European Review, Vol. 9, No. 4, 487–499 (2001) © Academia Europaea, Printed in the United Kingdom

Stress, ageing and quality of life

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This paper highlights the role of chronic psychosocial stress in accelerated ageing and age-associated degenerative diseases, referring to the free radical theory of ageing. Chronic work stress in midlife provides an illustrative case to explore these associations, with an emphasis on cardiovascular disease and its subclinical precursors. It is argued that lack of control at work and the experience of an imbalance between efforts spent and rewards received at work trigger continued stress reactions with adverse long term effects on health. These conditions impair the working person's successful self-regulation in a core social role in adult life – the work role. Self-efficacy and self-esteem, two important psychological components of well-being and health, are compromised if personal control and social reward are lacking. Selected empirical results derived from epidemiological and experimental investigations are reported to illustrate this argument. In particular, otherwise healthy middle-aged employees suffering from stress at work are twice as likely to report a new cardiovascular disease in a five year period compared with their less stressed colleagues. In another study, an increase in average ambulatory systolic blood pressure and heart rate is observed in a group of workers characterized by an imbalance between effort and reward at work. The implications of this research for improved quality of life and healthy ageing in early old age concern the provision of adequate social roles, which offer opportunities for experiencing continued personal control and social reward. At the socio-political level, new forms of social productivity in economic and non-monetarized sectors need to be developed.

Introduction

In science, the study of the disturbed conditions of a system often discloses some insight into the processes that underlie its normal functioning. Ageing of living organisms is a process that is still not sufficiently explained by current science; in particular, ageing in humans. It has been proposed that the study of conditions that accelerate or precipitate ageing might shed some light on the dynamics of normal ageing processes. In fact, several theories have been advanced

https://doi.org/10.1017/S1062798701000448 Published online by Cambridge University Press

along these lines, including the genetic theory of ageing with its impressive identification of specific genes that trigger accelerated ageing, the evolutionary theory of ageing[1], the somatic mutation theory of age[2], and the free radical theory of ageing.

This paper highlights the role of stressful experiences in accelerated ageing. By doing so it broadens the scope of analysis beyond genes and the bodily system to include the psychological and the social dimensions of human life. Without excluding other theoretical approaches, this work refers to the free radical theory of ageing as it offers the most explicit conceptual and empirical links between stress and ageing.

More than 40 years ago, Harman proposed the free radical theory of ageing.[3] This theory postulates that damage produced by enhanced endogenous oxidation of the organism is a major contributor to accelerated ageing and age-associated degenerative diseases. Targets of oxidative damage are lipids, proteins and DNA. As free radicals interfere with proteins and the DNA, they are able to generate cell and tissue lesions with possible long-term consequences for organ systems. Increased susceptibility of malignant neoplasms and increased atherosclerotic disease risk were related to the adverse long-term effects of endogenous oxidation. The human brain may be especially prone to free radical damage as it is exposed to a high amount of oxygen, utilizing about one fifth of the oxygen consumed by the body.[4] Moreover, there is an age-related increase in lipid peroxidation and also in iron, whereas the brain has relatively low levels of antioxidant enzymes that could activate defence mechanisms against reactive oxygen species. More recently, investigations have found support for a role of oxidative damage to brain ageing and neurodegenerative diseases such as Parkinson's disease and Alzheimer's disease.[5, 6]

In view of these systemic effects of endogenous oxidation on accelerated ageing and accelerated degenerative diseases, it is important to know what factors contribute to excess levels of reactive oxygen species within the organism. Increased metabolism is one such factor, and probably the most widely prevalent one. This is exactly where a link between stress and accelerated ageing or age-related degenerative diseases can be established. In fact, Liu and Mori[6] have put forward this idea and called it the 'oxidative damage hypothesis of stress-associated ageing acceleration'. Under normal metabolism, oxidant by-products are expected to produce some damage to the organism. However, antioxidant defence systems are activated to counteract these effects. Under stress-induced increased metabolism, this balance is disturbed. Increased generation of oxidants augments oxidative damage and accelerates ageing and age-related disease manifestation.

Increased metabolism is a common reaction to enhanced autonomic nervous system activation and the release of stress hormones, especially the catecholamines and glucocorticoids. These hormones play a critical role in triggering increased metabolism and associated endogenous oxidation. A limbic-hypothalamic-pituitary-adrenocortical system has been postulated as an integrating unit controlling physiological and behavioural responses to stress. This reaction manifests itself as altered turnover rate in norepinephrine, dopamine and serotonin in different brain regions. Moreover, activation of the hypothalamic-pituitary-adrenocortical (HPA) axis results in an elevation in plasma glucocorticoid levels. Stress-related elevation of glucocorticoids has been implicated in neuropathological lesions, especially so in hippocampal structures.[7] The action of plasma glucocorticoids which are released from the

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adrenal axis is well established. They stimulate the release of energy substrates into plasma while inhibiting glucose uptake, fatty acid storage, and protein synthesis at the storage site. Long-term effects of these reactions result in pathophysiological developments of the cardiovascular and cerebrovascular system and in reduced immunocompetence, among others. These and other effects have been described as the results of chronic adaptation efforts that produce an 'allostatic load' within the organism.[8] The critical question, then, is what psychological and social conditions elicit sustained or recurrent stress reactions within the organism and, thus, contribute to accelerating ageing.

Stress and ageing: a theoretical framework

Stress is best defined as a person's response to an environmental demand or threat that taxes or exceeds his or her ability to meet the challenge. This response is described at four different levels that act in concert – the cognitive (appraisal of danger and of own coping resources), the affective (negative emotions such as anxiety, anger), the autonomic nervous system (arousal of stress axes), and the behavioural (fight and flight reaction) level. Chronic stress results from exposure to demanding or threatening environmental challenges that cannot easily be avoided by physical or mental escape because these challenges are important for a person's need fulfilment. In humans, the most pervasive chronic stress is associated with socio-environmental rather than physical challenges and threats. Apart from rare life events that threaten one's physical survival, need fulfilment is mostly related to socio-affective processes, in particular comfort with one's self and with one's most proximate significant others.[9, 10]

To understand better the intensity of stressful experience associated with disturbances of meaningful socio-affective exchange it is important to point to the fact that humans are social beings *par excellence*. From early on in ontogeny, the individual strives to develop a psychosocial identity that is shaped and reinforced through social interaction with significant others.[11] A co-evolution of affective brain structures and of patterns of social interaction during the attachment formation period in early infancy underlies the powerful experience of positive and negative emotions during social exchange later in life.[12] Thus, successful self-regulation to a large extent is contingent on a responsive social environment that provides opportunities of acting and contributing (self-efficacy), of receiving feedback and reward (self-esteem), and of belonging and being connected (self-integration).

In adult life, these socio-environmental opportunities of self-regulation cluster in core social roles. A social role is defined as a set of typical behaviours that are expected to occur from a person holding a specific position, such as the position of a mother or a father, of a partner, of a working person etc. It is through the provision of social roles that individuals are enabled to act and contribute to their social environment, to receive feedback and reward from significant others, and to participate in social networks. Conversely, exclusion from core social roles, loss of or threat to the continuity of these roles elicits strong negative emotions and recurrent stressful experience as this prevents successful self-regulation.[13]

These positive and negative aspects of self-regulation by means of acting through core social

https://doi.org/10.1017/S1062798701000448 Published online by Cambridge University Press

roles in adult life are best illustrated by the work role. There are at least four important reasons for the centrality of work and occupation in advanced industrialized societies. First, having a job is a principal prerequisite for continuous income opportunities. One's level of income determines a wide range of life chances. Secondly, training for a job and achievement of occupational status are the most important goals of socialization. It is through education, job training, and status acquisition that personal growth and development are realized, that a core social identity outside the family is acquired, and that intentional, goal-directed activity in human life is shaped. Thirdly, occupation defines a most important criterion of social stratification in advanced societies. The amount of esteem and social approval in interpersonal life largely depends on the type of job, professional training, and level of occupational achievement. Furthermore, the type and quality of occupation, and especially the degree of self-direction at work, strongly influences personal attitudes and behavioural patterns in areas that are not directly related to work, such as leisure, family life, education, and political activity.[14] Finally, occupational settings produce the most pervasive and continuous demands during one's lifetime and they absorb the largest amount of active time in adult life. Exposure to adverse job conditions carries the risk of ill health by virtue of the amount of time spent and the quality of demands faced at the workplace. At the same time, occupational settings provide unique opportunities to experience reward, esteem, success and satisfaction.[15] It is therefore evident that chronic stress at work in midlife is a powerful determinant of accelerated ageing and of increased risk of stress-related ill health. It is important to understand the underlying processes and to assess the empirical evidence of these associations.

Chronically stressful experience at work has been identified in the recent past with the help of two theoretical models, the demand–control model and the effort–reward imbalance model (see below). These models are based on two more general constructs of health-related stress research, 'personal control' and 'social reward'. The construct of 'personal control' has provided the dominant perspective in health-related stress research during the past three or four decades.[16–18] The amount of control a person can exert over aversive environmental stimuli is considered a crucial determinant of the psychobiologic stress response (see Figure 1). The agency and perception of control, striving for control, and threats to, or loss of, control are associated with marked differences in neurohormonal, autonomic and immune responses, in emotional experience, and in cognitive and behavioural correlates. At the psychological level, control induces feelings of mastery and enhanced self-efficacy, of autonomy and self-determination. In a sociological perspective, control is an essential prerequisite of power and status, especially so, as it operates through access to scarce resources. The demand–control model of work stress derives directly from this construct.[19] According to this model, work is stressful to the extent that job tasks provide little opportunity for decision latitude and variety in task performance. Yet, it is the combination of low control and high demand at work that triggers stressful experience most intensely, as the working person's capacity for unwinding or restoring resources through positive emotions and anabolic physiological responses is compromised.

A second stress-theoretical construct has been proposed, the construct of social reward[12, 20, 21] (see Figure 1). There is now increasing evidence about the powerful regulatory role of a particular brain system implicated in motivation, reinforcement and reward in personal and interpersonal well-being: the mesolimbic dopamine system, which innervates the

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Personal Control	**Social Reward**
_threat of loss of control as a consequence of adverse environmental conditions	_inadequacy, threat or loss of reward in significant social exchange
neurobiological aspect	**neurobiological aspect**
_hypothalamic-pituitary-adrenocortical axis	_dopaminergic system ('cascade theory of reward')
_sympatho-adrenomedullary axis	_sympatho-adrenomedullary axis
psychological aspect	**psychological aspect**
_self-efficacy, self-confidence	_self-esteem, self-respect
_autonomy	_belonging
sociological aspect	**sociological aspect**
_status and power	_reward being part of a 'grammar' of reciprocal social exchange

Figure 1. Two stress-theoretical constructs.

prefrontal cortex, a brain region involved in cognitive function and anticipatory activity. Reward-sensitive neuronal structures in the orbitofrontal cortex elicit sustained stress reactions following the frustration of reward expectancies or the loss of anticipated gratifications. This mesolimbic system is believed to be involved in the control of basic motivations, such as sexual drive and appetite.[22, 23] In addition, it is considered a common pathway for processing experiences related to addiction. At the level of psychological self-regulation, reward induces positive feelings of self-esteem and self-respect, but also, equally importantly, feelings of belonging and of self-integration into a broader interpersonal or even spiritual context. These positive emotions seem to be as important as those associated with mastery and self-control. In an evolutionary sociological perspective, reward is considered part of a basic 'grammar' of social exchange, the grammar of reciprocity and fairness: spending effort and meeting demands contribute to a socially organized exchange process to which society contributes in terms of rewards. Violation of expectations of reciprocity in core social roles is likely to provoke sustained negative emotions and related stressful experience.[24]

To summarize, experience of personal control and social reward is essential for successful self-regulation in meaningful social exchange through role agency. Threats to this process may trigger prolonged stressful experience followed by adverse health consequences. Role termination by exclusion or loss is the most visible, and probably most stressful, experience of a whole series of constellations in societal life where control and reward are compromised.

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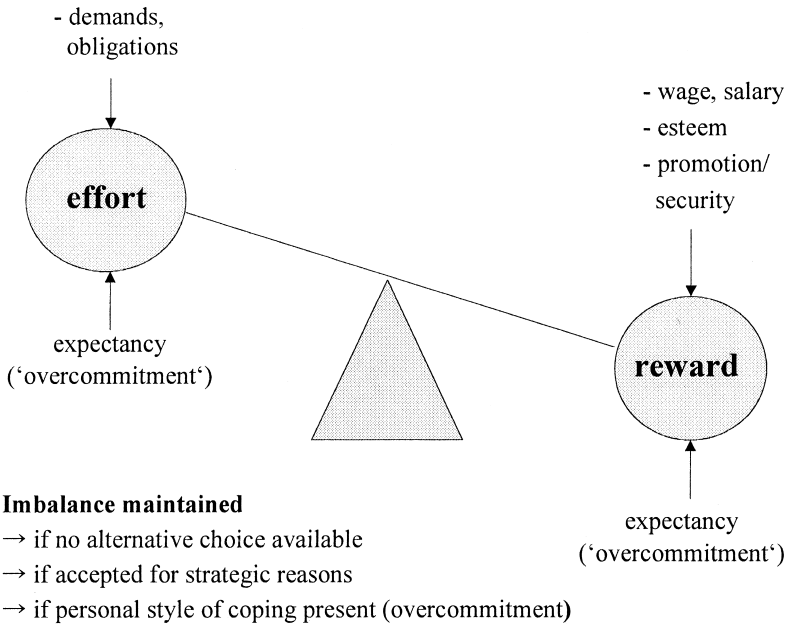


Figure 2. The model of effort-reward imbalance at work.[13]

The model of effort–reward imbalance

One such constellation has been identified as the imbalance between efforts and rewards in a core social role – the work role[13, 21]. Again, in view of the centrality of work and occupation in adult life, most intense effects of disturbed self-regulation are expected to occur in this context. The model of effort–reward imbalance maintains that the availability of an occupational status is associated with recurrent options of contributing and performing, of being rewarded or esteemed, and of belonging to some significant group (e.g. work colleagues). Yet these potentially beneficial effects are contingent on a basic perquisite of exchange in social life, that is, reciprocity. Effort at work is spent as part of a socially organized exchange process to which society at large contributes in terms of rewards. Rewards are distributed by three transmitter systems as scarce resources: money, esteem and career opportunities. The model of effort–reward imbalance claims that lack of reciprocity between the costs and gains (i.e. high cost/low gain conditions) defines a state of emotional distress with special propensity to autonomic arousal and neuroendocrine stress responses. For instance, having a demanding but unstable job, achieving at high level without being offered any promotion prospects, are examples of a particularly stressful working context (see Figure 2).

High cost/low gain conditions are maintained under the following three circumstances. First, when an alternative choice in the labour market is not available, anticipated costs of disengagement (e.g. the risk of being laid-off or of facing downward mobility) outweigh the costs of accepting inadequate benefits. Therefore, unrewarding jobs are held. Secondly, people may accept unfair job arrangements for a certain time for strategic reasons, as they may improve their chances for career promotion and related rewards at a later stage. The third reason for

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a continued mismatch between efforts and rewards points to a particular psychological make-up of the working person. People characterized by a motivational pattern of excessive work-related overcommitment and a high need for approval may suffer from inappropriate perceptions of demands and of own coping resources more often than their less involved colleagues. Perceptual distortion prevents them from accurately assessing cost–gain relations. As a consequence, they underestimate the demands, and overestimate their own coping resources.[13, 21] These three conditions, by acting separately or in concert, help to explain why people often are confined to certain social roles that offer low rewards despite the fact that continued high efforts are spent. Recurrent feelings of disappointment and frustration, of being treated unfairly and suffering injustice are associated with circumstances inducing a state of 'social reward deficiency' and impaired self-esteem.

Prolonged experience of effort–reward imbalance is not confined to the work role. It can result from conflictual marital relationships, from unsuccessful agency in family roles or in civic roles. The 'hidden injuries of class',[25] the feeling of not getting anywhere despite one's efforts, may even extend to the life sphere as a whole and trigger a sense of being locked in a totally unrewarding social environment. The cumulative experience of high cost/low gain conditions in a central role in adult life is critical as it compromises all three self-regulatory functions that depend on a conducive, favourably responsive social environment: self-efficacy, self-esteem and self-integration or belonging. In conclusion, 'loss of or exclusion from core social roles' (low control) and 'confinement to roles where social reciprocity is violated' (low reward) are proposed as two constructs that account for chronically stressful experience, a higher risk of age-related disease and accelerated ageing. The following section provides selective empirical evidence on this hypothesis with particular reference to the model of effort–reward imbalance at work.

Empirical evidence

The prospective epidemiologic investigation provides the 'gold standard' of a research methodology that tests hypotheses on a potentially causal association of psychosocial phenomena, such as effort–reward imbalance at work, with biological outcomes, such as cardiovascular disease. In this type of study, a baseline screening is conducted in a representative sample of men and women; for instance, in a large company or in a community. In this screening, information on current health status and on all conditions that are assumed to influence the development of the disease under study is collected. In the present context, studying the role of chronic work stress in the development of cardiovascular disease (see below) requires a reliable and valid assessment of each individual's level of work stress in terms of the models mentioned above. In addition, information on biological and behavioural cardiovascular risk factors is needed to adjust the hypothesized effects of work stress on cardiovascular disease for these established risk factors in respective statistical models. A positive test of the hypothesis is given if the rate of newly reported or diagnosed diseases in a follow-up period is significantly increased in the group initially defined by high levels of work stress compared with the group with low or no stress at work. This increased probability is indicated in a quantitative estimate termed *relative risk* or *odds ratio*. The higher an odds

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ratio the higher the probability that the predicting variable contributes to the development of an illness.

Prospective epidemiologic studies are time-consuming and expensive. Therefore, cross-sectional investigations are often conducted that assess predicting conditions and health outcomes simultaneously. Evidently, their scientific credibility is inferior to the one provided by prospective studies. Even in prospective epidemiologic investigations, supplementary research designs are needed to examine whether, and to what extent, causal inference is appropriate. Supplementary research designs include naturalistic studies where bodily responses are monitored under real-life conditions (e.g. 24 hour ambulatory registration of heart rate, blood pressure, cortisol measures by saliva samples). Additionally, laboratory experiments can be designed to simulate stressful conditions as defined by the theoretical models and to register biological responses under controlled conditions.[26–28]

In this section, cardiovascular risk factors and cardiovascular disease (CVD) are chosen as health outcomes in epidemiologic and experimental investigations on work stress. Owing to its high prevalence in midlife and in early old age, CVD provides an instructive example of age-related diseases. Moreover, studying the role of chronic stress in precipitating the development of CVD is thought to be helpful in understanding accelerated ageing as triggered by increased metabolism. The adverse effects of enhanced metabolic activity often manifest themselves in an increase in cardiovascular risk factors, such as elevated levels of glucose, insulin, fibrinogen and atherogenic lipids.[26] These latter conditions have also been studied in association with chronic stress at work.

Figure 3 gives an example of findings derived from a prospective epidemiologic investigation of some 10 000 male and female civil servants in London, the so-called Whitehall II study. This cohort has been followed over five years after baseline assessment of work stress and relevant biomedical and behavioural risk factors. New reports of coronary heart disease (CHD) were found to be more than twice as frequent among the group of employees defined by high effort and low reward at work, compared with the group of non-stressed workers (Figure 3, left-hand side). A similar independent association was found with respect to the group of employees who were confined to jobs with low task control or decision latitude (see Figure 3, right-hand side).[29] However, the combined effect of high demand and low control, as suggested by the theoretical model of job strain,[19] was not predictive of new CHD. It is interesting to note that the independent effects of the two formulations of work stress, social reward deficiency and lack of personal control, remained significant after statistical adjustment of a large number of confounding variables, most importantly biomedical and behavioural cardiovascular risk factors (see text of Figure 3).

Two additional prospective studies revealed similar findings on an association of effort–reward imbalance at work in midlife and an increased CHD risk.[30, 31] The evidence of a prospective link of low control at work with future CHD is even more convincing.[15] Moreover, in a four-year consecutive study of 940 male workers in Finland, the progression of carotid atherosclerosis (plaque height, as measured by ultrasound technique) was significantly advanced in the subgroup defined by high demands and low economic reward at work compared with the remaining group.[32]

A large number of studies have explored associations of work stress in terms of the two models with cardiovascular risk factors, mainly hypertension, atherogenic lipids, and elevated

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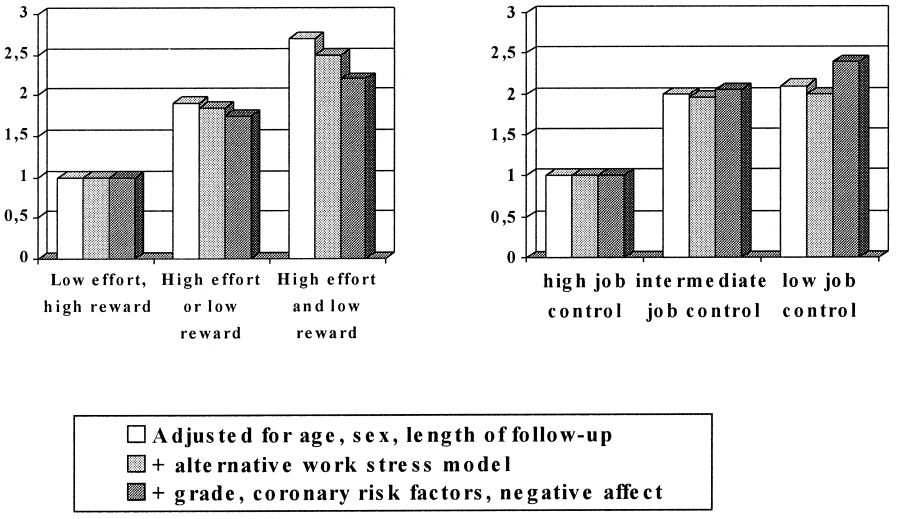


Figure 3. Effort reward imbalance/job control and new coronary heart disease reports in 6,489 male and female employees (Whitehall II Study)[29].

fibrinogen.[15, 26] For instance, among men characterized by an imbalance between effort and reward the relative risk of suffering from hypertension and hyperlipidemia was more than three times as high as the one among workers characterized by low stress. Components of the model were also found to explain hypertension or hyperlipidemia among working women.[33] These findings are not restricted to European populations. In a recent investigation of some 400 working women in Beijing it was found that the risk of being hypertensive was three times higher among those who suffered from low reward at work. Similar effects were observed with regard to low job variety and conflict between work and family. In this study, the significant impact of being overweight on hypertension was also confirmed.[34] As mentioned, scientific evidence based on epidemiologic associations of indicators of chronic stress with indicators of age-related diseases or accelerated ageing needs to be supplemented by experimental or ambulatory monitoring studies of biological processes that may underlie the observed statistical associations. Again, a couple of such investigations have been conducted in the recent past despite the many methodological challenges involved in this research.[30, 26–28]

To illustrate this approach, results from an ambulatory monitoring study of 109 male white-collar workers in the Netherlands are briefly summarized. Participants were monitored for 24 hours on two workdays and one non-workday for ambulatory blood pressure, heart rate and heart rate variability. A high work stress group was defined by an imbalance between high effort and low reward ($n = 23$) and mean cardiovascular reactivity of this group was compared to the reactivity of a low stress group ($n = 86$).[28] Men classified as suffering from work stress had a significantly higher work and home systolic blood pressure than non-stressed men, the difference being on average 3.9 mm Hg ($F = 3.98$; $p < 0.05$). Whereas no difference was found with regard to diastolic blood pressure, the two groups also differed significantly with respect to heart rate. During work and leisure periods on the working days the high-stress

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group had a higher mean heart rate compared with the low stress group (6.8 bpm; $F = 2.85$; $p = 0.01$). In addition, an index of vagal tone, based on registration of heart rate variability, showed a trend for the high imbalance group to have lower vagal tone during all periods compared with the low imbalance group ($F = 3.7$; $p = 0.059$).[28] These findings are consistent with results from studies testing the effects of high demand and low control at work on ambulatory blood pressure and heart rate.[26, 27]

Taken together, epidemiologic and experimental evidence is in line with the general assumption that chronic socio-emotional stress in a core social role in adult life – the work role – triggers enhanced metabolism and endogenous oxidative damage to the organism, which manifests itself in, among other things, an increased risk of cardiovascular disease. It is likely that the health burden produced by chronic socio-emotional stress in midlife is underestimated by the findings reported here as most studies were confined to one core social role, the work role. Exposure to additional stressors – such as unemployment, marital separation, chronic family conflicts, poverty, forced migration and social exclusion – have not been considered here. However, socio-epidemiologic research has indicated that each one of these conditions is associated with increased illness susceptibility.[35]

Implications for quality of life in early old age

The theoretical approach and the empirical evidence summarized above indicate that successful self-regulation through core social roles contributes to the protection of health and the promotion of normal ageing during midlife. In particular, experiencing self-efficacy in a work role that offers opportunities of personal control, and experiencing self-esteem in a work role that provides adequate social reward, seems to exert favourable effects on well-being and health or, to introduce a more general term, on the quality of life in adults. This conclusion is inferred from a series of findings demonstrating an increased risk of age-related disease manifestation (cardiovascular and especially coronary heart disease) and of its subclinical precursors (progression of atherosclerotic plaques in arteries, hypertension, hyperlipidaemia, enhanced activation of the cardiovascular system) among those who suffer from low control and from low social reward at work. What are the implications of these results for healthy ageing and enhanced quality of life in early old age?

First, it is evident that people who were more privileged during their economically active period in terms of a low level of chronic work stress are more likely to stay healthy and to exhibit signs of normal ageing when entering a stage of life that is now increasingly labelled as the third age or early old age; that is, the age range from 60 or 65 up to 80 years or so.[36] In view of an expanded healthy life expectancy in old age this conclusion is important as it points to the potential of improved quality of life for a growing part of elderly populations in advanced societies. On the other hand, people who were exposed to a high level of work stress in midlife are more likely to suffer from subclinical or clinical chronic degenerative diseases such as cardiovascular disease, when entering their third age. Their quality of life is reduced as a function of a continuously experienced impaired self-regulation in a core social role in midlife and as a function of their reduced health and well-being. Thus, these groups are expected to exhibit an increased vulnerability in the face of the many demands and threats that are inherent in the lives of the elderly.

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A second implication concerns the socio-political challenges of social productivity and enhanced quality of life in early old age. Provided the theoretical approach outlined in this contribution is valid, I conclude that healthy ageing in early old age is greatly enhanced if people are offered social roles that enable them to continue their favourable experience of self-efficacy, self-esteem and belonging. It is through continued exposure to a controllable challenge and to positive feedback from significant others to one's achievement that a sense of mastery, of worth, and of meaning is reinforced and that one's motivation and energy are mobilized. Society at large has not yet responded to this challenge of providing a variety of social roles to a growing part of the early old age population that is healthy, active and motivated to contribute and perform. These social roles may include work role arrangements beyond traditional retirement age, for instance part-time work, flexible work schedules and work recompensated on the basis of performance rather than seniority. However, these roles may also include new forms of social productivity apart from economic life. Examples of non-monetary social activities include honorary offices, membership in civic associations and networks and support activities of caring for the handicapped and the chronically ill. If healthy ageing and favourable quality of life for a majority of people entering the third age are considered important societal goals it is mandatory to face the challenges of developing new forms of social productivity. Recent scientific progress in understanding the links between socio-economic, socio-emotional and biological phenomena may be helpful in this process.

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https://doi.org/10.1017/S1062798701000448 Published online by Cambridge University Press