

Factors determining gender ratio in the Maltese population

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Abstract

Introduction: The Male/Female ratio at birth has been described to favour the male conceptus, a situation that persists throughout most of childhood and into the reproductive phase of life. The reasons behind this preferential male-favouring remain elusive.

Methodology: The various relevant obstetric and population national registers kept by the Department of Health information and the National Statistics Office of the Maltese Islands were reviewed to elucidate the age-related M/F ratios differences in the population starting with the third trimester of the antenatal period. In addition, third trimester M/F ratios in women with specific metabolic-related disorders were assessed and compared to the on-affected individuals. The role of foetal congenital malformations was also investigated.

Results: It would appear that the M/F ratio starts favouring the male conceptus as early as the third trimester of the antenatal period. It remains favoured right through the reproductive age reaching par after the age of 45 years when it shifts to favour the female. This relationship was significantly altered during the 1930s as a result of the emigration patters prevalent during that period. The results further show that the maternal nutritional and biochemical milieu may influence the M/F ratio at the beginning of the third trimester with women suffering from adiposity, diabetes and thyroid disease having higher M/R ratios. In spite of this preference to the male conceptus, malts have a higher mortality throughout life with mortality rates being higher for males from the third trimester up to the age of 75 years. On the other hand, female foetuses with malformations appear to have a higher mortality during intrauterine life than corresponding male foetuses.

Conclusion: The M/F ratio appears to favour the male conceptus during antenatal life and is definitely evident by the beginning of the third trimester of pregnancy, the selection mechanism possibly being a greater predisposition of female foetal loss in the presence of malformations. These biological observations may present advantages within the breath of human reproductive ecology, ensuring a healthy reproductive female individual who has the option of choosing her mate from a competing male community.

Keywords

Male/Female Ratio, Demography, Malta, Migration, Reproductive ecology

Introduction

The mechanism of meiosis whereby spermatozoa are produced should result in an equal distribution of X and Y chromosome carrying spermatozoa. Thus, the Male-Female potential determined by each ejaculate should be a ratio of 0.500. However, biological mechanisms appear to favour the male conceptus, so that proportionately more male than female infants are born.²⁰ This altered Male-Female [M/F] ratio is approximately maintained throughout childhood and adulthood, a factor that has long-term effects on a community's demography.¹⁹ The present study attempts to assess the mechanisms favouring the male

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conceptus in a small island population in the Central Mediterranean. This population has been shown to have maintained a steady live birth M/F ratio of 0.517 throughout the larger part of the twentieth century (1916-1995), though this had decreased from the 0.523 level during the late 19th century (1890-1899).¹³

Methodology

The present study attempts to compare the M/F ratios at various points from the intrapartum period to late adulthood during two particular periods – the 1930s and the 2000s. Data related to population gender distribution by age was obtained from Census Reports for 1931 and 2005.^{3,18} Gender-based mortality data by age for the periods 1930-1939 and 2000-2009 were obtained from published sources of the National Statistics Office and the National Obstetrics Information System [NOIS] database.^{8-9,19} The NOIS is a database that collects national data about all births registered in the Maltese Islands and is maintained by the Department of Health Information and Research. This database provided M/F ratios for stillbirths, live births and total births for the period 2000-2010. The latter can be assumed to represent the M/F ratio at the beginning of the third trimester. Stillbirths in this database are defined as the birth of a dead infant of a gestational age of 22 weeks [154 days] or more, or an infant born with a birth weight of 500 g or more. During the earlier period in the 1930s, stillbirths were defined as births of dead children after 28 weeks of gestation differentiating stillbirths from late miscarriages. Information relating to causality of deaths and congenital abnormalities for the period 2000-2009 was obtained from published sources reflecting the National Mortality Register and the Malta Congenital Anomalies Registry maintained by the Department of Health Information and Research.^{6,11}

The two periods under review reflect two contrasting periods in Maltese social history. The 1930s were characterised by a generally low socio-economic level of the population that resulted in a high emigration rate caused by low employment opportunities. The population was generally undernourished. The birth rate in 1935 was 34.0 per 1000 population, while the crude death rate was 23.5 per 1000 population. The stillbirth rate was 50.2 per 1000 total births; while the infant mortality rate was 285.7 per 1000 live births.⁸ The latter half of the twentieth century saw a major change in the socio-economic situation of the population resulting in better overall health and nutrition. In 2000, the birth rate was 11.1 per 1000 population, while the crude death rate was 7.8 per 1000 population. The stillbirth rate was 4.0

per 1000 total births; while the infant mortality rate was 6.1 per 1000 live births.¹⁹

The Male-Female ratio [M/F ratio] was calculated as the ratio of total males and the total population being assessed. Population-based M/F ratios were calculated for various age groups starting at the beginning of the third trimester of pregnancy thus including live births and stillbirths; at birth including live births, and at age groups 0-9 years, 10-24 years, 25-34 years, 35-44 years, 45-54 years, 55-74 years and 75+ years. Mortality-based M/F ratios at the various age groups were similarly assessed. Further information related to population losses through emigration was similarly assessed. Because of the relatively small size of the population, vital-event registration and statistics have been very accurate since the initiation of their compilation by formal legislation. Where appropriate, statistical significance of M/F ratios between populations with different characteristics was tested using the chi square test.

Results

During the 2000-2009 period, the M/F ratio at the beginning of the third trimester of pregnancy stood at 0.518. At birth the figure decreased minimally to 0.517 reflecting a proportionately higher mortality in males noted during the third trimester of intrauterine life. This figure further decreased slightly to 0.511 during the first decade of life and was approximately maintained until the age of 44 years. In the age group 45-54 years, the gender ratio was on par. It eventually shifted favouring females after 55 years of age. The gender ratio pattern during the 1930-1939 period followed a different trend. The gender ratio during the third trimester stood at 0.530 favouring males. The M/F ratio subsequently dropped to 0.523 in live births reflecting a higher stillbirth mortality in the male. The subsequent early years of life saw a further drop in M/F ratio reaching 0.505 at 24 years of age. The subsequent age groups exhibited a predominance of females in the population with a reversed M/F ratio reflecting a preponderance of females in the subsequent age groups (Table 1 / Figure 1).

The 2000-2009 NOIS data suggests that the nutritional and biochemical milieu of the mother may influence the M/F ratio at the beginning of the third trimester (Table 2). Pre-pregnant adipose women, defined as a pre-pregnancy BMI >25 kg/m², delivered live and stillborn infants with a gender ratio of 0.523 favouring males in contrast to the 0.507 figure noted in non-adipose women ($p=0.014$). Similarly women suffering from some form of diabetes during their pregnancy gave birth to live and stillborn infants with an elevated M/F ratio of 0.549, though this was not statistically significant ($p=0.14$) when compared to the

remaining non-diabetic population. Similarly, women with thyroid disorders appeared to have a similarly elevated M/F ratio of 0.558 ($p=0.36$).

Table 1 / Figure 1: Population-based M/F ratio by different Age groups – Census years for all age groups except for 3rd trimester and ‘at birth’ ratios estimated as mean of decades 1930-1939 and 2000-2009.

Age Group	1931	2005
3rd trimester	0.530	0.518
At birth	0.523	0.517
0-9 years	0.506	0.511
10-24 years	0.505	0.513
25-34 years	0.496	0.513
35-44 years	0.460	0.512
45-54 years	0.499	0.500
55-64 years	0.491	0.492
65+ years	0.485	0.424

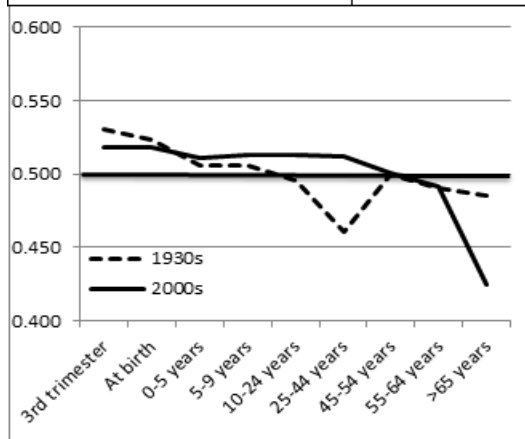


Table 2: Third trimester M/F ratios by maternal endocrine disorders: Maltese Islands 2000-2009

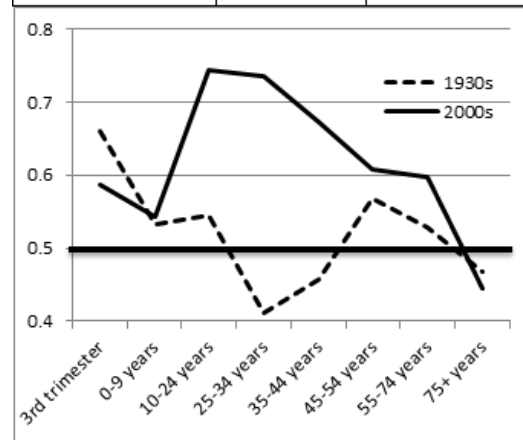
Age Group	With disease	Without disease	P value
Adiposity	0.523 [n = 11868]	0.507 [n = 11590]	0.014
Diabetes mellitus	0.549 [n = 481]	0.514 [n = 22950]	0.14
Thyroid disease	0.558 [n = 138]	0.515 [n = 23320]	0.36

The mortality M/F ratio data suggest that during the 2000-2009 period, male infants were more susceptible to death throughout life starting from the third trimester of the antenatal period. This male bias for mortality is particularly elevated in the 10-44 year age groups. This risk persists right up to the 75+ years age group when a shift occurs in risk and proportionately more females die. The generally higher mortality risk for males was also extant during the 1930-1939 period, though in the latter, a reversal in

mortality rates with proportionately more females dying in the 24-44 years age group is observed (Table 3/Figure 2).

Table 3 / Figure 2: Mortality M/F ratio by different Age groups

Age Group	1930-1939	2000-2009
3rd trimester	0.661	0.587
0-9 years	0.533	0.542
10-24 years	0.545	0.744
25-34 years	0.411	0.736
35-44 years	0.457	0.673
45-54 years	0.568	0.609
55-74 years	0.528	0.597
75+ years	0.468	0.446



Analysing the M/F ratio of foetal deaths (with >500g birth weight) for the period 2000-2009 confirms that male foetuses were more likely to die during intrauterine life than female foetuses (M/F ratio 0.601). However when analysed by cause of death, female foetuses appeared to have a greater likelihood of dying during intrauterine life from a congenital malformation than male foetuses (M/F ratio 0.483). This female bias is present in spite of the fact that more male infants were born with an identified malformation during the same period (M/F ratio 0.577). The reverse risk applies for deaths due to other causes with male foetuses having a greater risk of dying during intrauterine life (M/F ratio 0.627). Childhood deaths due to congenital malformations appear to show a bias towards male deaths (M/F ratio 0.574) attributable to the higher proportion of malformations present in male live birth (M/F ratio 0.579). In contrast, proportionately more males than females succumb during the childhood years (Table 4).

Population loss is dependant not only on mortality but also from the losses resulting from emigration. This loss has also a gender bias towards males. The period November 1918 to March 1931 had seen an emigration drive affecting particularly males rather

than females. This M/F bias in emigration persisted even when one considers the M/F proportion of returning migrants. The M/F ratio of remaining migrants who are thus lost to the overall population was 0.764 (Table 5).

Table 4: Mortality and birth M/F ratios by cause of death: Maltese Islands 2000-2009

Age Group	With malformation	Without malformation	Total	P value
Total births	0.577 [n=1297]	0.516 [n=43012]	0.518 [n=44309]	<0.001
Foetal deaths [>500g]	0.483 [n=29]	0.627 [n=134]	0.601 [n=163]	0.291
Total live births	0.579 [n=1268]	0.516 [n=42845]	0.517 [n=44113]	<0.001
Childhood mortality [0-14 years]	0.574 [n=115]	0.546 [n=207]	0.556 [n=322]	0.715

Table 5: Emigration statistics: Maltese Islands – November 1918 to March 1931¹

	Males	Females	Children Gender not identified	M/F ratio Excluding children
Emigrants	32671	3927	3606	0.893
Returning migrants	24533	1407	1670	0.946
Remaining migrants	8138	2520	1936	0.764

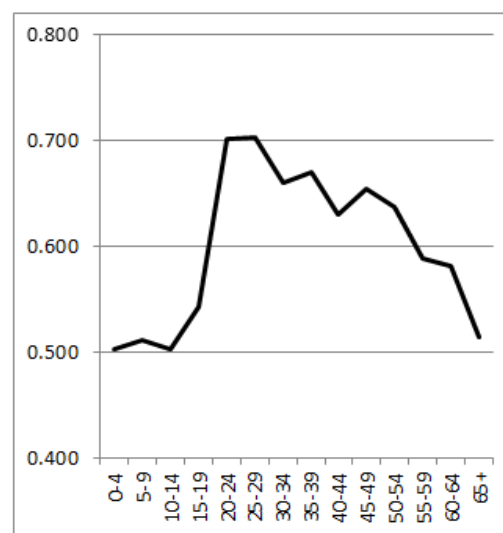
In 1930, the number of non-returning emigrants amounted to 916 persons including 560 males, 242 females and 114 children [M/F ratio 0.698]. The average number of emigrants of all genders and ages for the period 1931-1938 amounted to 1573 persons per annum. There was little or no emigration during 1939 because of WWII. The statistical data regarding emigrants during the 1930s is unfortunately incomplete. However, because of immigration legislative regulations, the larger majority of the migrants were persons in the reproductive age group, thus affecting adversely the demographic structure of the Maltese population.³ The increased bias towards male migrants aged 20-39 years can be observed by analysing the available statistical data for the period 1947-1957 (Table 6).

Mechanisms are therefore extant that help significantly skew the M/F ratio at the time of conception and during the first trimester of intrauterine life. The Y-containing spermatozoa are considered to be advantaged over the X-containing spermatozoa since it contains about 3-4% less DNA material. The differential motility thus allows the Y-containing

spermatozoa to reach the ovum earlier and thus stands a greater likelihood to achieve fertilization.

Table 6 / Figure 3: Gender ratios of emigrants by age groups – Maltese 1947-1957³

Age group	Male	Female	M/F ratio
0-4	905	896	0.502
5-9	3308	3155	0.512
10-14	3779	3745	0.502
15-19	2483	2098	0.542
20-24	6997	2982	0.701
25-29	6861	2898	0.703
30-34	4888	2518	0.660
35-39	3552	1750	0.670
40-44	1989	1166	0.630
45-49	1893	998	0.655
50-54	1218	694	0.637
55-59	685	480	0.588
60-64	391	282	0.581
65+	292	276	0.514



The skew may also be contributed to by other factors other than swimming speed. It has been demonstrated that bovine sperm actually swim at the same speed in stationary fluids, but differ in their linearity and straightness of path.²¹ The male conceptus in humans may also make the transition to blastocyst better than the female.²² The female zygote also appears to have a greater likelihood of being spontaneously miscarried during embryogenesis, implantation and early foetal development. Assessment of pregnancy material obtained during a spontaneous miscarriage at 10 weeks of pregnancy have shown a predisposition for female first trimester loss exhibiting a M/F ratio of 0.364. This predisposition towards increased loss of the female zygote has been partly associated to chromosomal and other congenital abnormalities. In this situation, the

M/F ratio has been shown to be 0.467, while in miscarriages caused by idiopathic or other causes, the M/F ratio has been reported as 0.270.⁷ Second trimester loss can occur but the numbers are not generally significant. This study has suggested that there is a predisposition towards a continued increased loss of the female foetus with a congenital malformation during the third trimester, further favouring an elevated M/F ratio at birth. The apparent protection of the male congenitally malformed foetus during intrauterine life appears to be lost after birth with these children being more susceptible to death than their female counterparts.

A number of environmental and biological factors have been postulated as being contributory to the altered M/F ratios noted in different circumstances. The observation that M/F ratio decrease with increasing latitude on the European continent has led to the suggestion that meteorological factors might play a role.¹³ While a seasonal trend could be observed in births from the Maltese Islands, these trends were not statistically significant.¹⁵ The present study has suggested a link between a raised M/F ratio to the nutritional and biochemical status of the mother with elevated ratios being noted in adipose, diabetic and hypothyroid women. A possible inter-relationship between gender determination and maternal diet has been previously postulated.²² There also appears to be a fall in M/F ratios at the beginning of the third trimester and subsequently at birth over the decades from the 0.530 level in 1931 to the 0.518 level in 2005. Such a decrease in M/F ratios has been previously described.²⁰ Various possible potential causes have been proposed.¹⁷ Socio-economic improvements would be expected to increase rather than decrease the M/F ratio. The observation linking congenital malformations with an earlier loss of the female conceptus with anomalies may explain the decreasing M/F ratio with time. Congenital anomalies are commoner in the elderly women.²⁴, and there has been proportionately a decrease in elderly women giving birth over the last decades. In 2005, the proportion of women aged more than 35 years delivering in the Maltese Islands was 10.7%.¹⁰ In 1959, the proportion was 18.0%.⁴

The mechanisms favouring the development and survival of the male embryo at the time of conception and throughout the first trimester ensures that proportionately more male embryos reach the end of the second trimester of pregnancy resulting in a current M/F ratio of 0.518. The subsequent intra-uterine existence during the third trimester presents particular hazards to the developing male foetus which exhibits a greater tendency to die in utero, during childhood and early adulthood. In spite of the increased male

mortality, the male gender in Maltese demography retains its majority well until the age 44 year age group, becomes proportionally on par with female in the 44-54 year age group, and subsequently falls into the minority in later age groups. The pattern was similar during the 1930s, although in contrast there appeared then to be a reversal in mortality gender ratios for the age group 25-44 years. This may be accounted for by gender-bias emigration resulting in the preferential loss of males from the population.

In spite of the apparent relative protection of the male congenitally malformed foetus during intrauterine life, there still appears a definite higher stillbirth rate in male fetuses. Various theoretical possibilities may contribute to this higher stillbirth M/F ratio noted in several population studies including the present study. The main causes for stillbirths identified in the first Report of the U.K. Perinatal Mortality Survey of 1958 included anoxia (48.2%), congenital malformations (17.5%), cerebral birth trauma (9.5%), and haemolytic disease of the newborn (4.4%).² In the Maltese population during the period 1979-1987, the commonest cause of perinatal death reported was antepartum anoxia that accounted for about 37.0% of cases. Prematurity and congenital malformations accounted for 27.4% and 23.9% respectively, while intrapartum anoxia or birth trauma accounted for 10.6%. The commonest contributor of antepartum anoxia was hypertensive disease of pregnancy causing placental insufficiency and subsequent antenatal death of the foetus. This was associated with 25.5% of all stillbirths and 8.2% of early neonatal deaths in 1979-1987.¹² There have been numerous reports of high M/F sex ratios in pre-eclampsia and eclampsia in singleton pregnancies with a reported M/F ratio of 0.529 suggesting that the primigravid woman carrying a male foetus is more likely to develop pre-eclampsia hence placing the male foetus at increased risk of placental insufficiency and an increased risk of dying during antenatal life.¹⁶ An alternative reason for a greater likelihood of the male foetus to be stillborn is the greater risk the generally higher weight male infant²⁵ has towards prolonged labour and intrapartum birth anoxia and/or trauma, though this is unlikely to play an important role in Maltese obstetrics today with a reported Caesarean section rate of 29.9% in 2001-2010.¹⁰

Several biological processes ensure that at birth the population is represented by a higher proportion of males over females. It appears that this preponderance of males remains right through middle age in spite of the fact that mortality rates are higher in the male population. The higher M/F ratio must present biological advantages within the wide breath of human reproductive ecology. While no information is

available as to the birth M/F ratios of our hunter-gatherer and Neolithic ancestors, it is reasonable to assume a similar pattern of male preponderance. This preponderance would have presented a competitive situation whereby the female reproductive element of the species has the choice of choosing the ideal male partner – the stronger more intelligent male – to the benefit of species development. A better understanding of the dynamics affecting the M/F ratio in human reproductive processes would help understand the possible effects of environmental, nutritional, hormonal and sociological changes on human reproduction and their consequences on human population ecology.

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References

1. Arrigo H. Report of the Emigration Department. In: Reports on the working of government departments during the financial year 1930-31. Malta: Government Printing Office; 1932. Section P.
2. Butler NR, Bonham DG. Perinatal Mortality. Edinburgh: Livingstone; 1963.
3. Central Office of Statistics. Census 1957: The Maltese Islands – Report on population and housing. Malta: Central Office of Statistics; 1959.
4. Central Office of Statistics. Demographic Review for the Maltese Islands for the year 1960. Malta: Central Office of Statistics; 1962.
5. Cui K. Size differences between human X and Y spermatozoa and prefertilization diagnosis. *Mol Hum Reprod* 1997; 3(1):61-7.
6. Debono R. National Mortality Register. Malta: Department of Health Information and Research; 2012 [cited 2013 Mar 15]. Available from: https://ehealth.gov.mt/HealthPortal/chief_medical_officer/healthinfor_research/registries/deaths.aspx.
7. Del Fabio A, Driul L, Anis O, Londero AP, Bertozzi S, Bortotto L, Marchsoni D. Fetal gender ratio in recurrent miscarriages. *Int J Womens Health* 2011; 3:213-7.
8. Department of Health. Annual Reports on the Health of the Maltese Islands during 1930-1939. Malta: Government Printing Office; 1931-1940, 10 volumes.
9. Department of Health Information and Research. National Obstetrics Information System (NOIS): Annual Reports 2000-2009. Malta: Department of Health Information and Research; 2001-2010, 10 volumes.
10. Department of Health Information and Research. National Obstetrics Information System (NOIS): Trends in Obstetrics – Malta 2001-2010. Malta: Department of Health Information and Research; 2011.
11. Gatt M. Malta Congenital Anomalies Register. Malta: Department of Health Information and Research; 2012 [cited 2013 Mar 15]. Available from: https://ehealth.gov.mt/HealthPortal/chief_medical_officer/healthinfor_research/registries/birth_defects.aspx
12. Grech ES, Savona-Ventura C. The Obstetric and Gynaecological service in the Maltese Islands: 1987. Malta: Department of Obstetrics & Gynaecology, University of Malta; 1988.
13. Grech V, Vassallo-Agius P, Savona-Ventura C. Declining male births with increasing latitude in Europe. *J Epidemiol Community Health* 2000; 54(4):244-6.
14. Grech V, Vassallo-Agius P, Savona-Ventura C. Unexplained differences in sex ratios at birth in Europe and North America. *BMJ* 2002; 324:1010-1.
15. Grech V, Vella CC, Vassallo-Agius P, Savona-Ventura C. Gender at birth and meteorological factors. *Int J Risk Safety Med* 2000; 13:221-4.
16. Hall MH, Campbell DM. Geographical epidemiology of hypertension in pregnancy. In: *Hypertension in Pregnancy: Proceeding of the 16th Study Group of the RCOG*. New York: Perinatology Press; 1986. p.33-50
17. James WH. What stabilizes the sex ratio? *Ann Hum Genet* 1995; 59:243-9.
18. National Statistics Office. Census of population and housing: 2005 – Volume 1: Population. Malta: National Statistics Office; 2007.
19. National Statistics Office. Demographic Reviews of the Maltese Islands for the years 2000-2009. Malta: National Statistics Office; 2001-2010, 10 volumes.
20. Parazzini F, La Vecchia C, Levi F, Franceschi S. Trends in male-female ratio among newborn infants. *Hum Reprod* 1998; 13(5):1394-6.
21. Penfold LM, Holt C, Holt WV, Welch GR, Cran DG, Johnson LA. Comparative motility of X and Y chromosome-bearing bovine sperm separated on the basis of DNA content by flow sorting. *Mol Reprod Dev* 1998; 50(3):323-7.
22. Quintans CJ, Donaldson MJ, Blanco LA, Pasqualini RS. Deviation in sex ratio after selective transfer of the most developed cocultured blastocysts. *J Assoc Reprod Genet* 1998; 15:4034.
23. Rosenfeld CS, Robers RM. Maternal diet and other factors affecting offspring sex ratios: A review. *Biol Reprod* 2004; 71:1063-70.
24. Savona-Ventura C, Grech ES. Risk factors in elderly patients. In: Grech ES, Savona-Ventura C, editors. *Proceedings: European Study Group on Social Aspects of Human Reproduction. Vth Annual Meeting, Malta, September 1987*. Malta: Government Press; 1998. p.41-54
25. Zammit V, Zammit P, Savona-Ventura C, Buhagiar A, Grech V. Maltese national birth weight for gestational age centile values. *Malta Medical Journal* 2010; 22(2):19-24.