

ERGONOMICS AS AN AGE MANAGEMENT TOOL IN THE ERA OF INDUSTRY 4.0

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1. Introduction

Aging population is one of the principal demographic and socioeconomic problems of the contemporary world. The distinctive features of an aging population are decreasing total fertility rates and increasing life expectancy. With age, individual ability to work changes, which is primarily caused by deterioration of physical capacity, fitness, and some psychophysical function (perceptiveness, reaction time, sensory function). At the same time, older people more frequently tend to suffer from cardiovascular, respiratory, and musculoskeletal disorders as well as hormonal imbalance and metabolic disorders. On the other hand, job demands, unless a change of jobs occurs, usually remain the same regardless of the worker's age, as a result of which the actual workload may in fact increase with age [Bugajska, Makowiec-Dąbrowska, Wągrowaska-Koski, 2010, p. 55]. This compels employers to seek measures to counter the shrinkage of working-age population.

In the era of Industry 4.0, enterprises strive to shift the burden of labor from human beings to automated machines and industrial robots – a solution which is still too expensive for businesses operating in Poland. According to the International Federation of Robotics [2018a], the global robot density in manufacturing in 2017 was 85 units per 10 000 employees. By region, it took the highest value for Europe – 106 units. For both Americas, it was 91, whereas for Asia – 75 units. Within Europe, Germany was the leader with 322 units per 10 000 workers. By comparison, in Poland the ratio is rather low: in 2016, it was a meager 32 units [2018b]. A rocketing rate of robot densification and automation of labor (frequently, rudimentary and not requiring specialized qualifications) entails a number of threats including increased social exclusion of the elderly and the disabled and further disadvantages them

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economically. Another counter measure is to acquire workers in remote regions. Enterprises may also entice workers to continue their employment by offering them incentives and accommodating the workplace to the needs of more age-diverse workers. Therefore, it appears imperative that tried and trusted strategies be implemented to facilitate in an economically viable and technically consistent manner decision-making processes as regards the rationality of work systems organization and design, and the replaceability of the human being with the machine in aging populations. The article makes a point of the role of ergonomics as one of the components of age management policy in the organization. Based on the literature review, ergonomic methods are presented that can support organizational decision-making strategies concerning age management including the replaceability of the human being with the machine in Industry 4.0.

2. Definition of 'an older worker'

All human beings age but the process of aging is characterized by significant intra- and interindividual variability. What is meant by interindividual variability is that not all functions determining the ability to work deteriorate with age by the same degree, and therefore, declining work ability does not affect all areas of the working life. However, it is important to be mindful of the fact that the range of interindividual variability increases as people get older because they do not all age at the same rate [Ilmarinen, 2005]. Thus, it is difficult to pinpoint the age that would mark the onset of this process. Koradecka, Bugajska, Pawłowska [2007, pp. 2-6] draw attention to the life period in which age-related changes in individual psychophysical function may hinder job performance posing a risk to the health and welfare of the worker and of others. Bugajska, Makowiec-Dąbrowska, Konarska [2008], Barnett, Spoehr and Parnis [2008] think that it would be reasonable to determine the so-called functional age by which age would be measured not only by reference to the number of years one has already lived but also by way of criteria to determine fitness and physical and psychological agility. It is worth remembering that human beings may exhibit features characteristic of several age groups at the same time depending on which criterion is used: chronological, biological, or psychological, where each determines their capacity for living and for working.

The World Health Organization divided the age of older people into several groups. For economically active people, a group of workers of 'pre-elderly age' is singled out, workers 45 to 59 years of age, and a group of 'young elderly' - workers aged 60 to 74 [Duda, 2013]. Whereas in EU reports and publications, the threshold age most frequently referred to for older workers is 50. Workers older than that are defined as 50+. Similarly, in general, in Polish research and in publications, people aged 50 and over are considered older (e.g. Rysz-Kowalczyk and Szatur-Jaworska

[2007], Schimanek [2006]) or people aged 45 and over (e.g. Korzeniowska [2004, pp. 129-138], Urbaniak [2008]). As for publications concerning age management – Walker [1998], Naegele and Walker [2006], Taylor [2006] among others, they do not specify a threshold age above which workers should be subject to actions aimed at supporting their capacity for work. Only a general term 'older workers' is used, which appears to be a specific conceptual shortcut and may be construed as a designation of people whose productivity is relatively low due to age-related decline in physical and/or cognitive capacity or due to discrimination by the employer. Therefore, it is rather an oversimplification because not all older workers are less productive than younger ones. Support actions should not be directed at older people but at people whose productivity is limited due to age. Otherwise, they could be considered discriminatory treatment of younger workers and therefore, a violation of law. Moreover, it is often emphasized that age management policy (or at least some of its instruments) should include all employees regardless of their age, which means that it should have provisions that span over the entire working life of the worker (life course approach) [Taylor, 2006; Liwiński, Sztanderska, 2010].

3. Global, European, and national demographic trends

The future of the economy and organizational management strategies are strongly determined by population changes. Therefore, information concerning populations of young and older people will be very meaningful for investors, entrepreneurs, and managers.

The UN projects that the global population will have risen from 7.3 billion to 9.8 billion by 2050. More than half of that growth will be contributed to by Africa, whose population is projected to double and reach 2.5 billion. The most probable estimates based on the available data indicate that the world population may reach 11.2 billion 2100 [Department of Economic and Social Affairs Population Division, 2017a].

Populations are getting older. Today's median age of 30 is expected to rise to 36 in 2050 and 42 in 2100, whereas today, one fourth of the population of Europe is aged 60 and over [Department of Economic and Social Affairs Population Division. *United Nations*, 2017b]. The world working-age population is projected to grow by 900 million in 2010-2030, which would mean a 20 percent increase. By comparison, the increase of 40% was recorded in the years 1990-2010. The annual rate of working-age population growth dropped from the record level of 2.2% in 1985 to 1.1% in 2015, and is projected to fall to 0.7% in 2030. The number of working age persons in general is projected to decrease, although significant variation by region and by development group is expected. Dissimilarities in the growth rate of working age populations by country are mainly attributable to differences in the growth rate of the youth in

working-age populations, which reflects variation in the rate at which fertility rates decline [Lam, Leibbrandt, 2015, p. 2].

Europe and China will experience declines in their working-age populations between 2010 and 2030, while many low-income African countries will have growth rates of over 2% per year [Lam, Leibbrandt, 2015, p. 14]. For Europe, aging population is currently one of the gravest socioeconomic issues. The changes will primarily pose a challenge for national job markets because they may entail shrinking workforce and increased proportion of older persons in working-age populations. Furthermore, as follows from the European Commission forecasts [2011], the trend is expected to continue at least until 2060. The population in 2060 is indeed projected to be larger than in 2017, yet it will also be much older. Obviously, it is an oversimplification to take the number of people of a certain age as an indicator of workforce availability. Nevertheless, in the case of manual labor on an assembly line, in the warehouse, in construction, shortage of workers capable of manual labor is certain to pose a serious problem for employers [Butlewski, 2017, pp. 29-30].

The European Commission estimates [2011] that in 2060, there will be two working age persons per one person aged 65 and over (by comparison, in 2008 the old-age dependency ratio was 4 to 1), whereas the proportion of people aged 65 and older in the total population is projected to rise to 30% by 2060 in comparison to 17.1% in 2008. As a result, fewer and fewer people will be entering the job market and it will become imperative to encourage older workers to remain in paid employment. Currently, potential older age human resources are used to a much lesser degree than they could actually be [Kołodziejczyk-Olczak, 2014, p. 20].

The United States need not be concerned about human resources shortages, which puts the country in a much privileged position in comparison to other highly developed countries. The United States are unlikely to experience demography-related problems that Japan and Western Europe are tackling any time soon [Kołodziejczyk, 2012].

Demographic prospects for Poland based on population projections do not diverge from the European trends. Poland should expect further steady population decline and significant changes in age distribution of its population (Figure 1). Poland finds itself at such a stage in its demographic development that even if the total fertility rate reached the replacement level fertility within a short time, the processes could not be reversed nor could population decline be halted. With the age distribution of its population so distorted, redressing demographic balance will be a slow process and will require consistent and sustainable action [Gross-Gołącka, 2018, p. 129]. By 2050, Poland will have become one of the European countries where the process of population aging will be the most advanced. It follows from the Eurostat forecasts for the 28 European Union states that by 2050 the total population of Poland will have decreased by close to 10%, whereas the total population of the EU-28 will have grown

by 3.6%. Poland will be one of the five oldest countries of the European Union, and will have the seventh largest percentage of population aged 65 and older. The process of population 'double' aging, the measure of which is the share of persons aged 80 and over in the total population, will proceed at a slower rate in Poland (Poland persistently lags behind other EU states as regards its mortality rates and life expectancy at birth), and in 2050, it is projected to have one of the smallest percentages [GUS, 2014, pp. 109-167].

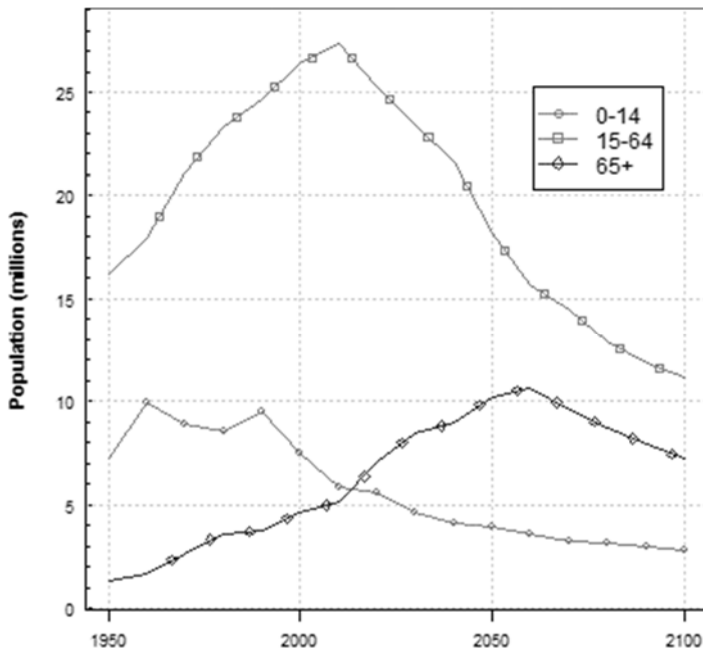


Fig. 1. Total population of Poland in 1950-2100 by age group

Source: Department of Economic and Social Affairs Population Division, *United Nations (2017), World Population Prospects 2017, New York, [online] <https://population.un.org/wpp/Graphs/DemographicProfiles/> date access: 11.08.2018.*

This demographic situation makes filling the gap left by the numerous birth cohorts of the 1950s and the first half of the 1960s gradually exiting the workforce the foremost challenge for many economies including Poland's [Gross-Gołacka, 2018, p. 133]. Aging workforce need not be – contrary to the mythicized belief – a burden on the economy but may become a valuable knowledge and experience resource as well as of increased purchasing power in the job market [Rudnicka, Surdej, 2013]. It is underscored in the literature that to manage the issue of the shrinking workforce it is necessary to draw on hidden reserves by, among others, engaging older people in the job market and building transgenerational singleness of purpose based on a high

level of participation of all age groups. These ideas inspire age management in the organization [Gross-Gołacka, 2018, p. 133].

4. Ergonomics and age management in enterprises

In the last 20 years, a growing interest in age management strategies has been observed both at the level of European institutional structures as well as at the level of national policies of member states. The term 'age management' is defined by Walker [1997] as referring 'specifically to the various dimensions by which human resources are managed within organizations with an explicit focus on ageing and, also, more generally, to the overall management of workforce ageing via public policy or collective bargaining'.

Walker [2005, pp. 685-697] points out five reasons why interest in age management systems has been growing:

1. Aging European workforce.
2. The paradox observed in the job market that consists in the declining economic activity of older persons in spite of an increasing share of this age group in the total population.
3. Social policy mandatory requirements.
4. Employer initiatives.
5. The urge to prevent age discrimination in employment.

Over the last several years, many aspects of age management have been codified on a number of occasions. One important example of such is 'Ageing in Employment: A Proposed European Code of Good Practice' developed by Eurolink Age in 2000 (Eurolink Age is an NGO which promotes the interests of older persons across the European Union) (Eurolink Age 2000). The Code provides a set of guidelines on good practices in age management, although whether an organization follows them or not is facultative for the organization. Recommended practices are grouped around the following seven aspects of age management: recruitment, training, development, and promotion; promotion and internal job change; flexible working practices and the modernization of work; workplace design and health promotion; employment exit and transition to retirement; changing attitudes toward older workers.

A similar classification was proposed by Naegele and Walker [2006] who, in their guide to good practice in age management, distinguished the following seven domains: recruitment, learning, training and lifelong learning, career development, flexible working time arrangements, health protection and promotion, and workplace design, redeployment, employment exit and transition to retirement. This classification is to a large extent consistent with the one specified in the Code of Good Practice. Admittedly, Naegele and Walker [2006] omitted to include change of attitudes toward

older workers in their guide yet it does not mean that they consider this type of actions non-essential. Quite the contrary, raising awareness of top management is regarded by them as the principal factor determining effective implementation of any activities related to age management [Liwński, Sztanderska, 2010].

Somewhat broader classification is employed by the European Foundation for the Improvement of Living and Working Conditions (EFILWC). In 1994-1998, the Foundation carried out the project 'Combating Age Barriers in Employment', under which activities undertaken by business organization in EU states to recruit or retain older workers were researched. According to the EFILWC, age management within organizations should include 11 areas of activities: recruitment; job changes; training and development; wage arrangements; health and well-being; flexible working practice; ergonomics and work organization; employment exit policy; comprehensive approach, and other policies [Ketsetzopoulou, 2007]. The catalogue is a compilation of age management dimensions included in the Code of Good Practice (Eurolink Age, 2000) and in the Naegele and Walker's [2006]. Two new dimensions are featured: wage policy and well-being.

Based on the previous discussion of actions and activities, it is evident that age management systems - even though they are implemented, among others, to improve competitiveness and flexibility of organizations coming to terms with the changes in the job market, to increase productivity or to facilitate the management of age-diverse workforce – tend to focus on the worker. Therefore, the type of work performed by workers is a relevant factor impacting on the type of actions taken by organizations as part of age management. For different actions should be taken for white-collar workers and different for blue-collar workers. Useful in this regard is ergonomics (reports on how ergonomic principles can be applied to workplace design can be found in Polak-Sopińska publications [Polak-Sopińska, Wiśniewski, 2010; Polak-Sopińska 2012, pp. 227-244; Polak-Sopińska, Górczyńska 2013, pp.136-159; Polak-Sopińska, Kucharska, 2014, pp. 141-172; Polak-Sopińska, 2019b, pp. 66-76] and by gerontechnology² whose aim is to match technology supporting older people participation to their health, housing, mobility, communication, leisure, and work [Knauth, Karl, Braedel-Kühner, 2005, pp. 11-16]. Due to the constraints concerning the recommended length of the article, issues related to gerontechnology in age management will be discussed in another publication.

² Gerontechnology is a branch of science addressing older persons' access to all goods, services, and infrastructure. Its aim is to promote older people's good health, full social participation and long, independent life. It also involves research, development, and design of products and service to improve the quality of life. Gerontotechnology is an interdisciplinary science combining gerontology and technology [Knauth, Karl, Braedel-Kühner, 2005, pp. 11-16], [Butlewski, 2018].

It is important to be mindful of the fact that redeployment carried out at the right moment in the course of an older worker's working life is a crucial point not only in age management systems but in occupational safety and health management systems in general, which also feature ergonomic activities. For there are many jobs which are excessively demanding for older workers but there are also jobs – such as work in special conditions – which should not be performed by the same worker throughout his/her entire employment. Redeploying the worker in another job with a reduced workload or less demanding, should be conducive to aging workers' good health, continued employment and job satisfaction, and should prevent their early exit. However, it needs to be accentuated that age management must not be looked upon as a policy of preferential treatment of older people, which would constitute a breach of discrimination, including age discrimination, regulations – but rather as a policy of providing equal opportunity to persons of different age. Actions aimed at boosting productivity will not be deemed discriminatory as long as the people at whom they are aimed have limited physical and/or cognitive ability (which are a natural consequence of aging) or have previously been subject to age discrimination by the employer e.g. in terms of access to training and advancement opportunities. In other words, so long as the support is provided based on the hardship a person experiences in the job market rather than on the person's age, there is no risk of discrimination.

Furthermore, it is important that a point be made of the fact that actions addressing workers are the most effective when they are sustained and distributed over the course of the working life due to the prolonged effect that factors such as health promotion and disease prevention, education, training, long-life learning, and workstation furnishings and equipment have on the ability to work [Karppinen, Buschak, 2006; Polak-Sopińska, 2017, pp. 79-92]. What is important is the objective of age management – to sustain economic activity of persons at least until they reach their statutory retirement age and possibly longer [Liwinski, Sztanderska, 2010, p. 10]. Industrial ergonomics strives to achieve a similar aim.

In considering actions taken in age management systems aimed at increasing employment participation of older persons, one needs to underscore the role that the individual ability to work shaped – according to the model developed by Finnish Institute of Occupational Health – FIOH, by many overlapping factors including education and skills, job demands, organizational factors, and finally, individual factors (physical capacity and fitness, health, attitude toward work) plays. Based on the model, the Work Ability Index (WAI) was developed, which is an instrument facilitating subjective assessment of the level of a person's ability, which is result of the interplay between a worker's ability and the demands of the workplace [Tuomi, Ilmarinen, Jahkola, et al., 1998; Pokorski, 1998]. According to Makowiec-Dąbrowska et al. [2008, pp. 9-24] the index is a good predictor of sustained economic activity, especially in such a contradictory situation where on the one hand in Poland, the most

frequent reason cited for early exit is deteriorating health, and on the other hand, the average life expectancy is rising suggesting at once that the health of the population is improving.

Conclusions that can be drawn based on the index should be regarded as meaningful guidelines for occupational medicine practitioners and managers in charge of age management programs in organizations on further actions concerning workers' employment [Ilmarinen, 2006, pp. 362-364]. Results of many international studies reveal a relationship between the ability to work and the type of work. Congruent findings have also been made by Polish researchers studying both healthy and ailing workers. Among the factors that statistically significantly increase the risk of low values of the Work Ability Index are work-related stress, heavy manual work, strenuous body posture, fast-paced work environment, carrying/lifting heavy loads, heat stress in the workplace, shifts longer than 8 hours, night shifts, fatigue [Malińska, 2007, pp. 16-20]. Results reported by [Camerino, Conway, et al., 2005], confirm the need to incorporate ergonomic methods and instruments in human resources management and in particular, in age management strategies.

5. Ergonomic methods and tools in age management

Ergonomics is provided with a number of tools to support the process of workplace adjustment to accommodate a range of different needs including those of the aging workforce. Based on the literature review, ergonomic methods and instruments were analyzed in terms of their fitness for age management strategy. The findings for the following eleven groups of methods are presented in Table 1 and 2:

- checklists;
- research questionnaires;
- worksheets to assess musculoskeletal disorder risk (MSD) related to working postures;
- worksheets to estimate the level of physical stress and MSD risk associated with manual material handling in the workplace;
- somatographic data collection methods;
- estimation and analysis methods for the evaluation of the work process and its effects;
- instruments to assess physical and functional capacity;
- tools to assess sensory function;
- monitoring physiological parameters at work task performance;
- old age simulators;
- Digital Human Model application software.

The most representative examples of each are provided.

The list presented in tables is a continuation of M. Butlewki's works [2017, 2018].

Table 1. Results of the analysis of ergonomic methods and instruments in terms of their fitness for age management strategy

Method group	Selected methods and instruments	Fitness for age management strategy
Checklists	<p>The Dortmund checklist (developed by G.C. Burger's research team) – the first comprehensive method for work environment diagnosis to incorporate ergonomic and occupational safety and health aspects. Its results may be used to modify work, its course and its conditions [Kania, 1980, pp. 28-49].</p> <p>NIOSH checklists – an instrument to prevent musculoskeletal impairments and disorders caused by working posture and movements at the stage of new workstation and product planning, and to identify ergonomic risk factors in the already existing workstations and products [Horst, Lubinski, 2003, pp. 83-96].</p> <p>Working Posture and Movement Audit (Audyt SWP) – checklist related to postures that are 'not recommended' according to ISO 11226 and EN 1005-4 [Horst, Dahlke, 2003, pp. 572-575].</p> <p>Washington State Department of Labour Industries (WISHA) Industry-specific physical job evaluation checklist, Washington State Department of Labour Industries (WISHA) caution zone checklist, WISHA Hazard zone checklist – this checklist can quickly assess levels of risk of injury (minimal, moderate, or high) for the back, shoulder, hand/wrist, and knee in a given job. The Physical Job Evaluation Checklist was developed from observations of work activities performed and the evaluation of WMSD risk is based on those observations [Washington State Department of Labour Industries, 2018].</p> <p>Checklist to evaluate job suitability for the needs and abilities of people aged 50 and older developed by A. Polak-Sopińska at al. [2011, pp.149-188; 2013, pp. 136-159] – the checklist facilitates ergonomic evaluation of a job taking into account specific needs of mature workers.</p> <p>Checklist to evaluate job suitability for the needs and abilities of people with different disabilities developed by A. Polak-Sopińska at al. [2007, pp. 103-114; 2010; 2015, pp. 276-278] – facilitates ergonomic evaluation of a job in terms of its suitability for people with different disabilities.</p> <p>Checklist to evaluate job suitability for the needs and abilities of people with different disabilities developed by the Central Institute for Labor Protection – National Research Institute – facilitates multidimensional ergonomic evaluation of jobs taking into account specific needs entailed by various</p>	<p>There are generic checklists but there are also specific checklists designed for particular groups of users including older and disabled persons [Polak-Sopińska 2007, pp. 103-114; Polak-Sopińska, Wisniewski, 2010; Polak-Sopińska, Górczyńska, 2013, pp. 136-159; Polak-Sopińska, 2015, pp. 276-278; Central Institute for Labour Protection 2014].</p> <p>The fact that checklists cover a lot of different factors influencing work process and workload is their advantage. They enable thorough analysis of conditions inherent in job task performance. However, one weakness of many checklists is that fail to provide evaluation criteria. Thus, supplementary data is required, i.e. familiarity with standards, recommendations as well as methods of calculating optimal parameters for specific types of situations and conditions under which job tasks are performed [Kania, 1980, pp. 28-49], which limits the range of their users to ergonomics specialists, OSH specialists, occupational medicine practitioners.</p>

Method group	Selected methods and instruments	Fitness for age management strategy
<p>Research questionnaires</p>	<p>disabilities. The checklist can be used by the employer as an instrument to assess the degree to which a job meets the needs of a worker with a specific disability once the project has been completed [Central Institute for Labour Protection, 2014].</p> <p>WAI (Work Ability Index) - an instrument for subjective assessment of the level of a worker's ability to work [Tuomi, Ilmarinen, Jahkola, et al., 1998; Pokorski, 1998].</p> <p>Self-assessment questionnaire for people with disabilities for careers guidance - an instrument for subjective assessment of the level of a disabled worker's ability to work [Kurkus-Rozowska, 2007].</p> <ul style="list-style-type: none"> - Ovako Working Posture Analyzing System (OWAS); - Rapid Upper Limb Assessment (RULA); - Rapid Entire Body Assessment (REBA); - Rapid Office Strain Assessment (ROSA); - Method to Analyze Jobs For Risk of Distal Upper Extremity Disorders – Strain Index (SI); - A concise index for the assessment of exposure to repetitive movements of the upper limbs (OCRA); - Assessment of Repetitive Tasks of the upper limbs (ART) tool; - Quick Exposure Check (QEC); - Method Assigned for the Identification of Ergonomic Hazards PLIBEL; - Key Item Method for Manual Handling Operations (KIM-MHO); - American Conference of Governmental Industrial Hygienists threshold limit value for hand activity level (ACGIH TVL HAL); - Manual Tasks Risk Assessment (ManTRA); - Posture, activity, tools and handling (PATH); - Method Assigned for the Identification of Ergonomics Hazards (PLIBEL). 	<p>Questionnaires enable to determine the level of ability to work, including of older and disabled persons'. Moreover, WAI is a good predictor of disability and death rate.</p> <p>No instruments enabling assessment of MSD risk caused by working posture in older people have been found. Evaluation worksheets, however, do allow for an assessment of the level of stress and strain, which enables the identification / specification of activities that could lead to disorders and early exit of workers (e.g. disability pension, bridging pension). These methods are used in DHM – Digital Human Model application software.</p>
<p>Worksheets to assess musculoskeletal disorder risk (MSD) inherent in the process of work tasks performance related to, among others: body posture, range of movements, muscular dynamics, grip types etc [Takala, Pehkonen, Forsman, et al., 2010, pp. 3-24; Schaub, Caragnano, Britzke, et al., 2013, pp. 616-639; Dempsey, Lowe, Jones, 2019, pp. 223-230; Dempsey, MCGorry, Maynard, 2005, pp. 489-503; Pascual, Naqvi, 2008, pp. 237-245; Cantley, Tanwo, Galusha, et al., 2014, pp. 57-65; HSE publications]</p> <p>Worksheets to estimate the level of physical stress and MSD risk associated with manual material handling in the workplace [Hartmann, Steinberg, 2017, Russell,</p>	<ul style="list-style-type: none"> - National Institute of Occupational, Safety and Health lifting equation (NIOSH); - Washington State Department of Labour Industries (WISHA) lifting calculator, Washington State ergonomics rule lifting calculator (WA L&I); - Key Item Method; - KIM for Lifting/Holding/Carrying of loads (KIM-LHC); - KIM for Pulling/Pushing of loads (KIM-PP); 	<p>In this group of methods, only KIM takes into account the age of the worker performing manual handling tasks as an additional risk factor. People below the age of 20 and above the age of 40 were deemed to be characterized by limited</p>

Method group	Selected methods and instruments	Fitness for age management strategy
Winnemuller, Camp, et al., 2007, pp. 91-97; Waters, Occhipinti, Colombini, et al., 2016, pp. 695-711; HSE publications]	<ul style="list-style-type: none"> - KIM for Manual Handling Operations (KIM-MHO); - Lifting Tables (Snook); - Manual Handling Assessment Charts (MAC); - Variable Manual Handling Assessment Charts (V-MAC); - Risk assessment of pushing and pulling (RAPP) toll; - American Conference of Governmental Industrial Hygienists lifting threshold limit values (ACGIH TLV- Threshold Limit Values for Lifting); - Variable Lifting Index (VLI); - Manual Handling Assessment Tables (MAT). 	<p>endurance, which may necessitate job redesign should the KIM value for the job be at the level allowable for people aged 20-40. The worksheets enable the identification of factors generating the highest risk during e.g. lifting, carrying, and collective handling of objects, pushing and pulling. They allow the user to predict the stress/strain level based on a description of planned tasks. Having identified the level of stress/strain, the user can single out tasks that could lead to disorders and early exit of workers (e.g. disability pension, bridging pension). These methods are used in DHM – Digital Human Model application software.</p>
Somatographic methods of data collection	<ul style="list-style-type: none"> - Anthropometric tables providing anthropometric data for design: - Atlas antropometryczny dorosłej ludności Polski dla potrzeb projektowania [Batogowska, Słowikowski, 1989]; - Atlas antropometryczny populacji polskiej – dane do projektowania [Nowak, 2000]; - Atlas miar człowieka. Dane do projektowania i oceny ergonomicznej [Gedliczka, 2001]; - Manikins to model workstation dimensions; - Graphic mapping of workspace; - Mock-ups. 	<p>There are anthropometric atlases and manikins that include measurements of older and disabled populations e.g. Atlas E. Nowak [2000]. They can be useful for designing furnishings, equipment, and workspace.</p>
Estimation and analysis methods for the evaluation of the work process and its effects	<ul style="list-style-type: none"> - Questionnaire to identify causes of accidents at work; - Statistical analysis of accidents at work; - Estimation of accident risk; - Pinpointing errors in communication, decision-making, and executive processes [Kania, 1980, pp. 69-75]; - Employee complaints and grievances. 	<p>This group of methods allows the user to establish the most frequent causes of accidents among older including disabled workers. This knowledge should be applied to workplace design.</p>

Method group	Selected methods and instruments	Fitness for age management strategy
Instruments to assess physical and functional capacity	<p>Verification of physical and functional capacity can be performed with e.g.</p> <ul style="list-style-type: none"> - the FCE (Functional Capacity Evaluation); - measuring instruments (hand-eye coordination testing device, reaction parameters analyzers, balance boards, handheld dynamometers to measure finger and palm strength, etc.); - computer-based assessment of reaction time included in the Vienna Test System. 	<p>These tools can be used:</p> <ul style="list-style-type: none"> - in the process of selecting jobs for older workers; - to adjust jobs to individual capacities of older workers; - to assess the impact of work; - to assess the level of fatigue of the worker.
Tools to assess sensory function	<p>Evaluation of sensory function may be carried out with e.g.:</p> <ul style="list-style-type: none"> - audiometer (hearing threshold, speech recognition); - pseudo-isochromatic Ishihara plates (color perception); - stereopsis tests (binocular vision, depth perception); - ACK apparatus (night vision and glare recovery time); - LEA Numbers Low Contrast Flip Charts (visual acuity). <p>Measurements of internal physiological parameters e.g.:</p> <ul style="list-style-type: none"> - energy expenditure with indirect and direct calorimetry, heart rate, estimation methods; - electromyography (EMG) to measure muscle response at task performance; <p>Measurements of spatio-temporal parameters of segmented motion – np. Motion Capture.</p> <ul style="list-style-type: none"> - FORD's Third Age Suit; - AGNES suit – Age Gain Now Empathy System. 	<p>These tools can be used:</p> <ul style="list-style-type: none"> - in the process of selecting jobs for older workers; - to adjust jobs to individual capacities of older workers; - to assess the impact of work. <p>These methods can be useful in the analysis of job suitability for older workers [Polak-Sopińska at al., 2019a, pp. 66-76; Polak-Sopińska, 2019b, pp. 77-89].</p>
Methods for monitoring physiological parameters at work task performance	<p>Measurements of internal physiological parameters e.g.:</p> <ul style="list-style-type: none"> - energy expenditure with indirect and direct calorimetry, heart rate, estimation methods; - electromyography (EMG) to measure muscle response at task performance; <p>Measurements of spatio-temporal parameters of segmented motion – np. Motion Capture.</p> <ul style="list-style-type: none"> - FORD's Third Age Suit; - AGNES suit – Age Gain Now Empathy System. 	<p>These methods can be useful in the analysis of job suitability for older workers [Polak-Sopińska at al., 2019a, pp. 66-76; Polak-Sopińska, 2019b, pp. 77-89].</p>
Old age simulators	<ul style="list-style-type: none"> - FORD's Third Age Suit; - AGNES suit – Age Gain Now Empathy System. 	<p>These methods make it possible to simulate mobility and movement, vision, and dexterity limitations. They are expected to enhance workplace designers' empathy with people with particular age-related dysfunctions and their needs [Butlewski, 2018, p. 137].</p>

Source: own study based on [Butlewski, 2017, 2018].

Table 2. Results of the analysis of DHM (Digital Human Model) application software in terms of their suitability for age management strategy

Method group	Name and functionality of the DHM model	Applied ergonomic methods	Suitability for age management
<p>DHM – Digital Human Model application software. They come as separate modules and can be integrated with other applications aiding the design process(CAD) or the manufacturing process (CAM) such as AutoCAD, Solid Edge, Solid Works, Catia [Dahlke 2014, pp. 21-32; Butlewski 2017, pp. 29-56]</p>	<p>Delmia includes DELMIA Ergonomics Analysis (EGA), DELMIA Ergonomics Evaluation (EGE) modules.</p> <p>EMA (Editor Menschlicher Arbeit) – allows the user to simulate workspace, worker motions, and to identify risk factors based on EAWS [Fritzsche, Jendrusch, Leidholdt, at al., 2011].</p> <p>3DSSPP (3D Static Strength Prediction Program) – developed by the University of Michigan Office of Technology Transfer allows the user to model workers' static postures and movements.</p> <p>JACK (Jack Human Modeling and Simulation Tool by Siemens) – allows the user to design work process and introduce a human model with specific anthropometric characteristics; it makes it possible to analyze the range and loading on the musculoskeletal system; thanks to Motion Capture extension it is possible to generate animations of real human motions in the Process Simulate environment.</p> <p>RAMSIS (Rechnergestütztes Anthropometrisch-Mathematisches System zur Insassen-Simulation) by Human SolutionsGmbH. Available modules:: Automotive, Industrial Vehicles, Bus & Truck, Aircraft, Anthroscan, Cognitive, 2008/2/EG, Safety, NASA Analyze, REFA Analyze, NIOSH</p>	<p>Rapid Upper Limb Assessment, Lifting and Lowering Analysis, Push, Pull and Carry Analysis, Biomechanics Analysis.</p> <p>EAWS (analysis includes working posture, force exerted by the worker, the weight of loads moved, manual materials handling equipment, repetition rate and movement trajectories, types of grips involved) [Schaub, Caragmano, Britzke et al., 2013, pp. 616-639].</p> <p>3D Static Strength equations developed by the University of Michigan (calculation and analysis of the force and momentum acting upon each joint).</p> <p>NIOSH Analysis, Rapid Upper Limb Assessment., Ovako Working Posture Analysing System, 3D Static Strength Analysis developed by University of Michigan.</p> <p>NIOSH Analysis; REFA Analysis; NASA Discomfort Analysis.</p>	<p>If a designer working in CAD on the design of a workstation uses the applications, s/he will be provided with a great deal of detailed information about the designed workspace. S/he can also perform a simulation of motions and generate a cumulative assessment of the risks the worker will be exposed to. Further, by scanning worker movements in a real-life workstation, s/he can process the data, which should make it easier for him/her to design adjustments [Dahlke, 2014, pp. 21-32].</p> <p>Veritas system and a tool developed by the national Institute for Labor Protection have been created to enable disability simulations. They allow the user to predict older and disabled workers' motions and manner of operation.</p>

Method group	Name and functionality of the DHM model	Applied ergonomic methods	Suitability for age management
	<p>Analyze; available as a separate application or a module in CATIA V5 and V6.</p> <p>Based on the anthropometric data computer tool to aid the design, ergonomic evaluation, and adjustment of jobs to meet the needs of the disabled developed by the National Institute for Labor Protection.</p> <p>VERITAS (<i>Virtual and Augmented Environments and Realistic User Interactions To achieve Embedded Accessibility DesignS</i>) – VERITAS is an Integrated Project (IP) within the 7th Framework Programme, Theme FP7-ICT-2009.7.2, Accessible and Assistive ICT</p>	<p>PN-EN 547 (Safety of machinery - Human body measurements), PN-EN 1005 (Safety of machinery - Human physical performance).</p> <p>VERITAS user models take into account motor, perceptual and cognitive impairments. Even multiple conditions can be simulated. Besides numerical simulation with graphical representation of the results VERITAS supports virtual product experience by using virtual reality technology including haptic devices. Designers can thus experience their designs through the eyes of a user with cataracts or feel the problems of operating a gas hob with the tremor of a Parkinson patient [Butlewski, 2018, pp. 135].</p>	

Source: own study based on [Butlewski, 2018, pp. 135; Dahlke 2014, pp. 21-32].

The literature review revealed that there are many ergonomic methods (of varying degree of complexity) which can be used as tools to support decision-making strategies of organizations with regard to age management. Unfortunately, the findings made by the author, by researchers affiliated with the Nofer Institute of Occupational Medicine, the Central Institute for Labor Protection, and with many other research institutions in Poland [Korzeniowska, 2004, pp. 129-138; Hildt-Ciupińska, Bugajska, 2013, pp. 297-306] as well as the findings reported by the National Labor Inspectorate lead to the conclusion that the application of ergonomic methods and tools in the process of designing and adjusting jobs to accommodate the needs of age-diverse workforce in enterprises operating in Poland is still rather rare. Awareness related to ergonomics among top management of large enterprises especially in the automotive and assembly industries has been observed to be rising. For small and medium-sized enterprises cutting costs continues to take priority to the health and well-being of the worker. It is the author's opinion that in order to extend the duration of economic activity of older persons, it is necessary to develop a model for the incorporation of ergonomic methods in the management of age-diverse workforce that will be adequate for the realities of the Polish business environment. Before such a model is developed, the following research questions will have to be answered:

1. Which ergonomic methods/tools are most often employed by certified ergonomists in Poland and in the world, and why?
2. Which ergonomic methods/tools are recommended by Polish and international research institutions, process engineers, designers, human resources specialists, and why?
3. Which ergonomic methods/tools are most frequently used by small, medium, and large enterprises in Poland, and why?
4. Which ergonomic methods/tools are preferred by OSH specialists, process engineers, designers, human resources specialists, and why?
5. How familiar are Polish employers, OSH specialists, process engineers, designers, human resources specialists with the presented methods?
6. To what extent do ergonomists determine the choice of ergonomic methods and tools to be used?
7. To what extent are ergonomic methods used by specialists relevant to specific risks in each industry?
8. In what ergonomic methods and tools are work organization; occupational safety and health; product and job design specialists trained in Poland?

The author shall present answers to the above research questions in her future publications.

6. Conclusion

Work that is in line with ergonomic requirements may contribute to the prolongation of a healthy life of workers. Optimization of working conditions needs to be a sustained process. It does not only involve designing but also correcting that takes into account changes that take place in the organization, in its environment, and in the workstation. The process should ensure safe working conditions that make intellectual and social (including physical) development of the worker possible, and should be conducive for the worker to take action to improve productivity. This is how ergonomic requirements fit in with the overarching – from the vantage point of economical sciences – objective of the organization that is the maximization of profits [Rembiasz, Górny, 2015, pp. 115-126].

Ergonomic workplace design and ergonomic physical working environment brings tangible positive results for the workers (especially, older ones) and employers (decreased fatigue, increased productivity, reduced number of occupational diseases and work-related accidents), and that is the reason why it is imperative that ergonomics become an integral part of a comprehensive age management strategy in the organization.

Based on the literature review, it has been proved that there are many ergonomic methods that can be applied in age management. In order to enhance the effectiveness of managing age-diverse workforce, it will be indispensable to develop a model of the incorporation of ergonomic methods in age management adequate to the realities of the Polish business environment which will require broader cooperation of employers, OSH services specialists, human resources, process engineers, production/assembly line workers, ergonomists, trade unions, and occupational medicine practitioners. Conceptualization of such a model shall be presented in future publications.

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