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An Evolutionary Framework for Understanding Sex Differences in Croatian Mortality Rates

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Abstract

Being male is the strongest demographic predictor of early mortality in Croatia. For every woman who dies between the ages of 15 and 34, three men die. Between the ages of 15 and 54, men are four times as likely as women to die from behavioral causes of death, such as accidents, homicides, and suicides. A causal explanation for sex differences in mortality must be based on an understanding of how sex differences were shaped by natural selection, and how those differences interact with environmental factors to create observed patterns and variations. In brief, males have been selected for riskier behavioral and physiological strategies than women, because of the greater variance and skew in male reproductive success. This paper examines the sex difference in Croatian mortality in three parts. First, we quantify the Croatian Male to Female Mortality Ratio (M:F MR) for 9 major causes of death across age group to provide a richer understanding of the sex difference in mortality from a life history framework. Second, we compare the Croatian M:F MR from behavioral, internal, and all causes with that of the available world population to demonstrate how Croatian mortality can be understood as part of a universal pattern that is influenced by unique environmental context. Third, we investigate how the War of Independence in 1991-1995 affected mortality patterns though its impact on behavioral strategies and the physical embodiment of distress.

Gardner (1993, p. 67) noted that young adult males form the front ranks of every nation's military, and "lacking the opportunity for warfare, some [young adult men] will find other ways to place their lives at risk." In Croatia and many other countries, being male is the strongest demographic predictor of early mortality. Men die at higher rates from both behavioral causes of death, such as accidents, and behaviorally mediated internal causes of death, such as

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cardiovascular disease (Kruger & Nesse, 2004). In recent decades, existing explanations of sex-based mortality differences based only on mechanistic factors have been augmented by explanations of how these differentials emerge from characteristics shaped by sexual selection that interact with environmental factors (including culture, for humans) (e.g., Wilson & Daly, 1993).

In humans and most other animals, females are better adapted than males to the environment, as demonstrated by their superior longevity. Differences between males and females are usually a result of sexual selection. In most species, males compete more intensely for mating access to females than females do for males. This is because females usually invest more in offspring, and are thus selected to be choosier in selecting mates (Bateman, 1948; Trivers, 1972). Male competition for mates can include fighting other males for rank or territory, as well as elaborate traits and displays that are attractive to females (Darwin, 1871). Those who succeed in these competitions will have higher reproductive success, and this selects for traits that foster such success, even if those traits also result in behavioral and physiological differences that increase the chances of injury, sickness, and early death. This is a classic illustration of the principle that selection shapes traits not for the welfare of individuals or species, but to benefit their genes (see Williams, 1957; Dawkins, 1976).

In highly polygynous species, a few males will have many offspring while many others will have none, generating powerful selection for traits that lead to success in mating competition (Betzig 1986). The results of this selection include elaborate ornaments (such as the peacock's tail) and armaments (such as a deer's antlers), all with substantial costs. Humans are far less polygynous than most other primates, but the variation and skew in male reproductive success is still substantially higher than that for females. In humans, displays of wealth and social status may literally be a costly signal analogue to the peacock's tail. Cross-culturally, men are evaluated by potential partners in terms of social status and economic power (e.g., Ardener, Ardener & Warmington, 1960; Buss, 1989, 1994; Feingold, 1992; Kenrick & Simpson, 1997; Townsend, 1989; Townsend & Roberts, 1993; Wiederman & Allgeier, 1992). Measures of male social status and economic power have a direct relationship to reproductive success across a wide variety of societies (see Hopcroft, 2006). During recent human evolution, males who do not have substantial resources or status may have been unable to establish long-term relationships. Thus, sexual selection helps to explain some sex differences in psychology and behavioral tendencies, including the stronger male tendencies for risk-taking, competitiveness, and sensitivity to hierarchy (Cronin, 1991). These attributes are related to competition for resources, social status, and mates (Daly and Wilson, 1985), competition which is hazardous and sometimes fatal (Betzig, 1986; Kaplan & Hill, 1985).

Selection pressures unique to females may have also contributed to the divergence in tendencies for risky strategies. Risk-taking is more costly for women because offspring survival depends more on maternal than paternal care and defense (Campbell, 1999). This may be related to the results of recent psychological research showing sex differences in behavioral responses to stress. The tissue-damaging “fight or flight” responses described universally in psychological textbooks may correspond more closely with male behavioral reactions to adverse circumstances. Women appear to have a "tend-and-befriend" response where nurturing and tending activities help protect and reduce distress in oneself and offspring (Taylor, Klein, Lewis, Gruenewald, Gurung & Updegraff, 2000). Tending and befriending activities help develop and sustain social networks facilitating recovery from stressful situations.

The shift in the male allocation of effort from mating to parenting over the life course helps to explain why the peak sex difference in mortality occurs in young adulthood, mostly from behavioral causes (Kruger & Nesse, 2006). The steep discounting of the future associated with risky behavior by young people could be a rational response to uncertain prospects for the future (e.g., Gardner 1993; Wilson & Daly, 1997). Male mating effort peaks in young adulthood, possibly in part because young men do not have outlets for parental investment, and they may be more attractive partners because they have not committed their current and future resources (Hill & Kaplan, 1999). In both ancestral and modern times, men who control more resources married younger women, married more women, and produced offspring earlier (Betzig, 1986; Low 1998). Even relatively egalitarian foraging societies have different levels of status, and higher status men have greater access to mates (Chagnon 1992; Hill & Hurtado 1996).

Male and female mortality rates are not however, genetically determined. All aspects of phenotype, including tendencies for risky behaviors, are influenced by environmental factors that vary by time and culture. Long term historical changes have affected mortality rates since the Pleistocene, including: increased spread of infectious diseases through increasing population size, mobility, and the domestication of animals (Diamond, 1997); public health measures such as improved sanitation and vaccination (McKeown, 1979); the emergence of scientific medicine including antibiotics; the increased availability and consumption of fatty foods, alcohol, tobacco, and other drugs (Eaton, *et al.*, 2002); and the widespread availability of automobiles and lethal weapons. These changes have resulted in both the recent dramatic decline in mortality from infectious diseases (Cutler & Meara, 2001) and the increasing prominence of mortality from causes directly or indirectly influenced by behavior, most of which disproportionately affect men. The decline in maternal mortality in recent decades has also dramatically decreased the female mortality rate and increased the divergence from the male mortality rate (Guyer, Freedman, Strobino & Sondik, 2000).

Recent historical events have also influenced mortality rates. The economic and political changes in the former Soviet Union led to increased inflation, unemployment, and lower wages (Little, 1998). Physical hardships, social disruption, and social distress associated with the 44% decline in Russia’s GDP are believed to have caused 3.4 million pre-mature deaths (Rosefielde, 2001). The increase in mortality rates was more pronounced for men than for women (Little, 1998), although a portion of the increased mortality differential can be attributed to inadequacies in heath care (Andreev, Nolte, Shkolnikov, Varavikova & McKee, 2003). Male life expectancy in Russia declined by six years between 1991 and 1994 (Cockerham, 1997).

Cultural factors such as social norms may increase or decrease risky behavioral tendencies that influence differential mortality risks (see Kraemer, 2000). For example, expectations for boys to be tough and not express emotions such as anxiety and shame may result in riskier behavior (Kindlon & Thompson, 1999). The (paradoxical) belief that men are inherently tougher may also result in discrimination in providing medical assistance in life-threatening situations (Moynihan 1998). Also, favoritism for male offspring in some cultures leads to higher female mortality rates in infancy and childhood owing to infanticide and neglect (Hrdy, 1999; Rahaman, Aziz, Munshi, Patwari & Rahman, 1982). Of course, social norms do not exist in a vacuum and may reflect a combination of the common heritage of adaptations to ancestral challenges and features of the current ecological environment.

The largest differences between male and female mortality rates occur from behavioral causes during young adulthood, but the greatest proportion in excess male life years lost result from behaviorally moderated internal causes (Kruger & Nesse, 2004). Sexual selection has shaped a riskier physiological strategy in males, which includes greater vulnerability to infection, injury, stress, physical challenge, and degenerative diseases (Kraemer, 2000). The epidemic of coronary heart disease in industrialized countries, resulting from increased consumption of dietary fats, affects men more so than women (Lawlor, Ebrahim, & Smith, 2001). Physiological susceptibility is exacerbated by higher rates of health adverse behaviors in males, including smoking, heavy alcohol consumption, and work in hazardous occupations (Hazzard, 1986). Elevated rates of alcohol consumption in males leads to increased risk of chronic liver disease and cirrhosis (Zhang, Sasaki & Kesteloot, 1995).

Our integrative evolutionary framework for understanding morality patterns can provide insight on sex differences in modern Croatian mortality. The Croatian Male:Female Mortality Ratio (M:F MR) is expected to share aspects of the universal human pattern, but also show variations based on unique local cultural and historical factors. Documenting the M:F MR across ages and causes will provide precise picture of the magnitude of mortality differences in Croatia and will provide a richer understanding beyond the acknowledgement of a general sex difference. Comparison of the Croatian population to other populations where high quality mortality data is also available can highlight distinctive aspects of Croatian demography that require cultural and historical explanations.

The Croatian *Homeland War* or War of Independence in 1991-1995 created a naturalistic experiment in which we can examine the impact of war and cultural disruption with high quality mortality data. These events include the sometimes forcible internal displacement of hundreds of thousands of individuals, influx of hundreds of thousands of refugees from Bosnia and Herzegovina and other nations, mortar shelling of urban populations, and rise in unemployment rates. We expect that the civilian M:F MR will rise due to the shift towards riskier behavioral strategies induced by evolved facultative adaptations responding to adverse and unstable environments. The mortality differences for internal causes of death are also likely to increase, as males may be more physiologically susceptible to substantial stress. The M:F MRs for some internal causes of death are expected to rise more so than others. For example, physiological distress is expected to have a greater impact on mortality rates from diseases of the digestive system, such as stress exacerbated ulcers, than on malignant neoplasms (cancers). Infectious disease rates are expected to rise due to the mass movement of individuals and probable decline in sanitation in areas affected by combat and/or massive population influx. Males are expected to be more susceptible to the increase in prevalence of infectious agents, resulting in a greater divergence of male and female mortality rates.

METHOD

We calculated the ratio of male mortality rate divided by female mortality rate (M:F MR) with data from the World Health Organization Mortality Database (http://www.who.int/whosis/). This ratio quantifies the divergence of male and female mortality rates, and thus indicates cultural features such as the severity of male-male competition and the degree of variability and skew of social status and material resources. We calculated the M:F MR in ten year age groups for the combined five most recent years of data available (1998-2002) for all causes, behavioral (external) causes, internal causes, and specifically for: infectious and parasitic diseases, malignant neoplasms, diabetes mellitus, diseases of the circulatory system, diseases of the respiratory system, diseases of the digestive system, accidents and adverse effects, suicide and self-inflicted injury, and homicide and injury purposely inflicted by other persons. We calculated the overall M:F MR, behavioral cause M:F MR, and internal cause M:F MR across the lifespan for all 71 other countries with available data. We note that data for the least developed nations are lacking, especially for sub-Saharan Africa.

We calculated changes in excess male mortality (deaths above the female mortality rate) between 1990 and 1994 and the M:F MR for war related causes between 1991 and 1994. We calculated the M:F MR for behavioral (accidents and adverse effects, suicide and self-inflicted injury, and homicide and injury purposely inflicted by other persons) and internal (infectious and parasitic diseases, malignant neoplasms, diabetes mellitus, diseases of the circulatory system, diseases of the respiratory system, diseases of the digestive system) causes for each year between 1990 and 1994. We did not calculate trends in later years, due to differences with disease definition and categorization between the International Classification of Diseases (ICD) version 9 and the ICD version 10, which was used beginning in 1995.

RESULTS

The M:F MR for all causes in 1998-2002 showed higher mortality rates for males than females across the lifespan (see Table 1). The M:F MR for all causes peaked at 3.27 in the 15-24 year age group, followed a modest decline after young adulthood, and then rose slightly in the 45-54 year age group, with a parabolic decline afterwards. The M:F MR for behavioral (external) causes peaked at 4.79 in the 35-44 year age group, and the M:F MR for internal causes peaked at 2.18 in the 45-54 year age group. The highest M:F MR was 6.47 for accidents and adverse effects in the 35-44 year age group. The highest M:F MR for types of internal causes was 4.47 for infectious diseases in the 45-54 year age group. There were 4 cause by age group categories (4% of total available categories) where female mortality rates were higher than male mortality rates. Except for diabetes in the 75 and older age group, mortality rates for these causes in these age groups were very low and thus the ratio is very sensitive to a small number of deaths.

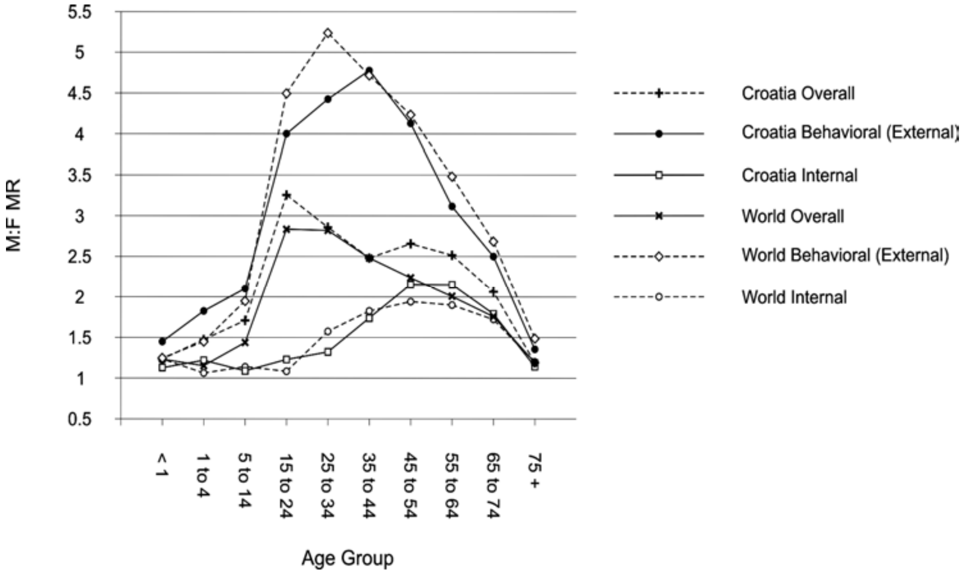
Table 1. Croatian M:F MR by Cause Between 1998 and 2002

Cause of death	Age Group									
	< 1	1-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	75+
Overall	1.22	1.48	1.72	3.27	2.86	2.50	2.67	2.54	2.08	1.19
All Behavioral (External) Causes	1.47	1.84	2.11	4.05	4.43	4.79	4.13	3.14	2.51	1.36
All Internal Causes	1.15	1.23	1.09	1.23	1.33	1.75	2.18	2.16	1.82	1.15
Infectious and parasitic diseases	1.05	1.44	1.48	.45	4.15	3.12	4.47	2.27	2.15	1.45
Malignant neoplasms		1.10	1.44	1.57	1.06	1.13	1.82	2.35	2.56	1.88
Diabetes mellitus					1.64	2.31	2.20	1.71	1.19	.87
Diseases of the circulatory system			1.48	2.18	1.89	3.32	3.27	2.57	1.78	1.03
Diseases of the respiratory system	1.23	2.40	.80	1.89	2.07	2.68	3.15	3.52	3.09	1.94
Diseases of the digestive system		2.36	1.55	2.47	2.93	4.41	3.33	3.08	2.72	1.72
Accidents and adverse effects	1.91	1.78	2.16	4.24	5.64	6.47	6.14	3.82	2.36	1.17
Suicide and self-inflicted injury			2.25	4.70	3.93	4.36	3.33	2.95	3.45	3.19
Homicide and injury purposely inflicted by other persons			1.16	2.46	3.95	2.84	2.07	2.17	1.89	.93

The Croatian overall, behavioral cause, and internal cause M:F MRs are similar in form to those of the measured portion of the global population, with three notable differences. The overall M:F MR peaks higher than for the measured portion of the global population in the 15-24 year age group, due to higher rates for internal causes of death. The behavioral cause M:F MR peaks later in life for the

Croatian population (in the 35-44 year age group) than the measured portion of the global population (25-34 year age group), and at a slightly lower level. The internal cause M:F MR for Croatia alternates between higher and lower levels in comparison to other populations. It is lower in early adulthood (25 to 34 years) and higher in middle adulthood (45 to 64 years).

Figure 1. Croatian M:F MR by Type of Cause Between 1998 and 2002 Compared to Remaining World Population



Between 1991 and 1994, 5759 men and 640 women died from war related causes (an M:F MR of 9.0). The amount of excess male mortality (above that of the female mortality rate) increased by 85% between 1990 to 1991, then declined by 15% in 1992, declined by 26% in 1993, remained level in 1994, and declined by 11% in 1995, back to 4% above the 1990 level. The M:F MRs for behavioral causes rose between 1990 and 1992 (see Figure 2). The M:F MR for accidents and adverse effects declined between 1992 and 1993, and declined more gradually between 1994 and 1994. The M:F MRs for homicides and suicides decreased between 1992 and 1993, then increased between 1993 and 1994. The M:F MRs for infectious and parasitic diseases and diseases of the digestive system increased between 1990 and 1992 and decreased between 1992 and 1993 (see Figure 3). The M:F MRs for diseases of the respiratory and circulatory systems decreased between 1990 and 1992. The M:F MR for malignant neoplasms (cancer) increased slightly from 1990 to 1991, then decreased gradually until 1994. The M:F MR for diabetes mellitus declined slightly from 1990 to 1991, then rose until 1993.

Figure 2. M:F MR for Behavioral (External) Causes, 1990-1994

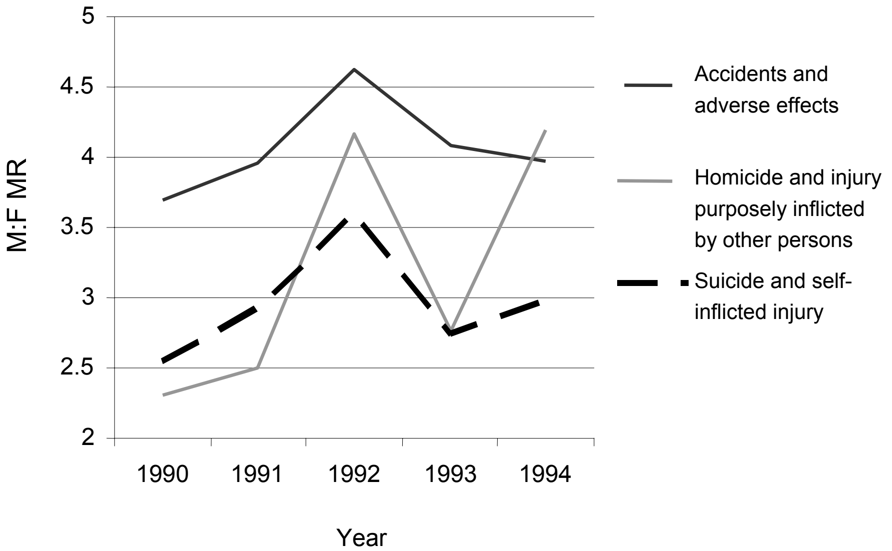
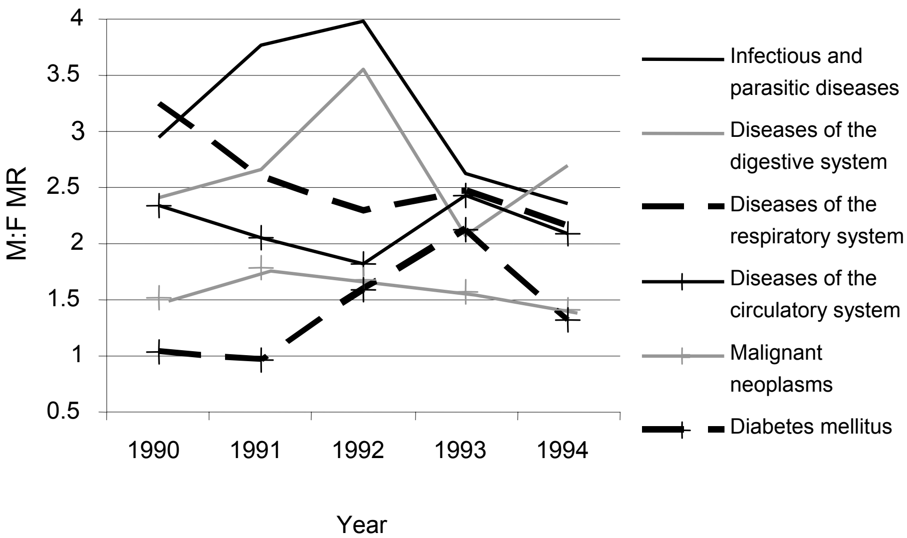


Figure 3. M:F MR for Internal Causes, 1990-1994



DISCUSSION

The results of this study have implications for understanding differences between male and female psychology. The cross-cultural consistency in the pattern of excess male mortality requires explanation based in our common evolutionary heritage. The mortality discrepancy is greatest in late adolescence and young adulthood, the ages men enter the mating market, and death in these age groups are primarily from behavioral causes. Our male and female ancestors have faced somewhat different challenges that have shaped differences in male and female psychology. Challenges that influence reproductive success of males more than females include accumulating resources, securing social status, and successfully attracting and retaining mates.

This study also demonstrates the importance of social and historical factors; showing that short-term environmental changes can influence both male tendencies for risky behavior and physiological susceptibility to disease. Comparison of the behavioral cause M:F MR between the Croatian population and the aggregate population of 71 other nations suggests that the shift in male focus on mating effort to parenting effort may occur later in the Croatian population, however male-male competition may be somewhat less intense than average. The secondary Croatian M:F MR peak in middle to late adulthood, primarily from internal causes, reflects a pattern common in industrial nations (see Kruger & Nesse, 2004). In these countries, food surplus and relatively benign environments lead to mortality predominantly from lifestyle-related causes rather than environmental hazards and infectious diseases. Unfortunately, high quality mortality data is not available for the populations of the least developed nations. Internal causes of death in these nations may be proportionally more from infectious diseases and environmental hazards, and less from the health consequences of ready access to foods that were rare in our ancestral environment combined with sedentary lifestyles. Less developed nations may also show higher peaks in the M:F MR from behavioral causes, due to an unpredictable resource supply and high skew in resource control, social instability, and frequent civil conflict.

The changes in the M:F MR during the Croatian War for Independence are consistent with our predictions derived from an evolutionary understanding of how traits shaped by sexual selection interact with aspects of the current environment to influence sex differences in mortality. The M:F MR increased substantially during this conflict. Although the highest mortality from war related causes was in 1991 (51% of total war mortality), and thus also the largest direct contribution of war to the M:F MR, the M:F MR from behavioral causes peaked in 1992. All three types of behavioral mortality followed this pattern, although the M:F MR from homicides rose again in 1994. When society was disrupted, the higher degrees of uncertainly and instability resulted in a shift toward riskier male strategies as reflected in increased male mortality, relative to female mortality. Extrinsic mortality risk is known to shape life history strategies (Low, 1998), and this behavioral shift may be based in evolved facultative adaptations that maintained reproductive success in ancestral conditions. For example, risky migrations into unknown areas in search of food, shelter, or better climate (see Hoffecker, 2002; Templeton, 2002) were likely a necessity during hominid evolution because of the rapid climatic fluctuation beginning around 2.000.000 years ago and the even more pronounced climatic variability from 200.000 to 10.000 years ago (see Ditlevsen, Svensmark & Johnsen, 1996). It is not necessarily the case that such a behavioral shift would be beneficial in the modern environment, just as risky male behaviors paired with technological innovations that greatly extend the consequences of behavior (e.g., automobiles) currently account for a substantial portion of male mortality.

As expected, the effects of the war on M:F MRs for internal causes of death were mixed. The M:F MR for infectious and parasitic diseases and diseases of the digestive system (including stress exacerbated ulcers) rose in 1991 and peaked in 1992. The M:F MRs for other types of diseases, such as those in the respiratory and circulatory systems, declined during this time. In contrast, the M:F MR for malignant neoplasm (cancer) increased slightly in 1991 and declined slightly in the following years. The mortality patterns from internal and behavioral causes appear to reflect the historical course of the war, which was most intense in 1991, followed by 1992, and then gradually lessening until the Dayton Agreement cease-fire in 1995.

These results suggest that the national M:F MR may be a useful indicator reflecting social conditions, and that decomposing the M:F MR into causes of mortality may provide insight into the impact of social conditions and historical events on behavioral patterns and physiological susceptibility to stressful events. Across cultures, trends in the M:F MR may reflect the severity of male-male competition, the relative variance and skew in social status and economic power, and perceptions of environmental instability.

Only some of the sex differences in mortality rates are a direct result of fights over women, many arise from competition over other resources and from bodily mechanisms shaped to facilitate this competition. Male tendencies for competition and risky behavior developed because they promoted reproductive success in our ancestral environment. Risky behaviors are not necessarily related to reproductive success in the current environment, which is quite different from the environments experienced by our ancestors. For example, our desires for sweet and fatty foods, which were previously scarce, are contributing to our modern obesity epidemic. Modern family planning technology has also helped to diminish the connection between sex and reproduction.

If Croatian male mortality rates could be reduced to those for females, over 24,000 lives would be saved annually. The number of male deaths in excess of female each year is equivalent to about 1% of the entire Croatian male population. This statistic suggests that there is merit in designing interventions to promote healthy behaviors and risk reduction. Research on evolution and mortality patterns reinforce traditional health promotion messages related to diet and exercise, and also suggest a novel avenue for intervention in the reduction of high-risk behavior (see Nell, 2003). Although it would be extremely difficult to boost male survival rates to female levels, especially given physiological sex differences, historical changes in mortality patterns suggest great potential. For example, the leading cause of death for both males and females in Croatia is cardiovascular disease, which is nearly absent in a hunter-gatherer culture with conditions more closely representing our ancestral environment (Hill & Hurtado, 1996).

Finally, our study illustrates how evolutionary explanations can offer a framework for understanding complex phenomena that result from the interaction of traits shaped by natural selection and environmental and cultural variations. The tendency to consider "biological" and "social" variables as mutually exclusive alternatives has faded as recognition grows that every phenotypic trait is a product of complex gene-environment interaction. An evolutionary perspective offers an integrative and comprehensive causal framework for understanding phenomena of crucial theoretical interest and great practical importance.

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