High-demand jobs: Age-related diversity in work ability?

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Abstract

High-demand jobs include ‘specific’ job demands that are not preventable with state of the art ergonomics knowledge and may overburden the bodily capacities, safety or health of workers. An interesting question is whether the age of the worker is an important factor in explanations of diversity in work ability in the context of high-demand jobs. In this paper, the work ability of ageing workers is addressed according to aspects of diversity in specific job demands and the research methods that are needed to shed light upon the relevant associated questions. From the international literature, a body of evidence was elicited concerning rates of chronological ageing in distinct bodily systems and functions. Intra-age-cohort differences in capacities and work ability, however, require (not yet existing) valid estimates of functional age or biological age indices for the specific populations of workers in high-demand jobs. Many studies have drawn on the highly demanding work of fire-fighters, ambulance workers, police officers, medical specialists, pilots/astronauts and submarine officers. Specific job demands in these jobs can be physical, mental or psychosocial in origin but may cause combined task-level loadings. Therefore, the assessment of single demands probably will not reveal enough relevant information about work ability in high-demand jobs and there will be a call for more integrated measures. Existing studies have used a variety of methodologies to address parts of the issue: task analyses for quantifying physical work demands, observations of psychological and physiological parameters, measures of psychosocial work demands and health complaints. Specific details about the work ability of ageing workers in high-demand jobs are scarce. In general, specific demands are more likely to overtax the capacities of older workers than those of younger workers in high-demand jobs, implying greater repercussions for health, although these effects also vary considerably within age cohorts. Functional tests for job-specific work ability should be developed for high-demand jobs in order to monitor individual functional ageing and to facilitate well-timed intervention. It is concluded that a shift from ‘no-diversity thinking’ to ‘diversity thinking’ is needed in the context of deciding about the work ability of ageing workers in high-demand jobs.

Keywords: Work ability; Ageing; High-demand job

1. Introduction

This paper presents topics relevant to the relationship between work ability and age, particularly in the context of high-demand jobs. High-demand jobs are those that involve potential public health implications because of the health risks that workers may impose upon others (e.g. colleagues and public) during the course of their work. These high-demand jobs may serve as a magnifying glass to facilitate the initial explanation of the work ability problems that are assumed to accompany ageing. High-demand jobs or high-risk jobs are those that include ‘specific job demands’. Following the Dutch Medical Examination Act from 1998, ‘specific’ job demands are defined as those that exceed exposure safety levels or average human capacities to meet such demands on a daily basis, leading to increased risk of work-related health problems. These specific demands cannot be eliminated with state-of-the-art (ergonomics) measures and can be classified into (or a combinations of) physical, mental, or psychosocial job characteristics.

All (ergonomics) professionals on ‘work and health’ face the challenges that the ageing workforce will bring us. Demographic changes will force older workers to work to an older age and relatively few young workers will be present in the workplace. In the context of high-demand jobs, questions then arise about ageing workers and their productivity or quality of work, and about their health risks and safety. When concerning the age of the user, the
ergonomist could normally incorporate elements from many subjects, including anatomy, physiology, psychology and design. Stated differently, normally options are available to ensure that people’s capabilities and limitations are taken into account. Jobs without specific demands will therefore probably not require additional ergonomics attention or actions to keep older workers fit in the job. However, in the context of high-demand jobs with specific job demands, several questions about age-related diversity in work ability still need to be addressed in more detail: What do we know about work ability and age in high-demand jobs? What are the main challenges that relate to the relationship between work ability and age in these job contexts? How should we study these challenges, and how should we monitor work ability and age in-service? Is no-diversity thinking in this context a valid way of thinking?

1.1. Aim

This paper presents an overview of the above-mentioned topics that concern the relationship between work ability and age, particularly within the context of several high-demand jobs. Diversity in work ability and ageing will be addressed from the perspective of different specific job demands and diversity in research methods that are needed. Although this paper is not a complete literature review, it does provide numerous examples from the literature on several high-demand jobs.

Determining how and why age is an important factor in explanations of diversity in work ability can be seen as ‘quite a job’ for ergonomics professionals. A few words about ageing and ageing workers, therefore, are in order before elaborating upon the two main perspectives in more detail. In studying work ability and age in high-demand jobs, it is not relevant to set age limits to define ageing workers or younger or older worker in advance (Sluiter and Frings-Dresen, 2004a, b). Questions regarding the relationship of age and work ability are important, as the workforce is expected to age dramatically in the decades to come (Ilmarinen, 2001). Our perception of this problem is shaped by recent demographic estimates, as discussed in the next section.

1.2. Ageing population and the number of aged workers

What differences currently exist across different geographical regions, and what differences will appear in the future? Fig. 1 presents United Nations population data (2000) for the USA, Brazil, China and Australia. Data in the Figure concern the number of people aged 60 years or older compared to the total population in that region. The Figure compares population figures from 2000 to forecasts...
for 2030. The trends are the same for all countries: a relative increase in the number of elderly people is expected in the coming 2.5 decades. The relative increase in older people, however, does not outpace the total population increase.

A more detailed examination of the data reveals a number of striking differences. The information in Fig. 2 provides more detail with regard to the percentages of the population in different age cohorts for various parts of the world. Population data from the 1950s are compared to...
data from 2000 and forecasts for 2050 (United Nations, 2005a,b). Using the percentage of people over the age of 60 years (indicated by the red portions of the Figure) as a reference point, the greatest ageing problem could be expected to occur in Europe and the Russian Federation. Population ageing is actually a problem of prosperity, as it reflects a general state of health that prevents people from dying at younger ages. As shown in Fig. 3, however, prognoses for specific countries differ, even within regions. Some geographic regions are left with relatively few young workers. Demographic changes may force older workers to postpone retirement in other regions. These projections raise questions about ageing workers and their productivity or quality of work, in addition to questions about their own safety and health. Most jobs may have no ‘specific’ job demands, and they require no special measures to keep workers physically and psychologically in a state to perform their jobs over longer periods. At present, however, the number of workers who are joining the ranks of the elderly, even in jobs that are purportedly non-problematic, varies considerably across countries and global regions. For example, governmental policies from the 1970s, 1980s and 1990s that were aimed at creating jobs for younger people in some parts of Europe are the main reason for the currently low percentages of workers above the age of 55 years (e.g. Siegrist, 2005). Employment rates do vary by gender: almost all males (as high as 80%) in some age cohorts participate in the labour force, while the female employment rate in most age cohorts rarely exceeds 60%. Fig. 4 shows variation in the situation in a number of geographic regions over the last 50 years (FIFARS, 2005). In 2002, the Netherlands had the lowest employment rate in Europe (37%) for people between the ages of 55 and 65 years (European Foundation for the Improvement of Living and Working Conditions, 2004). The data in Fig. 4 could be construed to confirm the hypothesis that, for most jobs, no problem should be expected regarding work ability and labour force participation up to the age of 70 years. However, these data do not relate specifically to high-demand jobs.

2. Specific job demands

The specific job demands that characterise high-demand jobs can be classified according to physical, mental and psychosocial job characteristics (van Dijk et al., 1988).
Physical demands may refer to energetic (aerobic or anaerobic), biomechanical (static and dynamic demands on the musculoskeletal system) or environmental demands. Mental demands require input from such cognitive domains as concentration, memory, decision-making or attention. Psychosocial demands refer to emotional demands, interpersonal relations, autonomy, time-pressure, irregular working hours or the appraisal of extreme environments. In the natural work environment, work tasks often involve a combination of various specific demands, possibly increasing their impact on the human system (Sluiter et al., 2000). Specific demands may be studied directly (e.g. by assessing the frequency, duration or intensity of occurrence of tasks or subtasks) or indirectly (e.g. by assessing human reactions during and after performing work tasks).

2.1. Definition of specific job demands

Following the Dutch Medical Examination Act from 1998, specific job demands are defined as job demands that cannot be eliminated by current state-of-the-art (ergonomic) measures and that may exceed exposure safety levels or average human capacities. The term also refers to demands that are thought to increase the risk of work-related health problems. Specific job demands refer to demands that could be met on a daily basis in that job.

Health, safety and worker capacity are important components of this definition. Work ability should be assessed in relation to the specific job demands. New rules and regulations regarding age discrimination in employment have altered the age limits for early retirement from several high-demand jobs, both in the USA and in most European countries. Although these changes also contribute to the ageing of the future workforce, we currently have no information about the performance of older workers in high-demand jobs. Several high-demand jobs may have important potential public health implications when workers are not able to fulfil their specific demands safely. This paper considers examples of specific job demands as faced by fire-fighters, ambulance workers, police officers, medical specialists, pilots/astronauts and submarine officers.

2.2. Diversity in specific job demands

This section presents a number of examples of specific job demands that are associated with the aforementioned high-demand jobs. Because of the selection criteria for these jobs, applicants tend to come from selected populations in terms of education, training and personal characteristics.

2.2.1. Physical demands

Lusa et al. (1994) asked 156 fire-fighters to list their heaviest physical tasks that involved aerobic activities. The following tasks were mentioned by both younger and older fire-fighters: (1) tasks in smoky environments, using self-contained breathing apparatus (SCBA) equipment; (2) removing debris with heavy hand tools; (3) fire suppression inside buildings; (4) fire suppression outside buildings; and (5) diving with self-contained breathing apparatus (SCBA).

Sothmann and colleagues (1992) assessed ten fire-fighters while they were engaged in suppressing fires inside buildings. The heart rates of these workers ranged between 146 and 171 b min$^{-1}$, and the tasks were performed at an average of 63% of their $V_{O2Max}$ (range 44–86%). Analyses by Sluiter and Frings-Dresen (2004b) revealed no age-related variation in either the average or range of percentages of heart-rate reserve (% HRR) during periods of technical-help turnouts or fire-extinction turnouts. Individuals varied widely within age cohorts (e.g. % HRR ranged between 10 and 56 in the 50–54 years age group); a workload that is not heavy for one fire-fighter may be quite heavy for another individual under natural working conditions in extreme environments. Workloads during technical-help or fire-extinction turnouts are usually classified as heavy, according to the present (% HRR) criteria.

Submarine, spaceflight and fire-fighting officers often encounter hyperbaric or hypobaric and hyperthermic or hypothermic physical environments. Although protective outfits and measures are available, they do not offer full protection from these environmental demands. These workers may therefore be at risk for (neuro) physiological and cognitive loadings, and their perceptual, cognitive and psychomotor abilities may be affected negatively within short periods of time (e.g. Conkin et al., 2003; Manzey and Lorenz, 1999; Robinson et al., 1999).
2.2.2. Mental demands

Mental demands during space flights are considered extreme, due to the tasks that are involved with maintaining technical systems and conducting a variety of experiments. In addition, tight schedules must be met under extreme time pressure. Microgravity, disturbed dark-light cycles and disturbed sleep may further decrease mental capacities in space (e.g., Manzey and Lorenz, 1999; Manzey, 2000; NASA, 2006; Sandal et al., 1995, 1996). The special mental demands that are faced by fire-fighters, ambulance workers and police officers include driving with flashing lights and sirens, working under time pressure when human life is at stake and making complex decisions in hazardous environments. Pilots of reconnaissance U2 airplanes fly at extreme altitudes in full pressure suits to protect them from high-altitude hazards. This environment involves high mental demands because of the decreased visual field, and it may evoke profuse sweating, fatigue, dizziness, decreased situational awareness and other bodily reactions.

2.2.3. Psychosocial demands

A study of 1396 Dutch fire-fighters revealed that older workers perceive their work to be more emotionally demanding than their younger colleagues do, although the levels do not exceed those of the general Dutch working population. In contrast, older ambulance workers (>49 years) experience higher emotional demands than their younger colleagues do, and the absolute values are high relative to those of other health-care workers. Both younger and older fire-fighters and ambulance workers tend to identify the same peak emotional demands. Although the impact of such events may vary according to personal life circumstances, the most severe events reported by all workers are as follows: severely injured or dead children or colleagues, resuscitations, dealing with dangerous substance procedures and sustained eye contact with severely injured victims (Sluiter and Frings-Dresen, 2004a, b). The intensity of an emotional event is the most powerful predictor of post-traumatic stress disorder in the military (Jones et al., 2003). Although the chance of experiencing peak emotional demands is the same for younger and older personnel, more frequent encounters may cause additional “wear and tear” in certain areas of the brain (e.g., McEwen, 1998; Miller and O’Callaghan, 2005).

During submarine missions and space flights, interpersonal relationships (social support), communication, context-specific stressors and other psychosocial demands are considered extreme; these demands are in addition to the demands of the hyperbaric and hypobaric physical environment. Context-specific stressors in space and submarine environments include isolation and confinement, crowding, noise, a hazardous external environment and the workload. These demands interact with personal characteristics that influence stress activity levels and coping, and they increase in importance with the length of missions. Research has shown that the level of such demands varies at crucial points during missions. To date, the maximum number of space-flights performed by any US astronauts is seven. The age of crew members during the last six missions that returned to earth safely varied from 37 to 54 years, with an average of 46 years (e.g., Manzey and Lorenz, 1999; Manzey, 2000; NASA, 2006; Sandal et al., 1995, 1996).  

2.3. From specific demands to work ability and age

Diversity within the various classes of demands (i.e. physical, mental or psychosocial) is an important factor to consider when exploring the relationship between work ability and age. Knowledge may be limited concerning the maximum bodily capacities that specific job demands require, whether they exceed the physiological fitness level of ageing workers and whether they affect the work ability of the older worker in high-demand jobs. Other questions concern the consequences that specific demands have for safe and healthy physical and psychological recovery, the effects of age on bodily capacities and the impact of various combinations of physical, mental and emotional demands on the capacities of ageing humans. The following section addresses several of these questions but starts with some general evidence of age-related effects on bodily capacities.

3. Work ability and age: where do we encounter diversity?

In this section, evidence is presented about age-related effects on bodily capacities and the relation between decreased bodily capacities and work (dis)ability. As will be shown, most existing studies focus on biological subsystems or context-free capacities. The knowledge base about human capacities with regard to age and the ability to perform integrative tasks in high-demand jobs is actually quite empty.

3.1. Age-related effects on bodily capacities

3.1.1. Kinetics of healthy human ageing

The normative declines in broad physiological fitness and health parameters that are associated with chronological age have been studied extensively. Research has revealed wide inter-individual variations in both the nature and rate of ‘normal’ decline among ‘healthy’ people within the same age-cohort in single-study populations. Sehl and Yates (2001) conducted a meta-analysis of the kinetics of ‘healthy’ human ageing (as measured by rates of senescence) between the ages of 30 years and 70 years. The annual percentage of decline from the reference value at age 30 years was calculated from 469 articles, representing research on 54,000 healthy people. Weighted average linear loss rates for 13 organ systems were between 0.3% and 0.5% per year for the central nervous system, the musculoskeletal system, the circulatory-haematopoietic
system and the renal system. Average declines of 0.5–0.7% per year were calculated for the integumentary system, chromosomal structure and functioning, gastrointestinal system, and endocrine (non-reproductive) system. Average declines for the respiratory system, the thermoregulatory system, the immunological system, the autonomic nervous system and the endocrine (reproductive) system were between 0.8% and 1.3% per year. For integrative tasks, which require the function and interaction of nearly all organ systems (e.g. when examining maximal oxygen consumption), average linear loss rates were 0.97% per year (range 0.1–1.6%). The average annual decline for organ-system variables and integrative variables combined was 0.65% (SD 0.56). A person’s functional capacity \( Y \) (of a certain organ system) at age \( x \) \((Yx)\) is thus defined as the percentage of the initial value remaining at age 30 years (being 100%). The measure is calculated by subtracting the senescence loss-rate times (the subject’s age minus 30 years) from 100%. Bortz states that symptomatic health impairments do not appear in most systems until 70% of maximal capacity has been lost (Bortz, 2005; Bortz and Bortz, 1996).

General cognitive abilities, reaction time, memory and decision-making are examples of integrated cognitive human functions. The most robust phenomenon in cognitive ageing is a general slowness (in milliseconds), which affects performance and is manifested most clearly in complex, mentally demanding task situations. An additional slowing factor reflects deficits in peripheral sensorimotor processes and a proportional slowing factor as a function of task complexity (Ilmarinen, 2001; Shock et al., 1984). Task-complexity requires processing resources, and individual workers may be limited in the following aspects: (A) time or rate of processing; (B) space or working-memory capacity; or (C) energy or attentional capacity. Intellectual abilities showed no change with ageing. Fluid abilities (speed of decision-making, short-term memory, attention and other cognitive functions) were more sensitive to decline with increasing age than were crystallised abilities (verbal, acquired or specialised skills), which are highly domain-specific (Kok et al., 1994; Shock et al., 1984). In practice, however, many tasks involve both fluid and crystallised abilities. For example, in a prospective eight-year assessment, Deary and Der (2005) showed that simple reaction time and choice reaction time become slower and more variable with increasing age (from 16 to 64 years). In the famous Betula study, age-related decline in episodic memory was observed between the ages of 35 and 80 years, but no change was observed in semantic memory, working memory or perceptual representation systems. Both retrospective and prospective episodic memory tasks showed deteriorated performance across age groups (Nilsson, 2003). In everyday decision-making tasks, older people typically seek less information and take longer to review each piece of information than do younger people. In addition, older people may rely more on heuristic processes than they do on analytical strategies. No age-related differences were observed in probabilistic decision-making, as measured by Bayesian probability estimates, number of conjunction fallacies or disjunction errors (Fisk, 2005). Older people may compensate for their decreasing working memories by applying alternative strategies for processing information.

Reaction time and fine-motor performance on a newly acquired task showed considerable variability between subjects, but the decline progressed more rapidly after 60 years of age (Smith et al., 2005). Maximum oxygen uptake serves as an integrated measure of cardio-respiratory fitness for physical exertion during work. Estimated declines of between 20% and 30% were found to occur between the ages of 18 and 53 years, with marked changes between the 40–44 years age cohort and the cohort of 49–53 years of age (Shock et al., 1984). Between 43 and 70 years of age, men who had participated in a physical training programme experienced declines of 5% per decade, while men who had dropped out of their exercise programmes experienced decennial declines of 19% (Kasch et al., 1995). Goldspink (2005) described the age-related decline in functional reserve capacities of the heart and skeletal muscles.

Another line of research addresses the development of an index of biological age (i.e. functional age, physiological age) as an alternative for chronological age. Conceptually, the index provides information on abilities or capacities. Although the index of biological age has been explored for decades, no gold standard has been developed. Karasik and colleagues (2005) proposed a combination of human biomarkers as a means of disentangling the genetic determinants of human ageing. An overview by Warner (2004) revealed a number of difficulties that have been encountered in the search for valid biomarkers of ageing in research programmes that involved several animal models of ageing. The few human studies that have been conducted have proposed test batteries that include changes in telomere length, cross-linking of collagen, inflammatory markers, immune function tests, genetic memory markers, hippocampal volume and other biomarkers of biological age. Such batteries include osteographic scoring systems as an indicator of skeletal age (Karasik et al., 2005; Larsson et al., 2004; Miller and O’Callaghan, 2005; Warner, 2004).

At the IEA 2000 conference, Kumashiro (2000) proposed a functional-age calculation for office workers and blue-collar workers. The bodily activities that were addressed in this calculation included visual acuity, standing trunk flexion, vital capacity, systolic blood pressure and jumping reaction time. Another non-exercise test model for predicting cardio-respiratory fitness from five health indicators (one of which was age) was proposed recently (Jurca et al., 2005).

In summary, a body of evidence provides general estimates for rates of ageing in specific bodily systems and for specific capacities. Information on the extent to which these indices correlate with work ability, however, is not available. In addition, general population data may not reveal valid estimates for the specific (and selected) populations that are relevant to the context of high-demand jobs.
3.2. How well do decreased bodily capacities predict work (dis)ability?

Work ability can be defined as still performing in the workplace, and the concept has been captured and measured with the widely used work ability index (WAI) (Ilmarinen, 1999). The operational definition for the WAI consists of the response to the following question: ‘How well is the worker at present, and in the near future, and how able is he or she to do his or her work with respect to the work demands, health and mental resources?’ (Ilmarinen et al., 2005). In their study of a representative sample of the Finnish working population, overall work ability was best explained by work factors and health (capacity). Cut-off scores for the WAI have been developed for (older) workers, and these scores have been applied by many researchers. WAI scores between 37 and 43 are considered good. In their study of 180 physicians in age cohorts from 26 to 55 years, Costa et al. (2005) found an average WAI of between 40 and 42 for all cohorts. Kiss et al. (2002) used the WAI in a study of 236 Belgian fire-fighters. The percentage of fire-fighters with insufficient work ability increased from a low of less than 5% in the 45–50 years age cohort to more than 30% in the age cohort of 56–59 years. Interestingly, these older fire-fighters were still on duty.

Few existing age-relevant studies consider scientific evidence on how measures of decreased bodily capacities could be used to help determine work (dis)ability. The application of specific bodily capacities, including VO\textsubscript{2}Max (assessed by a bicycle test) or grip strength (assessed by a hand dynamometer), as selection cut-off points for heavy jobs could result in the elimination of half of the presently available workers. For example, Saupe et al. (1991) conducted a laboratory assessment of 150 fire-fighters from various age cohorts. The results showed that, when an aerobic capacity criterion of 33.5 ml kg\(^{-1}\) min\(^{-1}\) was required, more than 60% of the fire-fighters between the ages of 40 and 45 years did not pass. This rose to 80% for fire-fighters between the ages of 50 and 55 years, and it was even higher (90%) among fire-fighters between the ages of 60s and 65 years. Nevertheless, all of these men were currently on active duty as fire-fighters.

A classic example of failed screening for psychological fitness for duty (the select-out principle) comes from screening studies for psychiatric vulnerability in the military during the First and Second World Wars. The number of false positives that were generated by the inventories greatly exceeded the number of true positives. Failures have also been reported for psychological select-in principles (Jones et al., 2003).

3.2.1. Where do we go from here?

The examples just shown have not been successful in providing sufficient evidence for classifying certain tasks or activities as too demanding for ageing workers. Ideally, an index could be developed for calculating work ability that could be applied to workers with specific job demands. Another option in the assessment of individual work ability for high-demand jobs is to consider the so-called more functional tasks in valid contexts, because this may increase the predictive validity of the used indicators. Because age discrimination in employment is prohibited, a base of evidence is needed to establish a kind of ‘biological age’ cut-off, after which a job can be considered (too) high risk. Such a cut-off could be used as indicator for necessary in-service examinations. Although functional performance or functional capacity may be the most critical predictor of good job performance, it is unclear whether this measure has been applied as a “medical” test of work ability within the spectrum of the research methods that have been used thus far. This is the subject of the next section.

When physiological or psychological limits are exceeded temporarily but frequently, decisions about work ability must take into account the shorter and longer-term consequences of exceeding worker capacity.

4. Diversity in research methods

The combination of specific job demands may be associated either with work-related health problems or with increased risks to the safety of workers and others. For this reason, the investigation of these issues requires a variety of research methods.

Knowledge concerning the interaction of the specific job demands and workers may be divided into the following categories: (i) the frequency, intensity and duration of tasks in relation to different human capacities; (ii) the extreme environment (i.e. environments to which humans are not naturally suited and that demand complex processes of psychological or physiological adaption (Manzey and Lorenz, 1999)); (iii) the relevant (combination of) capacities in the specific group of people that perform these jobs; (iv) the relevant health aspects of these workers, as compared to the general population; (v) the capacities of younger and older workers, relative to the demands; and (vi) age and safety risks. These multidimensional sources of knowledge call for a variety of methodologies and multi-disciplinary approaches that may consist of task analyses for quantifying physical work demands, observations of psychological and physiological parameters, measures of psychosocial work demands and health complaints (e.g. reference norms, expert interviews and self-reports), in addition to screening research.

4.1. Research methods in ageing research: useful for studying work ability and ageing in high-demand jobs?

In their comprehensive work on normal human ageing, Shock et al. (1984) warned that cross-sectional age-cohort research should account for confounding age-cohort effects. They urged researchers to be cautious in drawing conclusions about age-related changes, given that age-related differences are often caused by extraneous
variables, including birth-cohort effects. The rates of change and diversity among individuals are important. Longitudinal research is necessary to determine whether the average curve of age differences that is found in cross-sectional research represents the average progression of ageing in individual subjects. How rapidly does an individual change with respect to a specific variable or functional test? Longitudinal within-subjects data provide estimates of the rate of functional ageing and can help to identify significant events that may influence the variables under study. The appropriate use of predictive variables requires the specification of critical ‘performance’ levels.

The ergonomics community may be able to learn from designs that have been used in general ageing research (e.g. the Betula study (Nilsson et al., 1997, 2004)). As long as no longitudinal data are available for specific groups of workers, however, knowledge concerning the relationship between work ability and age must rely on a combination of data concerning work demands and relevant capacity outcomes during work. These indicators have been proposed as input for comparing age cohorts. Work-related bodily capacities and indicators of health and safety are of interest when making such comparisons.

Several hundred studies have been published in the international literature about fire-fighters and other high-demand jobs. At most, however, only 10% of these studies report on issues that are relevant to age. Most of the evidence comes from comparisons of cross-sectional age cohorts. Studies of fire-fighters have drawn on a variety of data sources, including the following: subjective workload ratings, national data on turnouts or accidents, laboratory test findings from stress-testing situations, functional test findings during simulations and physiological parameters assessed in the natural work environment (Sluiter and Frings-Dresen, in press). Few age-relevant studies of ambulance workers have been published. In the Netherlands, available data sets of fire-fighters and ambulance workers were re-analysed in order to examine age-related effects (Sluiter and Frings-Dresen, 2004a). Few age-relevant studies on pilots, astronauts, police officers and similar job categories are available in the literature.

4.2. The use of biomarkers to assess the bodily impact of work demands

How useful are biomarkers for estimating the bodily impact of specific demands? Most studies have used the VO2Max or lung parameters, or other cardiovascular markers. Conkin et al. (2003) assessed age differences in venous gas emboli (VGE) as predictors of decompression sickness after 238 simulations of diving and aviation decompressions from 10.2 to 4.3 psia (the operating pressure of the current US space suit) from various studies. The probability of finding the most severe grade IV VGEs increases linearly from 0.2 at 44 years of age to 0.7 at 60 years of age. Longer pre-breathing time with 100% oxygen lowered these probabilities. Few studies on fire-fighters, ambulance workers or police officers have examined hormonal or immunological responses. A recent study by Smith et al. (2005) revealed a fourfold increase in the adrenocorticotropic hormone (ACTH) levels of young firefighters (24–38 years) after fire-fighting drills. The data also revealed a twofold increase in the concentration of cortisol after repeated drills, with incomplete recovery up to 90 min thereafter. In a study by Sluiter et al. (2003), the cortisol concentrations of ambulance workers rose during and up to 30 min after emergency calls. Higher cortisol reactivity and slower recovery were observed in younger but not in older workers (Sluiter and Frings-Dresen, 2004a).

4.3. Simulations or assessments in the natural working environment

Simulations of fire-fighting operations inside buildings revealed that, although the aerobic capacity of fire-fighters generally decreases with age, wide inter-individual variation in task performance occurs during simulated fire-fighting subtasks, with more than sixfold differences in time-on-task and the percentage of heart rate reserve, both between and within age groups (Sluiter and Frings-Dresen, 2004b). The same task demands may thus be classified as average, high or very high in terms of the percentage heart-rate reserve (% HRR) for individual fire-fighters during turnouts. Simulated emergency periods involving a combination of stair-climbing and lifting tasks revealed that ambulance workers might experience peak loads of up to 40% HRR, with maximal heart rates up to 188 b·min⁻¹ (Gamble et al., 1991).

In natural working situations, the % HRR of firefighters and ambulance workers varied more within than between age cohorts (Sluiter and Frings-Dresen, 2004a, b). The average workload for fire-fighters during emergency events could be classified as heavy, according to current % HRR criteria. Ambulance work consists of (an) aerobic peak loads of short duration.

In a predictive-validity study, Sothmann et al. (2004) devised and performed a combination of tests to assess the minimal work capacity demand faced by American firefighters. On average, fire-fighters under the age of 30 years took less than 7 min to complete these tasks. Their colleagues over the age of 50 years required an average of more than 9 min. On average, females took 2 min longer than their male colleagues to perform the tests. A combination of three predictor tests was able to explain only half of the total time-on-task of the combined repressive activities.

4.4. Health indicators through accident registrations

In the Netherlands, 42 fire-fighter fatalities were recorded over a period of 33 years (Sluiter and Frings-Dresen, 2004b). Among US workers, firefighters face the greatest chance of dying during work (16.7 per 100,000 workers), followed by police officers (14.2) and ambulance
workers (12.7), compared to other workers (5.0). The fact that cardiac arrest was the cause of death in half of the US fire-fighter fatalities suggests that the safety of colleagues and the public may have been endangered. Registration systems have revealed that US fire-fighters over the age of 50 years have an increased chance of dying during work than do their younger counterparts. Being between 25 and 44 years of age is associated with the highest risk of on-the-job fatality among US ambulance workers. Various studies of the prevalence of non-fatal incidents during fire-fighting work showed no consistent age effect (Clarke and Zack, 1999; LeBlanc and Fahy, 2003; Maguire et al., 2002).

4.5. Health indicators through self-report

Sluiter and Frings-Dresen (2004b) assessed the self-reported health complaints of fire-fighting personnel from various age-cohorts. The 6-month prevalence of lower back complaints ranged from a low of 20% among workers who were younger than 25 years to a high of 39% among workers between the ages of 50 and 54 years. The 6-month prevalence of knee complaints ranged from 12% to 17% among workers who were younger than 49 years, while the figure for workers above the age of 54 years was 25%. In a study of 895 repressive fire-fighters, workers who were above the age of 49 years were three times more likely than their youngest colleagues to experience severe fatigue or work-related fatigue. Compared to their colleagues who were younger than 40 years, heart complaints were three times and five times more prevalent among fire-fighters who were between 40s and 49 years of age and those older than 49 years, respectively. Among workers who had complaints involving shoulders, lower back or knees, half of the repressive fire-fighters who were older than 49 years reported decreased work ability because of these complaints, as compared to 20% of fire-fighters who were younger than 30 years. The risk of work absenteeism due to work-related physical or psychological overload was between three times and five times higher for fire-fighters who were older than 49 years than it was for their youngest colleagues.

4.6. Where do we go from here?

Valid assessment techniques that can be applied during simulated or real task environments, and that can be assessed repetitively within subjects throughout the careers of workers are among the research methodologies that are needed to gather age-relevant data on work ability in high-demand jobs. Because almost no data are available concerning workers over the age of 60 years in high-demand jobs, within-subject monitoring may be the sole future solution. Relevant physical and psychological parameters could be monitored during these assessments, and objective criteria for the safe and sufficient execution of tasks should eventually be used to select and help workers ‘at-risk’. Developments in the area of functional testing or job-specific work ability indices and within-subject monitoring are likely to be the most fruitful direction of inquiry within the context of high-demand jobs.

5. Conclusions and recommendations for future assessments of work ability in high-demand jobs: from no-diversity thinking to diversity thinking

Although functional performance or functional capacity may be the most critical predictor of good future job performance, they have yet to be applied extensively as tests of medical work ability within the spectrum of research methods that have been used thus far. Functional performance has seldom been used as a test of medical work ability in pre-employment or in-service (job-surveillance) assessments. The results of a study on fire-fighters that was conducted by Sothmann et al. (2004) indicate that groups of incumbent professionals should establish future criteria for ‘successful’ and ‘unsuccessful’ performance. These criteria could be used to introduce functional testing for fire-fighters and increase the acceptance of these ‘new’ kinds of medical tests in the fire-fighting sector. Because catastrophes can occur for both workers and their environment when the time or duration of task performance in public health jobs is excessive, time-on-task (task duration) could serve as a valid criterion. The same study by Sothmann et al. (2004) proposed the 83% pass rate for functional tests as a benchmark for other municipalities. A second category of valid criteria could be developed to reflect situations in which workers have more than a twofold risk of experiencing health problems or accidents in comparison to their colleagues. These criteria could be used for decisions involving interventions or permission to continue working.

Being an astronaut is a very specific high-demand job that is performed by few workers. Age has not been a central theme in published research in this context, although behavioural health has (Palinkas et al., 2005). Selection, training and ‘in-flight support’ have all been used to prepare, monitor and intervene in order to keep space-flight workers fit enough for duty (Manzey and Lorenz, 1999). The monitoring of mental and psychological performance of astronauts during space flights of longer duration may therefore serve as an example of how to establish systems of pre-employment and in-service monitoring. Miller (2004) advocates similar procedures for US police officers. In Ireland, Ide (2000) has studied the repeated health surveillance of fire-fighters. From a human-factors perspective and following the ideas of Gledhill, Kuruganti and Rickards (2004) proposed a method for developing scenarios of actual practice. In the Netherlands, a pre-employment and in-service monitoring system for ambulance workers has been developed (Sluiter and Frings-Dresen, 2005), and a similar system is being developed for fire-fighters.
Our future knowledge base should be built upon valid and comprehensive assessment techniques. It should be supplemented by effective measures for: (i) keeping workers healthy in their jobs; (ii) increasing the safety of (co)workers; and (iii) optimising person–job interaction. We must make evidence-based pre-placement health decisions and improve the quality of health surveillance in the form of in-service medical assessments for workers who have longer careers in high-demand jobs. While continuing to use established pre-placement health decisions, periodic in-service (medical) assessments should be performed to identify individuals who have become susceptible to known workplace hazards. In addition, these measures must identify workers whose present health or capacities interfere with their ability to perform (part of) their jobs as safely as other employees, thereby endangering themselves or others. Once work ability problems have been identified, relevant personal, technical or organisational interventions (e.g. working fewer hours, move from front office to back office, physical or psychological counselling or training) must be available, introduced and evaluated.

Future activities include improving our understanding of the changes that are necessary, and shifting from the present pattern of no-diversity thinking towards diversity thinking with regard to functional age and high-risk jobs. If age is an important barrier to some high-demand jobs, is it more feasible to adapt these non-adaptable jobs to the majority of ageing workers, or should we try to adapt them to only some? With respect to diversity in age and work ability in high-demand jobs, my main ergonomic message for the near future is that, while high-demand jobs are definitely not for everyone, we must continue to adapt them to most of the workers who survived the pre-placement tests. Although it will require considerable effort, we should see this task as a challenge for the near future.

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References


