

GUEST EDITORIAL

Elderly suicide rates: the importance of a non-linear relationship with distal risk and protective factors

The elderly population size is increasing worldwide due to prolonged life expectancy and falling birth rates. Traditionally, suicide rates increase with age. For example, a recent cross-national study of 62 developing and developed countries reported an increase in suicide rates with aging in males and females in 25 and 27 countries respectively (Shah, 2007a). Thus, suicides in the elderly are an important public health concern. While much is known about proximal (individual level) risk and protective factors for elderly suicides (e.g. Conwell *et al.*, 1991; Cattell and Jolley, 1995; Harwood *et al.*, 2001), less is known about more distal (societal or population level) risk and protective factors (Rehkopf and Buka, 2006). Moreover, detailed knowledge of these distal factors may have greater public health relevance for the development of comprehensive prevention strategies (Knox *et al.*, 2004).

Proximal risk and protective factors have generally been examined either descriptively in case-series of elderly suicide victims (Shah and De, 1998) or analytically in case-control studies (Waern *et al.*, 2003). Such studies have primarily examined linear relationships between suicide and proximal risk and protective factors. This approach is understandable because: (1) in case-series studies the most prevalent characteristics of suicide victims have been interpreted to be the risk factors and the least prevalent protective factors; and (2) in case-control studies the statistically significant differences in the characteristics of suicide victims and case-controls have been interpreted to be the risk or protective factors.

The vast majority of early studies of distal risk and protective factors has also taken a similar approach and mainly focused on identifying presence or absence of linear relationships between these factors and suicide rates. For example, in countries with high socio-economic status, including Japan, England, and Wales, lower societal socio-economic status was reported to be linearly associated with increased elderly suicide rates (Kennedy *et al.*, 1999; Whitley *et al.*, 1999; Gunnell *et al.*, 2003; Fukuda *et al.*, 2005), and there was an absence of such a linear relationship with one measure of socio-economic status in a recent study (Shah *et al.*, 2008a). Presence or absence of such

linear relationships may be genuine. However, it is also possible that: (1) some such linear relationships may be erroneous and they may mask genuine non-linear relationships; and (2) the absence of a linear relationship may lead to erroneous conclusion of an absence of a relationship, although this too may mask a genuine non-linear relationship. These issues are examined below because of potentially important implications for the development of preventive strategies at a societal level. There are certain circumstances when consideration should be given to examining non-linear relationships between distal risk and protective factors and elderly suicide rates. These include:

- (1) when a predicted linear relationship is not discovered;
- (2) when an observed linear relationship cannot be explained;
- (3) when there are conflicting findings across studies (both across individual-level and societal-level and between both groups of studies) of any combination of positive, negative, and absent linear correlations, which could include conflicting findings between studies of general population and elderly suicide rates also; and
- (4) when there are *a priori* theoretical reasons to suspect a non-linear relationship. The discrepancies in the previous point may also lead to the generation of an *a priori* non-linear hypothesis.

Two examples of linear relationships that may have masked non-linear relationships are illustrated below. A series of studies reported a negative linear correlation between fertility rates and general population suicide rates (e.g. Leenaars and Lester, 1999; Lester, 1999). Based on these studies, the hypothesis that there would be a negative linear correlation between fertility rates and elderly suicide rates at a societal-level was examined and confirmed in a large cross-national study (Shah, 2008a). The latter findings were initially explained in part by the hypothesis that higher fertility rates would increase the number of younger people available to support the elderly and lead to reduction in elderly suicide rates (Shah, 2008a; Shah *et al.*, 2008b). However, closer re-examination of the original data with scatter plots suggested that a linear negative correlation might have masked a non-linear correlation (Shah, 2008b). This was confirmed

with curve estimation regression models testing the curvilinear relationship (U-shaped curve) fitting the quadratic equation $Y=A + BX + CX^2$ (where Y is the elderly suicide rate, X is the fertility rate, and A , B , and C are constants; Shah, 2008b). This led to modification of the explanatory model given for the linear relationship. Initially, as fertility rates increase, elderly suicide rates may decrease because increased numbers of younger people would be available to support the elderly, and is consistent with Durkheim's hypothesis suggesting a negative association between social integration and suicide rates (Shah, 2008a; Shah *et al.*, 2008b). However, if the fertility rate continues to increase, and beyond a certain critical point, this protective effect of fertility rates may be negated by competition for scarce resources within the family between younger members and the elderly, and lead to higher elderly suicide rates. This is also consistent with Durkheim's hypothesis that the overall cohort size (although in this case it is the family size) may influence suicide rates when there is more competition for scarce resources (Shah and De, 1998). This explanation has the potential to be rigorously tested in studies examining the relationship between elderly suicide rates and various family variables.

Another example of linear correlations masking possible non-linear relationship emerges from recent studies of socio-economic status. Socio-economic status, measured by income inequality (using the Gini coefficient, where higher scores reflect greater income inequality), was reported to have a negative linear correlation with elderly suicide rates in a large cross-national study (Shah *et al.*, 2008a). However, more recently, a curvilinear (inverted U-shaped curve) relationship between elderly suicide rates and socio-economic status fitting the quadratic equation $Y=A + BX - CX^2$ (where Y is the suicide rate, X is the socio-economic status, and A , B , and C are constants) was demonstrated using curve estimation regression models in a cross-national study (Shah, 2010a). Although this study measured socio-economic status using gross national domestic product (Shah, 2010a), the findings are identical when income inequality measured by the Gini coefficient is used as a measure of socio-economic status (unpublished data). These findings resulted in the modification of the original five-stage sequential explanatory model (Shah *et al.*, 2008a) and to the development of a four-stage epidemiological transition model (Shah, 2010a), which can also simultaneously explain the wide cross-national variations in (1) elderly suicide rates, (2) time trends for elderly suicide rates, and (3) age-associated trends in suicides rates. This epidemiological transition model is open to rigorous testing in both

longitudinal within-country and cross-sectional cross-national studies. There are other studies demonstrating linear relationships that actually mask non-linear relationships (e.g. Shah, 2010b).

An example of an absence of a linear correlation masking a possible non-linear relationship emerges from two recent studies of socio-economic status. Socio-economic status, measured by gross national domestic product, was reported to have no linear correlation with elderly suicide rates in a large cross-national study (Shah *et al.*, 2008a). However, more recently, a curvilinear (inverted U-shaped curve) relationship between elderly suicide rates and socio-economic status (measured by gross national domestic product) fitting the quadratic equation $Y=A + BX - CX^2$ (where Y is the suicide rate, X is the socio-economic status, and A , B , and C are constants) at a societal level was demonstrated by using curve estimation regression models in a cross-national study (Shah, 2010a).

An example of conflicting findings with linear relationships leading to the development and subsequent examination of non-linear relationships concerns intelligence and education. A cross-national study of 48 Eurasian countries reported a positive linear correlation between elderly suicide rates and intelligence at a societal level (Voracek, 2005). However, Voracek (2006a) reviewed this relationship and proposed that the relationship between intelligence and suicide rates in the general population and in the elderly followed an exponential-fit model rather than a linear-fit model. However, this exponential-fit model did not fully explain the observed relationship between suicide and lower levels of intelligence in individual-level studies (O'Toole and Cantor, 1995; Gunnell *et al.*, 2005) and an absence of a relationship between suicide rates and intelligence in societal-level studies within several countries (Lester, 1993; 1995; Voracek, 2006b). Given the strong relationship between intelligence and educational attainment (Voracek, 2006c), this exponential-fit model also does not fully explain the observed relationships between suicide and both high (Kowalski *et al.*, 1987; Fernquist, 2001) and low (Willis *et al.*, 2003; Abel and Kruger, 2005) levels of educational attainment in both individual-level and societal-level studies. A Canadian ecological study observed a negative linear correlation between educational attainment and suicide rates in elderly females at a societal level (Agbayewa *et al.*, 1998). The authors of this Canadian study also acknowledged that a possible non-linear relationship between elderly suicide rates and educational attainment might have been missed (Agbayewa *et al.*, 1998). These discrepant findings and the suggestion of a non-linear relationship

prompted a cross-national study which, using curve estimation regression models, reported a curvilinear (U-shaped curve) relationship between elderly suicide rates and educational attainment at a societal level fitting the quadratic equation $Y = A + BX + CX^2$ (where Y is elderly suicide rates, X is educational attainment, and A , B , and C are constants; Shah and Chatterjee, 2008). These findings led to the development of a possible unitary explanatory model explaining the various discrepant findings in both individual-level and societal-level studies (Shah and Chatterjee, 2008).

An example of *a priori* theoretical reasons to suspect a non-linear relationship concerns urbanization. A cross-national (Simpson and Conklin, 1989) and a single country (Stack, 1993) study reported a positive linear correlation between urbanization and general population suicide rates at a societal level. Studies from individual countries (Saunders and Langford, 1996; Yip *et al.*, 2000) reported a positive association between residence in rural areas and suicide in the general population. However, studies from advanced industrialized countries, including general population suicide rates in the USA (Kowalski *et al.*, 1987) and male suicide rates in the general population in Japan (Otsu *et al.*, 2004), reported a negative linear correlation. Moreover, a large cross-national study reported no such relationship (Zhang, 1998). Stack (1982; 2000) explained these conflicting findings by proposing a curvilinear (quadratic) relationship, whereby the suicide rate would initially increase in the early stages of urbanization due to social disruption following migration from rural to urban areas. Thereafter, the suicide rate would plateau, over several generations, as the new urban dwellers begin to adjust to living in urban areas (Stack, 1982; 2000). This adjustment may ultimately lead to a gradual reduction in the suicide rate (Stack, 1982; 2000). Stack (2000) argued that this curvilinear relationship was supported by a longitudinal study of general population suicide rates in Finland (Stack, 1993), whereby a 1% increase in the urban population increased the suicide rate by 0.22% between 1800 and 1900, and a 1% increase in the urban population increased the suicide rate by only 0.12% between 1900 and 1985 (Stack, 1993). However, this proposed curvilinear relationship was never formally evaluated and prompted a cross-national study at a societal level, which demonstrated a curvilinear (inverted U-shaped curve) fitting the quadratic equation $Y = A + BX - CX^2$ (where Y is elderly suicide rates, X is degree of urbanization, and A , B , and C are constants) in men using curve estimation regression models (Shah, 2008c). This study was able to confirm Stack's (1982; 1993; 2000) hypothesis and

explanatory model for men. Other examples of *a priori* theoretical reasons to suspect non-linear relationships concern population growth (Shah, 2009) and the Human Development Index (Shah, 2010b).

Non-linear relationships using techniques other than those discussed above have also been reported. Risk factors attributable to age, period, and cohort membership can independently influence suicide rates at a given age and given time in a given birth cohort (Shah and De, 1998). Suicide rates in individuals born in a particular cohort are peculiar to that cohort – the cohort effect. The specific age at any given time within the cohort will further influence suicide rates – the age effect. Environmental factors at any specified time period will further influence suicide rates – the period effect. Statistical techniques have been developed to partial out the effect of age, cohort, and period on suicide rates (Murphy *et al.*, 1986; Woodbury *et al.*, 1988; Surtees and Duffy, 1989; Skegg and Cox, 1991). For example, suicide rates for white American and New Zealand males increase with age, but the rates for females initially increase with age, peaking at menopause, and decline thereafter (Woodbury *et al.*, 1988; Skegg and Cox, 1991). Another example is the effect of a specified period of time on suicide rates including reduction in suicide rates related to the Second World War (Murphy *et al.*, 1986), changeover to non-toxic domestic gas (Murphy *et al.*, 1986; Surtees and Duffy, 1989), and restriction of barbiturate poisoning (Skegg and Cox, 1991).

Age-associated trends in suicide rates in men in England and Wales, Scotland, and Northern Ireland are low below the age of 25 to 34 years, peak at 25–34 years age, and then decline until age 55–64 years when they begin to rise (Shah and Coupe, 2009); this has been observed in other countries including Australia (Snowdon and Hunt, 2002). This appears to follow a cubic pattern of curve regression, but has not been formally tested.

Non-linear models examining the relationship between socio-economic status and other mental disorders in old age including dementia have been developed and partially tested with experimental data (Suh and Shah, 2001; Shah, 2007b).

Evidence has been presented from emerging studies that a non-linear correlation between distal risk and protective factors and elderly suicide rates is important. Detailed knowledge of distal risk and protective factors is likely to have greater public health relevance for the development of comprehensive prevention strategies (Knox *et al.*, 2004). Unless and until this is consistently and robustly examined, prevention strategies based on erroneous linear correlation or lack of such

correlations may lead to development of flawed public health preventive strategies at a societal level.

Conflict of interest

None.

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