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Designing for the Worker Who Has Seen Everything: An Ergonomics Framework for the Aging Manufacturing Workforce and the Risk Manager's Role in Retention, Injury Prevention, and Total Cost of Risk

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A R T I C L E I N F O

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A B S T R A C T

The manufacturing workforce is also aging rapidly in the United States, where the labor force of workers between 50 and older is projected to occupy about half the industry workforce by 2030. The measurable hazard of this demographic shift is that musculoskeletal disorders (MSD) become three to four times more costly to claim when a worker is over the age of 55 years. The present paper provides an ARM harmonized framework on proactive ergonomic investment in the aging factory workforce, discussing the physiological alterations and their part in task design, provides a six-domain system of ergonomic design principles of the 50+ worker, and evaluates the financial argument through the Total Cost of Risk (TCOR) technique. Research results have shown that the ergonomic absorption will achieve a direct-cost ROI of more than 7,500% into the 55-64 age group - one of the most compelling investment cases in the occupational health and safety portfolio.

INTRODUCTION

The manufacturing floor is undergoing a silent demographic revolution, which is receiving far less attention than it deserves from the occupational health and safety community. The inflection point has been reached because of the aging of the American workforce. The baby boom generation that entered the workforce in the late 1990s has been increasing in their lifestyles since that time. According to the predictions of the Bureau of Labor Statistics, by 2030, almost a quarter of the entire workforce in the U.S will be represented by individuals aged 55 and above, as compared to almost 12% in the year 2000. Indeed, due to the demand aspect of physical and craft work, which creates great workforce retention factors in manufacturing per se, the proportion ratio of the number of employees aged 50 years and more is already close to half the labor force in most industrial environment settings.

The musculoskeletal disorders are the associated risk of this demographic change that is specific and measurable. The most common manufacturing worker compensation cost is already on MSD claims, such as sprains, strains, overexertion injury, and repetitive motor disorder of the back, shoulder, neck, wrist, and knee, which constitutes about one-third of total lost-workday injury cost. The missing element in the aggregate claims data cannot adequately depict the age gradient that is dramatic in the data. The mean compensation of an MSD claim brought by a 58-year-old employee is three or four times more than the same clinical injury by a 28-year-old, and that can be attributed to the prolonged period of recovery, high chance of long-term disability, and the productivity secondary losses of a seasoned specialist in the line.

The article's heuristic is that the physiological and financial reasons to pursue the active implementation of ergonomic investment in the aging manufacturing workforce are strong, and what risk managers and ergonomists need is a clear, actionable framework for doing so. The aging worker is not a liability to be managed they are a valuable asset to be retained, provided the work environment is designed to support them.

LITERATURE REVIEW

The Workforce Demographic Shift: Scale and Trajectory

Age pattern regarding the labor force is an indicator that has several convergent forces. Mature employees, since the amendments of the Age Discrimination in Employment Act (ADEA) in 1986, which made it illegal to retrench an employee forcefully in the private sector, have been allowed to work as long as they wish. The extended working life has been brought about by financial reasons, given the fact that there are not enough retirement savings for a good number of the Baby Boom generation. Moreover, the habitual want of more skilled labourers in younger generations has not only diminished the number of perceivable old labourers, but has made them more than consumables. Manufacturers who have yet to incur the ergonomic consequences of this factual basis of the population demographic are experiencing an enormous and growing liability in MSD that their current workers' compensation data has not yet captured (BLS, 2025; Truxillo et al., 2023).

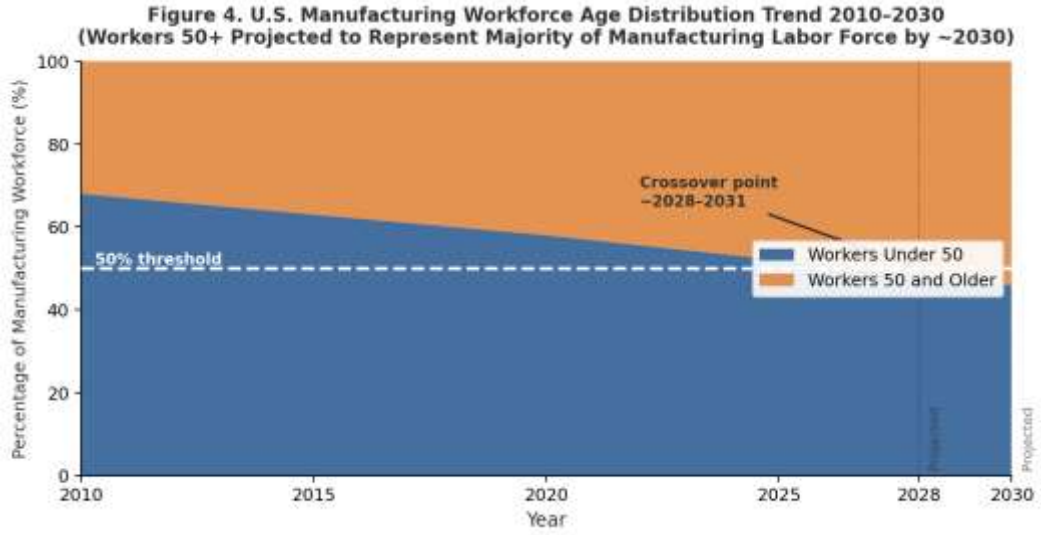

Figure 1. U.S. Manufacturing Workforce Age Distribution Trend from 2010 to 2030 (Projected).

Physiology of the Aging Worker: What Changes and Why it Matters

The ergonomics of older workers should begin with a simple appreciation of the normal aging physiological processes. These developments are sounding no alarm bells or dramatic headlines; these current changes are well established in the literature of the occupational physiology field of study and, in fact, exist, are progressive, and yield in most simple forms of implications on the job demands that manufacturing environments regularly place on them (Ilmarinen, 2001).

The peaks of the muscle strengths are usually at the end of the twenties, and afterwards the muscle strength gets weaker by an approximate of 1% to 2% each year, after the age of 40 years, and the strength reduces by a rate of about 3 percent per year after the age of 60 years. It would spell out to a manufacturing worker who is doing something that they designed when they were 35 years old that what was initially an average, difficult task would have shifted to the stage of achieving and possibly going beyond their current functional level when they are 55 years old. The ergonomical examination difficulty is that the reduction is gradual and imperceptible: the worker adapts, compensates, and endures — until that compensation itself becomes the mechanism of injury. The connective tissue formation contributes to this picture: since entering old age, tendons and ligaments no longer show the spring and become more exposed to trauma by the same strength, they are slower to recover after soft tissue injuries (Garg & Kapellusch, 2022).

Near visual acuity begins to decline considerably in the mid-forties--and it is so widespread that it even has a medical name of its own (presbyopia), and it is generally disregarded by the lighting standards used by workplaces designed with younger workers in mind. Hearing loss is age-related and accumulative in relation to age and workplace exposure to occupational noise, which not only affects communicative abilities but also the ability of a worker to utilize auditory cues as protective responses in a machine-noisy work environment. It is discovered that the reaction time increases very slowly with age, at least in terms of injury avoidance and equipment use with strict timing requirements. The phenomenon of cognitive ageing in healthy ageing workers is, critically but not always, never always negative: crystallized intelligence, or procedural knowledge, pattern recognition, and judgment, which are the results of decades of experience, do not decline during working life. The ergonomic driver is to reduce the physical stresses that constrain older employees and uphold the cognitive context in which their experience creates the highest value (Silverstein & Clark, 2022).

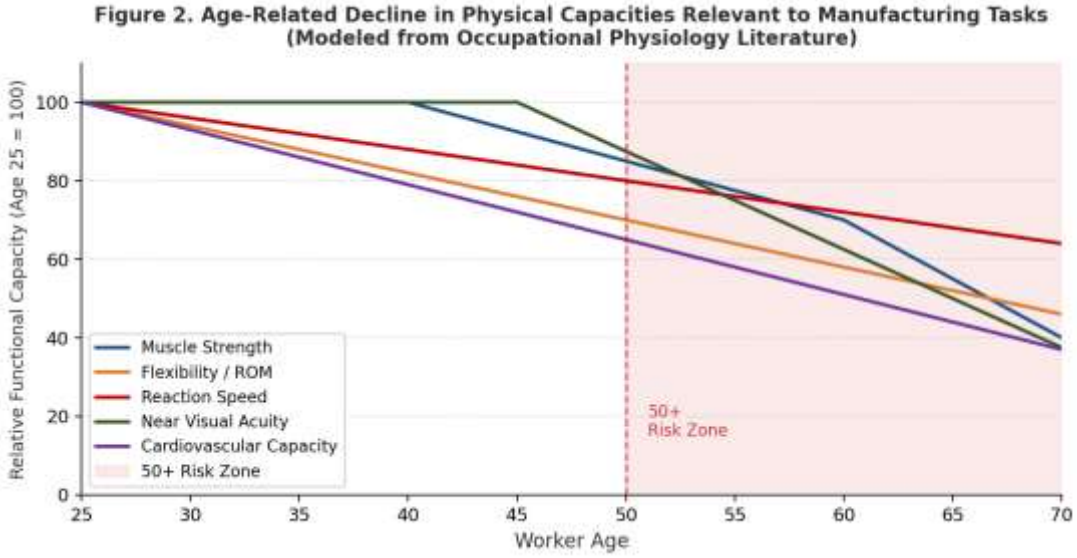

Figure 2. Age-Related Decline in Physical Capacities Relevant to Manufacturing Tasks, Modeled from Occupational Physiology Literature

METHODOLOGY

This article uses an occupational physiology literature and occupational workers' compensation claims data, as well as the ergonomics standards, to create a practice-based interpretation platform derived from the Associate in Risk Management (ARM) curriculum to result in a systematic aging workforce ergonomics model of the manufacturing setting. The analysis is organized based on four key areas, including (1) demographic analysis of manufacturing workforce age structures with the support of both the BLS and industry data; (2) occupational physiology analysis of any age-related functional changes and direct implications on manufacturing activities; (3) acquiring the financial exposure Total Cost of Risk (TCOR) framework of MSD claims by age group and ergonomic intervention ROI; and (4) the topographical mapping of the ergonomic design principles against the accepted professional standards (as in

the case of utilizing the NIOSH Revised Lifting Equation). All claims data refer to the 2023–2025 composite period drawn from the Liberty Mutual Workplace Safety Index and BLS Injury Cost data.

RESEARCH RESULT

The Financial Argument: MSD Claims, Recovery Costs, and TCOR

The claims statistics tell a story that most risk managers have known on instinct, and only a few have known on numbers: MSD injury rates rise with age, but the cost impact is rising at an even faster rate. The frequency of MSD claims is reduced by about 2.7 times in an employee aged between 55 and 64 years, but the average frequency is greater than four times that of an average recovery claim made by an employee aged 25-34 years due to the length of time to recover. When a traditional knowledge worker is off the floor 42 days accessed by the 4:1 indirect cost multiplier of the ARM TCOR framework on temporary labor, redistributed overtime, reduced output during the recovery period and the knowledge loss during the 42 days-out period, which is also the indirect cost that gets recorded, the real enterprise cost of a single MSD claim against a 60-year-old senior technician may range between $250,000 and $300,000 (Liberty Mutual Research Institute, 2024).

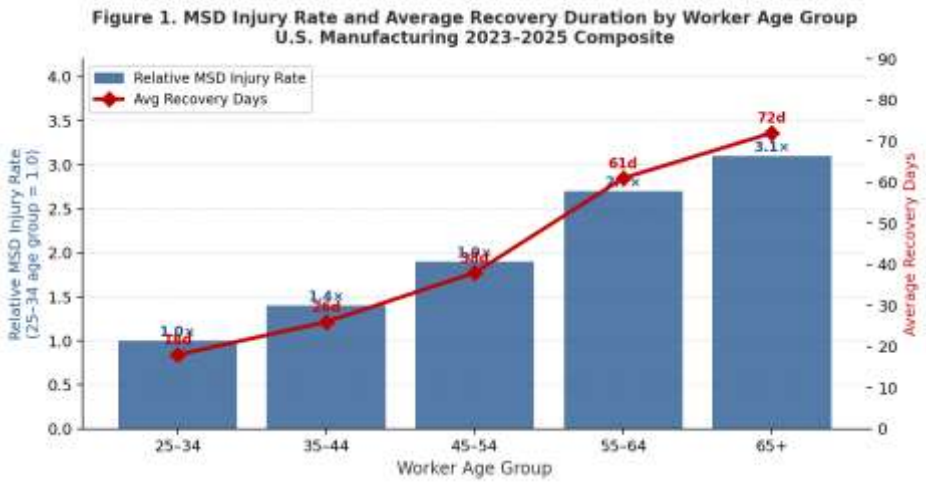

Figure 3. MSD Injury Rate and Average Recovery Duration By Worker Age Group in U.S. Manufacturing (2023–2025 Composite).

Ergonomic intervention costs work station modification, replacement of tools, and lift assist installation, which work out to approximately $ 800 per worker in a well-designed program. The average cost of the MSD claim of a 55-64 year old worker of 55-64 years in costs of $61,200 is more than 7,500% ROI on direct costs only. Add the multiplier of indirect costs with the financial argument, and, bluntly speaking, the argument in favor of the proactive introduction of the ergonomic investment in the aging workforce into the manufacturing factories becomes one of the strongest among the whole range of occupational health and safety (Dempsey & Mathiassen, 2023).

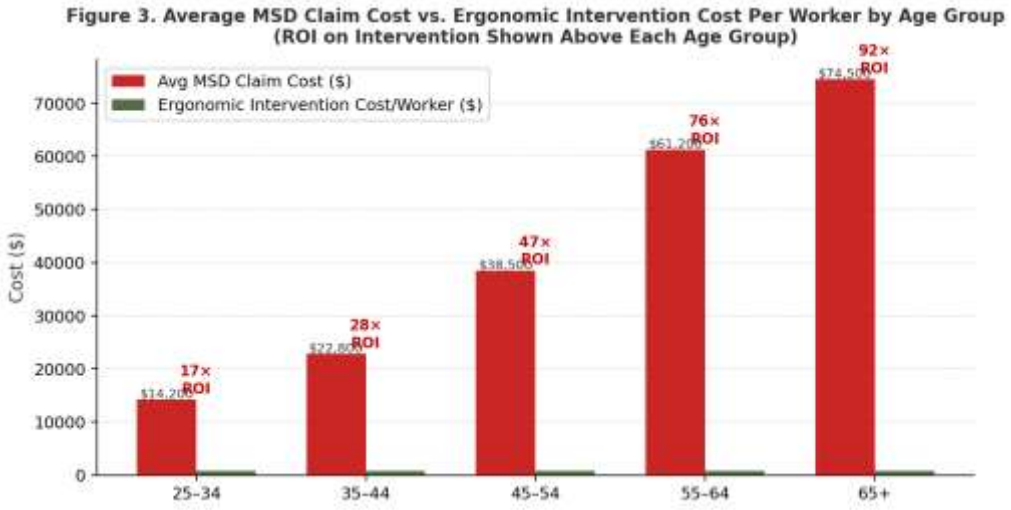

Figure 4. Average MSD Claim Cost Versus Ergonomic Intervention Cost Per Worker By Age Group

Ergonomic Design Principles for the 50+ Manufacturing Worker

The following framework will be applied in deciphering the physiological facts of aging into designer principles of actionable ergonomics. The latter is so because each principle is followed by its manufacturing usage and the related ergonomic standard or professional reference in regulating the latter. The framework is modeled based on the job task analysis (JTA) procedure, and each principle is a measurable task attribute.

Table 1. Ergonomic Design Principles for the 50+ Manufacturing Worker

Design Principle	Application for the 50+ worker	Ergonomic Standard / Reference
Force Reduction	Limit maximum acceptable lift to 35 lbs without mechanical assist; install powered lift-assist arms at assembly stations used by workers over 50; use counterbalanced tool balancers for repetitive tool use.	NIOSH Revised Lifting Equation (2021); ACGIH TLV for hand activity
Posture Optimization	Adjust workstation height to accommodate the 5th–95th percentile range of the older worker cohort, specifically, install anti-fatigue matting at standing stations; provide sit-stand flexibility at inspection and quality control stations.	ISO 9241-5; OSHA ergonomics guidelines for manufacturing

Repetition Management	Implement job rotation schedules that distribute high-repetition tasks across the shift; target ≤1 hour of continuous highly repetitive work before mandatory rotation for workers 55+; use automation for peak-demand repetitive cycles.	ACGIH TLV for hand activity level (HAL ≤0.56 for older cohort)
Grip and Handle Design	Increase handle diameter on tools and controls used by older workers (optimal grip range 1.25–1.75 inches); use textured, non-slip grip surfaces; reduce pinch-grip requirements through redesigned part handling fixtures	ISO 11228-3; ANSI/HFES 100-2007
Lighting and Visual Ergonomics	Increase task lighting to a minimum of 50 foot-candles at precision work stations; use adjustable magnification aids at inspection stations; minimize glare and high contrast between work surface and surround.	IES Lighting Handbook; OSHA 1910.303 (indirect)
Thermal Comfort	Maintain ambient temperature above 68°F in work areas where older workers are concentrated; older workers thermoregulate less efficiently and are more vulnerable to both heat and cold stress at exposures that younger workers tolerate	ACGIH Heat Stress TLVs; NIOSH criteria document on occupational heat exposure

Source: NIOSH (2021); ACGIH (2025); ISO 9241-5; IES Lighting Handbook.

The Participatory Ergonomics Imperative

One of the principles bridges all six ranges of designs and is therefore worth particular focus, namely, older workers are not passive consumers of ergonomic solutions. They are the most reliable source of prior knowledge of how to actually do the job, what physical stress should focus on, and what would be changed in the place, and that would do the most good. Further, participatory ergonomics, i.e., the gradual involvement of the workers in the problem formulation and the solution creation, is always more fruitful than the best engineering studies that interact with the top, and the outcomes are even more substantial in the situation when the workers themselves possess decades of experience in any process. Within 30 minutes of the structured interview of a 30-year machinist, the ergonomic discernment would come out that took days of observation on the part of an external consultant to discover alone.

The framing of the ergonomic intervention by the older worker cohort is also crucial. The communications about accommodations of aging employees create a clamor of self-defense, refusal, and reactive non-cooperation. Programs embedded in, as in work station optimization of our best experienced workforce, are ranked as such and therefore generate engagement and buy-in. The words matter.

Workforce Retention: The Hidden ROI

Financial analysis of MSD injury prevention is not the sole aspect of the ROI argument. Replacement cost of a skilled manufacturing worker: the cost of recruitment, training period, and gap between productivity at the ramp-up period has been quantified to be approximately between $15,000 to $45,000, depending on the level of technology of the position. In very specialized jobs in precision machining, instrumentation, or quality control, the replacement costs may be over 60,000. One can only pass on the fungible knowledge -skilled record-keeping of the skills and the process that can be learned- with these figures. They fail to generate the tacit knowledge: the accrued experience of when a machine starts to malfunction, how to debug the peculiarities of a certain production line, and the informal mentoring links in the impartation of craft knowledge to the young workers. When that knowledge leaves the building after a premature retirement caused by injury, the retirement has disappeared. It is not retrieved with no onboarding program (SHRM, 2024).

A productive working life. A three to five-year period will be added to the productive service of an aging expert, by redesigning the physical requirements of the position so as to match the present strength, the returns will be multiplied incrementally in each year of additional service. Viewed in terms of ARM, this is risk retention in its very literal sense, retaining the most valuable risk management asset, that of human judgment, which the organization has.

Implementation Roadmap: The ARM Six-Step Approach

The roadmap below will update the ARM Risk Management Process to fit the criteria of an aging workforce ergonomic improvement program. Step 5 does not imply the passivity of older workers present at the process or an optional part: they have to be part of the process until the quality of the offered solutions and also the sustainability of the program.

Table 2. ARM Six-Step Risk Management Process Applied to Aging Workforce Ergonomics

Step	Phase	Aging Workforce Ergonomics Application
1	Scan the Environment	The past five years stratify the workers' compensation MSD claims by the age group of workers. Calculate the average cost of claim, days to recovery, and the days to return to work. This analysis alone will likely indicate a significant financial case for a particular investment.
2	Identify Risks	Perform ergonomic job task analysis (JTA) at 5 workstations with the highest frequency of MSD. The NIOSH Lifting Equation, RULA, or REBA should be used to mark each task. Single flag assignments with scores above the suggested limits are specifically in favor of the older group of workers.
3	Analyze Risks	Cross-tabulate the high-risk task scores and the ergonomic risk scores between the workforce age groups: which stations are the highly concentrated 50+ workforce population with the highest ergonomic risk scores? These are your targets of intervention.
4	Select Techniques	During the selection of engineering controls, it is recommended to start with adjustable workstations, lift assists, tool balancers, and changes in the conveyor height. Secondary controls (administrative controls (rotation schedules, warm-up protocols)). PPE (wrist supports, knee pads) as an additional precaution.
5	Implement	Brief workers about the intent of the changes- make it clear that any changes are signs of respect towards experience and commitment in retention, and not a response to a lack. Engage older workers in solution design; process knowledge can generally emerge through them to the ergonomist in ways that are practical.
6	Monitor & Adjust	Monitor monthly MSD claim frequency, severity, and cost by age group at the quarterly level after implementation. Observe EMR change rate and gather organized feedback from workers after 90 and 180

		days—presentation of the current TCOR impact to leadership based on the ROI model of the Research Results section.

Source: ARM Risk Management Process; NIOSH (2021); Liberty Mutual Research Institute (2024).

DISCUSSION

The convergence of demographic trends, occupational physiology evidence, and TCOR financial modeling all point to the same conclusion: despite aging workforce ergonomics being no longer a compliance-related undertaking, it is an investment that has one of the largest returns on investment in the list of occupational health and safety undertakings. The risk manager who has the numbers of the cost of MSD claims between age groups and provides the calculations of the ROI of the interventions that presented to leadership will consider the figures to be almost inexplicable without the impression that an error has been committed. It is an investment of this kind that makes an equivalent of $61,200 on the direct costs and more than 250,000 on the indirect costs, including indirect costs, which is indeed exceptional in terms of investment (Liberty Mutual Research Institute, 2024).

This point is highlighted in the aspect of retention. The tacit knowledge of the 30-year machinist in making decisions is also not free at all since it cannot be bought; it can only be saved or lost. An ergonomics that increases productive working life by three or five years is effective in retaining this knowledge within the organization, and it constitutes a bridge upon which a knowledge of such nature can be methodically documented and handed over to the new generation. The most competitive manufacturing organizations in the environment that will be labor-constrained, at the end of the 2020s, will be those where the experienced workforce will not be a cost of any kind but a competitive advantage in the form of a design (Truxillo et al., 2023).

The legal aspect supports the strategic case. The responsibilities of the employers, as stipulated by the ADEA and the ADA models, are structured in such a way that they can be fulfilled in due course beforehand with great success in mitigating the compliance risk and interpersonal friction caused by the accommodation processes taking place as a reactionary measure. A global organizational improvement that functions sustainably to the benefit of all, coupled with a particular gain to those who are physically in more danger, is a legitimate and feasible one. The risk manager who presents the aging workforce ergonomics as the so-called universal improvement program (and not an age-related accommodation) not only gets good court outcomes but also positively affects the worker engagement (EEOC, 2024).

CONCLUSIONS AND RECOMMENDATIONS

The aging of the manufacturing workforce cannot be solved, but rather needs to be designed. The physiological disparities that follow old age are a reality, cumulative, and have actual MSD risks in the places of employment based on the understanding that the younger body was being utilized. Nevertheless, it is the very aging employees who represent decades of experience, wisdom, and tacit knowledge that cannot be halted on any workforce planning spreadsheet and would otherwise be purchased in days on recruiting budgets.

The risk manager who adopts the strategy of ergonomic aging workforce through the ARM prism lens of cost of claiming MSD by age group, cost of intervention ROI, value of further productive work life retention, and the creation of a systematic road map implementation will show a definitive picture as one of the most alluring investment cases within the entire OHS portfolio. Recommended actions include: classify MSD claims by age in order to quantify the cost gradient; do JTAs at high frequency workstations over age in order to score with age-specific; concentrate on engineering solutions (lift assist, adjustable workstation, tool balancer) rather than on administrative solutions or PPE solution; model all ergonomic solutions as universal workstation optimization solutions as opposed to age-specific solutions; and design the senior older employees themselves to be directly involved in the solution design. The numbers in the information are pointing in one direction. So does the right thing to do.

ADVANCED RESEARCH

The article has inherent limitations of its model format: financial models have been calculated using industry aggregate data, rather than individual firm longitudinal analysis of claims, and the principles of ergonomic design are based on the opinion of experts, rather than trial research applicable to the manufacturing context. Future research should explore age stratified ergonomic intervention mixes on age-related actuarial consequences of ergonomic intervention programmes; the improved effectiveness of participatory compared to top-down ergonomic program development in supporting older workforce; the mechanism of combining age-related physiological adaptations with personal manufacturing processes technology e.g. collaborative robots, AR assembly guidance system etc.; and the transfer of knowledge results of formal mentoring programmes that they assure accompany ergonomic accommodation under extended working life programme.

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