3$)	50.17	50.09	49.91	44.45	37.93	37.34	7.66
Air quality, sulphur dioxide (ppm)	0.003	0.003	0.003	0.003	0.003	0.003	0.003