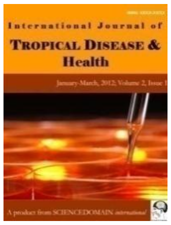

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An Analysis of Seasonal Variation and Climatic Influences on the Male to Female Ratio of Live Births in Malta

Grech Victor[1*] and Borg Tania[1*]

[1]*Department of Paediatrics, Mater Dei Hospital, Malta and National Statistics Office, Valletta, Malta.*

Authors' contributions

This work was carried out in collaboration between both authors. Author GV did the study design, wrote the protocol and performed literature searches. Author BT did the statistical analysis. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: In humans, male births occur in excess of female births. The ratio of male births to total births (MFR) is expected to approximate 0.515. Many factors have been shown to influence MRF and a seasonal pattern has also been described. This study was carried out in order to ascertain whether seasonal variation in MRF exists in Maltese live births and whether environmental influences exert any role.
Methods: Monthly live births subdivided by gender, were obtained from official Maltese government publications for the period 1958-2013. Analysis was carried out with SPSS, the Bio-Med-Stat Excel add-in for contingency tables and Demetra, using chi square tests, ANOVA, Freidman and Kruskall-Wallis tests, correlation, regression, and ARIMA models. Mean annual temperatures were available to 1958. Monthly data for maximum and minimum monthly temperatures, relative mean humidity, lowest relative humidity, hours of bright sunshine and rainfall was only available for 2001 to 2012.
Results: This study analysed 297254 live births (153652 males and 143602 females, MRF 0.5169,

*Corresponding author: Email: victor.e.grech@gov.mt, tania.borg@gov.mt;

95% CI 0.5151-0.5187). MRF exhibited a non-significant bimodal pattern (June and December peak). MRF displayed a significant negative correlation between MRF and average mean yearly temperature (p=0.049). There was an association between monthly mean relative humidity and MRF (p = 0.03).

Discussion: The nonsignificant seasonal pattern seen accords with that previously documented for other countries but the negative MRF correlation with mean annual temperature goes contrary to that previously documented in other countries. The humidity association has not been previously described.

Conclusion: Some seasonal variation may exist in MFR in Malta.

*Keywords: Malta; birth rate/*trends; periodicity; infant, newborn; sex ratio; seasons.*

1. INTRODUCTION

In humans, male births occur in excess of female births. The ratio of male births to total births (conventionally but erroneously referred to as MRF) is expected to approximate 0.515 [1]. The reason for this disparity is uncertain and the number of factors implicated are legion [1,2].

MRF has also been shown to exhibit seasonal variation. It has been postulated that this accedes to the Trivers-Willard hypothesis. Briefly, evolutionary theory proposes that mutations produce some individuals who may be fitter in a given environment and who are therefore likelier to survive and procreate, dispersing their advantageous genes. One such adaptation could be the ability of the individual to influence one's own MRF birth outcomes.

In polygynous species, only the fittest males reproduce. For this reason, parental investment in a "good quality" son may yield greater numbers of descendants than an equivalent investment in a "good quality" daughter. It may therefore be advantageous for a mother to produce sons when she has sufficient resources to give them a better than average edge that will then give them a greater chance to reproduce. And to produce daughters when she does not. This is known as the Trivers-Willard hypothesis [3].

Thus, the male excess has been shown to decrease when populations are stressed, and vice-versa [4]. Temperature has also been implicated as influencing MRF. Cold weather is an environmental stressor, acting directly on those who do not have adequate access to shelter. Such conditions also cause indirect influence, stressing populations by disrupting economies [5]. It has also been shown that cold weather exacerbates the effect of other stressors, particularly in unseasonably cold summer months, since such conditions mitigate against restorative behaviours [5].

According to the Trivers-Willard hypothesis, both direct and indirect mechanisms may cause pregnant females to abort frail male fetuses, lowering MRF. Indeed, European data for the period 1865-2003 shows an increase in MRF in warm years [6]. More specifically, a study of the Sami people (the only indigenous Scandinavian race) showed that a 1°C increase in mean temperature yielded 1% more sons annually [7].

It has also been shown that a 1°C increase in annual temperature predicts one more male than expected for every thousand females born in a given year [5]. For these reasons, it has been speculated that MRF may be a more environment sensitive indicator than fecundity [8]. Moreover, it has also been shown that more males are born in the spring and summer, possibly due to the fact that during this period of the year, food is more abundant [9].

This study was carried out in order to ascertain whether seasonal variation in MRF exists in Maltese live births and whether environmental influences exert any role.

2. METHODS

Monthly live births subdivided by gender, were obtained from official Maltese government publications for the period January 1958-December 2013 [9,10]. The quadratic equations of Fleiss were used to calculate exact 95% confidence limits [11]. The Statistical Package for Social Sciences (SPSS) was used to calculate correlations. Chi tests and chi tests for trend were used for trend testing of male and female births using the Bio-Med-Stat Excel add-in for contingency tables [12].

Seasonality pattern of data was analysed by analysis of variance (ANOVA) via SPSS. Prior to ANOVA testing, seasonal and annual trend patterns were plotted and a number of tests were carried out on the data to check for normality, homogeneity of variance and outliers, along with visual inspection (Fig. 1). Serial ANOVA was carried out with different period lengths: 1, 2 and 3 month groups. ANOVA was carried out on single years and then repeated for 2, 5 and 10 year cohorts at the different period lengths mentioned.

Seasonality was also analysed using Demetra (version 1.0.4.323) and a model based method (Tramo/Seats) was operated to fit an Autoregressive Integrated Moving Average (ARIMA) model to the data. Freidman and Kruskall-Wallis tests were used to test stable seasonality, while a further evolutive seasonality test was used to test moving seasonality. Data was grouped as in the case of ANOVA analysis.

Correlation and regression analysis were carried out between mean ambient temperature and MRF. Comparisons were made between estimated month of conception (9 months prior to recorded birth) and mean monthly temperatures. Any association between MRF and various environmental forces other than mean temperature was also investigated.

Monthly data for maximum and minimum monthly temperatures, relative mean humidity, lowest relative humidity, hours of bright sunshine and rainfall was only available for 2001 to 2012 and Spearman correlation was used on this short data range.

A p value <0.05 was taken to represent a statistically significant result. The null hypothesis was that there was no seasonal variation in MRF in Malta and that MRF was uninfluenced by climatic variation.

3. RESULTS

This study analysed 297254 live births (153652 males and 143602 females, MRF 0.5169, 95% CI 0.5151-0.5187). MRF exhibited a bimodal pattern with peaks in June and December (Fig. 2) but these peaks were not statistically significant. Total births and MRF appear to move in opposite directions but there was no significant correlation between these two variables.

All ANOVA assumptions were tested and verified. Normality assumptions were verified with the Q-Q plot, and the equal variance assumption was tested by the Levene's test. ANOVA showed no statistically significant associations between the different period lengths (1, 2 and 3 month groups) at single years. Seasonality was not present either in the 2, 5 or 10 year age cohorts.

Failure for seasonal pattern was also verified by the time series modeling. Notwithstanding this, the time series model ARIMA (0,1,1)(0,1,1) was fitted on the 2 month and quarterly group for the 5 year age cohorts, at p = 0.001. For the 2 month group, the model parameters were explained by the regular MA = 1 -0.6663 B (p = 0.001) and the seasonal MA = 1 -0.999 S (p = 0.001) (Table 1). The 5 year age cohorts quarterly group were described by the regular MA = 1 - 0.64403 B (p = 0.0001) and the seasonal MA = 1 - 0.8954 S (p = 0.005) (Table 2). However, for both models the further tests done on seasonality patterns indicated that there was no evidence of stable or moving seasonality.

Table 1. Parameter estimates of ARIMA (0,1,1)(0,1,1) model of the 2 month group - 5 year age cohorts

Parameter	Value	Std error	T-stat	P-value
Th(1)	-0.6663	0.0987	-6.75	0.001
BTh(1)	-0.999	0.1115	-8.96	0.001

Table 2. Parameter estimates of ARIMA (0,1,1)(0,1,1) model of the quarterly group - 5 year age cohorts

Parameter	Value	Std error	T-stat	P-value
Th(1)	-0.644	0.1493	-4.31	0.0001
BTh(1)	-0.8954	0.2975	-3.01	0.0045

Although there was no apparent seasonality in MRF with time, correlation analysis showed a significant correlation between annual MRF and average mean yearly temperature (r = -0.23, p = 0.049 – Table 3, Fig. 3). The regression equation from Fig. 3 (Y = -0.0029x + 0.5719, where x – mean annual temperature, Y – annual sex ratio) confirmed that an increase in the annual average temperature, resulted in a decrease in MRF.

There were 48277 births available for analysis for the period 2001 to 2012. Analysis of the various climate characteristics on a monthly basis indicated that there was an association between monthly mean relative humidity and MRF (Spearman Rank correlation coefficient rs = 0.154, p = 0.03 – Fig. 4).

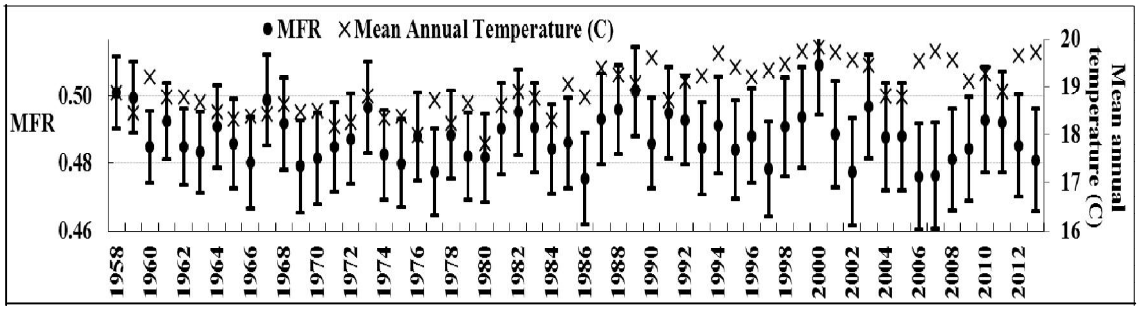

Fig. 1. Seasonal and trend pattern for annual sex ratio - %: 1958 – 2013

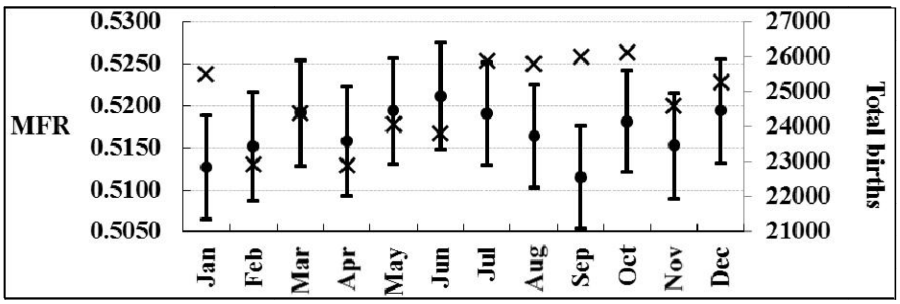

Fig. 2. Monthly totals for MRF and live births in Malta, January 1958-December 2013

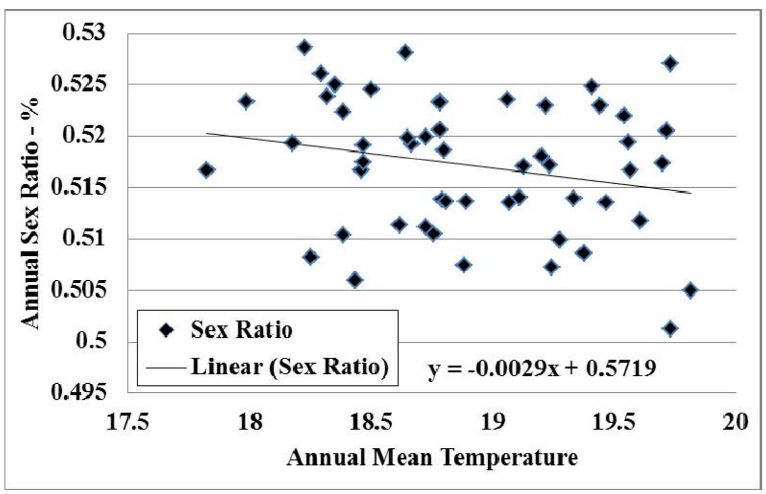

Fig. 3. Annual sex ratio versus annual mean temperature: 1958 – 2010 (p = 0.049)

Table 3. The effect of environmental characteristics on monthly MRF: 2001 – 2012

Environmental characteristic	Spearman rank correlation coefficient	p
Mean monthly relative humidity	0.154	0.03
Lowest monthly relative humidity	0.07	0.20
Mean monthly temperature	-0.095	0.13
Highest monthly temperature	-0.091	0.14
Lowest monthly temperature	-0.097	0.12
Mean hours of monthly bright sunshine	-0.101	0.11
Total monthly rainfall	0.068	0.21

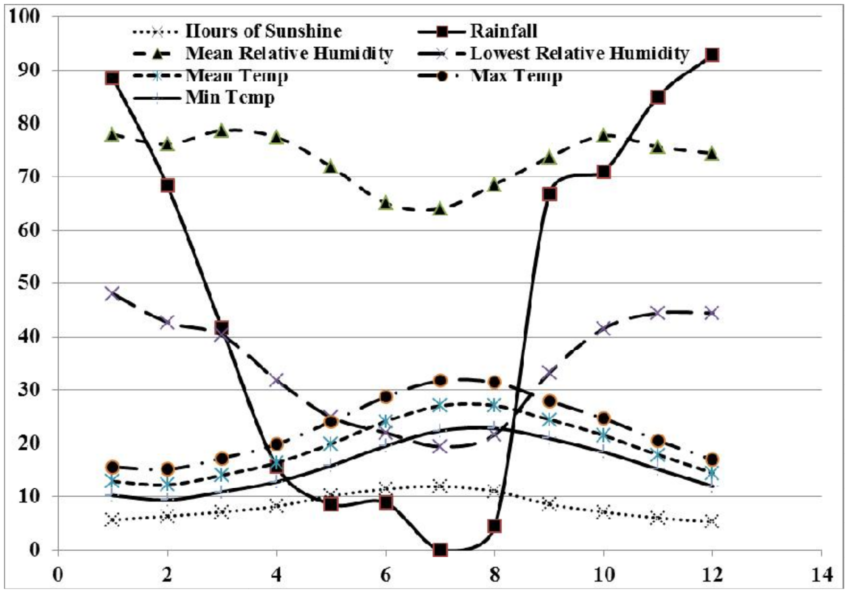

Fig. 4. Average monthly environmental characteristics and sex ratio 2001–2012

4. DISCUSSION

Seasonality in MRF has been previously described in other countries. For example, a highly significant seasonal pattern was found in western Siberia, with a peak in the second and a trough in the fourth quarter of the year [13]. This type of periodicity was also noted in Germany for the period 1946-1995, [14] a phenomenon that had been discovered in an earlier study in the same country over a shorter the time-frame 1946-1967 [15]. Intriguingly, seasonal variation (with a higher MRF in spring) was demonstrated in a smaller study in academic mothers, and less so in non-academic mothers employed at the University of Vienna [16]. Malta also exhibits seasonal MRF variation but this does not reach statistically significant levels. These results may be due to the relatively small number of births in the archipelago, resulting in a type 2 error.

In Italy, it has also been shown that MRF seasonality was influenced by pregravid maternal weight. Two seasonal peaks (March and October) were noted for births with low pregravid maternal weight and a single peak (October) was noted for births with a high pregravid maternal weight [8].

Another Italian study noted that MRF calculated at the time of conception showed a seasonal rhythm with peak values in September [16] this also supports the Trivers-Willard hypothesis which proposes that the male excess increases under favourable reproductive conditions [3].

Ambient temperature influences on MRF may have long-term effects. It has been shown not only that MRF is influenced by ambient temperature, but also that males from cold-stressed cohorts who have experienced cold weather *in-utero* culling have, on average, longer life expectancies. This has been calculated as an average decrease in male life-span by 14 days per 1°C increase from one year to the next among those who survived to one year of age [5].

These findings are reinforced by reports that cold conditions result in an excess of preterm deliveries and reduced birth weights [17]. Indeed, it has been hypothesised that ambient temperature may influence sex determination by somehow influencing the success rate of X- and Y-bearing sperm. Thus, the reason for locating the testicles outside the body cavity in most male mammals may somehow be related to gender determination [18].

The opposite trend was shown in this study in that overall warmer years were associated with a lower MRF. We are unable to explain why mean monthly relative humidity correlated positively with monthly MRF, a phenomenon that has not been described in the literature, and this may be a false positive result.

Interestingly, it has also been shown that maternal gonadotropin levels are dependent on variations in light stimulation [19] and that the seasonal variation in MRF is synchronous with dizygotic twinning rates. It has therefore been speculated that both factors may be influenced by maternal gonadotrophin levels [2].

The total number of births also hints at seasonality [20]. Proposed explanations for this periodicity have included temperature effects and photoperiod. It has been mooted that the latter may influence hormonal concentrations, sperm quality and/or sexual activity [21]. However, it has been shown that seasonality of births is also affected by socio-demographic factors. For example, in the Czech Republic for the period 1989-1991, birth peaks were noted in March to May with troughs in October to December. This variation was more pronounced in mothers who were 25-34 years old, had a higher level of education, were married, and were pregnant with their second or third child. However, seasonality was much weaker in mothers who were < or =19 years or > or =35 years old, unmarried, had lower education levels, and were expecting their first or fourth or higher order birth [21]. Since parental age, birth order, education levels, social status and marriage status have all been shown to influence MRF, (1, 2) it may be that factors that influence seasonality in birth numbers may also influence seasonality in MRF.

MRF has been shown to be affected by a wide variety of factors. These include pollution and population stress, both of which have been shown to reduce MRF [22]. Population privation, such as famine (as evidenced in the Great Famine of China during the Great Leap Forward) has also been shown to reduce MRF [23]. Conversely, long duration warfare has been shown to increase MRF [24]. As has been shown in the literature review and by this study's findings, temperature is yet another factor that influences MRF.

5. CONCLUSION

In conclusion, Malta exhibits nonstatisticaly significant seasonal MRF variation that is in keeping with that noted in other countries and no clear climatic influences have been found.

CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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