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Bariatrics in the Workspace: Ergonomic Considerations and Adaptations

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Abstract: Ergonomic adjustment of the workspace to suit the worker is essential to worker health, company success and efficient production.

Today's workspace includes a growing population of overweight and obese workers, who have been found to be at risk for various health problems, including increased rates of hypertension, diabetes, arthropathies, etc, and concomitant occupational restrictions, such as more frequent and lengthier absences, decreased production and increased rates of musculoskeletal disorders. This population may also find themselves struggling to function comfortably or efficiently at workspaces ill-adapted to their abilities and proportions.

The study of anthropometrics can provide us with certain parameters to ensure working comfort, but ergonomic adaptation to the obese worker may require more individualized consideration. This stems from functional characteristics including possible movement limitations, extreme joint overload and body proportions differing from those common among the non-bariatric working population.

We will discuss the specific limitations commonly found in adapting workspaces, including seated or manual handling tasks, to the overweight and obese worker population, and the possible interventions available.

Keywords: obesity, overweight, ergonomic fit, workstation adaptation, anthropometric

1. BARIATRICS IN THE WORKPLACE – A GROWING PROBLEM

Overweight and Obesity in the workforce

The proportion of the world population suffering from overweight or obesity is growing rapidly. According to statistics published by WHO in 2022, 43% of adults worldwide were overweight, and 16% obese. These figures have nearly doubled within the past 30 years. (World Health Organization, 2024) Accordingly, a large and growing proportion of adults currently participating in the global workforce are overweight and obese. Varying rates of workforce obesity have been measured throughout the world.

Gu and colleagues, using data from the US National Health Interview Survey (NHIS) developed by the CDC, found that just over a third (36%) of working American surveyed between 2004-2012 were normal weight. 37% suffered from overweight; 17 % from obesity Class I (BMI 30-34.9) and 10% from obesity II (BMI > 35). (Gu et al, 2014) US data collected in 2010 revealed a 28% rate of obesity. (Luckhaupt et al, 2014). In a survey conducted several years later, using data from the National Health and Nutrition Examination Survey (NHANES) between 2015 to 2016, Doerrmann et al, 2020) and colleagues of the NIOSH found that over 40% of the workers examined were categorized as obese.

An Italian survey of 8000 workers found rates of overweight 38% and obesity of 8.6% (Di Tecco et al, 2020). Keramat and colleagues reported an overweight rate of 29% and obesity of 19% among Australian workers. (Keramat et al, 2020)

Overweight and obesity are associated with reduced work ability (Schulte et al, 2007; Andersen et al, 2017) and absenteeism (Schulte et al 2007, Corbeil et al 2019, Capodaglio et al 2010). Injury rates are significantly increased among obese workers (Koepp et al, 2014; Lemus et al,2022; Schulte et al, 2007; Sethi et al, 2011, Gu et al, 2016), including musculoskeletal injury. Obesity is significantly associated with carpal tunnel syndrome. (Gyi et al, 2019; Smith et al, 2015, Schulte et al, 2007)

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1.1 Demographic factors

Obesity rates have been found to be associated with various demographic factors such as age, ethnicity and educational levels:

- Obesity rates increase with age (diTecco 2021). A survey of Spanish workers found overweight and obesity rates increased by 4% for each year of age (dePedro-Jimenez, 2022)
- Ethnicity has been shown to be significant, with Asian or Asian Americans showing lower rates of obesity, and those identified as Non-Hispanic Black significantly higher. (Doerrmann et al 2020; Luckhaupt et al 2014)
- Another demographic factor is educational level, with lower rates of obesity associated with higher levels of education Doerrmann et al 2020; Luckhaupt et al 2014) Conversely, higher rates of obesity have been shown among blue-collar workers (Myers et al, 2020)

1.2. Occupational factors

Researchers have also examined a variety of occupational factors and their association with overweight and obesity:

Longer working hours have been associated with obesity rates. Analysis of US data from 2015-2016 showed that people working 40 hours a week or more were significantly more likely to be obese (Doerrmann et al, 2020), echoing findings by earlier research (Luckhaupt, 2014). The authors suggested a connection to increasingly sedentary workplaces, with reduced work activity and therefore reduced caloric expenditure. (Doerrmann et al, 2020)

Shift work has also been associated with higher rates of obesity, particularly night shift work. American workers on night shifts were more than twice as likely to be obese as day shift workers. (Meyers et al, 2020). A study of Spanish workers found rates of overweight and obesity 20% higher in night or rotating shift work. (de Pedro-Jimenez, 2021). Italian female shift workers were also found more likely to be obese than day workers, (diTecco et al, 2020).

Psychosocial stressors in the workplace have been associated with increased rates of obesity. (Luckhaupt 2014; Schulte et al 2007; Sethi et al, 2011). Kim and coresearchers (Kim et al, 2015) found a significant correlation of overweight and obesity to higher levels of self-reported anxiety, and to reduced mental health-related quality of life among office workers. Research groups have suggested a possible bi-directional relationship, in which psychosocial workplace factors may increase the risk of obesogenic behaviors, and obesity may play a role in creating workplace stress. (Luckhaupt et al, 2014, Kim et al, 2015)

The occupational sector is also found to be a factor in obesity rates. Higher rates of obesity have been found among blue-collar workers (including machine operators and construction) (Meyers, 2021), protective service workers (Meyers, 2021; Luckhaupt,2014; Gu 2014), sales and office workers (Meyers 2020; Luckhaupt, 2014)

Conversely, rates of overweight and obesity were nearly 15% lower in sedentary workers in Spain than among non-sedentary workers. (de Pedro-Jimenez et al, 2021)

Among the sectors with the highest rates of obesity were healthcare, protective service and vehicle transport drivers (diTecco, 2020; Meyers,2020; Luckhaupt, 2014; Gu 2014), For example, a survey of truck drivers in the US found both men and women to be significantly heavier than the general population, including thigh and waist circumferences, measurements with high relevance both to vehicle operation and safety. (Guan et al, 2012)

2. CHARACTERISTICS OF THE OBESE OR OVERWEIGHT WORKER

Research has identified several specific physical and functional characteristics of the overweight or obese worker which may contribute to these increased risks and reduced efficiency in the workplace.

2.1. Body size and proportions

The most apparent issue is the worker's weight and size in relation to workspace designs based upon standard, or often outdated, anthropometric data. Gyi and colleagues found a discrepancy in weight of 50 kilograms between a surveyed "plus size" population compared to the prevailing anthropometric dataset for British adults (Gyi et al, 2019)

Oversize body shape and proportions also may differ from those of normal-weight workers. Though dimensions relating to length of body segments are not significantly different, measures of circumference at chest, waist and hip are significantly increased. (Gyi et al, 2019; Hamilton et al, 2013; Park et al, 2010)

Additionally, some sectors, such as motor vehicle operators, have been found to have rates of obesity higher than the general population. (Guan et al, 2012; Gyi et al, 2019; Luckhaupt et al, 2014; Meyers et al, 2020). Workers in those sectors are liable to experience greater difficulty in dealing with "standard" sized equipment, including seat belts.

2.2. Range of joint motion (ROM)

Obesity and overweight have been associated with reduced functional range of motion. Shoulder movements, including adduction and extension, hip movements (both flexion and extension), knee and ankle flexion were found to be significantly reduced among obese subjects, as were lumbar extension and side flexion (Jeong et al, 2018; Park et al, 2010). Park and colleagues attribute these limitations mainly to the mechanical interposition of adipose body tissue accumulation. (Park, 2010) Such joint limitations are likely to strongly impact the worker's ability to perform reaching or bending tasks. (Cavuoto & Nussbaum, 2014)

2.3. Fatigue and endurance

The greater size and muscle mass of obese and overweight workers would not seem to ensure greater strength or stamina.

Findings regarding muscle strength have been varied. Though Cavuoto and Nussbaum (2014) cite evidence of increased absolute strength, particularly in muscles of the lower extremities owing to the increased weight-bearing demand, the strength of obese subjects adjusted for relative mass has been estimated as 6-10% lower than that of normal-weight subjects. (Capodaglio et al, 2010); Bulbrook and colleagues found significant strength reductions up to 63% among subjects with Class II obesity (BMI above 35). (Bulbrook et al, 2021) Other evidence has suggested reduced handgrip and knee strength among obese women (Ghesmaty Sangachin and Cavuoto, 2016)

Findings regarding metabolic capacity and fatigue levels are less equivocal. Work and everyday functions performed by overweight or obese subjects require increased metabolic expenditure compared to normal weight subjects. (Lemus et al, 2022). Changes to respiratory and cardiac function, such as lower oxygen consumption, reduced pulmonary volumes and increased hemodynamic volume reduce metabolic capacity of obese workers (Capodaglio et al, 2010) Obese subjects were found to have reduced endurance and time to fatigue in manual handling tasks (Ghesmaty Sangachinet & Cavuoto, 2016; Boocock et al, 2024). In intermittent upper extremity exertions performed while seated, Cavuoto and Nussbaum reported up to 60% longer endurance times. (Cavuoto and Nussbaum, 2014)

2.4. Balance

Overweight and obesity also have a profound effect upon balance and the capacity to perform precision tasks in standing.

Obese subjects exhibit increased sway while performing standing tasks (Geiger,2013; Gyi et al, 2019, Colim et al, 2020), thus challenging upper extremity precision and coordination. Changes in body posture and center of gravity shift in obese persons have been compared to those occurring in pregnancy, with a forward shift of center of gravity (Capodaglio,2010). Decreased stability in standing will affect the ability to perform tasks requiring fine motor control, including slower movements in targeting objects. (Cavuoto and Nussbaum, 2014)

2.5. Walking

The effects of these limitations of strength, endurance and balance are apparent in the performance of basic functions such as walking.

Altered gait kinematics include a broad base of support, and reduced movement at the hip, knee and ankle (Jeong, et al, 2018; Park et al, 2010; Capadaglio et al, 2010). These attributes likely contribute to findings of lower gait speed among the obese compared with the normal-weight population, with reduced step length and frequency. (Capodaglio et al, 2010)

3. ERGONOMIC CHALLENGES IN THE WORKPLACE

These characteristics have far-reaching implications upon workplace comfort and performance.

3.1. Workplace fit

The most apparent limitations arise from worker size and dimensions. In their ground-breaking studies of "plus size" workers, Gyi, Masson and Hignett noted that many of the anthropometric dimensions of obese and overweight workers, particularly those of body circumference, breadth and depth, are not reflected in the design of workspaces, toilet cubicles or staff uniforms, even when those are intended designed to include the 95th percentile of British adults. (Gyi et al, 2019) Additionally, knee splay, or the distance between the lateral surfaces of the knees when sitting, is an important measure for determining chair and workspace fit, and yet is not included in standard anthropometric data. (Masson et al, 2015)

These misfitting dimensions relate largely to functional clearance, such as the ability to navigate a narrow staircase, to fit comfortably within a work cubicle, to cross one's legs beneath the desk, or to sit close enough to the desk to

comfortably reach the keyboard or mouse. (Masson, et al, 2015) All "plus size" workers surveyed reported facing discomfort in the workplace, the most common reports being of poor fit in seating (81% of respondents), inappropriately sized uniforms (62%), difficulty accessing toilet cubicles (73%) and restrictions in movement in and around the work area (62%). (Gyi et al, 2019).

3.2. Safety

A related, and critical, challenge facing overweight and obese workers is that of ensuring appropriate safety equipment. Overweight and obese workers must be certain that safety harnesses, seat belts and other safety gear/ personal protective equipment will be appropriate for their size and weight. (Flynn et al, 2017; CDC, 2014)

Motor vehicle operation and firefighting are among the occupations with the highest rates of obesity in the US. (Schulte et al, 2007; Gu et al. 2014). However, a NIOSH survey among firefighters found that their girth and size may not accommodate seatbelt use when in gear. (Guan et al, 2012; Geiger, 2015). Additionally, truck drivers surveyed noted difficulty accessing the driver's cab, and a low rate of seatbelt use while driving. Over 60% of those not using seatbelts attributed this to discomfort or poor fit. (CDC, 2014)

3.3. Manual material handling tasks (MMH)

Obese workers may have reduced biomechanical (Cavuoto & Nussbaum, 2014; Singh et al 2015; Corbeil et al 2019; Colim et al 2020; Boocock et al, 2014) and metabolic capacity for manual handling tasks (Capodaglio et al 2010; Cavuoto & Nussbaum, 2014, Lemus et al 2022) particularly in sustained or repeated lifting tasks, or those involving extreme variations in posture, such as reaching overhead or bending to the floor. This may be related to various factors increasing load, such as increased body mass, greater metabolic expenditure, more limited joint motion and increased tendency to musculoskeletal disorders.

Biomechanical stress upon the lower back of obese workers performing manual handling tasks has been found to exceed NIOSH recommended limits, even when lifting weights falling within the RWL (Singh et al, 2015. Boocock et al, 2024) Increased lumbar extension moment and asymmetrical moments have been reported. (Corbeil et al 2019; Colim et al 2020), related to findings of increased reach distance to the load among obese workers, and increased lumbar biomechanical loading. (Corbeil et al 2019; Colim et al 2020; Corbeil et al 2019; Cavuoto & Nussbaum, 2014; Boocock et al, 2024)

Metabolic stress, as evidenced by increased heart rate, respiratory rates and energy expenditure rates, results in earlier fatigue. Ghesmaty Sangachin and Cavuoto (2016) found that with prolonged lifting tasks, obese subjects show a greater decrease in coordination and variance of movement patterns than non-obese subjects, suggestive of higher risk of injury during prolonged lifting tasks or when faced with accumulating fatigue.

Therefore, the recommended parameters for lifting limits may not be protective of overweight and obese workers, who may be at increased risk for back disorders particularly with repeated or prolonged lifting tasks.

3.4. Seated work

As mentioned, poor seating or inappropriate chair fit may be a major cause of discomfort among overweight and obese workers. (Gyi et al, 2019)

The placement and height of the worksurface are equally important to proper fit and ease of function and may also present challenges to the obese worker. Seated tasks, such as assembly or other manual tasks, are best performed within the nearest work envelope, in order to avoid the increased biomechanical loading that accompanies awkward postures such as extreme forward reach and trunk inclination. For the obese worker, this represents an ergonomic challenge: forward functional reach has been found to be reduced in the obese population (Hamilton et al, 2013, Gyi et al, 2019; Boocock et al 2024) while increased chest and abdomen depth (Cavuoto and Nussbaum 2014) distance the worker from the work surface. Therefore, obese workers may need to adopt alternative biomechanical strategies when performing manual tasks at a seated workstation.

Eladly et al (2020) observed that obese sewing machine operators engage more cervical flexion, and less trunk inclination than non-obese workers while working on identical equipment. This would appear to increase cervical loading, particularly during prolonged tasks. (Eladly et al 2020) In other seated work tasks, Baek and colleagues measured significant increases in movement time, reaction time and performance time to activate a foot pedal among the obese subjects. (Baek et al 2021)

In an office setting, overweight and obese workers may be faced with challenges stemming not only from inadequate chair and desk fit, but from poor fit with other office equipment. Smith et al, while examining the effect of alternative keyboards upon office workers, note that the use of a standard keyboard will force obese workers into increased abduction of the arms and consequent ulnar deviation of the wrists, owing to the increased diameter of torso and chest.

(Smith et al 2015). These non-neutral positions, particularly when maintained over working hours, are liable to place increased biomechanical load upon the spine, shoulder girdle or wrists.

4. WORKPLACE ADAPTATIONS FOR OVERWEIGHT AND OBESE WORKERS

Despite these overwhelming effects of obesity upon workplace performance, comfort and safety, much of the prevailing focus of research has been upon the medical and public health aspects of the obesity epidemic and means for its prevention, both in the workplace and elsewhere. (Luckhaupt et al 2014; Kim et al, 2015; Caban et al 2005) As noted by Williams and Forde, fewer researchers have turned their attention to the ergonomic aspects of obesity at the workplace and the application of ergonomic principles toward improving workplace functioning. (Williams and Forde, 2009). There is a plethora of possible control measures and adaptations which might be implemented in various working environments.

4.1. Inclusive anthropometric data for design

Firstly, anthropometric databases should be both updated and revised to extend their relevance to the obese working population. As noted, (WHO 2024, dePedro-Jimenez 2022; Doehrmann et al, 2020), rapidly increasing obesity rates worldwide should be incorporated in anthropometric surveys worldwide, as the current data are not inclusive of oversize workers (Masson et al 2015, Guan et al 2012]. As suggested by Gyi, et al, dimensions including thigh depth, circumference of chest, waist and hip are particularly relevant. For male workers, hip breadth, and for female workers, abdominal depth, may be indicative of the increases in other body measurements. Measures of knee splay serve as an important addition to the researchers' datasets, replacing hip or shoulder breadth as the most relevant to functional space and clearance in the workspace. (Gyi et al 2019)

This data will be most particularly relevant in the design of safety equipment, including both size and weight limits. As noted by Flynn and colleagues, though many online distributors of safety equipment offer "alternative" sizes meant to address the needs of a diverse population, there is frequently a lack of information regarding precise sizing and measurements. The researchers recommend both an expansion of the databases used in product design, and increased visibility and promotion of alternative-sized products in online marketing materials (Flynn et al 2017).

4.2. Adaptations to the seated workspace

Efficient and comfortable performance of seated tasks requires that the physical workspace be adapted to the obese worker: firstly, as the chair paramount to worker comfort, employers must ensure that task chairs are appropriate both in size, width and weight capacity. Specifically, knee splay dimensions may be more adequate than measures of hip or shoulder breadth for comfortable width of seating space design. (Gyi et al, 2019) Adequate dimensions of the workstation or cubicle, particularly regarding clearance and approach, should be based upon anthropometric data pertaining to the obese or overweight population, including chest depth and circumference measures.

Workstation equipment impacts body postures in many ways. Improvement of tool access and usage may affect both upper extremities loading and posture but also can reduce load patterns elsewhere in the body. Smith and colleagues reported that both overweight and obese office workers expressed increased comfort of use after switching to ergonomic split keyboards. The impact was more marked among the obese participants, who further reported a significant decrease in lower and upper back discomfort. (Smith et al 2015) The reduction in shoulder abduction and internal rotation may have served to reduce loading upon the upper back and shoulder girdle. Offering obese workers, the choice of an adjustable split keyboard to reduce shoulder internal rotation and wrist ulnar deviation may reduce postural stress and increase comfort while working.

As the nearest work envelope is effectively unavailable to many obese workers, alternative work surfaces such as cut-out layout, or inclined tabletops may help avoid extended reach distances to work equipment.

Adjustable workstation parameters, including worksurface height and tilt, and adjustability of other equipment, may allow the overweight or obese worker to adapt the various components of the workstation to his or her individual needs. (Cavuoto & Nussbaum, 2014). Eladly and coworkers experimented with varying sewing machine height and angles, and concluded that obese workers found working at an elevated height (80 cm) and slight inclination (2º) more comfortable, attributing this preference both to increased clearance beneath the machine, and to improved neck posture. The researchers' conclusions are based upon worker preference, and emphasize the importance of worker involvement in ergonomic adjustments.. (Eladly et al, 2020)

For tasks involving the use of foot-operated pedals or controls. Baek has recommended accommodations to the increased performance time noted in obese subjects. These include bringing the foot activation closer to the operator, preferring lateral placement of controls to forward placement, and increasing control size or saliency of colors. (Baek et al, 2021)

Much recent research has focused on the effects of alternating office workstation postures between sitting and standing as a means to reduce the negative health effects of sedentarism. Thorp and colleagues examined the effect of alternating sitting and standing posture during the workday upon obese and overweight office workers. The use of an adjustable electric sit-stand desk in 30-minute bouts was found to significantly decrease reported fatigue levels and low back discomfort, with no notable effect upon work productivity (Thorp et al, 2014). As other studies have pointed to increased levels both of fatigue and of musculoskeletal discomfort among overweight and obese workers, (Ghesmaty Sangachin & Cavuoto, 2016; Boocock et al, 2024; Lemus et al, 2022) the use of sit-stand desks may be one means to attenuating the effects of prolonged seating in these workers.

4.3. Adaptations to manual handling tasks

Obese workers have been shown to be at greater risk for biomechanical and metabolic overload than their normal weight counterparts, even with loads falling within the accepted weight limit, (Boocock et al, 2024, Colim et al,2020; , Corbeil et al,2019; Singh et al, 2015).

Taking into account the reduced strength and endurance of obese workers, task requirements should be adjusted to avoid prolonged static effort. This includes adjusting task weight or speed as needed; altering work patterns to allow for longer recovery time between exertions; avoiding prolonged exertions and ensuring appropriate support for upper extremities and body parts to reduce static muscle load. (Capodaglio et al, 2010; Cavuoto& Nussbaum,2014; Corbeil et al, 2019). Capodaglio and colleagues recommend limit values in manual handling loads of between 4-5 kg (2-3 lifts by one worker with 30-minute intervals) to 14-15 kg (few lifts by 2 workers with 60-minute intervals), and an absolute limit of 15 kg. (Capodaglio et al, 2010)

Additionally, workstations should be organized to reduce the need for extreme reaching and bending, including forward and overhead reaching. The use of lifting equipment should be facilitated. As with other adaptations to the overweight or obese worker, these changes will facilitate tasks for all workers.

Finally, future research may determine safe lifting limits for the obese worker.

4.4. Functional evaluation of individualized worker capacity and fit

The effects of overweight and obesity upon worker characteristics and capacities are far-reaching, touching upon almost all aspects of work performance. Use of the accepted anthropometric parameters of size, dimension, and strength may not sufficiently encompass this population's needs at work. Therefore, in order to optimize the fit between the worker and the specific task, employers should obtain accurate assessment of the specific worker's capabilities by means of a targeted evaluation of work capacity and job demands. This evaluation should explore the specific limitations reported by the worker and their effect upon his or her performance, while identifying the specific subtasks which are most problematic. A targeted evaluation will lead to effective adaptation strategies to mitigate workplace challenges. (Capadoglio et al, 2010; JAN, 2024)

5. CONCLUSION

While much attention has been placed upon directing medical and workplace interventions toward prevention and reduction of obesity, the growing population of obese and overweight workers will increasingly require appropriate workspace adaptations to their individual capacities. Successful ergonomic adaptations will include considerations of reduced effort and length of sustained effort, fewer reaching and bending requirements, less static sitting or standing, and will be based upon appropriate anthropometric data and accompanied by individualized work capacity assessments. Workplace mitigation strategies should include changes to the physical and psychosocial environment, workstation equipment and workplace arrangements.

6. REFERENCES

Andersen, L. L., Izquierdo, M., & Sundstrup, E. (2017). Overweight and obesity are progressively associated with lower work ability in the general working population: Cross-sectional study among 10,000 adults. *International Archives of Occupational and Environmental Health*, *90*(8), 779–787. https://doi.org/10.1007/s00420-017-1240-0

Baek, S., Jung, J., Moon, P., & Park, W. (2021). Obesity impacts on task performance and perceived discomfort during seated foot target reaches. *Ergonomics*, *64*(12), 1569–1578. https://doi.org/10.1080/00140139.2021.1933202

Capodaglio, P., Castelnuovo, G., Brunani, A., Vismara, L., Villa, V., & Maria Capodaglio, E. (2010). Functional limitations and occupational issues in Obesity: A Review. *International Journal of Occupational Safety and Ergonomics*, *16*(4), 507–523. https://doi.org/10.1080/10803548.2010.11076863

Boocock, M., Naudé, Y., Saywell, N., & Mawston, G. (2024). Obesity as a risk factor for musculoskeletal injury during Manual Handling Tasks: A systematic review and meta-analysis. *Safety Science*, *176*, 106548. https://doi.org/10.1016/j.ssci.2024.106548

Bulbrook, B. D., La Delfa, N. J., McDonald, A. C., Liang, C., Callaghan, J. P., & Dickerson, C. R. (2021). Higher body mass index and body fat percentage correlate to lower joint and functional strength in working age adults. *Applied Ergonomics*, *95*, 103453.

Caban, A. J., Lee, D. J., Fleming, L. E., Gómez-Marín, O., LeBlanc, W., & Pitman, T. (2005). Obesity in US workers: The National Health Interview Survey, 1986 to 2002. *American Journal of Public Health*, *95*(9), 1614–1622. https://doi.org/10.2105/ajph.2004.050112

Capodaglio, P., Castelnuovo, G., Brunani, A., Vismara, L., Villa, V., & Maria Capodaglio, E. (2010). Functional limitations and occupational issues in Obesity: A Review. *International Journal of Occupational Safety and Ergonomics*, *16*(4), 507–523. https://doi.org/10.1080/10803548.2010.11076863

Cavuoto, L. A., & Nussbaum, M. A. (2014). Influences of obesity on job demands and worker capacity. *Current Obesity Reports*, *3*(3), 341–347. https://doi.org/10.1007/s13679-014-0105-z

Centers for Disease Control and Prevention. (2014, June 6). *Improved safety for truck drivers: Designing safer cabs based on Driver Body Dimensions*. Centers for Disease Control and Prevention. https://www.cdc.gov/niosh/docs/2011-188/default.html

Colim, A., Arezes, P., Flores, P., & Braga, A. C. (2020). Kinematics differences between obese and non-obese workers during vertical handling tasks. *International Journal of Industrial Ergonomics*, *77*, 102955. https://doi.org/10.1016/j.ergon.2020.102955

Corbeil, P., Plamondon, A., Handrigan, G., Vallée-Marcotte, J., Laurendeau, S., Ten Have, J., & Manzerolle, N. (2019). Biomechanical analysis of manual material handling movement in healthy weight and obese workers. *Applied Ergonomics*, *74*, 124–133. https://doi.org/10.1016/j.apergo.2018.08.018

de Pedro-Jiménez, D., Romero-Saldaña, M., Molina-Recio, G., de Diego-Cordero, R., Cantón-Habas, V., & Molina-Luque, R. (2021). Relationships between work, lifestyles, and Obesity: Cross-sectional study based on the 2017 spanish national health survey. *European Journal of Cardiovascular Nursing*, *21*(3), 243–253. https://doi.org/10.1093/eurjcn/zvab072

Di Tecco, C., Fontana, L., Adamo, G., Petyx, M., & Iavicoli, S. (2020). Gender differences and occupational factors for the risk of obesity in the Italian working population. *BMC Public Health*, *20*(1). https://doi.org/10.1186/s12889-020-08817-z

Doerrmann, C., Oancea, S. C., & Selya, A. (2020). The Association Between Hours Spent at Work and Obesity Status: Results From NHANES 2015 to 2016. *American journal of health promotion : AJHP*, *34*(4), 359–365. https://doi.org/10.1177/0890117119897189

Eladly, A. M., Abou-Ali, M. G., Sheta, A. M., & EL-Ghlomy, S. H. (2020). A flexible ergonomic redesign of the sewing machine workstation. *Research Journal of Textile and Apparel*, *24*(3), 245–265. https://doi.org/10.1108/rjta-10-2019-0050

Flynn, M. A., Keller, B., & DeLaney, S. C. (2017). Promotion of alternative-sized personal protective equipment. *Journal of Safety Research*, *63*, 43–46. https://doi.org/10.1016/j.jsr.2017.08.004

Geiger, J. 2013 *Ergonomics for all sizes: Overweight at Work*.(Heb) Israel Institute for Occupational Safety and Health accessed 13.5.24 https://www.osh.org.il/UploadFiles/work_obesity_joan.pdf

Geiger, J., *2015 Anthropometry Saves Lives – CDC-NIOSH research among workers at ris*k (Hebrew). Israel Institute for Occupational Safety and Hygiene. https://www.osh.org.il/heb/articles/article,431/ accessed 25.5.24

Ghesmaty Sangachin, M., & Cavuoto, L. A. (2016). Obesity-related changes in prolonged repetitive lifting performance. *Applied Ergonomics*, *56*, 19–26. https://doi.org/10.1016/j.apergo.2016.03.002

Guan, J., Hsiao, H., Bradtmiller, B., Kau, T. Y., Reed, M. R., Jahns, S. K., ... & Piamonte, D. P. T. (2012). US truck driver anthropometric study and multivariate anthropometric models for cab designs. *Human factors*, *54*(5), 849-871.

Gu, J. K., Charles, L. E., Bang, K. M., Ma, C. C., Andrew, M. E., Violanti, J. M., & Burchfiel, C. M. (2014). Prevalence of obesity by occupation among US workers. *Journal of Occupational & Environmental Medicine*, *56*(5), 516–528. https://doi.org/10.1097/jom.0000000000000133

Gu, J. K., Charles, L. E., Andrew, M. E., Ma, C. C., Hartley, T. A., Violanti, J. M., & Burchfiel, C. M. (2016). Prevalence of work-site injuries and relationship between obesity and injury among U.S. workers: NHIS 2004–2012. *Journal of Safety Research*, *58*, 21–30. https://doi.org/10.1016/j.jsr.2016.06.001

Gyi, D., Masson, A., & Hignett, S. (2019). Plus size and obese workers: Anthropometry estimates to promote inclusive design. *Ergonomics*, *62*(9), 1234–1242. https://doi.org/10.1080/00140139.2019.1622791

Hamilton, M. A., Strawderman, L., Babski-Reeves, K., & Hale, B. (2013). Effects of BMI and task parameters on joint angles during simulated small parts assembly. *International Journal of Industrial Ergonomics*, *43*(5), 417–424. https://doi.org /10.1016/j.ergon.2013.08.003

JAN (2024). Job Accommodation Network. *Accommodation and Compliance: Obesity*. https://askjan.org/disabilities/Obesity.cfm?csSearch=6223385_1. Accessed 21.4.24

Jeong, Y., Heo, S., Lee, G., & Park, W. (2018). Pre-obesity and obesity impacts on passive joint range of motion. *Ergonomics*, *61*(9), 1223–1231. https://doi.org/10.1080/00140139.2018.1478455

Keramat, S. A., Alam, K., Gow, J., & Biddle, S. J. (2020). Gender differences in the longitudinal association between obesity, and disability with workplace absenteeism in the Australian working population. *PLOS ONE*, *15*(5). https://doi.org/10.1371/journal.pone.0233512

Kim, D., Park, S., Yang, D., Cho, M., Yoo, C., Park, J., ... & Yang, Y. (2015). The relationship between obesity and health-related quality of life of office workers. *Journal of physical therapy science*, *27*(3), 663-666

Koepp, G. A., Snedden, B. J., & Levine, J. A. (2014). Workplace slip, trip and fall injuries and obesity. *Ergonomics*, *58*(5), 674–679. https://doi.org/10.1080/00140139.2014.985260

Lemus, S. A., Volz, M., Tiozzo, E., Perry, A., Best, T. M., & Travascio, F. (2022). The effect of clinically elevated body mass index on physiological stress during manual lifting activities. *PLOS ONE*, *17*(12). https://doi.org/10.1371/journal.pone.0278858

Luckhaupt, S. E., Cohen, M. A., Li, J., & Calvert, G. M. (2014). Prevalence of obesity among U.S. workers and associations with occupational factors. *American Journal of Preventive Medicine*, *46*(3), 237–248. https://doi.org/10.1016/j.amepre.2013.11.002

Masson, A. E., Hignett, S., & Gyi, D. E. (2015). Anthropometric study to understand body size and shape for plus size people at work. *Procedia Manufacturing*, *3*, 5647-5654.

Myers, S., Govindarajulu, U., Joseph, M. A., & Landsbergis, P. (2020). Work characteristics, body mass index, and risk of obesity: The National Quality of Work Life Survey. *Annals of Work Exposures and Health*, *65*(3), 291–306. https://doi.org/10.1093/annweh/wxaa098

Park, W., Ramachandran, J., Weisman, P., & Jung, E. S. (2010). Obesity effect on male active joint range of motion. *Ergonomics*, *53*(1), 102–108. https://doi.org/10.1080/00140130903311617

Schulte, PA, Wagner, G.R., Ostry A,. Blanciforti L., Cutlip, R.G., Krajnak, K.M., Luster, M., Munsen, A.E., O'Callaghan, J.P., Parks, C.G., Simeonova, P.P., Miller, D.M. (2007) Work, Obesity, and Occupational Safety and Health. *Am J Public Health.* ;97:428–436. doi:10.2105/AJPH.2006.086900

Sethi, J., Sandhu, J. S., & Imbanathan, V. (2011). Effect of body mass index on work related musculoskeletal discomfort and occupational stress of computer workers in a developed ergonomic setup. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology*, *3*(1). https://doi.org/10.1186/1758-2555-3-22

Singh, D., Park, W., Hwang, D., & Levy, M. (2015). Severe obesity effect on low back biomechanical stress of manual load lifting. *Work*, *51*(2), 337–348. https://doi.org/10.3233/wor-141945

Smith, M. L., Pickens, A. W., Ahn, S., Ory, M. G., DeJoy, D. M., Young, K., Bishop, G., & Congleton, J. J. (2015). Typing performance and body discomfort among overweight and obese office workers: A pilot study of keyboard modification. *Applied Ergonomics*, *46*, 30–37. https://doi.org/10.1016/j.apergo.2014.06.004

Thorp, A. A., Kingwell, B. A., Owen, N., & Dunstan, D. W. (2014). Breaking up workplace sitting time with intermittent standing bouts improves fatigue and musculoskeletal discomfort in overweight/obese office workers. *Occupational and environmental medicine*, *71*(11), 765-771.

Williams, N., & Forde, M. (2009). Ergonomics and obesity. *Applied Ergonomics*, *40*(1), 148-149.

World Health Organization. (n.d.). *WHO 2024 Factsheet: Obesity and overweight*. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight. accessed 30.4.24