

1 **An analysis of seasonal variation and climatic influences on the male to female ratio of**
2 **live births in Malta**

3 **Running title**

4 Seasonal M/F in Malta

5 **Key words**

Malta

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6 **Article type:** original research

7 **Abstract**

8 ***Aims***

9 In humans, male births occur in excess of female births. The ratio of male births to total births
10 (conventionally but erroneously referred to as M/F) is expected to approximate 0.515. Many factors
11 have been shown to influence M/F and a seasonal pattern has also been described. This study was
12 carried out in order to ascertain whether seasonal variation in M/F exists in Maltese live births and
13 whether environmental influences exert any role.

14 ***Methods***

15 Monthly live births subdivided by gender, were obtained from official Maltese government
16 publications for the period 1958-2013. Analysis was carried out with SPSS, the Bio-Med-Stat Excel
17 add-in for contingency tables and Demetra, using chi square tests, ANOVA, Freidman and Kruskall-
18 Wallis tests , correlation, regression, and ARIMA models. Mean annual temperatures were available

19 to 1958. Monthly data for maximum and minimum monthly temperatures, relative mean humidity,
20 lowest relative humidity, hours of bright sunshine and rainfall was only available for 2001 to 2012.

21 **Results**

22 This study analysed 297254 live births (153652 males and 143602 females, M/F 0.5169, 95% CI
23 0.5151-0.5187). M/F exhibited a nonsignificant bimodal pattern (June and December peak). M/F
24 displayed a significant negative correlation between M/F and average mean yearly temperature
25 ($p=0.049$). There was an association between monthly mean relative humidity and M/F ($p = 0.03$).

26 **Discussion**

27 The nonsignificant seasonal pattern seen accords with that previously documented for other
28 countries but the negative M/F correlation with mean annual temperature goes contrary to that
29 previously documented in other countries. The humidity association has not been previously
30 described.

31 **Introduction**

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

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

40 In polygynous species, only the fittest males reproduce. For this reason, parental investment in a
41 "good quality" son may yield greater numbers of descendants than an equivalent investment in a

42 “good quality” daughter. It may therefore be advantageous for a mother to produce sons when she
43 has sufficient resources to give them a better than average edge that will then give them a greater
44 chance to reproduce. And to produce daughters when she does not. This is known as the Trivers-
45 Willard hypothesis.(3)

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

52 According to the Trivers-Willard hypothesis, both direct and indirect mechanisms may cause
53 pregnant females to abort frail male fetuses, lowering M/F. Indeed, European data for the period
54 1865-2003 shows an increase in M/F in warm years.(6) More specifically, a study of the Sami people
55 (the only indigenous Scandinavian race) showed that a 1°C increase in mean temperature yielded 1%
56 more sons annually.(7)

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

62 This study was carried out in order to ascertain whether seasonal variation in M/F exists in Maltese
63 live births and whether environmental influences exert any role.

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66 **Methods**

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

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

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

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

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

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

92

93 **Results**

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

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

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

109 Although there was no apparent seasonality in M/F with time, correlation analysis showed a
110 significant correlation between annual M/F and average mean yearly temperature ($r = -0.23$, $p =$
111 0.049 – figure 3). The regression equation from figure 3 ($Y = -0.0029x + 0.5719$, where x – mean
112 annual temperature, Y – annual sex ratio) confirmed that an increase in the annual average
113 temperature, resulted in a decrease in M/F.

114 There were 48277 births available for analysis for the period 2001 to 2012. Analysis of the various
115 climate characteristics on a monthly basis indicated that there was an association between monthly
116 mean relative humidity and M/F (Spearman Rank correlation coefficient $r_s = 0.154$, $p = 0.03$ – figure
117 4).

118 Discussion

119 Seasonality in M/F has been previously described in other countries. For example, a highly significant
120 seasonal pattern was found in western Siberia, with a peak in the second and a trough in the fourth
121 quarter of the year.(13) This type of periodicity was also noted in Germany for the period 1946-
122 1995,(14) a phenomenon that had been discovered in an earlier study in the same country over a
123 shorter the time-frame 1946-1967.(15) Intriguingly, seasonal variation (with a higher M/F in spring)
124 was demonstrated in a smaller study in academic mothers, and less so in non-academic mothers
125 employed at the University of Vienna.(16) Malta also exhibits seasonal M/F variation but this does
126 not reach statistically significant levels. These results may be due to the relatively small number of
127 births in the archipelago, resulting in a type 2 error.

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

131 Another Italian study noted that M/F calculated at the time of conception showed a seasonal rhythm
132 with peak values in September.(16) This also supports the Trivers-Willard hypothesis which proposes
133 that the male excess increases under favourable reproductive conditions.(3)

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

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

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

148 Interestingly, it has also been shown that maternal gonadotropin levels are dependent on variations
149 in light stimulation,(19) and that the seasonal variation in M/F is synchronous with dizygotic
150 twinning rates. It has therefore been speculated that both factors may be influenced by maternal
151 gonadotrophin levels.(2)

152 The total number of births also hints at seasonality.(20) Proposed explanations for this periodicity
153 have included temperature effects and photoperiod. It has been proposed that the latter may
154 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 ≤ 19 years 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 M/F,^(1,2) it may be that factors that influence seasonality in birth numbers may also influence seasonality in M/F.

M/F 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 M/F.⁽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 M/F.⁽²³⁾ Conversely, long duration warfare has been shown to increase M/F.⁽²⁴⁾ As has been shown in the literature review and by this study's findings, temperature is yet another factor that influences M/F.

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

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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

225 **Table 2. Parameter estimates of ARIMA(0,1,1)(0,1,1) model of the quarterly group - 5 year age**
 226 **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

227

228 **Table 3. The effect of environmental characteristics on monthly M/F: 2001 - 2012**

Environmental Characteristics	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

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230

231 Figure 1: Seasonal and trend pattern for annual sex ratio - %: 1958 - 2013

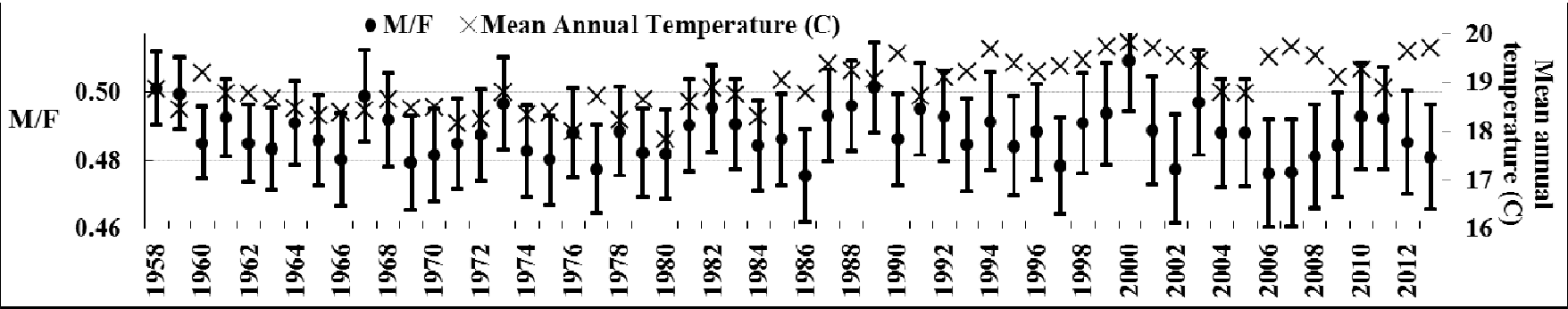


Figure 2: Monthly totals for M/F and live births in Malta, January 1958-December 2013.

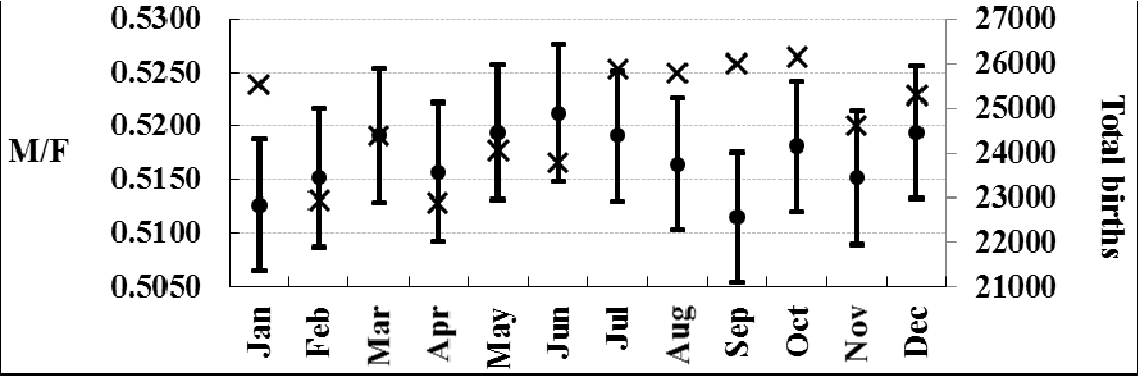
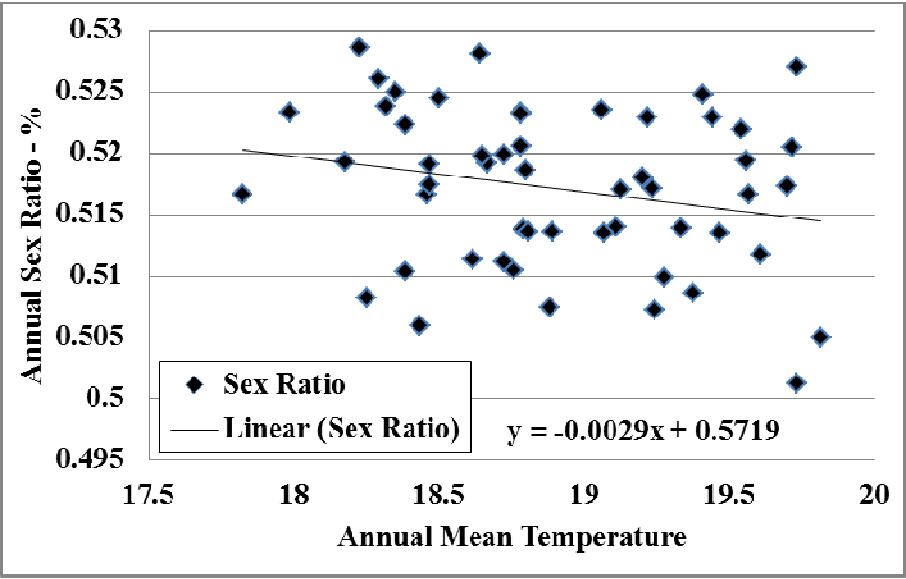


Figure 3. Annual sex ratio versus annual mean temperature: 1958 – 2010 ($p = 0.049$).



241 **Figure 4: Average monthly environmental characteristics and sex ratio 2001–2012.**

