

Offspring sex ratios among male tobacco smokers in Khartoum, Sudan

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Abstract

Objectives: To explore any association between paternal tobacco smoking and the offspring secondary sex ratio, as well as the effect of duration and intensity of smoking on gender ratio.

Methods: The cross-sectional study was conducted around major public areas within Khartoum, Sudan, between August and September 2008 and involved 458 married Sudanese males with offsprings. The sample consisted of 111 (24.2%) smokers and 347 (75.8%) non-smokers who were evaluated using a questionnaire on their offspring gender. Data on duration and intensity of smoking was also collected from the smokers' group. SPSS 16 was used for statistical purposes. Chi-square test was used to test for significance of associations between variables. Analysis of variance (ANOVA) was used to test for significance between ratios.

Results: The number of cigarettes smoked in males increases the likelihood of having a male offspring. The gender ratio in non-smokers was 1.11, while it was 1.15 in smokers.

Conclusion: Paternal smoking increases the offspring sex ratio.

Keywords: Gender ratio, Sudan, Offspring. (JPMA 62: 1045; 2012)

Introduction

Many environmental conditions and factors have been known to alter the human sex ratio in different ways, though the mechanisms by which specific factors do so are much less well documented.

The secondary sex ratio is defined as the proportion of male to female births or the number of male births per 100 female births. Worldwide there is a slight male excess of births, and, hence, a relatively high secondary sex ratio. The reason for this male predominance has been the subject of various studies and many theories have been put forward.

Several studies have suggested that the male excess in human births is not due to any consistent bias in spermatogenesis or fertilisation. There is no male excess at fertilization. The excess appears at the time of clinical recognition of the pregnancy due to the "preferential loss of females during embryogenesis".¹ In mammalian embryos, the stage before clinical recognition is more rapid in male embryos than in female embryos,² thus a male excess is clinically recognizable.³

Evidence was put forward stating that "there are circumstances under which unequal numbers of male and female zygotes are formed".⁴ Another area of research involves the changes in the secondary sex ratio which have been reported in various countries. Over 45 years, there was a decrease in the secondary sex ratio in 16 countries (mainly northern and eastern European countries as well as Portugal, Greece and Mexico).⁵ Reasons for the apparent deviation from what is customary, as was found by studies,⁵ need to be explored.

In Japan, a study to determine the effect of methyl mercury pollution on the secondary sex ratio of offspring in Minamata City showed a decrease in male births overall, as well as an increase in the number of male stillborn fetuses.⁶ The decrease in male births was significant when the mother and father or only the mother were exposed to methyl mercury pollution, but not when only the father was exposed. The study concluded that perhaps "male fetuses were more susceptible to the pollution than their female counterparts".

In New York City, the effect of stress and anxiety caused by the September 11, 2001 attacks on the secondary sex ratio was evaluated.⁷ It was found that the ratio fell significantly (to a sex ratio of 1) during the period between the January 1, 2002 and January 8, 2002 (about 4 months after the attacks). This supports the idea that male foetal losses⁸⁻¹¹ were responsible for the decrease in the secondary sex ratio.

Tobacco smoking was the target of this study due to its ever-growing prevalence as a personal habit as well as being a practice which has been found to alter the physiology of the body in a vast number of ways — contributing to countless

pathological processes.

A study exploring the relationship between the smoking habits of both parents and the likelihood of their offspring being a male or female found a decrease in the sex ratio when either one or both parents smoked more than 20 cigarettes per day compared with couples in which neither parents smoked.¹² In conclusion, they stated that "peri-conceptional smoking of the parents reduces the frequency of conceiving male children". Despite these findings, a study in Hong Kong found that "the male-to-female sex ratio was higher for infants whose fathers smoked than for those who had non-smoking fathers".¹³

On the other hand, a study involving 2 cohorts of children born between 1984 and 1987, and 1990 and 1999 showed that "no association between paternal and maternal smoking habits around the time of conception and sex ratio in the offspring (existed)".¹⁴ A study in Italy found that the sex ratio was lower, though not statistically significant, in offspring of women smoking more than 20 cigarettes per day and offspring of both-smoking parents.¹⁵

Interestingly, a prospective study of newborns born between 1993 and 2002 to assess the offspring sex ratio in smoking and non-smoking mothers in relationship to parity yielded a distinct set of results.¹⁶ It showed that more males were born in primiparous smokers and women with parity more than or equal to 3 compared to the non-smokers. However, it is important to stress that this study was based on the smoking status of the mother only, and thus any possible effects of paternal smoking were not included.

It is possible that these factors may influence parental hormone levels in such a way that more offspring of a certain sex predominate atypically. It has been hypothesised that there is a relationship between high levels of paternal testosterone (and possibly low levels of gonadotrophins) and a higher probability of having a son, and that low levels of oestrogen and testosterone are associated with a higher probability of having a girl.¹⁷ It has also been suggested that smoking in females has an antiestrogenic effect.¹⁸ It can thus be assumed that the decrease in oestrogen in females caused by smoking would lead to a higher probability of having a girl and thus decreases the sex ratio. Whether it is possible that smoking affects paternal hormone levels in such a way that would alter the sex ratio is not yet established.

This study was planned to find an association between paternal tobacco smoking and the offspring secondary sex ratio in Khartoum, Sudan.

Subjects and Methods

Married Sudanese males with offspring were the main targets of the study. Males were chosen as a target population because the study aimed at relating the effect of smoking

(exposure) on the gender of the child (outcome) which is genetically determined by the paternal sex chromosome.

The study was undertaken in various parts of the three cities within the Khartoum State — Khartoum, Khartoum North and Omdurman. Data was collected from participants passing by major public places, such as hospitals, restaurants, public transportation areas, universities, etc. The data was collected between August and September 2008.

The sample consisted of 458 married Sudanese males with offspring chosen by convenience sampling. These included smokers and non-smokers with offspring of either gender. The sample size was not calculated before the study began. Consent to present and publish the contents of the main study was obtained.

During each study visit for data-collection, questionnaires were given to randomly chosen individuals who comprised the study population. Variables of the study were recorded through the questionnaires and organised according to outcome and exposure. Subjects were grouped into 'Smokers' and 'Non-Smokers' and then further according to age. The subjects were divided into five groups on the basis of their age: A= 18-25 years; B= 26-35 years; C= 36-45 years; D= 46-55 years; and E= >55 years.

Number of cigarettes smoked per day was also included as a variable for the 'Smokers' group. The year in which the subject began smoking and the year in which the subject got married were also included. Ratios of male:female offspring were calculated for the smokers and the non-smokers as well as for each age group. The average numbers of cigarettes within each age group were also determined.

Tests of statistical significance on the differences between offspring sex ratios in smokers and non-smokers were analysed using SPSS 16. Chi-square test was used to test for significance of associations between variables, while analysis of variance (ANOVA) was used to test for significance between ratios.

Results

Out of 458 subjects, 111 (24.2%) were smokers and 347 (75.8%) were non-smokers and the overall offspring sex ratio in non-smokers was 1.111765 and 1.149171271 in the

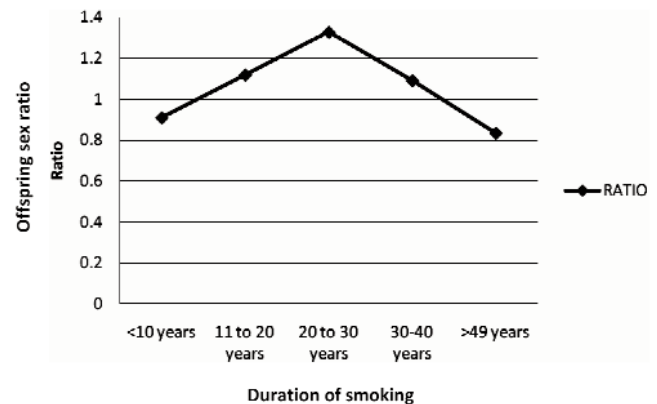


Figure-1: Effect of the duration of smoking on the offspring sex ratio.

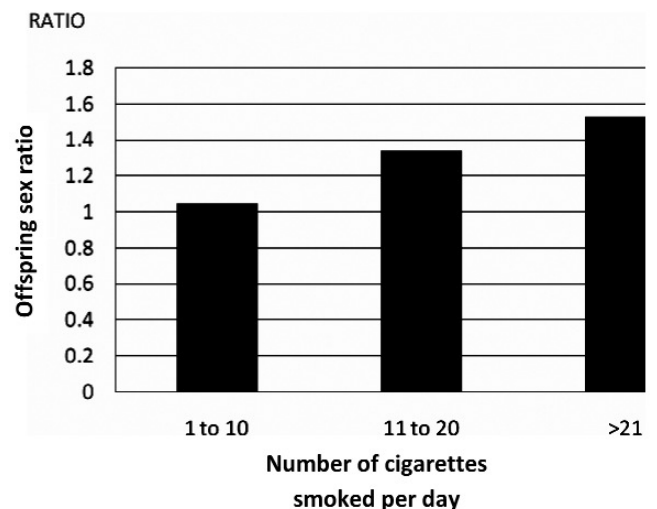


Figure-2: Effect of the number of cigarettes smoked per day on the offspring sex ratio.

smokers.

The highest offspring sex ratio was seen in age group 'B' (1.58) in the smokers, and the lowest in group 'A' (0.46) in the non-smokers (Table).

In terms of the effect of the duration of smoking on the offspring male-to-female sex ratio, there was a steady increase with the increase in the duration of smoking. The highest ratio

Table: Offspring sex ratio according to age groups in smokers and non-smokers.

Age Group	Smokers			Non-smokers		
	No. of Offspring	Male-Female%	Ratio	No. of Offspring	Male-Female%	Ratio
A. 18-25	3	33.3/66.7	0.5	22	31.8/68.2	0.466666667
B. 26-35	80	61.3/38.8	1.58064516	183	53.0/47.0	1.127906977
C. 36-45	168	51.2/48.8	1.04878049	497	51.5/48.5	1.062240664
D. 46-55	91	56/44	1.275	455	54.7/45.3	1.208737864
E. >55	47	44.7/55.3	0.80769231	279	52.7/47.3	1.113636364
Total	389	53.5/46.5	1.14917127	1436	52.6/47.4	1.111764706

was from 20-30 years duration and then steadily fell to reach its lowest at >49 years (Figure-1).

The data showed an obvious increase in the sex ratio with the increase in the number of cigarettes smoked per day (Figure-2).

Discussion

The most prominent finding of the study was a steady increase in the male to female ratio with increasing number of cigarettes consumed per day. However, unlike other studies,¹⁹ we found only a slight difference between the overall offspring sex ratios in the non-smokers (1.11) and the smokers (1.15). From these results it is possible to conclude that in the smokers, the number of cigarettes consumed per day significantly increases the likelihood of conceiving more males than females (sex ratio = 1.52 in those smoking more than 21 cigarettes per day), but, interestingly, the duration of smoking does not seem to have the same effect. In relation to duration of smoking, the ratio climbed steadily from 0.90 to a peak of 1.32 in those smoking for 20-30 years, but then fell to 0.83 in those smoking for more than 49 years.

It has been suggested that high levels of paternal testosterone increase the likelihood of conceiving a male and thus increases the sex ratio.²⁰ Therefore if the link between smoking and offspring sex ratio can be attributed, at least in part, to levels of parental hormones, then it can be postulated that, based on our findings, smoking somehow increases the levels of paternal testosterone with a subsequent increase in the offspring sex ratio. The suggested positive correlation between smoking and testosterone levels has also been concluded in other studies.^{21,22} Other studies have found no significant increase in bio-available testosterone, but increase has been reported in total testosterone levels in male smokers.²³ A very interesting theory on how levels of sex hormones can act as confounders in cross-sectional studies (such as the current one) states that when testing the association between an exposure such as smoking and a hormone-dependent condition (in this case an alteration of the sex ratio), the character trait known as "sensation-seeking" must be considered.²⁴ Patients with this largely genetically determined trait are much more likely to pursue risky behaviour, such as smoking, and have a higher level of testosterone than controls. It is important to note that while these patients have high testosterone levels when they start smoking, the levels were found to decline (more rapidly than in the non-smoking controls) with time and number of cigarettes smoked.²⁵ Further extensive research is needed to prove this link and to determine the mechanism by which tobacco smoke modifies paternal hormones in this manner.

If this is assumed to be the case, then the effect of tobacco smoke, based on our results, is most likely related to the concentration of tobacco substances in the body (i.e. the number of cigarettes smoked per day) and not to prolonged

exposure (i.e. duration of smoking). However, the pattern of the sex ratio in relation to duration of smoking (starts low, steady increase then decrease) may be explained by a physiological pattern of hormone levels influenced by tobacco smoke. This is because: individuals smoking for less than 10 years have relatively low testosterone levels; individuals smoking for 20-30 years have relatively high testosterone levels; and individuals smoking for more than 49 years have relatively low testosterone levels.

This pattern may be due to the age of the individuals. Those smoking for less than 10 years are more likely to be younger than those smoking for 20-30 years, while those smoking for more than 49 years are more likely to be even older. This may affect hormone levels. In addition, it was found that in both the smokers and the non-smokers, the highest sex ratios were found in the age groups in the middle (26-55 years of age). Thus, perhaps testosterone levels are normally high in this age group ("normally" indicating the non-smoker group) and that the effect of smoking is to further increase these levels (as seen in the 'smokers' group). This would mean that the other age groups (18-25 years, and more than 55 years - who had low sex ratios in both smokers and non-smokers) have low testosterone levels normally which are also increased by smoking - but not to a level approaching the middle-age groups. This may explain the reason for the effect of duration of smoking on the sex ratio.

In terms of limitation, the sample size was not calculated using any known method, but was determined on grounds of feasibility alone.

Conclusion

The amount of tobacco smoked in males increases the likelihood of conceiving a male - that is to say, increases the offspring sex ratio.

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