Review

Progress in Research of Nutrition and Life Expectancy[*]

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Life expectancy is an important indicator to evaluate the social development of a country. Health and longevity can not only improve people's life quality but also ensure them to have more time to pursue their life goal. A one-year increase in life expectancy during 'China's Twelfth Five-Year Economic and Social Development Plan' period has been used as an indicator to evaluate whether the goal of improving people's living standards continuously is met. Nutrition is one of the important factors affecting people's health. Both malnutrition and overnutrition are risk factors for disease and death. Many studies of the relationship between nutrition and life expectancy have been conducted in the world, and the results of them are quite valuable for China to improve people's life expectancy by targeted nutrition intervention strategy. This paper summarizes the progress in research of nutrition and life expectancy in the world.

The concept of nutrition covers both nutrition intake and nutritional status; which are known to affect life expectancy and healthy life expectancy. The worldwide used indicators which reflect nutrition intake in nutrition research include calorie consumption per capita, protein consumption, fruit and vegetable intakes, and breastfeeding, etc. Regional food production has also been used in some studies. Nutritional status has also been reflected by anthropometric indicators such as body height, body weight, birth weight, body weight change, body mass index (BMI), waist circumference, waist to hip ratio, and skin fold. In addition, some studies used composite indicators. For instance, one composite indicator used was built by using BMI and nutrition intake to reflect the nutritional status of the population. The measurement of malnutrition or overnutrition was usually according to the value of the anthropometric indicators. As the data came from different sources, the methods of nutrition and life expectancy research also varied.

This paper further explains the content of these studies in three parts. First, the relationship between nutrition and life expectancy, including nutrition intake and life expectancy, body weight and life expectancy; second, the relationship between malnutrition and life expectancy; third, the relationship between overnutrition and life expectancy.

RESEARCH OF GENERAL RELATIONSHIP BETWEEN NUTRITION AND LIFE EXPECTANCY

Dietary Pattern and life Expectancy

Dietary pattern is crucial for human's survival and work capability. The works of Fogel suggested that chronic malnutrition and durative starvation during famines were related to people's survival and work capability[1-2]. Fogel estimated the caloric consumption in France and England at the end of 18th century and found the estimates were consistent with the diet of various social classes and the death rates of each nation. The improvement of nutritional status explained nearly all of the decline in mortality rated in England, France, and Sweden between 1775-1875[2].

Food availability is an important factor to influence life expectancy. Ferda[3] analysed the determinants of life expectancy in Turkey using time series data from 1965 to 2005. Regional public medical expenditures, nutrition intake, cigarette smoking rate, illiteracy rate, crime rate, and urbanization level were selected as determinants. Nutition intake was assessed by using the food production index. The study data were collected from 2007 World Development Indicators of the World Bank (WB), 2007 International Financial Statistics of the International Monetary Fund (IMF), the Economic and Social Indicators of the Turkish Statistical Institution, the Annual Health Statistics of the Turkish Ministry of Health. This study suggested that the most important factor in influencing life expectancy was food availability or nutrition, while

the effect of health expenditure was positive but small.

The dietary pattern is one aspect of a healthy lifestyle. Khaw et al.[4] analyzed the influences of healthy lifestyle on mortality rate by using the data of the European Prospective Investigation into Cancer (EPIC). They identified four healthy behaviors: being physically active, non smoking, moderate alcohol consumption, and adequate intake of fruit and vegetables. The result suggested that there was a 14-year difference in life expectancy between people with all these behaviors and those without these behaviors. Harrington et al.[5] set a score to each healthy behavior to analyze the relationship between these four behaviors and health, obesity, and mental health. They concluded that the protective lifestyles were associated with positive self-rated health, normal body weight, and mental health.

Dietary pattern is also an important factor in infant mortality. Abrahams et al.[6] analyzed the relationship between nutrition transition and death in 40 countries in Sub-Saharan Africa. Data was obtained from the World Health Organization, Demographic and Health Surveys and the Food and Agriculture Organization of the United Nations. A six point score was developed to identify each country's stage in the nutrition transition, and multiple linear regression analysis was used to explore the determinants of infant mortality. This study showed that underweight-for-age, protein and the percentage of exclusively breastfed infants were related with infant mortality.

Dietary pattern affects mortality as a result of disease. The main findings on dietary pattern and mortality in cohort studies and meta-analysis are shown in Table 1. Nutrition affects the mortality of cardiovascular disease and cancer, as well as the overall mortality rate.

The research on food availability at country-level or at regional-level and the research on dietary pattern at individual-level showed that dietary pattern was one of the most important factors for life expectancy based on its influences on human's work capability, infant mortality, and disease-specific mortality.

Nutrition Status and Life Expectancy (death)

Body weight and BMI are the most common indicators to reflect nutrition status. Most studies have found a U- or J-shaped association between BMI and mortality[15-17]. Casper concluded the main results of these studies, on the whole, moderately overweight individuals have been found to have a higher survival. However, the curvilinear relationship were not always been confirmed due to the different sample size, length of follow-up, and controlled factors[3]. Waaler's (1984) study on Norwegian population and Stevens et al.'s (1998) study on American population found the effect of age on the association between BMI (or body height and body weight) and mortality risk[18-19]. Harris et al. found the pre-existing disease was related to the relationship between higher risk of mortality and lower BMI in nonsmoking men and women by using the data of the Framingham cohort study[20]. Lindsted's study of Seventh Day Adventist men showed no evidence for a U-shaped relationship between BMI and all causes of mortality in males. He especially found mortality from cancer and cerebrovascular mortality significantly increased with BMI[21]. Stern et al. and Stevens et al. found that the relationship between mortality and weight/BMI varied with race[22-23].

To conclude, most studies support U- or J-shaped association between BMI and mortality, however, these associations varied by control factors such as age, disease, and race.

MALNUTRITION AND LIFE EXPECTANCY (DEATH)

Malnutrition in Early life and Life Expectancy

Exposure to adverse conditions in early life may causally affect health and mortality in later life[24-25]. The relationship can be explained by the effects suggested in the 'Fetal Origin Hypothesis of diseases' of Barker, which postulated that vital organs and the immune system might develop inadequately if the body faces adverse nutritional events in utero and/or the first stages of life, and that may increase predisposition to chronic diseases in later life[24]. Malnutrition in early life also affects the health of child, and influence their future education, income level, and health.

Most evidence is based on studies using birth weight, or other anthropomorphic measures at birth or in infancy to reflect the conditions of early life. Most studies found associations between early life indicators and increased morbidity rates in later life[26]. However, infant outcomes may depend on unobserved factors such as genetic and socioeconomic factors too, which may also affect the health of older population.

Table 1. Selected Findings on Dietary Pattern and Mortality

Authors	Methods	Results
Sarah J. Nechuta et al. (2010)[7]	Data from Shanghai Women's Health Study in China. Participants included 71 243 women 40 to 70 years old enrolled during 1996-2000 who never smoked nor drank alcohol regularly. Average follow-up of 9 years, finished on December 31, 2007.	The population risks attributable to lack of 4-5 healthy lifestyle factors were 33% for total deaths, 59% for cardiovascular disease (CVD) deaths, and 19% for cancer deaths. Those healthy lifestyle factors referred to normal weight, lower waist-hip ratio, daily exercise, never exposed to spouse's smoking, higher daily fruit and vegetable intake.
Masayo Kojima et al. (2004)[8]	A prospective study of 45 181 men and 62 643 women aged 40-79 years between 1988 and 1990 in Japan. During the follow-up period (average 9.9 years), there were 284 colon cancer deaths (138 men and 146 women) and 173 rectal cancer deaths (116 men and 57 women).	The association between green leafy vegetable consumption and male colorectal cancer mortality was significant (hazard ratio, HR, 0.6, 95% CI, 0.3–0.9). Yogurt intake was inversely associated with male rectal cancer mortality (HR, 0.5, CI, 0.2-1.0). However, women with high fruit consumption had increased colon cancer mortality (HR, 1.6, CI, 1.0-2.6). Small sample size and measurement errors occurred in the food-frequency questionnaire survey should be noted.
Sauvaget Catherine et al. (2004)[9]	Beginning in 1980, using a cohort of 36 228 atomic-bombing survivors in Hiroshima and Nagasaki. They were followed up for 20 years to understand the cancer mortality.	A daily intake of fruit and vegetables was beneficial to the persons exposed to radiation to reduce their risk of cancer death. (The risk reduction by vegetables was from 52% to 32%; risk reduction by fruit was from 52% to 34%).
Pham Truong-Minh et al. (2010)[10]	Japan, beginning between 1988 and 1990, a cohort study, among 25 730 males and 37 673 females, lasting until December 31, 2003	The "vegetable" pattern showed no association with stomach cancer mortality in both males and females; the "dairy product" pattern was significantly associated with a decreased risk of stomach cancer in males, with multivariate HRs of 0.82, 0.74, and 0.72 for the second, third, and fourth quartiles respectively, compared with the first quartile. The "animal food" pattern tended to be associated with an increased risk in females but not significant.
Lunet Nuno et al. (2005)[11]	A meta-analysis of 17 relevant published cohort studies about the association between fruit and vegetable intake and gastric cancer incidence identified from inception to 2004 in PubMed, EMBASE®, and LILACS.	The associations between fruit intake and gastric cancer incidence was significant (RR=0.82, 95% CI, 0.73-0.93), and stronger for follow-up periods of ≥10 years (RR=0.66, 95% CI, 0.52-0.83), but no significant when the outcome was death (RR=1.08, CI, 0.86-1.13). For vegetables intake, the RRs were 0.88(with all studies), 0.71 (longer follow-up), and 1.05 (the outcome was mortality).
Fulvio Lauretani et al. (2008)[12]	Beginning in August, 1998. Longitudinal study among 1 043 adults aged ≥65 years, a population-based cohort of adults living in a community in Tuscany, Italy. During eight years of follow-up, 310 (29.7%) of participants died.	The mortality of the elderly with the highest plasma carotenoid level was lower than those with the lowest plasma carotenoid level. Hazards Ratio was 0.81 (CI 0.65-0.99).
Teresa T. Fung et al. (2010)[13]	Two large, long-term cohort studies in America. Study of 85 168 women (aged 34 to 59 years) and 44 548 men (aged 40 to 75 years) who were followed up from 1980 (women) and 1986 (men) to 2006.	The animal-oriented low-carbohydrate diet group's score was associated with higher all-cause mortality (HR, 1.23, CI, 1.11-1.37). In contrast, the vegetable-oriented low-carbohydrate diet group's score was associated with lower all-cause mortality (HR, 0.80, CI, 0.75-0.85).
Ellen Smit et al. (2007)[14]	Beginning in 1964, Puerto Rica, America, a cohort study of 9 824 men aged 35-79 years who were followed up until 2005.	Legume intake was not associated with prostate cancer mortality. Fruit intake (consuming 1-2 servings of fruit) was negatively correlated with prostate cancer mortality (OR, 0.05, 95% CI, 0.32-0.77).

Some studies used techniques based on 'natural experiments' to identify causal links between nutrition and death. 'Natural' events (such as timing of birth, famine, and disease epidemic) or macro-events (such as economic changes) are taken as sources of external variation to better understand the causal mechanisms. Lindeboom[27] used the nutritional conditions as a result of exposure to the Potato Famine in the Netherlands in 1846-1847 to investigate whether exposure to a nutritional shock in early life negatively affected survival at older ages. The individual data is collected from the registers of birth, marriage, and death certificates of a random sample of 13 718 individuals born in the provinces of Utrecht, Friesland, and Zeeland from 1812 to 1 922. The observation stopped on December 31, 1999. A total of 9 271 individuals were included in the analysis. Multivariable survival analysis was conducted, including variables such as: age, gender, mother's marital status, father's occupation, whether the father was a farmer and whether he was illiterate, province and season at birth, and whether the individual was born in a city or not. The result showed that mortality rates at older ages (50+) were significantly higher for those born during the Potato Famine. The life expectancy at age 50 years was reduced by about 3 years. After controlling the individual characteristics at birth and early life, the effects of exposure to infectious disease and economic conditions remained significant. This finding confirmed the hypothetical link between adverse nutritional exposure in early life and survival in later life. However, the author also discussed that the observed relationships may still be partly explained by exposure to excessive stress during periods of severe famine. They also found an independent and strong effect of economic conditions at birth that individuals from lower social classes were more severely affected by exposure to the Potato Famine at birth than individuals from higher social classes.

The research on the direct effect of malnutrition in early life on life expectancy is rare because of the shortage of related data, however, there is enough evidence to support the association between early life indicators and increased morbidity rates in later life.

Adult Malnutrition and Life Expectancy

The heights, weight, BMI of adults were used as the measurement of nutrition status. Fogel used the Waaler surface, which brought height, weight, BMI and the mortality risk among Norwegian males aged 50-64 in a single diagram, to analyze the relationship between nutritional status and mortality risk. The increase of height would be associated with an increase in life expectancy. The analysis with the estimated French height and weight at four dates implied that factors associated with height and weight explained about 90 percent of the estimated decline in French mortality rates from 1785 to 1870[28].

In areas with adequate food supply, malnutriton is often not due to lack of food supply, but due to environmental conditions. In Western countries, the elderly who lived in hospitals or nursing homes suffered the highest risk of malnutrition and higher mortality rates[15].

Global Burden of Disease (GBD, 2006) estimated that 2.8% of total deaths were induced by low birth weight and 2% were caused by malnutrition in 2001[29]. Population attributable rate (PAF%) was used to estimate the influences of iron deficiency anemia, vitamin A deficiency, zinc deficiency, low fruit and vegetable intake on the burden of disease. Globally, the percentage of iron deficiency anemia, vitamin A deficiency, zinc deficiency, low fruit and vegetable intake attributed to death was 1.1%, 1.4%, 1.5%, and 4.7% respectively. In low and middle income countries, the percentage was 1.3%, 1.7%, 1.8%, and 4.8%, while in high income countries it was 0%, 0.1%, 0%, and 4.2%. These risk factors accounted for 1.6%, 1.6%, 1.8%, and 2.4% of the decrease of disability-adjusted life years (DALYs) across the world[30]. These rates were higher in low and middle income countries.

At the present time, adult malnutrition is not the main cause of death in high income countries, but is still an important factor for life expectancy in low and middle income areas.

Weight Loss and Life Expectancy

If weight loss is the consequence of long-term malnutrition, it may increase mortality. There are also studies which show that weight loss may reduce mortality[15]. Pamuk et al.[31] studied 5-year survival rates of men and women (45-74 years) from the First National Health and Nutrition Examination Survey. Within the normal BMI range (26-29 kg/m^2) and for overweight women (>29), the risk of death increased with severe weight loss, whereas moderate (5%-15%) weight loss reduced mortality risk in men. There are some studies showing that people diagnosed with

diabetes who had lost weight were found to have a lower mortality rate and live longer[32].

For population development, fighting malnutrition plays an important role in increasing life expectancy. As the world's nutrition is in a transition period, especially in developing countries, the issue of overnutrition has also begun to have a serious effect on life expectancy.

OVERNUTRITION AND LIFE EXPECTANCY

The result of more nutrition intake on the basis of unchanged or decreased calorie consumption level is the increase of body fat. Researchers related food and work to body weight in accordance with the theory of energy balance. Basal metabolism, the thermic effect of food consumption and digestion (about 10% of the calories consumed), and physical activity are the main ways to use energy. Calories taken in excess are stored in the body as fat. For each 3 500 kcal taken in excess of expenditures, one pound of body fat is stored[33]. To conclude, overweight or obesity is the reflection of overnutrition .

Overnutrition and increased body size have facilitated the epidemic of chronic diseases and reduced life expectancies. Samaras et al.[34] analyzed the relationships between absolute body weight and longevity and mortality. The findings suggested that absolute body size was negatively correlated with longevity and life expectancy. The slope of the trend line for average age at death versus body weight is -0.4 years/kg. Peeters et al.[35] in their work based on a prospective cohort study showed that obesity had decreased life expectancy by 6-7 years at the age of 40 years. Steven's study showed that the increase in risk of death with each unit increase of BMI declines progressively with age but remains substantial until the age of 75 years and older[19]. Peeters et al. studied the relationship between obesity and disability by using the Framingham Heart Study cohort with an analysis of 46 and 20 years of mortality tracking data. The results indicated that obesity at ages 30 to 49 was associated with a 2.01-fold increase in suffering from ADL limitations 46 years later[36]. The UK Government estimated that overweight/obesity decreased the life expectancy at birth of English men by 2 years and, given the progressive epidemic of obesity, the effect will increase to 5 years by 2050[37].

The influences of overweight and obesity vary in race, gender and age. Fontaine et al.[38] estimated the expected number of years of life lost (YLL) due to overweight and obesity across the life span of an adult in America. The data was collected from the US Life Tables (1999), Third National Health and Nutrition Examination Survey (NHANES III; 1988-1994); and First National Health and Nutrition Epidemiologic Follow-up Study (NHANES I and II; 1971-1992) and NHANES II Mortality Study (1976-1992) to estimate the YLL for adults aged 18 to 85 years. The subjects were divided into 6 groups according to their body mass index (BMI) integer-defined categories (i.e. <17; 17 to 18; 18 to19; 20 to 21; 21 to 45; or >45). A BMI of 24 was used as the reference category. A J- or U-shaped association was found among the white. The optimal BMI was approximately 23-25 for white participants and 23 to 30 for black participants. For any given degree of overweight, younger adults generally had greater YLL than older adults. The maximum YLL for white men aged 20-30 years with a severe obesity (BMI>45) was 13, and was 8 for white women. For men, this would represent a 22% reduction in expected remaining life span. Black participants at younger ages with severe obesity had a maximum YLL of 20 for men and 5 for women.

Obesity can also affect the mortality rates of certain chronic diseases. Brønnum-Hansen et al.[39] estimated the impact of obesity on the life expectancy of chronic restrictive disease among Danes. The data of the Danish Health Interview Survey 2000 was used, with a random sample of 22 486 persons selected from the Danish Civil Registration System. Professionals from the Danish National Institute of Social Research interviewed 16 690 persons. The data from the Danish national cohort study, Danish health Interview surveys in 1987, 1991, 1994, and 2000 and those in the Danish Civil Registration System and other national registers were compiled by a unique personal code, which made it possible to estimate relative risks for death by level of risk factor. In this study, 96% of the diseases were reported to had been diagnosed. Risk factor level-specific life tables were constructed. The results showed that: compared with 25-year-old Danish people with normal weight, obese men lost life expectancy by 2.0 years and obese women lost life expectancy by 3.2 years. Overweight also reduced male life expectancy. However, moderate overweight of men tended to increase life expectancy without illness by 1.4 years. Women who were overweight reduced women life expectancy by 0.7 years, and reduced their life expectancy without

illness by 4 years. Losina et al.[40] estimated the quality-adjusted life-year losses due to knee osteoarthritis and obesity in the U.S population aged 50 to 84 years. Total losses of quality-adjusted life-years per-person ranged from 1.857 in non-obese persons with knee osteoarthritis to 3.501 for persons affected by both conditions. Mehta et al.[41] assessed secular trends in the association between obesity and mortality among cohorts of middle-aged adults from 1948 to 2006 by using three long-running US data sources: the Framingham Heart Study, the National Health and Nutrition Examination Survey, and the National Health Interview Survey. They found substantial declines over time in the magnitude of the association between obesity and overall mortality and, in certain instances, cardiovascular-specific mortality. Chong-do Lee et al.[42] (2011) explored the impact of lifestyle on cancer mortality in the U.S. population. They made followed-up for 24 731 men aged 20-82 years recruited in the Aerobics Center Longitudinal Study. Over an average of 14.5 years of follow-up, a total of 384 cancer deaths occurred. Adjusted for age, examination year, and multiple risk factors, men who were physically fit, never smoked, and had a normal waist girth had a 62% lower risk of total cancer mortality compared with men with no low-risk factors. Men with all 3 low-risk factors had a 12-year (CI, 8.6-14.6) longer life expectancy compared with men with no low-risk factors.

More researches on relationship between overnutition and life expectancy are conducted in recent years. Overweight and obesity, often used as an indicators of overnutriton, have a significant influence on life expectancy, and the influences vary with race, gender, and age.

CONCLUSION

A large number of studies have confirmed that the improvement of nutritional status can increase life expectancy and improve quality of life, and there is adverse impacts from malnutrition and overnutriton on life expectancy. Furthermore, the effects vary with multi factors, such as race, gender, age, health status, and economic status etc. According to the research purpose and the available data used to explore the relationship between nutrition and life expectancy, the studies can generally be classified into three types. The first type was to establish the direct relationship between nutrition and death. This type was based on

individual data, involving both nutrition-related indicators and mortality data; most of these studies used cohort study data. These studies directly answered the question of the impact of nutrition on life expectancy. The second type established the indirect relationship between nutrition and death by using population attributable risk rate to provide evidence to support that nutritional status affects the incidence of disease and that diseases are the main cause of death. For instance, the GBD study used the PAF to estimate the relationship between nutrition and death. In this type of study, both cross-sectional data and cohort study data of death, cause of death, disease and nutrition indicators were used. The third type was mainly the analysis on regional nutrition level and life expectancy; these studies used the regional time-series economic development data to reflect the contribution of nutrition to social development.

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REFERENCES

1. Fogel RW. Second thoughts on the European escape from hunger: Famines, chronic malnutrition, and mortality rates. In: Nutrition and Poverty, OSMANI, S.R. (Editor), 1992; 243-86, Clarendon Press, Oxford.
2. Fogel RW. New sources and new techniques for the study of secular trends in nutritional status, health, mortality and the process of aging. Histor. Methods, 1993; 26, 5-43.
3. Ferda H. Modeling life expectancy in Turkey. Econ Modelling, 2011; 28, 2075-82.

4. Khaw KT, Wareham N, Bingham S, et al. Combined impact of health behaviors and mortality in men and women: the EPIC-Norfolk prospective population study. PLoS Med 2008; 5, e12.

5. Harrington J, Perry IJ, Lutomski J, et al. Living longer and feeling better: healthy lifestyle, self-rated health, obesity and depression in Ireland. Eur J Public Health, 2010; 20, 91-5.

6. Abrahams Z, Mchiza Z, and Steyn NP. Diet and mortality rates in Sub-Saharan Africa: Stages in the nutrition transtion. BMC Public Health, 2011; 11, 801-13.

7. Nechuta SJ, Shu XO, Li HL, et al. Combined impact of lifestyle-related factors on total and cause-specific mortality among Chinese women: prospective cohort study. PLoS Med, 2010; 7, 1-11.

8. Kojima M, Wakai K, Tamakoshi K, et al. Diet and colorectal cancer mortality: results from the Japan Collaborative Cohort Study. Nutr Cancer, 2004; 50, 23-32.

9. Sauvaget C, Kasagi F, Kasagi, et al. Dietary factors and cancer mortality among atomic-bomb survivors. Mutat Res, 2004; 551, 145-52.

10. Pham TM, Fujino Y, Kikuchi S, et al. Dietary patterns and risk of stomach cancer mortality: the Japan collaborative cohort study. Annals of Epidemiol, 2010; 20, 356-63.

11. Lunet N, Lacerda-Vieira A, and Barros H. Fruit and vegetables consumption and gastric cancer: a systematic review and meta-analysis of cohort studies. Nutr Cancer, 2005; 53, 1-10.

12. Lauretani F, Semba RD, Dayhoff-Brannigan M, et al. Low total plasma carotenoids are independent predictors of mortality among older persons: the InCHIANTI study. Eur J Nutr, 2008; 47, 335-40.

13. Fung TT, Van Dam RM, Hankinson SE, et al. Low-carbohydrate diets and all-cause and cause-specific mortality: two cohort studies. Annals of Int Med, 2010; 153, 289-98.

14. Smit E, Garcia-Palmieri MR, Figueroa NR, et al. Protein and legume intake and prostate cancer mortality in Puerto Rican men. Nutr Cancer, 2007; 58, 146-152.

15. Casper RC. Nutrition and its Relationship to Aging. Exp Gerontol, 1995; 30, 299-314.

16. Tsukamoto H and Sano F. Body weight and longevity: Insurance experience in Japan. Diabetes Research of Clinical Practice, 1990; 10, S119-S125.

17. Cornoni-Huntley JC, Harris TB, Everett DF, et al. An overview of body weight of older persons, including the impact on mortality. J Clin Epidemiol, 1991; 44, 743-53.

18. Waaler HT. Height, weight and mortality: The Norwegian experience. Acta Med Scand, 1984; Suppl, 679, 1-56.

19. Stevens J, Cai J, Panuk ER, et al. The effect of age on the association between body-mass index and mortality. N Engl J Med, 1998; 338, 1-7.

20. Harris T, Cook EF, Garrison R, et al. Body Mass Index and mortality among nonsmoking older persons: The Framingham Heart Study. JAMA, 1988; 259, 1520-4.

21. Lindsted K, Tonstad S, and Kuzuma JW. Body mass index and patterns of mortality among Seventh-day Adventist men. Int J Obesity, 1991; 15, 397-406.

22. Stern MP, Patterson JK, and Mitchell BD, et al. Overweight and mortality in Mexican Americans. Int, J. Obesity, 1990; 14, 623-9.

23. Stevens J, Keil JE, Rust PF, et al. Body Mass Index and Body Girths as Predictors of Mortality in Black and White Men. Am J Epidemiol, 1992; 135, 1137-46.

24. Barker DJP. Mothers, Babies, and Health in Later Life, 2nd edition. Churchill Livingstone, Edinburgh, New York, 1998.

25. Fogel RW. The Escape from Hunger and Premature Death, 1700-2100: Europe, America, and the Third World. Cambridge University Press, Cambridge. 2004.

26. Barker DJP, Godfrey KM, Fall C, et al. Relation of birth weight and childhood respiratory infection to adult lung function and death from chronic obstructive airways disease. Br Med J, 1991; 303, 671-5.

27. Lindeboom M, Portrait F, and Berg GJ. Long-run effects on longevity of a nutritional shock early in life: The Dutch Potato famine of 1846–1847. J Health Econ. 2010; 29, 617-29.

28. Fogel RW. Nutrition, Physiological Capital and Economic Growth, A lecture prepared for presentation at the Senior Policy Seminar on Health, Human Capital, and Economic Growth: Theory Evidence and Policies of the Pan American Health Organization (PAHO) and Inter-American Development Bank (IADB) 2002. http://www.paho.org/English/HDP/HDD/fogel.pdf.

29. Jamison DT, Breman JG, Measham AR, et al. Disease Control Priorities in Developing Countries (second edition). Oxford University Press and the World Bank, 2006; 31.

30. Alan DL, Colin DM, Majid E, et al. Global Burden of Disease and Risk Factors (second edition). Oxford University Press and the World Bank, 2006; 10.

31. Pamuk ER, Williamson DF, Madans J, et al. Weight loss and mortality in a national cohort of adults, 1971-1987. Am J Epidemiol, 1992; 136, 686-97.

32. Haslam DW and James WPT. Obesity. The Lancet, 2005; 366, 1197-209.

33. Abdus S and Rangazas P. Adult nutrition and growth. Rev Econ Dynam, 2011; 14, 636-49.

34. Samaras TT, Storms LH, and Harold E. Longevity, mortality and body weight. Ageing Res Rev, 2002; 1, 673-91.

35. Peeters A, Barendregt JJ, Willekens F, et al. Obesity in adulthood and its consequences for life expectancy: a life-table analysis. Ann Intern Med, 2003; 138, 24-32.

36. Peeters A, Bonneux L, Nusselder JW, et al. Adult obesity and the burden of disability throughout life. Obesity Res, 2004; 12, 1145-51.

37. Department of Health. Choosing health: making healthy choices easier. Norwich: Stationery Office, 2004. Available from: www.tso.co.uk/bookshop.

38. Fontaine KR, Redden DT, Wang C, et al. Years of life lost due to obesity. JAMA, 2003; 289, 187-93.

39. Brønnum-Hansen H, Juel K, Davidsen M, et al. Impact of selected risk factors on expected lifetime without long-standing, limiting illness in Denmark. Preventive Med, 2007; 45, 49-53.

40. Losina E, Walensky RP, Reichmann WM, et al. Impact of Obesity and Knee Osteoarthritis on Morbidity and Mortality in Older Americans. Annals of Int Med, 2011; 154, 217-74.

41. Mehta NK and Chang VW. Secular Declines in the Association Between Obesity and Mortality in the United States. Population and Development Rev, 2011; 37, 435-51.

42. Chong-do L, Xuemei S, Steven PH, et al. Combined Impact of Lifestyle Factors on Cancer Mortality in Men. Ann Epidemiol, 2011; 21, 749-54.