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Occupational Health and Safety

A Multi-Regional Perspective

Edited by Manikam Pillay and Michael Tuck

OCCUPATIONAL HEALTH AND SAFETY - A MULTI-REGIONAL PERSPECTIVE

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Notice

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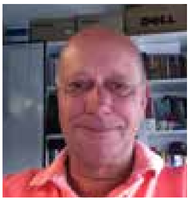
Meet the editors

Dr. Manikam Pillay is a lecturer and a lead researcher in organizational safety management at the School of Health Sciences, University of Newcastle, Australia. His research seeks to narrow the gaps between work as imaged and work as performed by integrating contemporary and advanced approaches to health, safety, and risk management. He currently supervises seven PhD degree researchers in these areas. He has published over 30 technical articles and received over $135K in research grants. He holds memberships with the Academy of Management, Australasian Institute of Mining and Metallurgy, Safety Institute of Australia, and International Council for Research and Innovation in Building and Construction Committee WO99 (Health and Safety in Construction). He is also a part of the Scientific Advisory Board of the Applied Human and Ergonomics Conference Series and the *Journal of Global Education and Research*.



Michael Tuck is an associate professor of Mining Engineering within the School of Engineering and Information Technology at the Federation University Australia. Prior to that, he was a research fellow at the Department of Mining Engineering, University of Nottingham, UK. He holds his Bachelor of Science (Honors) and PhD degrees from the University of Nottingham. His major research interests include mine ventilation, heat and mine climate, blasting, water demand management, and numerous other areas. He is a member of the Australasian Institute of Mining and Metallurgy, Society of Mining Engineers, Mine Ventilation Society of Australia, and Society of Mining Professors. Aside from his teaching and research duties at the university, he has undertaken a wide range of consultancies in numerous countries.

Contents

Preface

Occupational health and safety (OHS) continues to be the focus of governments in both developed and developing nations. This is because there are over 2.78 million fatal and 374 million nonfatal work-related injuries and illnesses experienced by employees every year [1]. The social and human costs of these are enormous, with an economic burden of poor OHS practices estimated at 3.94% of global gross domestic product (GDP) annually. Reducing these is the heart of decades-long quest to improve OHS by governments and organizations throughout the world. Many of these are giving OHS a higher priority in spite of many pressures to cut back on such measures [2]. The Global Plan of Action for Workers' Health [3] has identified that, although a lot of progress has been made since the 1950s, the world is constantly being reshaped through globalization, changing technology, new employment patterns, and changing working conditions; all of which are likely to continue impacting on OHS performance. There is also a growing realization that apart from the physical conditions, working condition, organizational, cultural, physical, and social environments all play an important role in OHS and that a multidisciplinary approach is required to find effective solutions [4-6]. For this reason, countries and regions throughout the world deal with OHS problems in a vast array of ways depending on what OHS hazards and risks are important to them.

This is where we believe that this book seeks to make a contribution, by examining how some contemporary OHS hazards and risks are being addressed in different parts of the world. We believe that bringing these together in the manner we have done is an important first step in addressing an age-old OHS problem through a multiregional collaboration.

This book has six chapters, each of which addresses a selected aspect of OHS.

Chapter 1 investigates the link between sleep and occupational safety. Disturbed sleep due to night work and long working shifts has been previously implicated in disasters such as Chernobyl and Three-Mile Island [7]. However, with an increasing proportion of women working in medicine and healthcare industries, this emerging hazard is becoming more pronounced [8]. In this chapter, Associate Professor Hitka and his Slovakian colleagues focus on how this risk can be better managed by paying attention to ergonomically designed beds.

Chapter 2 examines heat disorders in the working environment. Workers in industries such as manufacturing, mining, and construction continue to face an increased risk of heat stress from the working environment and climate change [9]. Associate Professor Hitka and his team from Slovakia discuss a range of behavioral and organizational strategies that can be used to address this ongoing contemporary hazard.

Combustible dusts continue to present a significant OHS hazard in process industries [10], including food manufacturing companies.

In Chapter 3, Dr. Haliham and Ms. Yoong examine the impact of a range of interventions on the psychological well-being of Malaysian injured workers.

Globally, industries are moving rapidly to take advantage of the new opportunities and prospects afforded by engineered nanomaterials (ENMs). However, there are currently a number of knowledge gaps with regard to their behavior, chemical and biological interactions, and their toxicological properties [11]. Addressing this is imperative in ensuring that these are used in a safe manner. Watjanatepin and Prodanov from Belgium investigate the occupational health risks of selected ENMs used in semiconductor industries in Chapter 4. They also provide a range of tools and techniques that users can utilize when identifying, assessing, and managing the risks of these emergent technologies.

Chapter 5 considers the issue of workers' behavior. Most studies in this area consider aspects of participation and compliance [12, 13]. However, Associate Professor Amponsah-Kwesi provides an another insight into considering how sociocultural practices can influence workers' behavior. The chapter, while written from a Ghanaian perspective, also has some relevance in other contexts from increased levels of migrations.

Safety professionals are increasingly being asked to utilize existing processes and approaches for managing OHS hazards and risks. While this may be a good approach, the suggested processes may not be clearly understood, especially if there is very little research available to support their use. So, they need to be adapted to suit the context.

In Chapter 6, Dr. Pillay investigates the utility of an adapted risk management process based on ISO 31000 risk management [14] for managing organizational safety in Australian workplaces.

We would like to thank our collaborators and contributors for being a part of this multiregional initiative on advancing OHS research and practice in selected contexts. We also acknowledge the assistance of Julian Virag, Publishing Process Manager, for his constant reminders, which helped us complete this project in a timely manner.

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Bed Size, Quality Sleep and Occupational Safety: An Investigation of Students at Slovak Universities

Miloš Hitka, Pavol Joščák, Silvia Lorincová and Žaneta Balážová

Additional information is available at the end of the chapter

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Abstract

All devices and equipment helping humans to do everyday things are adapted to human body proportions. Projects would not meet the needs of customers regardless their proportions. Therefore, anthropometric measurements are a key factor in manufacturing any products. Sampling unit consisted of Slovak adult population. Empirical measurements of selected attributes of actual population were conducted in the years 1993–2015. Sampling unit consisted of 3358 students. Gained data were processed and described using descriptive statistics. Results are based on calculations of arithmetic and weighted mean. Standard deviation, asymmetry coefficient, percentiles, standard error, symmetry, and pointing were used for further processing. Following the outcomes associated with the body dimensions of Slovak population, we can propose the dimensions of bedroom furniture corresponding to the dimensions of actual adult population. Bed dimensions must be 102 × 222 cm (95th percentile) to satisfy the needs of people, their comfort, and health. Therefore, testing must be focused on strength and structural properties of bed as well. Increase in dimensions can result in the increase in product price. Staff of the finance department must deal with this issue to prevent economic damage of the company.

Keywords: healthy sleep, bedroom furniture, ergonomics, anthropometric measurements of adult population, occupational safety

1. Introduction

Changes in human population, especially in the anthropometric measurements, throughout history are and always will be the essential criteria for the conscious creation of projects and architecture [1]. Anthropometry as the scientific study of measurements and proportions of human body is one of the most important tool in the process of designing devices and work aids [2]. It is defined as a set of physical properties and personality traits adapting to the environment. Not only technology development but also economic growth results in an increase in demand for development of machinery and equipment used industrially. Therefore, greater interaction between humans and machines can be observed. Subsequently, anthropometric data collection has to be updated [3]. Insufficient number of quality machines and devices can cause an increase in the number of workplace injuries as well as a decrease in productivity of work performance [4]. Sector of industry does not affect the rate of accidents in workplaces so much as the poor posture at work. Therefore, it is a major cause of back pain [5]. The appropriate use of anthropometry can affect human health, comfort and safety in workplaces in a positive way [6].

The modern man is exposed to various environmental risk factors at home as well as at work. Rise in demands for time is a typical feature of today's society. That is why people dedicate less time to relax and sleep more than ever before. At the same time, it is evident that costs associated with correcting the errors caused by lack of sleep are much higher than most people can admit. Sleep deprivation or long-term insomnia can lead to a number of different negative consequences. In the case of chronic insomnia, various effects on physical and mental health can be observed, for example, coordination impairment, concentration problems, decrease in employee performance on the one hand and on the other hand fatigue and stress, low mood, depression as well as migraine development. Lack of sleep as well as poor quality sleep can increase the risk of mistakes, or even accidents in the workplace with fatal injuries and high level of compensation. Lack of sleep and its poor quality have a negative impact on the bodily functions.

At present, there is little or no time to rest because of work or other activities. Sleep is the only chance to relax, to switch off the brain. Sleep is a normal, indeed essential part of our lives. Choosing the right bed and mattress make an important contribution in getting a good night's sleep.

Quality sleep is significantly affected by the comfort of a bed. Bed size is a factor that must be taken into account when the comfort bed is evaluated. Therefore, the use of bed size not reflecting the body dimensions can affect quality sleep in negative way.

Sleep is defined as a resting state in which body is not active; it means sleep is definitely the main thing in recovery affecting mental as well as physical well-being. Sleep has been characterized in many species from humans, birds and fish. The main aim of sleep is to have a rest that helps the body to recover. Adequate levels of sleep help to provide mental health, hormonal balance and muscular recovery. Pretty much most of our bodily functions slow down during sleep and our bodies begin to repair—breathing and heart rate slow down, sensitivity to external stimuli reduces, on the contrary, anabolism produces growth and differentiation of cells. From the point of view of health sciences, sleep is an altered state of consciousness when central nervous system relaxes and the organism is in a completely relaxed state.

The importance of sleep is the same as of food and fluid intake or breathing; it helps to restore the immune, nervous, skeletal, and muscular systems. Sleep disorders are very common problems. As it is mentioned in research studies, one-third of adult population suffer from insomnia and 13% are severely sleep deprived, putting them more at risk of mental health and affecting their everyday life in negative way. The mentioned percentage depends upon the age. Therefore, almost one-half of the population who are 65+ suffer from mild sleep deprivation. In terms of health sciences, we can speak about a really big health problem. Moreover, lack of sleep affects not only personal health but people prone to insomnia are at higher risk of various types of depression and suicide. Sleep disorders belong to the most important reasons for lower labor productivity, higher sickness absence rate or a higher number of occupational injuries. There is not enough evidence for an assessment of the importance of sleep and its crucial role for organs other than the brain. Doctors suppose that higher level of growth hormone during sleep could be one of the impacts of sleep disorders. However, it can be only food intake compensation. One of the major functions of sleep is to allow the brain to recover and repair itself. The days with lack of sleep are followed by non-REM sleep, that is, non-rapid eye movement sleep. The role of non-REM sleep is seen in the recovery of brain energy. On the other hand, the role of REM sleep (rapid eye movement sleep with loss of muscle tone, also called paradoxical sleep) is not as clear. However, the brain is highly active and REM sleep is associated with dreaming. Higher brain activity during REM sleep is supported by increased blood flow and glucose metabolism. In particular, it is vital for memory formation. The fact that REM sleep prevails most after birth, and diminishes with age can be considered interesting. Scientists found out that a man waking up in each REM stage in the course of 5–7 days would die [7].

So why is getting enough quality sleep important? Sleep needs are high-priority physiological needs. Quality and regular sleep belong to essential human needs. Sleep disorders have occurred since time out of mind. The number of people not suffering from sleep disorders decreases as the civilization develops. Sleep plays an important role in physical as well as mental health, for example, sleep is involved in locomotive organs recovery, muscle tone decline, decrease in heart rate and cardiovascular system activity, impaired breathing, brain recovery and in some way regulating the psyche [8]. Lying and relaxing positions have been common for people for ages, especially because of the horizontal direction necessary for good sleep. However, there are different positions that people can adopt while still lying. From the point of view of medicine, relaxing positions are those to help relieve pain while sleeping [9]. While sleeping in relaxing positions, gravity causes your breasts to hang downward which can stretch the ligaments over time. It is very beneficial to our health as our body is compressed after sitting at work all day. Moreover, we can bend the knees and curl legs slightly toward upper body into a semi-fetal position and for keeping hips vertical we can place a firm pillow or two in between the knees so that legs are propped about hip-width apart [10]. Only a high-quality bed with dimensions suitable for the average population allows people to adopt mentioned sleep positions.

2. Development of selected anthropometric parameters

Anthropometry is one of the essential methods of anthropology. It is focused on human body proportions and it is used to identify proportion differences, whereby the measurements used are easy and effective [11, 12]. Moreover, they are used to determine various aspects, such as muscle growth and reduction, body part dimensions as well as the nutritional assessment, that is, whether patients are overweight or malnourished (body fat percentage) considering several factors like height and age. Measurement is based on the assessment of items located on upper and lower limbs, head and trunk. The measured values are used to qualify the adequacy of body size—BMI index [13]. According to the BMI index the number of overweight or obese people has been increasing recently [14]. Following the measurements, we come to realize that female and male height is changing significantly over time. Adolescence as a transitional stage of physical and psychological development is getting faster. All these changes affect essentially the shape as well as common object sizes [15]. Factor of time is necessary to take into account. In case of manufacturing standardized products used by the largest group of population, knowledge of data statistically evaluated has to be taken into account [16]. On the other hand, when our manufacturing should be as effective as it is possible, we have to focus on specific groups of people. That is why the groups are created to identify with specific variety of human physique (standard DIN 33402).

Over time, changes in population height and weight occur. Therefore, data associated with proportions of selected sampling units have to be collected due to various reasons (e.g., lifestyle, eating and nutritional care, etc.) at a specific time [15–27]. Secular trend can be understood as the growth of body proportions of consecutive generations comparing to former generations. There are various reasons why it is interesting. It is a sign of public health, it determines the relation between economic growth and living standards [28, 29] and shows physiological aspects—getting taller and heavier over the generations. According to the authors Jirkovský [22], Vignerová [30] and Vignerová et al. [24], research studies aimed at determining anthropometric data of child and adult population show long-term changes in body sizes. In general, we can speak about so-called positive changes; it means measured parameters are growing. Height is the most commonly observed parameter describing the changes in the best way.

Keeping standards, recommendations and regulations can have a tremendous impact on the feeling associated with the use of the bedroom furniture. The fact that most of the regulations and standards are based on data collected round the year must be taken into account [31]. Anthropometric database of Slovak population used presently originates in the former Czechoslovak Socialistic Republic. It is published in the journal of the Ministry of Health of the Slovak Socialistic Republic entitled Vestník MZ SSR in the year 1987 where the average proportions of the population are mentioned [32]. Another important factor is that each new generation is getting bigger in size in terms of anthropometric proportions. The changes are significant from a long-term perspective. It is statistically proven that average height of young men has increased by 4.5 cm in comparison to their fathers and by 7.5 cm compared to their grandfathers. In the year 1950, the average male height was 170 cm and in 1991 it was 176 cm. Similar trends can be detected when we observe females. The height of young women has increased by 3 cm in comparison to their mothers and by 5 cm compared to their grandmothers [33]. Kotradyová [32] dealt with the issue of anthropometric measurements in the project entitled "Principles of Designing New Furniture." She carried out the research into body proportions of 202 respondents. Results of the research confirmed the fact that the size of population increased by 5 cm in average in comparison to data published in Vestník in the year 1987 [34]. Extreme increase in female height (by 8 cm) as well as in weight was observed.

2.1. Methodology

Sampling unit consisted of Slovak adult population, that is, people at the adult age in terms of human growth—people who were 18+. Empirical measurements of selected attributes of population aged 18–25 were conducted in the years 1993–2015. Sampling unit consisted of 1538 males and 1820 females, students of the Technical University in Zvolen, University in Zilina, University of Economics in Bratislava and University of Presov. Altogether, 3358 students attending selected universities mirror the population of various parts of Slovakia, that makes the sample more representative. Gained data were processed and described using the tools and methods of descriptive statistics.

Results are based on calculations of arithmetic and weighted mean. Arithmetic mean can be defined as the average of a set of numerical values of specific attribute x_i calculated by adding them together and dividing by the number of terms n in the set. If the values are not divided into individual subgroups, the weight of all individual values is equal.

$$\overline{x} = \frac{x_1 + x_2 + \ldots x_n}{n} = \frac{\sum_{i=1}^{n} x_i}{n}$$

where $x_1, x_2, \ldots x_n$ are individual values of a given attribute; n is a number of terms in a given set.

Weighted mean can be calculated when we know individual arithmetic means of given sets $\overline{x}_j$, and we also know the weights of sets n_j. If all the weights are equal, then the weighted mean equals the arithmetic mean.

$$\overline{x} = \frac{n_1 * \overline{x_1} + n_2 * \overline{x_2} + n_m * \overline{x_m}}{n_1 + n_2 + \ldots n_m} = \frac{\sum_{j=1}^{m} n_j * \overline{x_j}}{n}$$

where $\overline{x_1}, \overline{x_2}, \ldots \overline{x_m}$ are arithmetic means of individual sets; $\overline{x}$ is a weighted mean of the whole; $n_1, n_2, \ldots n_m$ are weights of individual sets; and n is a number of sets in a given set.

Further, calculated value is median that is the middle score for a set of data that has been arranged in order of magnitude. If we suppose that the values of a given attribute are rearranged into the order of magnitude (smallest first), median is calculated as follows:

$$\frac{n+1}{2}$$

where n is a number of sets in a given set.

Standard deviation is the square root of the variance where the variance is defined as the average of the squared differences from the mean. If we study a set, the most commonly used deviation is with the degree of freedom N-1. The following formula can be used to calculate standard deviation:

$$s_x = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{n-1}}$$

where x_i is a sum of values of given attribute; $\bar{x}$ is an arithmetic mean; and n is a number of sets in a given set.

The asymmetry coefficient is usually called the coefficient of skewness and it is the most frequently employed measure of the asymmetry of a distribution. Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point. The skewness for a normal distribution is zero, and any symmetric data should have a skewness near zero. Negative values for the skewness indicate data that are skewed left and positive values for the skewness indicate data that are skewed right. By skewed left, we mean that the left tail is long relative to the right tail. Similarly, skewed right means that the right tail is long relative to the left tail. If the data are multi-modal, then this may affect the sign of the skewness.

$$A = \frac{\sum_{j=1}^{k} n_j \left(x_j - \bar{x}\right)^3}{n * \ s_x^3}$$

kde x_j are values of a set; $\bar{x}$ is an arithmetic mean; s_x^3 is a standard deviation powered to the third; and n is a number of sets in a given set.

2.2. Results

Following the empirical assessment, besides common descriptive characteristics, the most important percentile range (5th, 50th, 95th percentile), standard error, symmetry and pointing were determined (**Table 1**). Height growth of Slovak adult male population in dependence on time is illustrated in **Figure 1**. Dispersion in height of male population is shown in **Figure 2**. The increase in both height as well as weight of male population can be seen. The height increased by 0.15 cm per year and the body weight by 0.31 kg per year. Therefore, standard bed size prevent men with the height of 180 cm and more from sleeping comfortably. Dispersion in height of male population in a given year is illustrated in **Figure 3**. Dispersion in body weight of male population is shown in **Figure 4**.

Average	Median	5th percentile	50th percentile	95th percentile	Standard deviation	Standard error	Symmetry	Pointing
182.1	182.0	172.0	183.0	194.0	6.7	0.3	0.2	0.0

Source: [own data processing].
Values are in cm.

Table 1. Result analysis of the size of adult population—males (years 1992–2016).

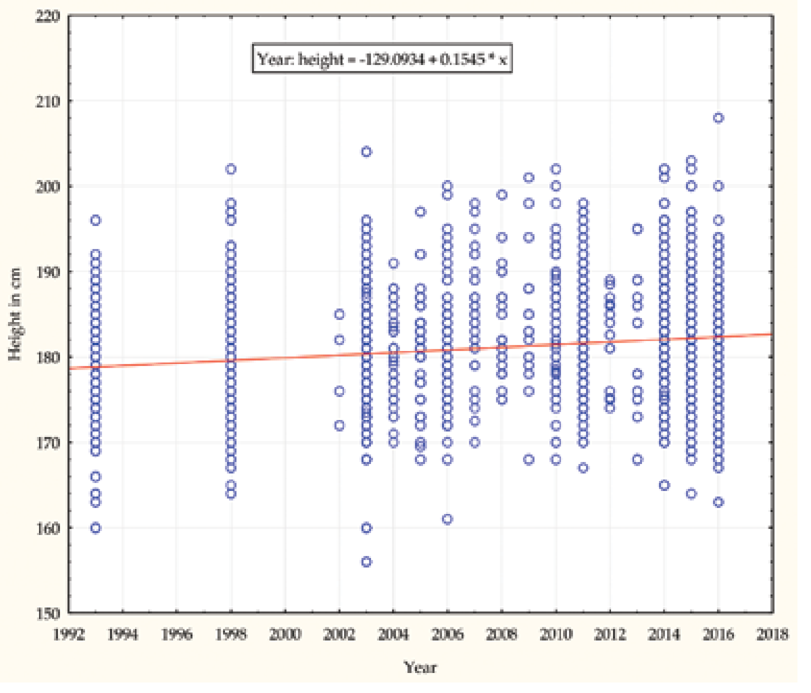

Figure 1. Height growth of Slovak adult population—male (Source: [own data processing]).

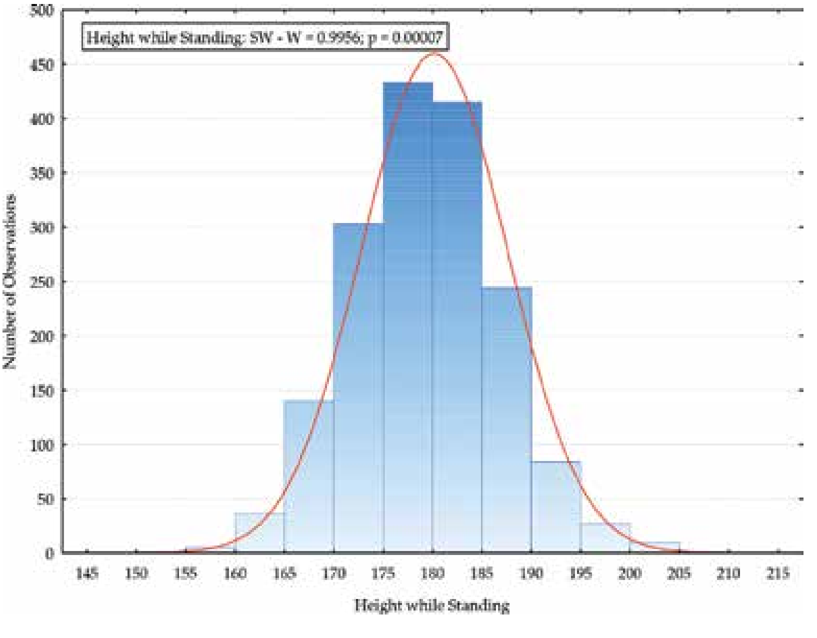

Figure 2. Histogram of male height (Source: [own data processing]).

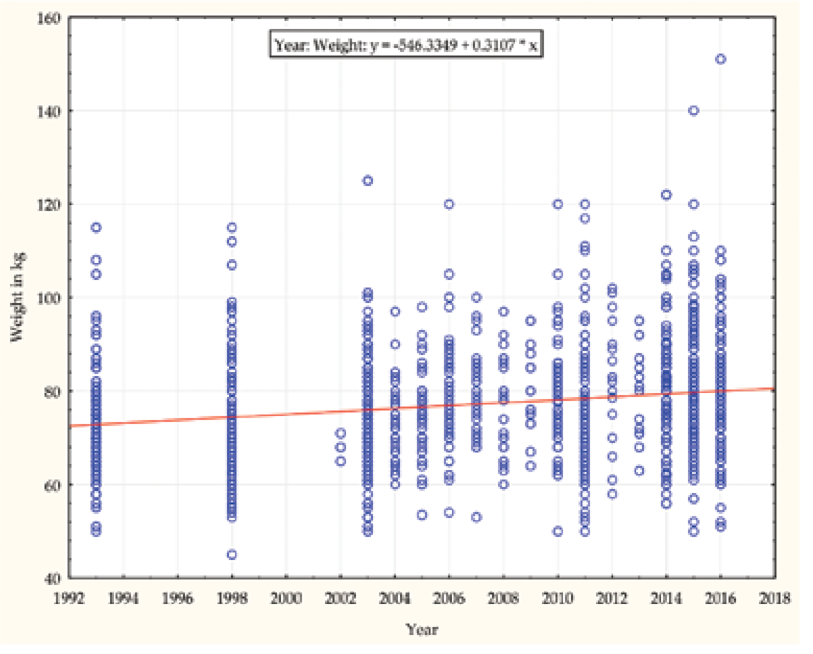

Figure 3. Body weight development of Slovak adult population—male (Source: [own data processing]).

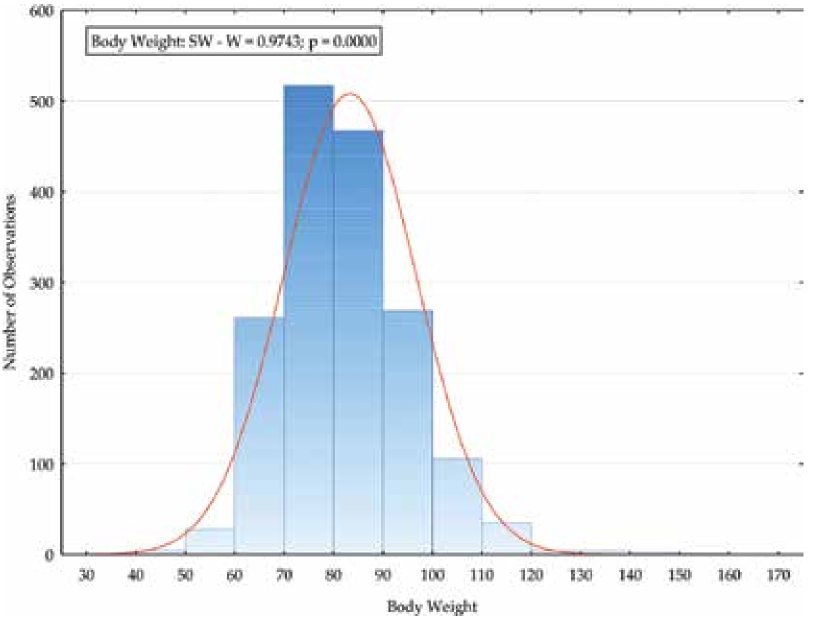

Figure 4. Histogram of body weight—male (Source: [own data processing]).

Our chapter deals with the analysis of proportions of adult female population. **Table 2** shows descriptive characteristics associated with females. Height growth of Slovak adult female population as well as weight in dependence on time is illustrated in **Figures 5** and **7**. In case

Average	Median	5th percentile	50th percentile	95th percentile	Standard deviation	Standard error	Symmetry	Pointing
168.2	167	159.7	169.5	179	5.9	0.2	0.2	0.0

Source: [own data processing].
Values are in cm.

Table 2. Result analysis of the size of adult population—Females (years 1992–2016).

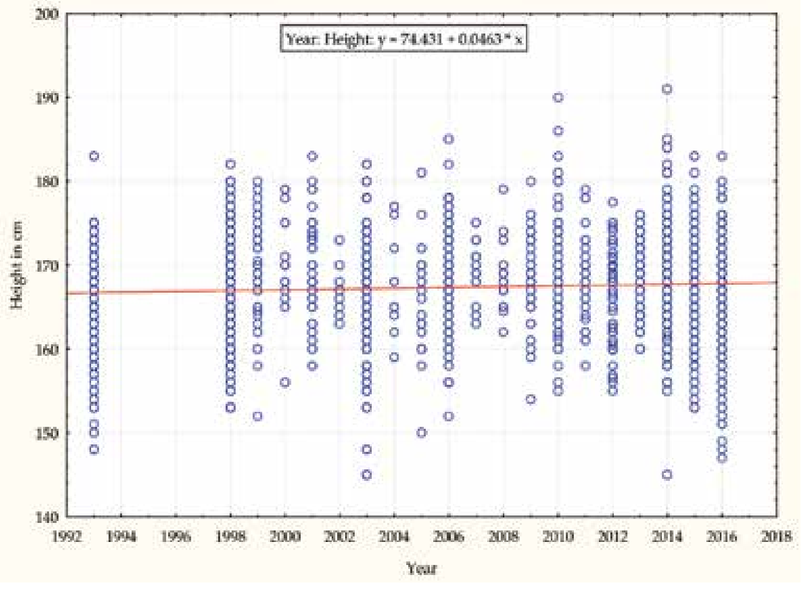

Figure 5. Height growth of Slovak adult population—female (Source: [own data processing]).

of females, the increase in both the height (0.05 cm per year) and body weight (0.03 kg per year) is slower. **Figure 6** shows dispersion in height of female population in a given year. Dispersion in body weight of female population is illustrated in **Figure 8**. Height growth of female population is not as distinctive as of female population. The slight increase in the weight of women compared to men can be affected by the effort to follow fashion trends and to have perfect female body.

Mentioned analyses are carried out in regard to future opportunities to manufacture furniture according to individual needs of population in terms of height and weight (e.g., made-to-measure furniture, or furniture in different sizes—S, M, L, XL, etc.). Moreover, furniture can be defined pursuant to the gender in the future. At present, people preferred living single (because of the career or after splitting up with a partner). Histograms of male as well as female height are shown in **Figures 2** and **6**. Histograms of male as well as female weight are illustrated in **Figures 4** and **8**.

Following the actual research studies [15, 16] secular trend of growing of body proportions of adult population in Slovakia can be stated. Secular trend can be considered a global phenomenon. Results of various international projects and research studies confirm the

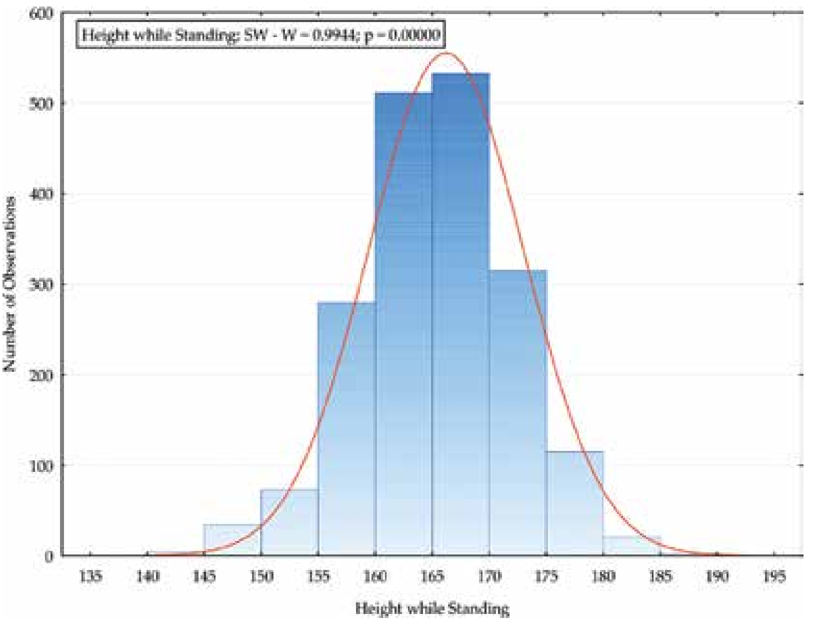

Figure 6. Histogram of female height (Source: [own data processing]).

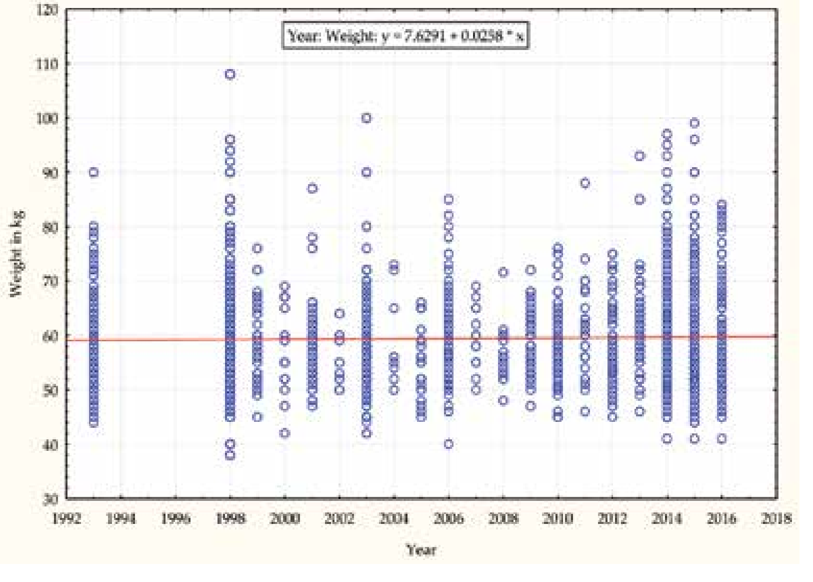

Figure 7. Body weight development of Slovak adult population—female (Source: [own data processing]).

trend as well [1, 19, 20, 23, 35–37]. At present, the size of men is much bigger than before, that is, men are much taller and heavier. It results in the increase in the value of BMI. Rapid increase in male weight can be explained by fashion trends preferring muscle men. Due to

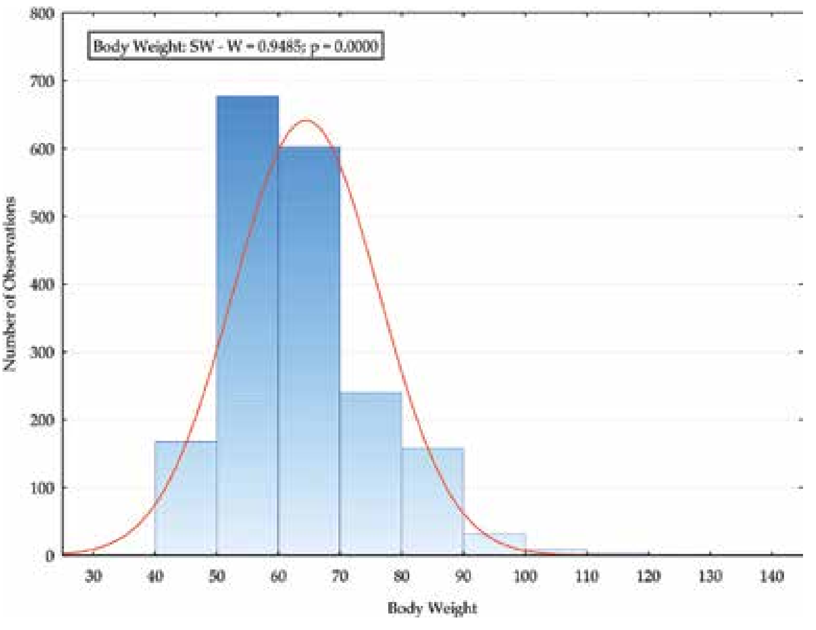

Figure 8. Histogram of body weight—female (Source: [own data processing]).

given reasons, research into secular trends of adult population in Slovakia is carried out. Sampling unit consists of Slovak adult population, that is, people at the adult age in terms of human growth—people who are 18+. Data are gained using the method of direct detection, which means through measurement of selected anthropometric data (height, weight, Bi-deltoid shoulder width, etc.). Anthropometer is used to measure height and pelvimeter is used to measure shoulder width. Gained data are processed and described using tools and methods of descriptive statistics. Scale and oscillation of measured values are characterized by averages, standard deviations and variation coefficient [38].

Modern furniture design ranges feature bedroom furniture, living room furniture, dining room furniture and home accessories and must follow the size and weight of present as well as of future generation. The minimum bed size and dimensions designated for present generation exceeds the European standard size. Following our outcomes, we can state that individual parameters of bedroom furniture at present, specifically length of bed, does not correspond with the need, that is, body proportions of present generation. Therefore, it is necessary to deal with the data upgrade. Standard size modification asks for cooperation between designers, furniture manufacturers, and health worker. Only a multidisciplinary approach can provide useful and meaningful results leading to manufacturing healthy furniture with positive impact on the population development.

Present Slovak generation is getting bigger. It is a generation affected by political changes in Slovakia over the last three decades (change in political regime, joining the EU). Impacts of the changes can be seen in changes in eating habits as well as in globalization of the Slovak society. Opening borders bring together people of differing ethnics and people of various backgrounds mix together. Consequently, body proportions of present adult population in Slovakia change as well. Better nutrition, higher socio-economic status (following GDP), urbanization, lower incidence of specific diseases can be mentioned as further reasons affecting the proportions of population. Forasmuch as height is an essential parameter determining the size of bed, it must be taken into account in order to provide for the basic necessity of life—quality sleep.

Jirkovský [22] mentions that growth acceleration has slowed down and the body weight has been increasing gradually since the second half of the 1980s; thus, secular trend typical especially after the Second World War tends to slow down. Despite all these facts, slight increase in the average height of the Czech population can be observed. Results of the research into Norwegian population carried out by Bolstad et al. [19] support the fact about secular trend slowdown as well. During the years 1900–1994, height of Norwegian men increased from 170 to 179.8 cm; however, during the years 1994–2000, the change in height was not observed. The authors of an anthropometric research into Norwegian population suppose that further increase in height of Norwegian men will be very slight or none. Norwegians reached their full growth potential. Similar trend can be observed in female population as well. The female height increased from 162.8 to 166.1 cm in the course of 57 years. In the area of body weight of Norwegian men, an increase by 5.6 kg was observed in the years 1991–1995 comparing to the years 1963–1972. The body weight of Norwegian women increased only by 1.3 kg in the mentioned period of time. The slight increase in the weight of Norwegian women can be affected by the effort to follow fashion trends and to have a perfect female body. Cole [29], as well as the abovementioned authors, states in his research aimed at secular trends that an increase in body height slowed down in the second half of the twentieth century, whereas the weight continues to grow as part of global obesity epidemic. Secular trends associated with the proportions of Croatian population is observed in the anthropometric research carried out by Grbac et al. [39]. Authors state that young Croatian population grew up by 5 cm over the last 30 years. This trend continues and an increase by 2 cm over 10 years was observed. Besides the abovementioned countries, secular trend was observed in other European countries as well. It is confirmed by the research conducted by Lozovina and Lozovina [40]. Following the findings, it can be stated that results of the research studies into development of body proportions of Slovak adult population can be compared to the results of the research conducted home and abroad as well. Results show a tendency to increase the body proportions (especially height) of consecutive generations, that is, a secular trend that starts to slow down. Abovementioned research studies confirm the development of secular trends.

Ergonomics plays an important role, inter alia, in daily products, for example, furniture. Furniture is like a silent partner. It is a part of the environment. When designing or manufacturing new furniture, not only body proportions of present generations but of future ones as well must be in the center of our attention. Familiarity with actual anthropometric data of population is an essential factor necessary for furniture modification and subsequent quality sleep. Quality sleep provides employees with enough rest, therefore, it is a prerequisite for occupational safety as well as injury prevention.

The bed is one of the fundamental objects of furnishings. No other part of furniture must respect so strict quality standards as bedroom furniture. Human individuals spends more than one-third of life asleep. Lying area is adapted to the sleep and rest in a flat position [41].

In terms of anthropometry, physiology and hygiene, the bed size must fit the human measurements and changes in sleeping positions during sleep. A firm mattress is recommended in order to allow the spine to rest and regain its natural curve. Along these requirements, mattress must be fully breathable with a special hygienic treatment applied to the mattress material. Moreover, it must provide optimal thermal comfort as well as psychological well-being, that is, safety sense during the hypnagogic state [42].

The length, width, and the height of bed are the most important bed parameters (**Figure 9**). The length and width affect the size of lying area, whereas, the height of bed provides comfort when sitting on the edge or getting up. General requirements for bedroom furniture in terms of physiology and hygiene are as follows:

- the bed size must fit the human measurements and changes in sleeping positions during sleep;
- a firm mattress must allow the spine to rest and regain its natural curve (sleep on the back, side and stomach);
- thermal comfort and breathability (sweat absorption), that is, mattress must be breathable and must allow sweat absorption in order to provide thermal comfort as well as thermoregulation of organism;
- psychological well-being;
- hygiene (special hygienic treatment must be applied to the mattress); and
- comfort while using in general [43].

Bedroom furniture is designated for regular or occasional sleep routine. Beds can be designed as static, dynamic or fold-out beds for various groups of users, in terms of age—children, students, adults, seniors; in terms of the state of health—healthy, ill, temporary or permanently disabled; in terms of sensitivity—insensitive users or users sensitive to geopathic stress zones or electromagnetic smog [44].

Functional dimensions of bedroom furniture, its height, width and length are in accordance with standards [44]. Requirements for the height of bed are as follows: the height of bed including the mattress from the floor is 420–600 mm, the height of headboards and foot ends from the lying area is minimum 200 mm, the height of lower edge of the bed frame from the floor is minimum 200 mm, the height of bed should provide comfort when getting up effortlessly or sitting on the edge, the height of 420 up to 450 mm from the floor is considered a standard height of bed (zone of ground level air circulation is up to 300 mm). The height of bed must be increased by 20–25% in order to provide comfort in lying down and getting up for older or disabled people, that is, to the height of 500–600 mm. The height of bed plays an important role in making up the bed or tidying up the bedroom. The higher the bed is, the more difficult it is to put a sheet on it. The height of bed ranging from 450 to 500 mm provides comfortable making up in beds with the width of 850 mm. The lower edge of bed frame should be 250 mm above the floor level in order to provide comfort in tiding up under the bed. The standard length of lying area is 1,950, 2,000, 2,050 and 2,150 mm (**Figure 10**).

Figure 9. Basic parameters of a single bed (Source: [own data processing]).

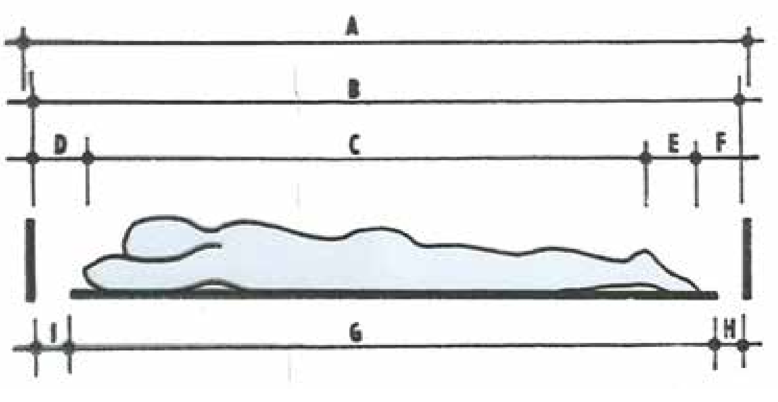

Figure 10. Factors affecting the length of lying area (Source: [59]). A—Length of bed; B—inside length of bed; C—length of a sleeper; D—space for hand supporting the head; E—spare space for feet; F—free space next to legs; G—length of mattress; and H, I—space for making up a bed.

Results of the survey mentioned in the **Figures 2** and **4** show the fact that not only height but also male and female weight is increasing. This fact should result in the changes of parameters of furniture mechanical testing aimed at improving furniture safety to ensure comfortable environment. Strength under static loading, mattress durability, impact of cycling loading on the durability, resistance to shock loading are performed in the process of bed testing. Lateral edges of bed frame should be tested as well, for example, the strength under static loading. Bunk beds and high sleeper beds for children and adults should be included in testing, too. Especially testing of stability of bedsteads and bunk beds, ladder strength test should be carried out. Moreover, upper bunks must have effective safety rails with the top of the upper rail at minimum of 200 mm above the upper surface of the mattress. We suppose the changes will cover also mattress performance and mattress cover fabrics (ticking)—physical tests are carried out on the fabric to check for strength and durability. Changes in testing parameters will affect not only the bedroom furniture safety but also its quality and, subsequently, the quality of sleep.

Following the research, we submit a proposal to change the dimensions, especially length of bed, determined for the present population in Slovakia. We focus on determining the size and dimensions of single bed (bed intended for one adult person) due to body proportions of present generation, body dimensions of men. Therefore, the length of bed (lying area) results from the measurement of male height that becomes a determining factor. The upward trend in population growth is expected to continue over the next 10 years, so two standard deviations were added in order to ensure that bed size following the trend in population growth will fit next generation as well.

Following the outcomes of the actual statistical properties associated with the body dimensions of Slovak population, we can determine proposed dimensions of bedroom furniture. Bed size is based on the measurement of body dimensions of male population because of a general rule, men are taller in average than women. Male height (TV_m) was a determining dimension for the length of bed:

$$L = V_m + 2\,s_x + N_p \text{ [cm]} \tag{1}$$

Data summation result in three alternative lengths of bed due to the fact that Np changes according to the bed placement as follows [44]:

- 15 cm if there is not enough space (e.g., studio flat);
- 25 cm if there is enough space but no extra (e.g., flat); and
- 35 cm if there is a space big enough (e.g., detached house).

Single bed meeting the requirements for the new anthropometric data and the placement should be of the length mentioned in **Table 3**. At the present time, the standard size of single bed is 90 × 200 and 100 × 200 cm. This size does not correspond to the secular trend of the increase in body proportions of a human individual nowadays. Dimensions of bed satisfying the needs of present people, their comfort and health, must be 102 × 222 cm (95th percentile) (**Table 2**). At

Bed placement	Length of lying area (cm) when the percentile is			Proposed length of lying area (cm)
	5th	50th	95th	
Studio flat	200.2	211.7	222.2	213
Flat	210.2	221.7	233.2	223
Detached house	220.2	231.7	243.2	233

Source: [own data processing].

Table 3. Proposed length of bed following the proportions of present population.

the same time, we can state that weight gain trend of population is observed as well. Therefore, testing must be focused on strength and structural properties of bed in the future, too.

Width of bed must meet following requirements. The width of lying area of one person can be 780, 850, 900 and 1000 mm. The width of bed for two persons can be 1600, 1700, 1800 mm. When determining minimum lying area width (b1) Bi-deltoid (shoulder) width was an essential factor (see **Figure 1**). Firstly, it must be extended by 50% and subsequently two standard deviations must be added due to the trend in population growth. Each human individual changes the sleeping position many times during the night. Therefore, the minimum width of bed must be extended by next 25%. Final width of bed, that is, lying area is determined according to the formula [45]:

$$b_1 = 1.5\left(\check{S}_R + 2\,s_x\right) + 0.25\left(1.5\,\check{S}_R + 2\,s_x\right)[\mathrm{cm}] \tag{2}$$

Lying area width b is determined by the width of human body and the area necessary for movement during night. Sleeping on back, on stomach or on side with relaxed arms are considered basic sleeping positions. Bed width refers to the size of the widest point of a human body extended by 10–15%. Each human individual changes the sleeping position many times during the night. Therefore, the standard lying area determined by the basic width must be extended by 20–25% to ensure comfort sleep. Minimum lying area width ranges from 800 up to 850 mm. Narrower dimensions can be used only in case the lying area is bounded by bed frame or side edges of lying area are reinforced.

Human individual must be assessed as a mechanism consisting of joints and bones in order to determine optimum bed width allowing users not only to sleep but also to make up a bed in a comfortable way. For the purpose of more comfortable making up of the bed, the bed width can be determined using the bed height (w = 5d) in dependence on a forward bend (angle α) and the easy access to the farthest side of the mattress (angle σ). Navrátil and Klein [46] dealt with this issue and following the solutions of trigonometric equations they found out that the angle of a forward bend starting from the waist α ranging from 101 to 120° and the arm inclination angle ranging from 30 to 45° ensure maximum comfort when making up the bed. Still comfortable lying area width can be determined in association with the values of angles using relations mentioned in **Table 4**. The value of a part d is defined as 1/20 of the human height (technique of the golden section).

The height of bed reflects the needs of people to put both their feet firmly on the ground and push off the bed with their knees bent. The height of 420 up to 450 mm from the floor is considered an optimum height of bed (zone of ground level air circulation is up to 300 mm). For lying down and getting up, elderly people ask for rising a bed by 20–25%, that is, to 500 or 600 mm. The bed height was determined according to the following formula [46]:

$$w = 5d\ [\mathrm{cm}] \tag{3}$$

The bed height calculated using the formula fit 95% of population. Therefore, we propose the bed height of 42–60 cm.

Values of angles (°)			Width of bed b1 determined in multiples of parts
α	β	σ	
101	124	45	9.02 p
101	139	30	11.74 p
105	120	45	9.37 p
105	135	30	12.01 p
110	115	45	9.75 p
110	130	30	12.33 p
115	110	45	10.10 p
115	125	30	12.63 p
120	105	45	10.42 p
120	120	30	12.90 p

Source: [46].

Table 4. Width of bed.

3. Conclusion

Ergonomics plays an important role, inter alia, in daily products, for example, furniture. Furniture is like a silent partner. It is a part of the environment. When designing or manufacturing new furniture, not only body proportions of present generations but of future ones must be in the center of our attention as well. Ergonomics plays an important role in furniture design, in its shape and size; it means the quality of furniture and materials used. Familiarity with actual anthropometric data of population is an essential factor necessary for furniture modification. Quality sleep provides employees with enough rest, therefore, it is a prerequisite for occupational safety as well as injury prevention. Anthropometric characteristics of population can change over the period of time. Secular trend exists. Its increase can be expected in the future. The average height of Slovak men could reach the value of 184.27 cm in the year 2025.

The reasons why most body dimensions follow trends which involve rapid growth can be explained in many ways. The change in style of living, better health and nutrition care as well as sport activities can be one of them. Political changes in Slovakia over the last decades (change in political regime, joining the EU) could result in the changes of body proportions. Impacts of the changes can be seen in changes in eating habits as well as in globalization of the Slovak society. Moreover, opening borders bring together people of differing ethnicities and people of various backgrounds mix together.

Bed is one of the essential parts of furnishings. A human spends more than one-third of his/her life on it. Good quality sleep can affect the employee performance at work in positive as well as in negative ways. It can also help to prevent accidents in the workplace. Bed size in the context of body proportions of adult population in respect to occupational safety is defined in the chapter.

Bedroom furniture is designed to satisfy the need of users, especially to have a rest and sleep that helps the body to recover. Only bed following the anthropometric requirements of final users can meet mentioned needs. When implementing the actual anthropometric data of Slovak population in modification of bed sizes, the minimum lying area of 108 × 221 cm can be defined. The mentioned dimensions fit present human individual in terms of sleep comfort. Recommended bed height is 46 cm above the floor.

A total of 3358 students from Slovak universities were analyzed in the chapter. Gained data were processed and described using the tools and methods of descriptive statistics (standard deviation, asymmetry coefficient, percentiles, standard error, symmetry and pointing). Following the outcomes of the actual statistical properties associated with the body dimensions of Slovak population, we propose the dimensions of bedroom furniture which correspond to the actual adult population with minimum dimensions of 102 × 222 cm (95th percentile). After updating, it is necessary to start looking at adjustments of calculations when pricing the bed furniture in furniture companies, as the increase in dimensions will be reflected fundamentally in the product price. Economic damage may occur in the company, if the employees of the economic department do not deal with this problem [47–49].

Sleep is a complicated process, therefore, research studies of modern neurology focus more on it. Lack of sleep as well as poor quality sleep can increase the risk of mistakes or even accidents in the workplace with fatal injuries. Bad sleepers cause seven times more injuries than people with good sleep. Lack of sleep and its poor quality have a negative impact on the bodily functions, for example, reduced attention span, alertness and reaction time. Motivation, flexibility and logical thinking are affected by lack of sleep as well. Researchers claim missing sleep can make you stupid. During sleep, new learning and memory pathways become encoded in the brain, and adequate sleep is necessary for those pathways to work optimally. Another important impact of sleep is confirmed by researchers. They suggest that memory consolidation takes place during sleep through the strengthening of the neural connections that form our memories. Moreover, sleep likewise supports immunological memory formation. A full night's sleep post vaccination boosts the immunological memory. Research shows that sufficient sleep plays an important role in weight management and decreasing the risk of metabolic disorders such as insulin resistance and diabetes as well as other sleep-related problems. With too little sleep, the body is also more likely to produce the stress-response hormone cortisol [7]. Quality sleep is a significant factor affecting occupational safety. The size and condition of the bed as well as the mattress has a major effect on the quality of sleep.

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Conflict of interest

Authors declare no conflict of interest.

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Chapter 2

Preventive Measures of Heat Disorder in the Workplace

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Additional information is available at the end of the chapter

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Abstract

Human adaptation to varying degree of heat stress receiving great attention in the last few decades. Scientific studies confirm that higher temperature can significantly impact on productivity and leads to stress, loss of concentration, and increased tiredness and that reality can become a health and safety issue especially for unwell and older workers in the workplace. The aim of our systematic review is to examine related ailments of heat exposure, when and why heat disorder (HD) occurs, also preventive measures, and first aid and emergency measures when HD is suspected. Nonetheless, guidance for management of working environment is discussed. We can conclude that organizations can do a great deal to be indwelt, creating a healthy workplace environment and promoting education and guidance toward welfare of employees.

Keywords: working environment, older people, health, safety, heat exposure

1. Introduction

Although the central Europe has a generally mild climate, there have been occasions when the weather has been particularly hot, especially in the midsummer when temperature exceeds 30°C in many parts of Europe. Exposure to heat is one of the physical hazards that can cause health problems in the workplace, heat is one of the most important and common occupational health problem in workplace. Inappropriate thermal conditions can impact the health and productivity of workers. However, successful control of occupational heat stress begins with the early identification of high-risk workers, but this task is not straightforward. Climate changes directly increases occupational heat stress for workers, which impacts their health and productivity. Heat stress is a physical hazard and potential health risk that can lead to a range of conditions [1].

In our contribution we have opportunity to access already synthesized evidence and inform its practice. Our overview attempts to survey the literature in selected domain and describe its characteristics. Presented analysis is conceptual and thematic; synthesis is narrative and includes comprehensive searching. The aim of the study is to review related ailments of heat exposure, when and why heat disorder (HD) occurs, also preventive measures, and first aid and emergency measures when HD is suspected. Nonetheless, guidance for management of working environment is discussed.

When the workplace environment gets too hot, comfort is more than an issue about convenience. But also, if the temperature goes too high, it can become a health and safety issue especially for unwell and older workers in the workplace [2]. It is usually accepted that people work best at a temperature between 16 and 24°C [3], although this can vary depending on the kind of work being done and the gender. Despite of all that, strenuous work is better performed at a slightly lower temperature than office work. The HSE [4] recommends the following temperatures for different working areas (heavy work in factories, 13°C; light work in factories, 16°C; hospital wards and shops, 18°C; offices and dining rooms, 20°C). However, the law does not state a minimum or maximum temperature, but the temperature in workrooms should normally be at least 16 or 13°C if much of the work involves rigorous physical effort.

Scientific studies confirm that higher temperature can significantly impact on productivity and leads to stress, loss of concentration, and increased tiredness, which means there is an increase in the likelihood to put workers or coworkers at risk [5]. Heat can also aggravate other medical conditions and illnesses as well as interact with or increasing the effect of other workplace hazards. Heat disorders have been in the news more frequently in recent years due to climate changes caused by global warming [6]. Heat disorders can occur not only when our body is exposed to direct sunlight in the summer, when someone is working strenuously in direct sunlight in the summer, but also at the beginning of the summer, when people's bodies have not yet adjusted to the heat. HD can occur in hot, humid indoor environment as well. When the symptoms are severe, HD can be life-threatening but can be prevented if we are aware of precautionary measures. Prolonged or intense exposure to hot temperature can cause heat-related illnesses such as *heat syncope* where blood pressure decreases due to the dilation of the blood vessels in the skin, resulting in decreased flow of the blood to the brain. The person's pulse becomes quicker and weakens. Its manifestation includes dizziness, fainting, facial pallor, and quickening and weakening of the pulse [7]. On the other hand, *heat cramps* characterize cramps that are accompanied by pain in the legs, arms, and abdomen; symptoms occur when the concentration of salt (sodium) in the blood decreases due to heavy sweating, with fluid replaced by water only. Its manifestation can include muscle pain usually in the abdomen, arms, or legs, spasm, and muscle convulsion [7]. In *heat exhaustion*, a person is sweating profusely; if rehydration is inadequate, the person will become dehydrated and exhibit symptoms of heat exhaustion. Its symptoms include general feeling of malaise, nausea-vomiting, headache, dizziness, thirst, irritability, fast heartbeat, decreased ability to concentrate or make decisions, as well as cool, moist skin and heavy sweating [7]. *Heat stroke* is a condition where core bodily functions are impaired due to an excessively high body temperature [8]. Heat stroke may result in impairment of consciousness (slow reactions, unusual speech and behavior, loss of consciousness), where the body is going into a state of shock. Its manifestation includes high body temperature, disturbance of consciousness, slow reaction to calls and stimuli, unusual speech and behavior, wobbly, also excessive sweating, or red, hot, dry skin. Not the last, *heat edema*, swelling in the legs and hands, can occur when we sit or stand for a prolonged time in a hot environment. Ultimately, we mention *heat rash*, also known as prickly heat, that is referring to skin irritation caused by sweat that does not evaporate from the skin. Heat rash is considered the most common problem in hot work environment. Its display includes clusters of red bumps on the skin, often appearing on the neck, upper chest, and folds of the skin [9].

2. Why heat disorders occur

Our body maintains a balance between heat production and heat loss; HD can occur when this balance is disrupted (body cannot transfer heat effectively or external heat gain is excessive). Our body produces heat constantly (thermogenesis) by allowing heat to escape from the body (heat loss). The human body maintains an internal temperature within a very narrow range. A normal temperature is 37°C but can fluctuate in a healthy person by about 0.6°C over the course of a day [10, 11]. This physiological adaptation can be a result of varying activity levels, and in women they can result from regular hormonal changes. Moreover, during work lots of heat is produced by the muscles, and as a consequence body temperature may rise. In fact, during times of heavy exertion, additional energy is expended, and nearly 75% of that energy is directed to heat rather than energy [12, 13]. At the same time, when it is hot outside, direct sunlight or reflected heat can result in a rise in body temperature even when the body is not active. When body temperature rises, blood flow at the body's surface (under the skin) increases, to make it easier for heat to escape from the body. When this happens, not enough blood flows to the brain, resulting in a lack of oxygen reaching the brain, which may cause dizziness or lightheadedness perhaps loss of consciousness. Sweating is another way the body allows heat to escape when body temperature rises considerably. If the water that is lost through sweating is not replaced adequately, this can result in dehydration; dehydration symptoms can include generalized malaise and nausea or vomiting; headache may occur. Sweat is product of the blood plasma. When sweat evaporates, heat is efficiently lost outside the body, lowering body temperature. Sweat contains electrolytes (ions), and sweating therefore results not only in the loss of water but also electrolytes. The electrolyte that is most easily lost in sweat is sodium, which is the most common electrolyte in blood plasma. And therefore, when we drink only water when we are sweating and does not replenishing it, the loss of salt may result in an inadequate salt balance in the body. Because salt plays a role in regulating muscle activity, insufficiency of salt can result in muscle spasms and cramping. If this condition persists, the body's mechanisms for regulating body temperature cannot keep up; body temperature can rise, and as a result, the brain is affected; the person may collapse and lose consciousness, which is extremely dangerous [14].

3. Occurrence of heat disorder and its potential risks for some groups of people

As we have already mentioned, higher than normal temperatures began in May, and by the end of August, the average temperatures are about 30% higher than normal for the season [15, 16].

Emergency hospitalizations due to a heatstroke occurs mostly in midsummer days when the temperature is above 30°C and can increase rapidly on very hot days to above 35°C [17].

In that context, when the temperature remains high night after night, a person's body temperature remains high even at night; this reality can initiate some health problems. Also, when the body is exposed to sudden high temperature, at these times, the body has not yet become adjusted to the heat and cannot sweat adequately and is therefore not capable of effectively regulating body temperature. Hence, when it is hot for a number of days in a row, the body can accommodate that heat by the process of heat acclimation. However, caution is needed when the conditions such as a high temperature, high humidity, no wind, direct sunshine, high temperatures brought on by reflected heat of the sun, or nearby heat sources are present that are typical for workplace environment. Although everyone needs to be careful about HD, there are some age groups that are particularly in danger to become subject of HD.

Older workers (40–65 years of age) are generally less able to cope with heat. In older adults, heart function becomes less efficient, and sweating starts later and occurs at a slower rate [18]. Statistics showing [19] that a higher percentage of males aged from 15 to 69 dies from HD than females. Men have a higher muscle mass and generally experience higher delivery while doing more strenuous physical work [20].

Within working people that possess higher risk for suffering from HD as we noted, we can include older workers. A general decline in bodily functions puts the older cohorts at particular risk for HD. As people age, their level of body fat tends to increase, and the proportion of their body that is water (their body water content) tends to decrease. Therefore, if older person is placed in the same environment as a non-older person, older person will be more susceptible to develop HD. The older is also less likely to notice the heat or become thirsty and are therefore less likely to drink enough liquid. In addition, because the older has decreased heart and or liver function, if they develop HD, their symptoms are more likely to become more severe. In comparison, body water content in child is 70–75%, adult male 60%, and older person 50–55% [20].

Recommended preventative measures for older cohorts include rehydration even when not thirsty, checking the location temperature frequently, and exercise enough to work up a sweat once a day. The older are at particular risk of heat disorders because of the factors such as older cohorts are less likely to feel the heat and the thirst. More likely they do not have enough fluid in the body [21]. Temperature control system tends to be delayed, and heat is likely to be trapped inside the body [13]. Also, when older cohorts eat less, the amount of take-in water decreases in line with the decrease in meal volumes; they have tendency to keep liquid intake low as to avoid having to go to the toilet so often. However, it is important for the older person to pay attention to his/her physical condition and get an adequate amount of water and salt (sodium) intake. The tips for preventing heat disorders in the older workers include rehydrating frequently and cooling the body with a shower and damp towels. Ensure good indoor airflow. Use air conditioning and fans effectively, and at the same time monitor the indoor temperature. Wear cool clothing. Know who to contact in case of emergency.

Further, to the group of people that are at higher risk for developing HD, we can include overweight or obese and people with low physical strength and endurance, i.e., people with low fitness level and people who are not acclimatized to the heat. Seven out of ten heat-related deaths that occur in workplace are found in obese individuals [22, 23]. When there is more subcutaneous fat, heat does not escape from the body easily, and more heat is produced in moving a heavier body frame. Also, people who are low in fitness, are not accustomed to exercise, do hard work, and are not familiar with the conditions of their own bodies are more likely to overestimate their own potential. Temperature regulation systems of people who are in poor acute physical condition because of a lack of sleep, fatigue or are dehydrated as a result of drinking alcohol night before, these people are also at higher risk of developing HD. Here we can likewise include people with preexisting diseases and people who have previously had heat stroke. At that, people being treated for diabetes, hypertension, heart disease, kidney failure, psychiatric disorders, or extensive skin disorders are known to be more likely to develop HD [24].

4. Rehydration and food intake in hot environment

In general, a person loses approximately 2.5 l of water per day (approximately 1.5 l in urine, 900 ml through perspiration, and 100 ml in stools) [12, 13]. During the summer, we need to remain aware of the need to replenish the water lost through sweating. We need to be aware of the fact that when a person drinks a lot of water at once in order to replenish water that has been lost, this disrupts the electrolyte balance in the body that may result in a suboptimal physiological balance. As a rule, the amount of water intake should match the amount of water lost. Replenishing water lost alone is not enough. The salt lost through sweating also needs to be supplemented [10, 25].

The blood circulating in our body contains about 0.9% sodium, and some of this amount is lost when we sweat that is why our sweat tastes salty. If we sweat a lot (and thus lose sodium) and then drink only water, the concentration of sodium in our blood will become diluted, and we will stop wanting to drink water in order to prevent the sodium concentration from falling any further. We will also simultaneously eliminate excess water from the body as urine. This will result in not being able to replenish the volume of bodily fluid we had before we started sweating. Our ability to exercise will decrease; our body temperature will increase, and therefore we become more susceptible to develop heat disorders.

Rehydration technique includes intake of salt and sugar. When continue working in hot environment for an extended period of time, it is recommended to increase the sodium concentration in the body that will protect blood plasma to fall that may result to heat cramps.

Beverages containing carbohydrates are recommended because the sugar encourages fluid absorption in the gastrointestinal tract; that mechanism involves glucose which acts as a cotransporter with sodium in the intestinal tract; consequently water is absorbed due to the osmotic gradient produced by the coexistence of sugar and sodium. Marček et al. [13] recommend to include drinking beverages that contain sugar 0.1% to 0.2% and salt (40–80 mg sodium per 100 ml) for rehydration to prevent HD. Particularly when working for extended period of time, 1 h or longer in hot environment, beverages containing 4–8% sugar should be drank. Although it is easier to drink chilled soft drinks or oral rehydration solutions, we can also make our own drink by dissolving half a teaspoon of table salt (2 g) and several sugar cubes in a 1 l of water.

Number of human studies [12, 26] have documented voluntary decreased of food intake in hot environment as an adaptive mechanism to ameliorate the increased need for thermoregulation. Optimal nutrition is compromised if intake decreases to the extent that inadequate levels of key nutrients are consumed. In that respect, we have to look on self-selected food pattern of individual engaged in similar activity in hot versus temperate climate as well as consider and determine the effect of stress on appetite, with temperature as a major variable. With such information available, we should be in position to develop basic recommendations for types of food that should be part of rations in hot environment, as well as determine if specific supplements with improved palatability be used when workers are in hot environment, where depressed appetite for prolonged periods of time may prevent adequate nutrient intake. A healthy diet is important when working in a hot environment; therefore we suggest meeting with a dietician familiar with high heat, high exertion environment such as workplace and to create a personalized plan that will lead to overall better acute and unexpired physical condition of employees.

5. Workplace environment acclimation and management

We can split up factors contributing to heat disorders in workplace into *environment factors* that encompasses temperature, humidity, direct sunlight, the presence or absence of wind, and onset of a heatwave in the working environment. *Individual factors* include particular differences in aerobic and anaerobic fitness level, general health condition, the person's physical health and level of fatigue, the degree to which the person is acclimated to the heat, clothing, acute and chronic mental state, etc. And *at work factors* embrace the plan for acclimatizing to the heat, regular rehydration and intake of salt, health checkup, and education. In that context when working in hot and humid work side, employer should set up a cool, air-conditioned rest area alongside the place, where you will have ice packs in coolers, thermoses of cold beverages (0.1–0.2% saline, electrolyte beverages, oral rehydration solutions, etc.), concurrent prepared salty snacks to enable periodic replacement of fluid and salt (sodium). It is advisable to have on the side cold damp towels and to take showers and other means that allow workers to cool themselves down.

Occurrence of HD is a consequence of inadaptability of the human body to cope with excessive heat. When the body is exposed to high intensity work, time is required for heat acclimatization. Plank et al. [25] claim that worker should spend 7 or more days gradually lengthening the time of exposure to heat.

From the physiological perspective, even if one is not thirsty, fluid and salt must be replaced periodically during work, as well as before and after work. Employees should have 0.1-0.2% saline, electrolyte beverages, and rehydration solutions prepared at convenient locations, such as work site and rest area. People with restricted salt intake should consult their doctor or company physician. Superiors are expected to check and provide thorough instructions regarding the replacement of fluid and salt.

Also, when working under direct sunlight, it is advisable to wear something that wards off the sun, such as a cap or a cool helmet. Bright colors that reflect radiant heat are recommended, and the use of cold packs can be effective. Workers should try to wear moisture permeable wearing apparel and clothing with good ventilation properties. When the pulse rate of the employee exceeds (220 minus the age of the person), or the body temperature does not return to the temperature before starting work during a break. Or else, body weight had decreased by more than 1.5% since the start of work. On the proviso symptoms such as acute fatigue, nausea, dizziness, or loss of consciousness are observed. If any of the abovementioned signs of heat stroke are discovered, the body must be rested and cooled immediately. In that context the work place should provide rest areas with medical thermometers and weight scales so that people's physical conditions can be checked if necessary immediately.

Further, the appropriate management action should be taken in response to the results of health checkups. When abnormalities are found during a general health checkup, opinion of a physician should be taken into consideration. Managers are required to take measures in such a case to change the worker's work site or work assignment or to lighten the workload [27]. The work site must be changed or the work switched, in reference to the opinions of a physician or other competent individuals, for people with a condition that could affect the development of HD (e.g., diabetes, high blood pressure, heart disease, kidney failure, neuro-psychiatric disorders, and a wide range of other elements).

Simultaneously, managers should monitor daily physical aspects of their workers; conditions such as lack of sleep, hangovers, fever from a cold, and dehydration from diarrhea can increase the risk of HD. At such times, the condition should be reported in order to prevent HD. Moreover, managers and superiors should periodically check workers health condition and their intake of fluids before and during working hours. It is also effective and advisable to check on fellow workers for changes from their usual condition, since heat stroke at times occurs quite unexpectedly and abruptly [28].

Last but not least, managers and workers should learn about HD before it starts to get hot following the winter season. They should be informed about signs and symptoms of HD, to know preventive measures, also to know how to manage HD first aid for emergencies, and last but not least to become familiar with the case studies of HD from the past.

6. First aid and emergency measure when heat disorder is suspected

Concurrently, superior should prepare an emergency contact network and ensure workers are aware of it. Relevant people should be made aware of emergency manuals and the phone numbers and locations of hospitals and clinics. If someone develops the symptoms of heat disorders at a hot and humid work site, it is important at first to move the person to a cool location, remove his/her clothing, and cool the body. If the person cannot drink fluid on his/her own, take the person to a medical facility immediately, even if the person remains conscious. There are various signs and symptoms to look out for that may indicate a heat disorder. We should take appropriate countermeasures immediately if we notice initial symptoms such as dizziness or lightheadedness. As heat disorders can be life-threatening, it is important to be aware of what to look out for and to follow the appropriate first aid procedures if a heat disorder is suspected. If one of the following conditions is observed, we should get medical attention immediately. And that includes dizziness, loss of consciousness, muscle pain, rigidity, profuse perspiration, headache, malaise, nausea, vomiting, fatigue, despondency, impairment of consciousness, convulsions, impaired motor functions, and elevated temperature. If the person is unconscious or shows impaired consciousness, it is important to call an ambulance immediately. Emergency measures must be taken to cool the person while waiting for the ambulance to arrive [29].

Immediate on-site emergency measures should be implemented, whether an ambulance is called or not. If a heat disorder is suspected, the person should be moved to a cool place, cooled, and rehydrated with fluids and electrolytes, regardless of the severity of symptoms. Fluid should only be given if the person is capable of consuming them on his own. We should move the person to a shaded place with good air circulation or to an air-conditioned place.

Follow by removal of or loosening up tight clothing to let heat escape, dampen the exposed skin with cold water, and use a paper or electric fan to cool the body. If ice packs are available, we may use them to cool areas with large blood vessels near the surface of the skin, such as the neck, under the arms, and the groin area. If the person is conscious, have him consume a cold beverage containing an appropriate number of electrolytes. A sports drink (containing 40–80 mg of salt per 100 ml) or oral rehydration solution that can replenish electrolytes lost through perspiration is recommended. If the person does not respond to stimuli or shows signs of impaired consciousness, do not force him to drink, as fluid could enter the respiratory tract. If the person is nauseous or vomiting, fluids should be given intravenously at a medical facility [30].

However, the person must be taken to a medical facility if their body temperature is high, if he/she is unable to consume fluids or electrolytes (saline solution) on their own, or if symptoms worsen or fail to improve. Even in the absence of clear symptoms, we should call an ambulance, immediately if the person shows slowed reactions and impaired speech or movement. Last but not least, if heat exhaustion or heat stroke is suspected, examination at a medical facility is recommended as the person's condition may change suddenly even after symptoms improve.

7. Guidance about management of HD in working environment

Management in working environment should establish at each work side some risk factors indicators to evaluate the risk of HD. The risk indicator factors are device that indicates heat stress levels by measuring temperature, humidity, wind, and radiant heat. That can be used as a measure for evaluation of the risk for HD. Management should create additional air-conditioned rest areas if necessary, considering the number of workers engaged in the emergency work and the distance they transfer to that place.

Management responsibility includes to work sensibly and pace work schedules by establishing maximum working hours and avoiding heat by working in the early morning or in the evening when the temperature is relatively cool. Workers should be advised to avoid any severe work conditions. For example, do not work during the higher temperature period from 2 to 5 PM in the months of July and August, when fatal accidents due to heat disease have been frequently observed among workers [31]. Time should be given to workers to become adjusted to the high-temperature work environment while they determine their best pace of work and frequencies of rest. Work managers and superiors should raise awareness among their workers about water and salt intake and make sure that the workers are provided with sufficient supply of water and salt regardless of their conditions. In addition, work managers should evaluate the physical conditions of each worker with a check sheet. Ensure workers wear functional clothing that keeps their body temperature cool. Appoint person who will be responsible for monitoring workplace, inspecting working conditions and ensure that the above-mentioned measures are thoroughly implemented.

It is strongly recommended that work superior confirms physical conditions of each worker before work. More specifically sleeping hours, whether they had breakfast, whether alcohol intake on the previous day, and whether they are suffering from fever or diarrhea or any other health issues should be evaluated with a check sheet or other appropriate means.

Work managers should be aware of any underlying chronic disorders or issues of workers such as, diabetes, hypertensions, cardiac disease, kidney failure, and so forth, which could potentially heighten risks for HD. Further, implement appropriate measures such as setting maximum working hours for these special needs workers.

From the educational point of view, company should provide training and inform its workers about the symptoms of the HD, methods for heat disorders prevention, and emergency measures for protecting employees from radiation, in addition to providing education for work management and superior. Furthermore, critical information about emergency measures should be disseminated to every worker by posting flyers at designated area.

8. Technics and norms for evaluating hot environment working conditions

Between acceptable measures and methods of heat stress assessment technic, we can include measurement of environmental parameters and direct measurement of body temperature and also the measurement of other physiological responses, such as heart rate. The most common and widely used throughout the world environmental measurement tool is the heat stress index more specifically the "Wet bulb globe temperature" (WBGT). It was developed in a US Navy investigation into heat casualties during training [32] as an approximation to the more cumbersome corrected effective temperature (CET), modified to account for the solar absorptivity of green military clothing. The WBGT combine the effect of humidity and air velocity (natural wet bulb), ambient air temperature, velocity, and radiant energy (global temperature), as well as air temperature (dry bulb temperature) that is framed into a single value. On the other hand, direct measurement of body temperature includes measurement of the core body temperature and heart rate. Core body temperature can be measured either direct using oral or tympanic (eardrum/canal) temperature. Oral temperatures are determined by measuring temperature at the base of the tongue. The worker must not drink or eat anything cold or hot for at least 15 min before measurement. The thermometer must be inserted under the tongue, as far as possible, for about 5 min, and the mouth must be kept closed as much as possible. Oral temperature is approximately 0.4°C lower than rectal temperature [25].

Also, the recovery heat rate during rest periods following a work cycle in a hot environment is a measure that can be used to monitor heat stress. There are two models for recovery of heat rate. The first [33] recommends a heart rate criterion level of 110 beats per minute during the first minute of a rest period after work in a hot environment, followed by a reduction in heart rate of 10 beats per minute by the end of the third minute of rest. Levels above these values are indicative of exposure to a heat stress environment. The second model [34] recommends that the heart rate in the third minute of a rest period after work in a hot environment should not exceed 90 beats per minute. In that context, mean skin temperature, internal body temperature, heat rate, and mass loss will be of interest that will provide guidance for medical supervisor. An overall assessment predicts if unacclimatized workers is suitable for work that could be carried out in an 8-h shift without undergoing unacceptable (thermal) physiological strain.

Despite of all that in fact, there is no single comprehensive and specific standard that covers working in hot environments. However, we have available for use “heat index” for people working outdoor in hot weather. The heat index is a single value that takes both temperature and humidity into account. The higher the heat index, the hotter the weather feels, since sweat does not readily evaporate and cool the skin. The heat index is a better measure than air temperature alone for estimating the risk to workers from environmental heat sources.

Table 1 can emerge as a guide that helps employers and worksite supervisors to prepare and implement hot weather plans to determine when extra precautions are needed to protect workers from environmental contributions to heat-related illness [45]. Nevertheless, workers performing strenuous activity, workers using heavy or non-breathable protective clothing, and workers who are new to an outdoor job need additional precautions beyond those warranted by heat index alone. Moreover, the index values were devised for shady, light wind conditions, and exposure to full sunshine can increase heat index values by up to 15°F, 9°C. To account for solar load, added precaution is recommended. Nonetheless, heat stress is not only an outdoor health hazard. Employees working indoors in elevated temperature can also demonstrate symptoms of heat-related illness especially in the factories where similarly valid

Heat index	Risk level	Protective measures
Less than 91°F, 33°C	Lower (caution)	Basic heat safety and planning
91°F,33°C, to 103°F, 39°C	Moderate	Implement precautions and heighten awareness
103°F, 39°C, to 115°F, 46°C	High	Additional precautions to protect workers
Greater than 115°F, 46°C	Very high to extreme	Triggers even more aggressive protective measures

http://osha.gov/SLTC/heatillness/heat_index/

Table 1. Criteria for heat stress exposure.

measures should be taken. By contrary, in the office environment temperature and humidity are a matter of human comfort. There are no regulations specifically addressing temperature and humidity in an office setting. However, American Occupational Safety and Health Administration [35] recommends temperature control in the range of 68°–76°F/20–24°C and humidity control in the range of 20–60%. This standard discusses thermal comfort within the context of air temperature, humidity, and air movement and provides recommended ranges for temperature and humidity that are intended to satisfy for the majority of building occupants. We must also not forget that in 2003 the heatwave across Europe reportedly claimed 35,000 lives [36], and as a result, Public Health England (PHE) introduced the Heat-Health Watch system that operates in England from June 1 to September 15 each year, in association with Public Health England. It is based solely on temperature factors, and their potential health impactions cover whole of England. That leads to warnings being made if a daytime temperature in excess of 30°C, or nighttime temperature in excess of 15°C is expected, This, enables organizations, frontline staff, and individuals to take action to minimize the impact of the heat on people's health. This also can be seen as one of the monitoring techniques as a preventive measure for heat-related issues.

9. Discussion

As we have mentioned, the increase in global temperatures and relative humidity has a direct effect on the human body, thus increasing the incidence of heat stress. Workers more vulnerable to these effects include those with long-term conditions, particularly those with comorbidities, and these are more likely to affect the older rather than the younger workers. In that reality, it is easier to look for ways to prevent HD conditions rather than having to treat them. From our perspective, appropriate monitoring criteria and working control mechanism should be in place on the each working site, embracing general as well as specific criteria, depending on the workplace circumstances where some professional judgment is required. The individual performing the monitoring should be knowledgeable of the monitoring methods and know which criteria to use in determining whether a worker is suffering from a HD or else is ready to return to work under hot conditions. In that reality it is important to create continuous effort to study monitoring methods that from our view plays an important role in assessing employee ability to maintain work under certain conditions.

Furthermore, there is a need to train workers not only in times of heat waves but also before hot work day begins, outlining employer-specific policies and worksite-specific conditions. We have to take into consideration that a single worksite may have some job tasks that are low risk for HD and others that are at high risk [46]. Therefore, training will be more effective if it is matched to job tasks and conditions and is reviewed and reinforced throughout hot weather conditions. Also, workers should be aware of the heat index for the day and identify all of the precautions.

The training for employees should be designed to be short, participatory, and easy to follow [44]. It is necessary to emphasize lifestyle of employee and its domains (physical condition, nutritional status, and mental state) that can to a great extent influence an overall health of the employee. To make employee to understand, why it is important to prevent heat illness, that includes health effects of heat, how to respond to symptoms and how to prevent heat exhaustion. Over and above, the occupational and environmental health nurses and their role as front runners have to be stressed. Supervisors should know their duties that include recognition and treatment of the broad range of symptoms that can result from exposure to high temperatures. They must work together with interdisciplinary teams to provide education and training for the workforce so that workers will be able to take appropriate measures to prevent the onset of a heat-related illness, recognize the early symptoms, and seek adequate treatment. Interdisciplinary teams must ensure that competent controls in the work environment reduce the risk of heat exposure and related heat stress disorders. From our perspective, proper education and early intervention are the key to avoid heat-induced illnesses in order to eliminate or minimize the effects of high-temperature environmental conditions.

Looking into the past, Occupational Safety and Health Administration (OSHA) of the United States enforces heat illness cases and declares heat-related illness to be the most common cause for work-related hospital attendances among workers [37, 43]. This is mainly among construction and outside workers. It was also reported that two-thirds of the fatalities that occurred between 2012 and 2013 happened between the first and third days of work [38]. That reality can help us to emphasize priorities in preparation for dealing with such complex issues. Potential difficulties may arise also in countries, where extreme heat is infrequently experienced and workplaces have limited practice skills of dealing with such issues. Occupational health and safety professionals in those countries should be well advised and trained to consider how working in elevated summer temperatures is best managed. In that context, countries with extended knowledge, skills, and experience should be supportive in their expertise, providing manpower (experts) solely but for most part communicate and share knowledge in advance.

10. Conclusion

In conclusion, health effects from increased temperatures can have both positive and negative effects. An increased sense of well-being and positive energy can be experienced when temperatures start to increase and the sun starts to come out after the prolonged cold and darker winter. Contrary, health symptoms such as fatigue, irritability, and inability to concentrate along with all the other negative health effects related to heat stress provide a negative experience.

Nearly a third of the world's population in now exposed to climatic conditions that produce deadly heatwaves. Global warming and other environmental changes are driving the likelihood of extreme heat events higher at a time when we are seeing continued urbanization, industrialization, and an aging population. The nexus between these environmental and social factors places us on a certain path toward severe and lethal heat waves in the future, with nearly half of the world's population set to suffer periods of deadly heat by the end of the century even if greenhouse gases are radically cut [39, 40]. Study of Mazdiyasni et al. [41] shows that risks have climbed steadily since 1980 and the number of people in danger will grow to 48% by 2100 even if emissions are drastically reduced.

Therefore, it is important to understand and create effective measures to prepare, to predict, and to manage heat waves that we may experience in the future. In the future, more cross-sectional, longitudinal studies are needed in order to shed light to understand mechanism and factors that influence connection between heat exposure on the human body as well as its environmental, social, and economic impact on the individual and the society.

Organizations can do a great deal to assist, by creating a healthy workplace environment and promoting education not only for superior and health workers but also for employees. Enhance workers' comfort as a way of reducing turnover and increasing retention of employees [42]. At the same time, support older workers to remain in the workforce with lower risk. This will in turn have benefits for the recruitment and retention of the workers, especially in times of rapid aging of the European population.

Also, professionals in the field should develop cybernetic-based computer program that will embrace a multitude of environmental and personal variables that can predict potential risk for development of health disorder.

At the very end, we should emphasize that only healthy worker (health with age has tendency to deteriorate) can successfully deal with such threat condition as heat exposure no doubt represents. We believe that modification of individual lifestyle (their domains) places crucial role, and this is no doubt individual responsibility. In that context employee should stretch further to educate, motivate, and create condition for its employees to be healthy that on the end will benefit not only individual and his close and distance environment but also society as a whole. On the very end, we can conclude that only healthy men can create safe, prosperous, and well-performing working environment, and that is the goal.

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Chapter 3

Tools for Assessment of Occupational Health Risks of some Engineered Nanoparticles and Carbon Materials Used in Semiconductor Applications

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Additional information is available at the end of the chapter

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Abstract

Engineered nanomaterials (ENM) are used in a wide variety of applications: from cosmetics and paints to sportswear and semiconductor chips. While for chemicals there are established regulatory frameworks dealing with the risk for the consumers, workers, and the environment, this is not the case for nanomaterials. This is precisely why ENMs are used—the properties of matter change at the nanoscale and become dependent on the particle morphology and size. Our understanding on how such nano-systems react with biological matter, such as cells and tissues, is far from complete, and this brings about an increasing level of uncertainty in the research and development process. This chapter will give an overview of several materials, which are either used or have potential applications in nanoelectronics. While silicon dioxide and metal oxide nanoparticles are used in semiconductor processing in standard polishing steps, applications of carbon materials may be more disruptive. As promising materials with broad applications, we focus on carbon nanotubes and graphene. So-identified materials are used to illustrate the use of different risk assessment tools in the occupational setting of nanoelectronics. The application of such tools in itself is also a growing area of research efforts supported by international stakeholders, such as the European Commission.

Keywords: nanosafety, nanomaterials, nanotechnology, semiconductor

1. Introduction

An increasing number of engineered nanomaterials (ENM) enter the market in everyday products spanning from healthcare and leisure to electronics, cosmetics, energy, agriculture, food, and transport. By 2014, there have been more than 1600 nanotechnology-enabled products in

Sector	Applications/products	Nanomaterial
Electronics	Electrically conductive polymers	CNTs
	Abrasive particles in CMP processes	SiO_2, CeO_2, Al_2O_3
	Sensors	CNTs, graphenes
	Supercapacitors	CNTs, graphenes
Energy	Electrodes in energy conversion and storage	CNTs, graphenes, other metallic NPs
	Batteries	Al_2O_3
	Fuel cells	Graphenes
Textiles	Nanofibers and antibacterial textiles	Nano-Ag
Construction	Insulation	Silica-aerogel
	Light transmission	Silica-aerogel
	Dirt-repellent paints	SiO_2
Medicine	Drug carriers	SiO_2, CeO_2
	Biomedical imaging	SiO_2
	Dental implants	Al_2O_3, SiO_2
	Biosensors	CNTs, graphenes
Automotive	Hydrogen storage	MOFs
	Antifog coating for windshield/mirror	TiO_2
	Scratch proof lacquer	Nanoceramics
	Fuel additives	CeO_2
	Catalysis	SiO_2
Cosmetics	Sun screen	TiO_2
Various	Nanofillers	CNTs, graphenes
	Nanocomposites	CNT/polymer matrix, CNT/ceramic matrix
	Filters	CNTs
	Anticorrosive coatings	Graphenes
	Nanofilms	

Sources: Refs. [2–5].

Table 1. Leading industrial applications of common engineered nanomaterials.

commerce [1]. A summary of ENM applications is given in **Table 1**. While there are natural sources of nanoparticles, such as volcanoes, forest fires, or sea storms, the engineered nanomaterials are purposefully made to achieve certain prescribed functionality. Such desirable characteristics can include increased strength of the material, its chemical reactivity, or altered electrical properties. The terms ENM and nanomaterials will be used interchangeably throughout the chapter.

Nanomaterials can be classified broadly as particles, which have oval shapes; fibers, which are tube-like but may exhibit complex branching; and sheets, which are film-like but again may exhibit branching or defects. Interested readers are directed to Buzea et al., for a review [6]. The European Commission defines nanomaterials as "natural, incidental or manufactured material containing particles, in an unbound or as an aggregate or agglomerate and where 50% or more in the number size distribution, one or more dimensions is in the range of 1–100 nm."

The size cutoff in common definitions is somehow arbitrary. It, however, conveys the understanding that properties of the material features at the nanoscale (i.e., the so-called nanoforms of materials) can substantially differ from the properties of materials in bulk. This can be explained by two main factors affecting the physicochemical properties because of their small sizes—surface effects and quantum effects [7]. The surface effects occur due to the fact that as the size of nanoparticle decreases, the surface area relative to the volume increases as the inverse power of the diameter ~$1/d$. The relative increase in area provides a greater overall surface per unit mass available for reactions as well as higher charge and energy densities, which influence the surface chemistry of ENM (reviews in [6, 8]). Quantum effects result from the confinement of electrons when the particle radius decreases [6]. Electron confinement in turn influences the capability for electrons to be donated or accepted, hence influencing their electrical charge distribution and the catalytic capability.

This chapter aims to familiarize readers with nanomaterials, which are either used in the semiconductor manufacturing or have current and promising future applications in electronics industries. Due to the limited volume, we have focused on silica, certain metallic nanoparticles, and carbon materials, such as carbon nanotubes and graphene. The applications of these ENMs will be discussed in Section 2. At the same time, the use of ENMs raises questions about potential unintended risks for the workers, consumers, or environment. Consequently, an overview of the nanotoxicological studies for all these three classes of nanomaterials is presented in Section 3. Since the manipulation and use of ENMs warrant for safety precautions, different relevant control banding tools for risk assessment will be summarized in Section 4. Finally, the concept of tiered risk assessment approach is introduced in Section 4.5 as a flexible framework, which is able to decrease uncertainty as new information becomes gradually available.

2. Applications

2.1. Nanoelectronics as a case study

Nanoelectronics relies on multiple semiconductor processes resulting in pattering of macroscopic objects (silicon wafers) on the nanoscale. Overall, the semiconductor industry can be considered predominantly as a downstream user of nanomaterials. Nanoelectronics enjoys a very fast innovation cycle governed by Moore's law. This brings about a variety of new materials and combinations into production, while some of them are in nanoform. As a result, new materials, including a variety of nanoparticles, have been introduced in the development of advanced technology nodes predominantly in polishing operations. Engineered nanomaterials are used in several processing steps, but they can also be generated as side products of several generic processes.

The background of materials studies in the field of occupational health naturally focuses on the release, monitoring, mitigation of exposure, and health implications. The relevance of the work for the semiconductor industry is in those studies proven by naming few examples for the application of nanomaterials in semiconductor technology [9]. The semiconductor industry can be taken as a use case on how potential occupational and environmental risks brought about by nano-enabled products are governed. Specifics of this industry, which make it interesting, are several:

- Semiconductor mass manufacturing employs top-down high-precision approaches, which are highly standardized.
- Nanoelectronics enjoy a very fast innovation cycle.
- Due to the fast innovation cycle, there is a safety culture used to dealing with uncertainties.

An example of such standardized process is the complementary metal-oxide-semiconductor (CMOS) fabrication, which is the focus of the safety assessment undergoing in the H2020 project NanoStreeM [4]. The project findings demonstrate that chemical mechanical planarization (CMP) is the most common standard process, where ENMs are used. It should be noted that wafer-scale integration of carbon nanomaterials is not yet industrially available.

2.2. Metal oxides NPs and silica

Semiconductor industry uses nanoparticles in several processing steps, particularly in CMP, which is a standardized processing step during the manufacturing of semiconductors, for example, the CMOS processing. The purpose of CMP is to achieve a high degree of planarity for the wafer surface and remove the excess of deposited material. The importance of having very flat surface is due to the fact that even very slight undulations, or small defects and scratches on the wafer surface, would degrade the yield from a wafer and thus result in an economic loss [5, 10, 11].

The planarization process employs a mechanical force to synergistically work with the chemical reactions to remove metallic surfaces in order to achieve planarity for the wafers [12]. During CMP processing, the wafer is loaded onto the wafer carrier. Then the slurry emulsion is released from the dispersing head and reacts with the wafer surface so that chemical reactions help create chemically modified surface. Simultaneously, slight force is applied downward so that friction force develops between the wafer carrier, polishing pad and the abrasives in the slurry. This results in removal of deposited materials. Additionally, CMP tools also require pad conditioning. This conditioning is needed in order to maintain a stable rate of material removal. These pad conditioners are usually disks with diamond particles that will help stabilize the surface roughness of the pad [10].

Besides nanoparticle abrasives different slurries are composed of proprietary components, which optimize the desired functionalities. The roles of each component can be summarized in general as [5, 12]:

- Molecules for pH adjustments maintain stable pH for the slurry.
- Complexing agents aid in the solubilization of the dissolved metallic components.

- Oxidizers improve the selectivity of the slurry by promoting dissolution or protecting against the removal of a certain surface component.
- Corrosion inhibitors stop the corrosive effects on the wafer surfaces.
- Biocides inhibit growth of biological organisms.
- Abrasive particles increase the frictional force needed to remove the chemically modified surfaces during the CMP process.

The abrasive particles are nanoparticles in the range of 20–100 nm [10]. An important point for the use of nanoparticles in the CMP slurry is that the nanoparticles tend to aggregate or agglomerate into bigger sizes. Agglomeration and aggregation of particles can cause pH variations at different areas of the slurry. This in turn causes nonuniformity on the wafer surfaces after the polishing process [11]. To avoid the agglomeration or aggregation of the abrasive nanoparticles, CMP slurries are often mixed on site prior to the use via a CMP slurry mixing and distribution system. Alternatively, coating of the abrasive nanoparticles can also be used to maintain stability. Currently, the most widely used nanoparticles acting as abrasives in CMP slurries are silica (silicon dioxide), alumina (aluminum oxide), and cerium oxide [5].

2.3. Carbon nanotubes

Carbon nanotubes (CNTs) were discovered in 1991 and since then have found many applications [13, 14]. There are three main categories of CNTs based on the wall structure: single-walled carbon nanotubes (SWCNTs), double-walled carbon nanotubes (DWCNTs), and multiwalled carbon nanotubes (MWCNTs) (overview in [13]). The main structural difference between MWCNTs and the SWCNTs is that MWCNTs contain multiple concentric carbon sheets [14]. CNTs possess many unique physicochemical properties that supersede other carbon-based materials used formerly, such as graphite, diamond, and fullerenes. The main physicochemical properties of CNTs are summarized in **Table 2**.

In the field of energy conversion and storage, CNTs are mostly applied in mainly two applications: electrodes in lithium-ion batteries and supercapacitors [13, 14]. The use of CNTs provides high surface area. CNTs, especially SWCNTs, are good candidates for use as electrodes for Li-ion batteries. It was shown that SWCNTs exhibit good intercalation of Li-ions on their walls as well as have higher interstitial density than the traditionally used graphite electrodes [15]. Additionally, the incorporation of CNTs as electrodes for Li-ion batteries has a simpler fabrication process than those of the conventional electrodes [16]. This is because layers of metal mixture substrates and electrical conductor must be deposited on the conventional electrodes, while CNTs can be directly grown onto the electrodes themselves. However, the potential discharge of the CNT electrodes is lower than those of the conventional types [14]. Beyond the use with Li-ion batteries, CNTs are also depicted and studied as candidate material for supercapacitors.

Supercapacitors are considered as a high-performing alternative for Li-ion batteries. The energy storage properties of supercapacitors are highly dependent on the surface area since the energy is stored in a charged double layer that is formed after the application of a voltage source. Hence, CNTs, having high surface-area-to-volume ratio, are especially suitable [17].

Property (unit)	SWCNTs	MWCNTs	Graphenes
Tensile strength (GPa)	50–500	10–60	>1000
Elastic modulus (TPa)	≈1	0.3–1	1
Electrical conductivity (S/m)	1.3–1.5	1.8–2.0	2000
Specific surface area (m^2/g by BET)	>1000	>500	2630
Source: Ref. [3].			

Table 2. Properties of SWCNTs, MWCNTs, and graphenes.

CNTs are also widely used in the field of sensors due to their unique properties like the high surface area, electrical conductivity and adsorptive properties. These properties contribute to a simpler fabrication of the CNT-based sensor with lower response time and higher sensitivity. The easier fabrication steps also led to easier incorporation into various electronic circuits, miniaturization of the component, and lower production cost and energy consumption [14].

CNTs could be functionalized with metals, metal oxides, polymers, or biomacromolecules [3]. Although CNTs are promising candidate materials for use in electronics industry, the synthesis and purification of CNTs are two of the biggest concerns. The syntheses of CNTs are mostly conducted either via *chemical vapor deposition*, arc discharge, or laser ablation [14, 17]. All of these processes require metal catalysts during the synthesis. These metallic catalysts left residual particles on the CNT surfaces which decrease the purity of the obtained CNTs. Impurities or changes in surface composition can affect the surface effect of the nanomaterial, which in turn modifies the physicochemical properties of the aforementioned nanomaterial. Subsequently, their environmental fate, uptake, and toxicological properties will also be affected and can differ from other nanomaterials of the same kind. Many purification steps involving liquid/gas phases as well as oxidation reactions were proposed, but these methods affect the physicochemical properties of the CNTs accordingly [18, 19].

2.4. Graphene

Graphene contains sp^2 planar carbon sheet structure. Due to this two-dimensional structure, graphene is one of the thinnest yet mechanically strongest nanomaterials available [20, 21]. Additionally, graphenes also possess excellent optical properties as well as high mobility of electrons. The physicochemical properties of graphene are summarized in **Table 2**. When referring to graphene-based materials, the other two derivatives of pristine graphene are also included: graphene oxide (GO) and reduced graphene oxide (rGO).

When referring to the field of energy storage and conversion, graphenes are mostly used in Li-ion batteries as well as in optoelectronic devices, such as solar cells [3, 22, 23]. In Li-ion batteries, graphene-based nanomaterials, specifically, graphene oxides (GO), are mostly used as buffers to prolong the storage lifespan. The unique tensile strength and electrical conductivity of graphene-based nanomaterials protect the electrodes from being pulverized and facilitate the charge–discharge cycles of the batteries [20]. In the applications with solar cells, graphene-based nanomaterials are functionalized with quantum dots (QDs) to form a hybrid matrix that raises the performance of a photovoltaic array [20, 22]. In contrast to CNTs, graphene-based materials

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are more flexible due to their mechanical properties. The use of graphene-based materials for sensors is increasing gradually. Owing to their extremely high available surface-area-to-volume ratio and electrical conductivity, graphene-based sensors have a performance on par or even higher than those of CNTs or Si-based sensors [20].

In contrast to CNTs, the problems of impurities faced during the synthesis of graphenes are much less. However, the degree of reproducibility during the fabrication of graphene-nanoparticle matrix is a topic of concern [3, 20, 21]. It is particularly complicated to obtain uniformly dispersed nanoparticles on these graphene sheets. Hence, the nonuniformity can and will affect the physicochemical properties of these graphenes and eventually hinder the industrial use of graphenes. Therefore, additional studies on the industrial applications of graphene-based nanomaterials are still needed to overcome this drawback and exploit the potential of the material in the electronics industry.

3. Nanotoxicology

3.1. Nanotoxicology of silica

Silica ENM is used in slurry formulations. Their density is 2.196 (amorphous) g/cm^3 [24]. Recent publications have demonstrated that silica NPs can become cytotoxic both in vitro and in vivo in a dose-, size-, and cell-type-dependent manner [25–27]. The most common route of exposure for silica NPs is via inhalation [28–30]. On a second place is the ingestion exposure route.

In vitro studies have demonstrated that silica NP toxicity is mostly caused by the production of reactive oxidative species (ROS) [31–35]. The surface silica radical groups can generate free radicals and ROS by the Fenton reactions. In particular, ROS can be generated by the failed phagocytosis of silica NPs. The latter mechanism is valid for all cases of incomplete phagocytosis of NPs; thus, it is also applicable for alumina and cerium oxide. Fubini, Hubbard, and Lehman demonstrated that the fractured silica surfaces, which are more prone to release free silanol radicals, can initiate Fenton reactions in water [35, 36]:

$$
\begin{gathered}
{}^{\bullet}O2^{-} + 2H^{+} + e^{-} \rightarrow H_2O_2 \\
-SiOO^{\bullet} + H_2O_2 \rightarrow -SiOH + HO^{\bullet} + O_2 \\
-\ SiO^{\bullet} + H_2O \rightarrow -SiOH + HO^{-\bullet}
\end{gathered}
$$

which are catalyzed by the Fe oxidation as $Fe^{2+} + O_2 \rightarrow Fe^{3+} + {}^{\cdot\bullet}O_2^{-}$ [33]. The hydroxyl radicals can increase cytotoxicity by increasing oxidative stress (e.g., the intracellular concentration of hydrogen peroxide). It was also shown that when undergoing incomplete phagocytosis, cells tend to produce ROS and increase the level of intracellular oxidative stress [31]. Subsequently, this leads to an increase in cytotoxicity and damage to various cellular compartments. Excessive intracellular ROS concentration has been reported to contribute to higher cytotoxicity by directly increasing cellular stress and by indirectly damaging the mitochondria and macromolecules which can further lead to genetic damage, carcinogenesis, or reproductive defects [8, 37].

As noted previously, as the particle size decreases, there is an increase in the surface area fraction which influences the surface chemistry. Moreover, the small size of the NPs helps them to evade clearance mechanisms in the body; therefore, the retention time is further increased, rendering them more biopersistent [7]. These factors contribute to a increased potential for reactivity, resulting in higher ROS production, lipid peroxidation, and the damage to cell membranes [38–40]. This can ultimately lead to apoptotic cell death.

Several in vitro studies emulating ingestion as a route of exposure by using cell lines from the gastrointestinal tract have been conducted. According to a recent review, in vitro studies of immunotoxicity were conducted mainly on monocytes and macrophages which showed inflammatory responses more severe than exposure to silica in the micron range [25]. However, this result is not representative of the entire immune system; hence, further studies are still needed before firm conclusions can be drawn.

The 2016 Organization for Economic Co-operation and Development (OECD) dossier on silicon dioxide suggested that amorphous nanosilica seems not to exhibit carcinogenic, mutagenic, and reprotoxic (CMR) properties [41]. This is in accordance with other studies showing no genotoxic effects of silica NPs [42].

In vivo studies with nanosilica were mostly done to study inhalation exposure. The numbers are significantly less when compared to in vitro studies, and no chronic exposure study was found. The results reported in literature are conflicting due to different dosages, sizes, and animal species used. At present, it is still not possible to draw definite conclusions from the in vivo studies due to their limited number. Moreover, most of these studies do not follow a standardized operating procedures, and therefore, it is not possible to compare the results or difficult to interpret the results [43]. Readers are directed to the recent review of Murugadoss et al. for more information [25]. Different studies have shown that silica NPs can induce cytotoxicity by forming ROS due to their small sizes resulting in increased reactivity. Although ROS formation has also been linked to CMR properties, no CMR effects were found after exposure to silica NPs. In addition, the studies have shown that silica NPs are capable of forming protein corona which influences the effective concentration used in toxicological studies. This further puts an emphasis on the importance of the appropriate dosage/concentration selection for in vitro and in vivo studies as the NPs could interact with the biological media and form aggregates/agglomerates or protein corona which could give non-representative toxicity results.

3.2. Nanotoxicology of CeO_2

Cerium oxide nanoparticles are widely used as catalysts in automotive industry, components in the fuel cells, or hydrogen production in energy-related industry, additives for consumer products like sunscreen, drug carriers in the pharmaceutical industry, and as abrasive particles for semiconductor industry [44, 45]. The mass density of CeO_2 is 7.215 g/cm^3 [24]. The variety of applications for nano-cerium oxide warrants occupational health studies to ensure safety of production, use, and disposal throughout the life cycle. Literature studies have shown that the main route of exposure for cerium oxide NPs is via inhalation [28–30, 44–46].

Nano-cerium oxide exerts both protective and toxic effects due to its oxidative properties [44, 45]. Cerium oxide NPs can scavenge radicals, which lowers the amount of ROS present in cells.

However, cerium oxide can also increase cytotoxicity by increasing the intracellular hydrogen peroxide levels as well as increasing the ROS levels in some studies [44]. Red-ox reactions involving Ce^{2+} ions were proposed by Korsvik et al. to explain the possible mechanism of ROS formation [47]:

$$O_2^{\bullet -} + Ce^{4+} \rightarrow O_2 + Ce^{3+},\ E_0 = 1.61\,V$$
$$O_2^{\bullet -} + Ce^{3+} + 2H^+ \rightarrow H_2O_2 + Ce^{4+},\ E_0 = -2.34\,V$$

Several studies have demonstrated contradicting results whether nano-cerium oxide is related to the synthesis method, particle size, and cell type [24, 44, 45]. It was shown that the temperature can influence the size and subsequently the zeta potential of the NPs [48]. This in turn affects the aggregation behavior of the NPs as well as their cytotoxicity. Another study showed that the difference in synthesis temperature can influence the size of the NPs which could in turn lead to a higher Ce^{3+}/Ce^{4+} ratio on the surface of the particle as the size of the of the NP decreases.

As is the case for silica, the cytotoxicity of nano-cerium oxide can also involve the formation of ROS, which, in excess, can increase the cellular stress and decrease cell viability.

An in vivo study showed a time-dependent increase in oxidative stress in the spleen and liver as well as the presence of hepatic granuloma when male Sprague-Dawley rats were infused intravenously with 70 mg/kg (30 nm cerium NPs) [49]. Another study demonstrated that cerium oxide NPs were able to induce DNA damage in leukocytes and liver cells as well as form micronuclei in the bone marrow and blood cells when female Wistar rats ingested 1000 mg/kg of 25 nm cerium oxide NPs [50]. The study also established a dose-, time-, and organ-dependent relationship with the bioaccummulation of cerium oxide NPs after performing histopathological analysis.

In summary, cerium oxide NPs can exhibit both adverse and protective effects. This depends on the synthesis method, the cell types being studied, and possibly the particle size, although the latter should be studied in more detail as at present is not possible to draw a definitive conclusion. As is the case for silica, standardized tests should be performed so that the results will be more comparable and a more definitive conclusion can be made. Nanoceria is suspected to have CMR properties; however, this still needs to be demonstrated in vivo in relevant doses.

3.3. Nanotoxicology of Al_2O_3

Nano-aluminim oxide (alumina) has been used in various applications ranging from being components in cements, acting as catalysts and surface coatings, to being abrasive particles in semiconductor production [46, 51]. The mass density of Al_2O_3 is 3.987 g/cm^3 [24]. Despite their wide use, alumina NPs are the least studied of the three nanoparticles presented so far. This is reflected by the limited number of toxicological studies for alumina NPs as well as the absent of an OECD dossier for alumina NPs. As is the case for most NPs, the most common route of exposure for nano-alumina is via inhalation [28–30, 46, 51].

Several studies have shown that alumina NPs are also able to induce excessive ROS production which could in turn damage other cellular compartments like the plasma membrane and mitochondria, thus decreasing the cellular activity and/or viability. Moreover, excessive intracellular ROS could interact with the cellular genetic material that could further lead to mutations [6–8, 28, 30, 37, 52, 53]. According to present toxicological reports [51, 54–57], alumina NPs are less cytotoxic than NPs, such as cerium oxide, gold, silver, or copper oxide NPs, but they may be also capable of inducing sufficient amount of ROS to decrease cell viability. In addition, it was shown that nano-alumina can cause impairments to the cellular innate defense mechanisms against airborne pathogenic organisms [58]. Similarly, another in vitro study demonstrated that RAW264 macrophages that were incubated with 13 nm alumina NPs at 200 and 400 μg/mL for 72 hours exhibit changes in the morphology as well as a dose-dependent cytotoxicty which results in the decrease in cell viability by up to 40% of the control [54].

It should be noted that the choice of cell line used can also influence the outcome of the toxicological assay [51]. In this study, six cell lines (BEAS-2B representing the lung, Chang for the liver, HaCaT for the skin, H9C2 for the heart, T98G for the brain, and HEK-293 for the kidney) were exposed to 5 and 20 μg/mL 180–200 nm of nano-alumina for 48 hours. The results showed that there is a dose-dependent decrease in the viability for all six cell lines ranging from a 15% decrease to as much as 50%. The most sensitive cell line was HaCaT and BEAS-2B.

In summary, nano-alumina has been shown to be able to induce cytoxic damages via the producion of ROS which in turn reduce the cell viability. However, the number of articles focusing on cytotoxicity of alumina NPs and the exact mechanism of toxicity is very limited and nonexistent, respectively. As in the case of mutagenicity, conflicting reports of alumina NPs render their possession of CMR properties inconclusive. The difference between toxicological studies can possibly be explained by the synthesis method or the cell culture conditions or differences in cell types sensitivity. Therefore, standardized tests should be conducted so that different results become more comparable.

3.4. Nanotoxicology of CNTs

Carbon nanotubes are believed to fit the fiber paradigm on par with asbestos [28–30, 46]. In summary, the fiber paradigm refers to any (nano)materials with:

- Diameter less than 3 μm
- Length of more than 10–20 μm
- Aspect ratio greater than 3
- Aerodynamic diameter of less than 10 μm
- Biopersistent and rigid

Therefore, many toxicological studies have been conducted so far [28–30, 46, 59–63]. Published in vivo studies have shown that CNTs can enter the body via several pathways including inhalation, oral uptake, and dermal uptake. Many of these articles focus on the inhalation or intratracheal instillation; however, the most relevant exposure route to humans based on the electronic and biomedicine applications of CNTs would be oral uptake or intraveneous injection [60, 61]. The studies based on the latter two exposure routes are, unfortunately, presently quite limited.

The mechanism of CNTs toxicity is believed to be also linked to the excessive ROS production induced by oxidative stress [59–63]. Due to size limitations, this chapter will not discuss in vitro studies. Interested readers are directed to [61] for an overview.

An in vivo intratracheal instillation study showed that mice that were instilled with 0, 1, and 0.5 mg of SWCNT exhibited granulomas after 7 days with a dose-dependent relation and severe inflammation in the lungs after 90 days [59]. The dimensions of the SWCNT are reported as aerodynamic diameters. A 9-day intratracheal instillation study on F344 rats was conducted where 0.5 μg/ml MWCNTs was given five times a day [63]. The results showed hyperplastic lesions and inflammations in a dose-dependent manner. The MWCNT was of 13 μm in length and more than 50 nm in diameter. Interestingly, an inhalation study where C57BL/6 mice were exposed to maximally 5 mg/m^3 MWCNTs for 14 days showed no inflammation in the lung or any other tissue damage [64]. Finally, the study conducted by Poland et al. [62] demonstrated that MWCNTs that were injected intraperitoneally at a dosage of 100 μg/ml into the body of the C57Bl/6 mice for up to 7 days induced asbestos-like effects such as inflammation and granulomas. The MWCNT samples used in the study were quite polydisperse, having a diameter ranging from 10 to 165 nm and length ranging from 1 to 56 μm.

In summary, most in vivo toxicological studies for CNTs concur on the fact that the mechanism of CNT toxicity is linked to overproduction of ROS. This property can be exacerbated or mitigated by the specific physicochemical properties of the CNTs [60, 61]. Although many articles exist on the toxicological studies of CNTs, the results obtained are difficult to be compared to each other due to the lack of standard characterization of CNTs as well as the protocol for exposure and cytotoxic assays. As for the CMR properties of CNTs, different studies suggested that CNTs may exhibit genotoxic properties and, hence, more standardized studies should be conducted to yield more comparable results between different studies so that a definite conclusion can be made.

3.5. Nanotoxicology of graphene

Graphene-based nanomaterials are the most novel group of nanomaterials covered in this review. In comparison to CNTs, toxicological studies of graphene-based nanomaterials are less but gradually increasing and are less coherent in terms of their conclusions [65–68]. This can be most likely attributed to differences in synthesis methods. As is the case with the metallic nanoparticles and the CNTs, the most probable routes of exposure are inhalation, followed by oral and dermal routes [28–30, 46, 65, 66]. It should be noted that the available in vivo studies up to date have focused on intravenous and oral administration with the intent of studying the mechanistic effects and biodistribution rather than relating to the relevancy of occupational exposures.

Analogous to the in vitro studies, most in vivo studies also showed a dose-dependent toxicity for the exposure of graphene-based nanomaterials. Zhang et al. conducted an intravenous injection of GO, with the size of 100–800 nm and a thickness of 1 nm, into Kun Ming mice at a dose of 1 and 10 mg/kg [69]. After 14 days, inflammation and the formation of edemas and granulomas were observed during histopathological analysis in a dose-dependent manner. The studies of Singh et al. demonstrated how functionalization can influence the degree of toxicity of the graphene oxides [70, 71]. Pristine GO and GO functionalized with amine (NH2) having size range between 0.2 and 5 μm were injected intravenously into Swiss male mice at a concentration of 250 μg/kg. Histopathological analysis was conducted after 15 min and found that mice injected with aminated GO showed no sign of thrombotoxicity, whereas on the other hand, mice injected with GO showed thrombotoxicity as well as aggregation of blood platelets in as much as 48% of the lung blood vessels. Finally, an oral uptake study in ICR mice showed atrophic characteristics in all major organs as well as lowered weight of the body and tail length [36]. The mice were fed with 0.05 and 0.5 mg/ml of GO (size of 2000 nm and height of 1.8 nm) in drinking water.

Studies on the CMR properties of graphene-based materials are very limited. Bengtson et al. conducted an intratracheal instillation study with GO and multilayer reduced GO into C57BL/6 J mice at a dose of 18 up to 162 μg/mouse. Analysis was performed at various time points during the 90-day study period [72]. In addition to inflammatory responses, it has been observed that both GO and reduced GO were able to cause DNA damage in the BAL cells at the lowest dose of 18 μg/mouse from day 3 of the study. However, DNA damage was not significantly observed in the lungs or liver. Another study demonstrated micronuclei formation in B and T lymphocytes as well as the primary lymphocytes when these cell lines were exposed to 6.25–400 μg/ml of GO (size ranging from one to tens of μm) [73].

The toxicological mechanisms of graphene-based nanomaterials are believed to be related to the excessive formation of ROS [65–68]. When internalized within a cell, graphenes could disrupt the electron transport chain which causes the production of excess peroxide and hydroxyl radicals. Subsequently, the homeostasis of the intracellular reactive oxidative species is disrupted. Additionally, graphenes may cause membrane disruptions as well as damage the cell integrity directly by their sharp edges [65, 66]. Nevertheless, the exact mechanism of graphene-based nanotoxicoloy is still largely unknown [65–68].

In vivo studies suggest that graphenes could have been taken up and retained in various organs for a prolonged period of time. However, most in vivo studies focused on explaining the mechanism of the toxicity and did not take the realistic dosage or route of exposure into account [66]. Hence, more uniform in vivo studies with regard to occupational settings will have to be conducted in the future in order to draw a definite conclusion from these studies. Finally, limited number of genotoxic studies suggested that graphenes are capable of interacting with DNA and could hold genotoxic properties.

3.6. Overview of the nanotoxicological properties of studied ENM

There is an emerging consensus in literature that the toxicity of engineered nanomaterials seems to be higher than the toxicity of bulk material (review in [74]). The toxicodynamic mechanisms are summarized in **Table 3**. Furthermore, an insufficient hazard characterization leads to limited availability of data on physicochemical properties, (eco)toxicological properties, and the environmental fate information, all of which are prerequisites for comprehensive and quantitative risk assessment [52]. According to Pietroiusti et al. [74], the following knowledge gaps of ENM can be listed at present:

ENM	OEL [1/cm^3]	Source
SiO_2	40,000	IFA, SER
CeO_2	20,000	IFA, SER
CNT	0.01	IFA, SER, BSI

IFA, German Social Accident Insurance (Germany); SER, Social and Economic Council (Netherlands); BSI, British Standards Institute (UK).

Table 3. Summary of the toxicological mechanisms of target ENM and proposed OEL.

- Data gaps in toxicokinetics of ENM in organisms and cells
- Insufficient understanding of the mechanisms of toxicity
- Nano-specific biomarkers of ENM toxicity or ENM-induced diseases
- Predictive models of ENM toxicity

All this leads to impossibility of establishing OEL for the predominant majority of ENMs rendering quantitative risk assessment for nanomaterials impossible.

The OELs for bulk parent materials can significantly differ from their nano-counterparts due to the discussed differences in their physicochemical properties. The complexity also arises from the fact that the best metric (by mass, concentration, or number) for nanoparticle exposure characterization is still debatable [75–77]. OELs for nanomaterials are available only in few cases (see **Table 3**).

Due to this situation, the concept of OEL has been replaced by nano-reference value (NRV), however, without regulatory significance. Such NRVs can be sector or organization specific. Furthermore, quality of available data can be also problematic. This is a concern already recognized in literature [76, 78]. These recent publications have demanded for a uniform standard operating procedure so that results obtained from different studies can be compared faithfully. Such standardized protocols should meet the criteria of the nanomaterial testing program coordinated by OECD [41].

Target	Mechanism	Type of NP
Plasma membrane	Mechanical action, ROS	SiO_2, CeO_2, graphenes
	Receptor activation	SiO_2, CeO_2, CNT
Lysosomes	Membrane disruption	CeO_2
Mitochondria	Membrane disruption, protein downregulation	SiO_2
Nucleus	Transcription inhibition	SiO_2
	Inhibition of cytokines	CNT
Cytosol proteins	Actin	SiO_2
	CYP450	SiO_2
	Fibrillar proteins	CeO_2

Contents are based on Refs. [74, 79].

4. Elements of nanomaterial risk assessment

The process of chemical or nanomaterial risk assessment is conducted in order to estimate the risks associated with a particular operation and materials. In a further step, the risk assessment derives a set of protective measures that allow for reduction of the risk for the workers and the environment. The availability of the toxicological data defines which type of risk assessment method can be used. If extensive data is available, quantitative risk assessment can be used to derive OELs for a particular material. Subsequently, the emission could be controlled to confirm that the exposure does not exceed the predetermined OELs. Almost by definition, this is not the case for novel ENM, which may bring about unanticipated interactions that alter their safety profile compared to the bulk material.

Challenges in the traditional chemical risk assessment approach can be traced to the assumption that the hazard and the risk can be quantified in an absolute way [86]. In contrast, since hazard profile data for novel material are inherently uncertain, the risk can be estimated only in a relative way. Such reasoning is supported also by the facts that there are conventional strong anthropogenic sources of nanomaterials, such as wax candles, radiator, frying, burning cigarettes, and traffic [87]. A way to estimate the risk is by grouping of materials based on certain similarity metrics. Such an approach favors categorical risk assessment tools, which result in a classification into a hazard and control band for the process under investigation (**Table 4**).

Control banding was developed in the pharmaceutical industry as a pragmatic tool to manage the risk resulting from exposure to a wide variety of potentially hazardous substances in the absence of firm toxicological and exposure data [88]. Its applications to safety of nanomaterials have been reviewed in [89]. The control banding approach is based on two pillars: the fact that there are a limited number of control approaches and that many problems have been met and

Tool	Hazard bands	Exposure bands	Risk bands	References
ANSES	5	4	5	[80]
CB Nanotool*	4	4	4	[81]
ISO	5	4	5	[82]
Imec	3	4	3	[83]
Nano Stoffenmanager	5	4	3	[84]
NanoSafer**	4	5	5	[85]

*Scores from 0 to 100.

**Score ranges.

ISO, ISO Technical Standard ISO/TS 12901-2:2014 "Nanotechnologies—Occupational risk management applied to engineered nanomaterials".

Table 4. Summary of control banding tools.

solved before. The second pillar assumes that risks are at least qualitatively similar, even if no numerical probabilities can be assigned to them.

4.1. Hazard banding

For most cases, control banding tools follow a decision tree approach to characterize the hazards. The ISO Technical Standard 12901-2:2014 "Nanotechnologies—Occupational risk management applied to engineered nanomaterials" (in short ISO tool) uses only few physico-chemical parameters of the NPs, namely, the water solubility and fibrocity, as preliminary questions to decide whether the NPs can be classified. Eventually, the NPs will be designated into one of the five classes of hazard bands (HB) based on the available toxicological data. In the case where the toxicological data are insufficient or unknown, the ISO tool makes use of the hazard band of the bulk or an analogous substance with an additional penalty. Similarly, the hazard banding for ANSES also follows a decision tree. Three preliminary questions are used to identify the "nanorelevance" and to determine whether the use of the ANSES tool is warranted. Interestingly, according to the ANSES tool, a persistent fiber will automatically be designated the highest HB of 5. This is also the case for the ISO decision tree. Subsequently, a substance of reference (be it a bulk or an analogous material) is used in order to assign a hazard band with additional penalties depending on the physicochemical properties like water solubility and chemical reactivity in the nanoform. One point of interest is that the ANSES tool does not include toxicological information, such as acute toxicity or the CMR properties when designating hazard bands.

The hazard banding of Stoffenmanager Nano tool follows a tiered approach which results in a decision tree. If the material is "nano-relevant," the decision tree can be followed to the next tier. Subsequently, physicochemical properties of the nanomaterials including the water solubility, fibrocity, as well as the toxicological information are used to designate a hazard band for the material of interest. In the case where the toxicological information of the nanomaterial is not known, Stoffenmanager Nano refers to the data available for the ENM studies conducted by OECD, or if the material of interest is not ranked or included within the OECD framework, the toxicological information from the bulk materials will be used.

The hazard banding for the Imec tool is a questionnaire assessment. Several physicochemical parameters are collected, such as solubility, persistency, and dispersibility in water, the size, and morphology and the toxicological information of the nanomaterial. The CB Nanotool sums points based on severity factors which are related to both the physicochemical properties and the toxicological information in the nanoform as well as the bulk form. Of the maximum 100 points, a maximum of 70 points are designated for nanoform properties, while the other remaining 30 points are for the bulk material properties. Every set of severity factors contains a questionnaire-type questions which, depending on the answer, will result in points that will be accumulated for the hazard banding. When a property is unknown, 75% of the maximum points for that property will be allocated.

LICARA Nanoscan has a different characterization approach. It provides risk benefit/analysis but not a definite risk categorization. The risks score is shown on a scale with 0–0.33 being low risk, 0.33–0.67 being medium risk, and 0.67–1 being high risk. LICARA Nanoscan assumes the worst-case scenario when a question is not answered or the detail is unknown.

Finally, the NanoSafer approach for hazard assessment first takes into account whether the nanomaterial has a high aspect ratio, in which case the highest hazard is attributed. Other factors, such as the surface modification and the OEL for the analogous material, also contribute to the designation of a hazard factor that will be later used in the calculation of the hazard score. Finally, additional input physicochemical information asked by NanoSafer includes the dimensions, the specific density, the specific surface area, powder dustiness, and, most importantly, the hazard sentences. The hazard assessment of NanoSafer incorporates accumulative sum of the hazard score from the hazard sentences found on the safety data sheet of the nanomaterial.

4.2. Exposure banding

The exposure characterization for the ISO tool also follows a tiered approach which results in a decision tree. However, unlike hazard banding, there are several decision trees available, and one must select the most relevant one depending on the physical state of the NPs (embedded in a solid matrix, dispersed in liquid suspension or as nanopowders) or based on the manufacturing process. The endpoints will be given in exposure bands 1–4, where 4 represents the highest exposure probability. Similarly, the banding of the emission potential for ANSES tool depends largely on the physical state of the nanosubstance where aerosols would result in the highest emission potential.

The exposure banding for the Stoffenmanager Nano comprises different factors, each with its own reference table. The factors taken into account for the exposure include information about the substance, handling, location of the emission (near field or far field), local controls for the emission source, dispersion/transmission conditions, receptors (present of personal enclosure and/or protection equipment), background exposure, duration, and frequency. Stoffenmanager Nano requires, by far, the most extensive input parameters in order to determine the exposure band, specifically 26 inputs in total [90].

For the exposure estimation of the Imec tool takes several factors into account, including the localization (far or near field) and duration of the manipulation involving the ENM and the amount used. The exposure banding for the CB Nanotool assigns scores based on different probability factors related to the manipulation and scenario which involves the nanomaterial of interest. A maximum probability score of 100 can be summed based on the answers given to the questions pertaining to the probability factors. An unknown answer will result in a 75% allocation of the maximum point for that probability factor.

The exposure characterization for NanoSafer is calculated using the emission rate, the default activity energy factor, and the mass flow/amount used in the process. Both the convection and the rate of ventilation are taken into account for the near-field and far-field model calculation [85].

4.3. Control banding

The output of a control banding tool is a recommended set of measures which reduce the potential of exposure. For example, the ISO standard provides the following groups:

Control Level 1. Natural or mechanical ventilation.

Control Level 2. Local ventilation—extractor hood, table hood, etc.

Control Level 3. Enclosed ventilation—fume hood, biosafety cabinet, ventilated booth, etc.

Control Level 4. Full containment (continuously closed systems).

Control Level 5. Full containment and review by a safety specialist.

Some tools, for example, LICARA Nanoscan, only provide a decision support scheme (whether to continue with this nano-product or not) or, such as Stoffenmanager Nano, only give prioritization on the task of concern.

4.4. Comparison of the input parameters of used control banding tools

The hazard parameters of so-described tools are summarized in **Table 5**. All control banding tools required the primary particle diameter of the NP, solubility in water, and the fibrocity/aspect ratio. Most tools demand the CMR and toxicity information but differ in whether this information should be taken from the the nano- or the bulk form. This highlights the fact that risk assessment is a very dynamic process that can always change depending on the availability of data and that different control banding tools should be compared for the process of interest to have a well-rounded risk assessment.

Among all control banding tools presented here, the approach of Imec took into account the most physicochemical properties in order to assign hazard bands with a total of nine physicochemical parameters as inputs. On the other hand, the ISO standard recommends collection of much more parameters for future use. In view of the information presented so far, this can be considered as a shortcoming since most of the prescribed parameters are not readily available in the material specifications and safety data sheets.

For the case of toxicological information, no single property is shared by all control banding approach. The CB Nanotool required most toxicological information with a total of up to 12 input parameters, while the ANSES control banding approach required just one. Interestingly, not all CB tools agree on the question of whether toxicological information is needed from the nanoform or from the bulk form. The ISO standard and the CB Nanotool required both the nanoform and the bulk material toxicological information in order to assign a hazard band. This is unrealistic for the state of the art at present.

The Stoffenmanager Nano and LICARA Nanoscan only require the nanoform toxicological information, while the Imec approach, NanoSafer,and the ANSES CB tool only require toxicological profile of the parent form. According to the 2016 evaluation report of OECD, the CMR properties as well as the acute, subacute, chronic, or specific organ toxicity are rarely known

Parameter	ISO	ANSES	NSM**	Imec	Nanotool	LICARA	NanoSafer
	Physicochemical parameters*						
Reactivity/surface chemistry		Y		Y (bulk)	Y	Y	Y
Aspect ratio/fibrocity	Y	Y	Y	Y	Y	Y	Y
Particle diameter	Y	Y	Y	Y	Y	Y	Y
Solubility	Y	Y	Y	Y (bulk)	Y	Y	Y
Biopersistency		Y		Y (bulk)			
Dispersion capacity				Y (bulk)			
Aggregation/agglomeration				Y			
Physical form				Y			
	Toxicological parameters*						
Dermal			Y		Y	Y	Y (bulk)
Acute	Y		Y		Y	Y	
Acute, bulk	Y	Y		Y	Y		Y
CMR, bulk				Y	Y		Y
CMR	Y		Y		Y	Y	

*Concerning nanoform if not stated otherwise.

**NSM, Stoffenmanager Nano; ISO, ISO Technical Standard ISO/TS 12901-2:2014 "Nanotechnologies—Occupational risk management applied to engineered nanomaterials"; CMR, carcinogenic, mutagentic, and reprotoxic.

The number of hazard parameters required to completed the ISO tool is less than those of the approach of Imec and the CB Nanotool but still more than those of ANSES and Stoffenmanager Nano. The total number of hazard parameters required is the same for the ISO tool as for NanoSafer and LICARA Nanoscan.

Table 5. Summary table of input parameters.

for the nanoforms [41]. Therefore, this implies that users will be more likely to take the unknown penalty while completing the control banding approaches that require nanoform toxicological information which can differ in the degree of conservativeness from tool to tool. For instance, the CB Nanotool assigns 75% of the severity score for unknown information, while LICARA Nanoscan assumes the worst-case scenario in the case where a question is left unanswered.

In conclusion, different CB tools emphasize differently on the parameters taken into account for the hazard characterization. The CB Nanotool requires extensive toxicological information of the nano- and the bulk form, while the Imec approach focuses more on the physicochemical properties of the nanomaterial for the hazard banding assessment.

4.5. The NanoStreeM's tiered risk assessment framework

The NanoStreeM consortium derived a list of activities that can potentially cause the release of nanoparticles [91]. Described activities include, among others, processes from the operation and cleaning and maintenance of certain processing tools. Based on this survey, the consortium further developed a guidance for performing nano-risk assessment for the semiconductor

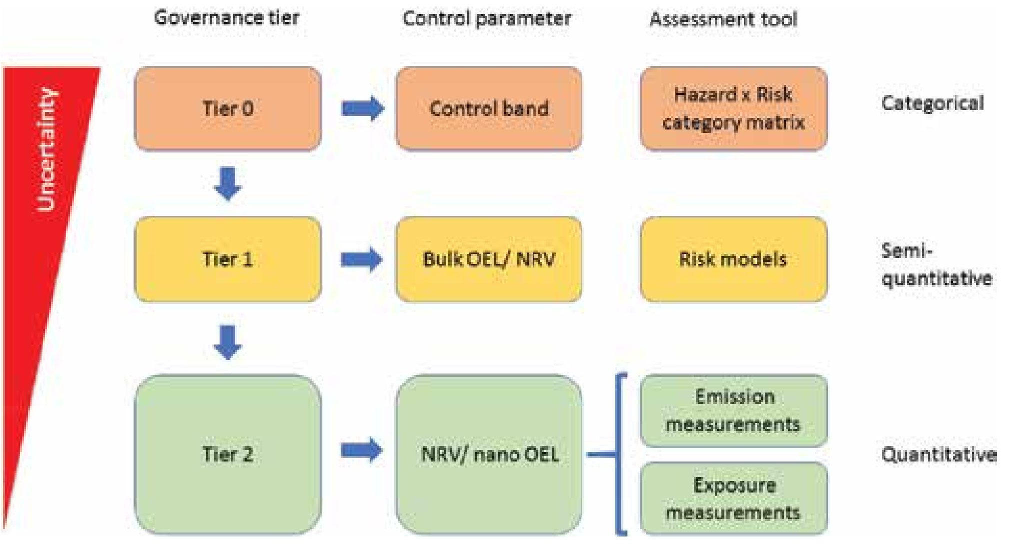

Figure 1. Generalized tiered risk assessment approach.

industry (Deliverables 3.1, [4]). The framework proposed a tiered approach, based on the principles of prior OECD work, to identify specific scenarios or tasks that warrant further detailed risk assessment. According to the guidance prior to the start of the risk assessment, characterization information of the substance, the toxicological information, and the use scenario should be well described. On the other hand, performing complete physicochemical characterization and toxicological studies of the nanomaterial is not always feasible or desirable since the results are not likely to be applicable in other contexts or settings as well as being costly and time-consuming. Therefore, there is a need for flexible frameworks that can give the user a focusing point onto which task or use scenario most urgently requires further hazard and exposure characterization.

The initial tiered approach framework can be further generalized (**Figure 1**) as to include future versions of so-described risk assessment tools or even novel sector-specific tools. As the amount and quality of information improve, the risk assessment can gradually proceed from control bands to NRV and finally regulatory relevant nano-OELs. This can be achieved following the precautionary principle without compromising the necessary safety measures even if the hazard characterization information is uncertain.

The three tiered risk assessment methodologies can be described as follows:

Tier 0 gives an overall screening of the situation including hazard and exposure assessment. The output is a categorical ranking of prioritization for the subsequent Tiers 1 and 2. As Tier 0 method, the consortium has identified the ISO Technical Standard.

Tier 1 gives a semiquantitative result for the exposure and the hazard assessment to further elucidate the hotspots. Tier 1 consists of application of a risk model, providing refinement of the Tier 0 result in the case of an identified concern. The outcome of this tier is an indicative estimate of the expected exposure (i.e., a NRV) and a prescription on how the exposure can be controlled.

Tier 3 requires the use of actual exposure measurement or toxicological data for risk assessment. Tier 2 consists of designating of specific monitoring and control strategies for the exposure or emission of nanomaterials, which validates or refutes the estimate of Tier 1 and also refines the identified control strategies.

5. Conclusions

This chapter provides an overview of several control banding tools for risk assessment of ENM. Their application to semiconductor production processes has been presented as a preliminary use case in view of the information collected in the NanoStreeM project. While the page count limitations do not allow for thorough overview of nanoparticle toxicology, identified gaps in the state of the art demonstrate the main advantages and limitations of the different control banding tools. Substantial knowledge gaps can be identified for even widely used by the industry ENM, such as CeO_2 and Al_2O_3 nanoparticles. The situation is even worse for materials with promising nanoelectronic applications, such as CNTs and graphenes. Furthermore, it was found that the ISO Technical Standard ISO/TS 12901-2:2014 needs further clarification in order to improve its usability. The presented NanoStreeeM generalized tiered risk assessment approach allows for the use of different, possibly even sector-specific tools, in combination with emission or exposure measurement field studies.

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List of acronyms

CB	control canding
CNT	carbon nanotube
CMOS	complementary metal-oxide-semiconductor
CMP	chemical mechanical planarization, chemical mechanical polish
SWCNTs	single-walled carbon nanotubes
DWCNTs	double-walled carbon nanotubes
MWCNTs	multiwalled carbon nanotubes

http://dx.doi.org/10.5772/intechopen.76567

ENM	engineered nanomaterials
NP	nanoparticle
GO	graphene oxide
CMR	carcinogenic, mutagentic, and reprotoxic
QD	quantum dots
ROS	reactive oxidative species, reactive oxygen species
OEL	occupational exposure limit
OECD	Organization for Economic Co-operation and Development
NRV	nano-reference value

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Impact of Intervention on the Psychological Well-Being of Injured Workers

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Additional information is available at the end of the chapter

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Abstract

This chapter examined the impact of an intervention program on the psychological well-being of injured workers. Data consisted of 4041 injured workers who were insured with Social Security Organization (SOCSO) and participated in the case management rehabilitation program from 2012 to 2015. Psychological well-being was measured using the Visual Analogue Scale (VAS) and Depression, Anxiety and Stress (DASS) consisting of seven and three components, respectively. The assessments were conducted before commencement and after completion of rehabilitation. Results showed significant improvement in all 10 components of VAS and DASS. Workers registered higher scores on skills, career goals, independence, self-esteem, confidence, health condition and pain tolerance in the post-intervention assessment while significant reduction was observed in the level of depression, anxiety and stress. This improvement suggested the importance of a structured disability management program in enhancing the quality of life and motivation for workers to return to work.

Keywords: intervention, case management, injured workers, psychology well-being, return to work (RTW)

1. Introduction

The trauma of work related injuries and occupational diseases as well as associated emotional stress due to physical impairment and social-psychological conditions may affect the workers' behavior and ability to perform job functions in the workplace. Some injuries result in temporary disablement while other more serious injuries may result in permanent impairment or a morbid condition which requires a long-term medical care. Permanent loss of capacity to work will lead to a permanent loss of income support for the workers and their families that could be detrimental to their emotional and psychological wellbeing. Injuries and illnesses are costly to employers as a result of reduced employee productivity, loss of working days, compensation and cost of hiring.

The increasing pressure and cost of work related injuries and illnesses to the workers, employers and societies has increased the demand for comprehensive and intensive rehabilitation programs that are effective in helping injured workers to return to work. Depending on the type and severity of injury and illness, the process of recovery and rehabilitation may require not only medical treatment and physical therapy, but also sessions of counseling and behavioral therapy. It has been shown that even partial impairment severely erodes employment opportunities for workers and that people with disability find it difficult to obtain employment [1].

It is well recognized that structured post-injury intervention programs such as rehabilitation programs, psychosocial interventions, case management and workplace-based return to work strategies can bring positive outcomes to injured workers. While there are many factors influencing the success of any intervention program including injury related factors, individual worker's attitude, family and workplace support, to a large extent these intervention strategies have improved injured workers' general health condition, reduced the duration of work disability and helped injured workers to return to work [2, 3]. It has also been shown that early intervention would lead to early return to work and better overall well-being of workers [4].

Past studies have examined the factors associated with injured workers' abilities to return to work which include demographic, injury-related, prognostic, psychological and psychosocial factors, the role of stakeholders and return to work coordinators [3, 5–11]. For example, Seyedmehdi et al. [5] explored the determining factors that may affect return to work after disc herniation surgery and found that positive expectations about the outcome of surgery, encouragement by the physician, job characteristics and job satisfaction have direct effects on the return to work. Similarly, Li-Tsang et al., Eggert and Gustafsson et al. [3, 7, 11] indicated the importance of psychological factors and self-perceived capacity in ensuring the successful return to work of injured workers. Recognizing the complexity in return to work processes and outcomes, Jetha et al. [12] applied a sociotechnical systems perspective in particular system dynamic modeling to examine the relationships between individual, psychosocial and organizational factors and its influence on return to work. Additionally, Cancelliere et al. [13] performed a synthesis of systematic reviews to identify factors affecting return to work across different health and injury conditions and their associations with return to work outcomes. While the focus of previous studies was on the factors related to return to work, the present study examines the effect of an intervention program using a case management rehabilitation and psychosocial approach on the psychological wellbeing of the injured workers.

2. Data and methodology

Data for this study were extracted from the Social Security Organization (SOCSO) database comprising injured workers who participated in the rehabilitation program from 2012 to 2015. Individual record includes information related to the worker's demographic profile,

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employment, injury, rehabilitation, outcome of the program as well as the psychosocial measures before and after completion of the rehabilitation program. The psychosocial assessment is based on the Visual Analogue Scale (VAS) and the Depression, Anxiety and Stress Scale (DASS). The DASS is a set of three self-report scales designed to measure emotional states of depression, anxiety and stress among adults [14, 15]. Each component of DASS contains three items giving a total of 42 items. A shorter version of DASS is DASS21 which contains 21 items, seven items in each component. In general the full DASS is often preferable in clinical work while DASS21 is used for research purposes.

The items in DASS21 were selected based on good factor loadings, coverage of all subscales within each scale and item means such that DASS21 scores for each scale should be very close to exactly half the full scale score. Hence DASS21 scores are multiplied by 2 so that they can be compared to the DASS normative data and other published DASS data [15].

The variable of interest is the VAS and DASS21 scores measured before and after rehabilitation of the injured workers. The VAS contains seven components which include worker skills, career goals, independence, self-esteem, self-confidence, health and tolerance for pain measured on a range of 0–10 point scale with value 0 referring to the minimum level experienced and 10 the highest level experienced. For example, for item independence, a score of 9 indicates a higher level of independence than a score of 4 as reported by the participants.

The DASS21 consists of three components namely depression, anxiety and stress each containing seven items measured on a 4-point rating with values ranging from 0 to 3. The value 0 refers to the item 'Did not apply to me at all', 1 refers to 'Applied to me to some degree, or some of the time', 2 'Applied to me to a considerable degree or a good part of time' and value 4 refers to 'Applied to me very much or most of the time'. The DASS21 scores were then multiplied by 2 to obtain the full DASS scores for purposes of analysis. The DASS scores range from 0 to 42 with recommended cut-off scores for conventional severity levels shown in **Table 1**.

The analysis was based on 4041 participants who had information on the VAS and DASS scores both before and after rehabilitation representing 42.6% of the total sample at the commencement of intervention. Paired tests were performed to examine the mean differences in the psychosocial factor assessment before and after rehabilitation program for the total sample as well as for those who were successful and unsuccessful in returning to work.

	Depression	Anxiety	Stress
Normal	0–9	0–7	0–14
Mild	10–13	8–9	15–18
Moderate	14–20	10–14	19–25
Severe	21–27	15–19	26–33
Extremely severe	28+	20+	34+

Source: Lovibond and Lovibond [12].

Table 1. Cut-off DASS scores for conventional severity levels.

3. Social security organization (SOCSO) rehabilitation program

SOCSO is a statutory body established under the Ministry of Human Resources Malaysia in 1971 in accordance with Employees' Social Security Act 1969. It is mandatory for Malaysian workers earning RM4000 and below to monthly contribute to SOCSO together with their employers. SOCSO administers the Employment Injury Insurance Scheme and the Invalidity Pension Scheme by providing comprehensive social protection in the form of medical, cash benefits and rehabilitation to insured members due to work related accidents or illnesses. However, intensive rehabilitation program was only introduced in 2007 through a biopsychosocial case management approach designed to assist injured workers to return to work in a safe and timely manner. Case management strategy was adopted such that each injured worker is first screened for suitability of rehabilitation and subsequently assigned to one case manager who will facilitate the customized intervention program which integrates all multidisciplinary services. Hence, the rehabilitation for one injured worker involves a case manager, medical and rehabilitation professionals and may take from a couple of weeks to a few months. All these take place at SOCSO Rehabilitation Centre which has a 350 bed facility providing medical rehabilitation services and focuses on areas such as physiotherapy, occupational therapy, optometry, audiology, work hardening, vocational rehabilitation, vocational retraining and job-readiness program. The SOCSO disability management program is designed with one goal in mind and that is to promote the highest degree of independence, recovery and improving well-being in order for an injured worker to be placed back into the job market. Since its introduction to end of 2015, nearly 13,000 injured workers have been rehabilitated and successfully returned to work.

4. Results

The mean DASS scores before and after rehabilitation for the three components are shown in **Figure 1** suggesting that injured workers did suffer mild depression and moderate level of anxiety before the commencement of their rehabilitation. However their mean stress score

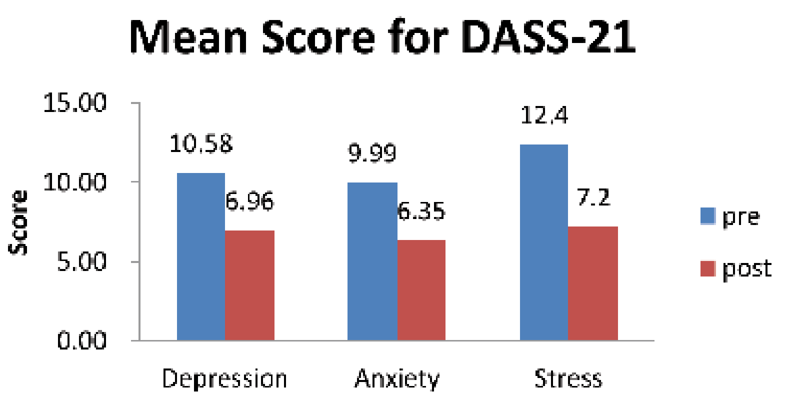

Figure 1. Mean DASS scores before and after rehabilitation.

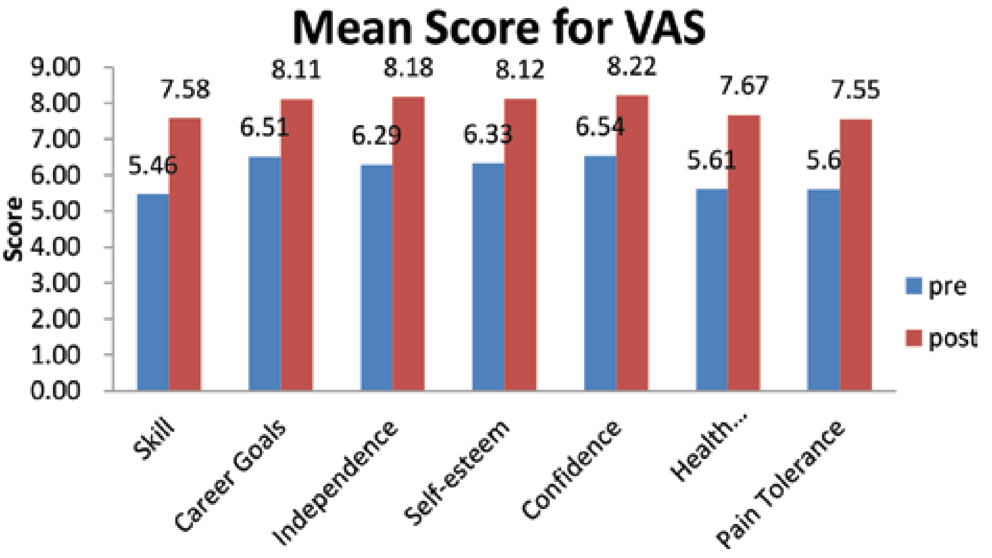

Figure 2. Mean VAS scores before and after rehabilitation.

was within the normal range. The mean scores for depression, anxiety and stress decreased substantially to within its respective normal level range after completion of rehabilitation.

Similarly, substantial improvement is observed with regard to the mean score for the seven components of VAS after completion of rehabilitation. Each of the components which consists of skills, career goal, independence, self-esteem, confidence level, health condition and tolerance of pain showed a mean score between 5.5–6.5 and 7.6–8.2 before and after rehabilitation, respectively (**Figure 2**).

Paired tests were performed on the mean difference between the mean scores before and after rehabilitation for all the 10 components of DASS and VAS assessment (**Table 2**). The mean

Variable	Mean difference	95% Confidence interval	t-Statistic
Skill	2.117	2.048–2.186	60.301**
Career Goal	1.597	1.530–1.665	46.245**
Independence	1.889	1.821–1.956	54.943**
Self-Esteem	1.786	1.720–1.853	52.687**
Confidence	1.687	1.621–1.753	50.053**
Health Condition	2.059	1.991–2.126	59.611**
Pain Tolerance	1.945	1.874–2.015	54.171**
Depression	−3.619	−3.943–−3.294	−21.879**
Anxiety	−3.639	−3.950–−3.329	−23.005**
Stress	−5.195	−5.519–−4.871	−31.459**

** Significant at 1%

Table 2. Mean difference of VAS and DASS scores before and after rehabilitation.

Variable	Successful return to work			Unsuccessful return to work		
	Mean difference	**n**	**t**	**Mean difference**	**n**	**t**
Skill	2.196	3807	61.045*	0.537	190	4.854*
Career goal	1.670	3821	47.446*	0.112	187	0.825
Independence	1.965	3836	55.668*	0.433	201	3.980*
Self-esteem	1.854	3834	53.266*	0.488	201	4.198*
Confidence	1.753	3839	50.743*	0.436	202	3.493*
Health condition	2.139	3831	60.386*	0.527	201	4.836*
Pain	2.026	3821	55.005*	0.419	203	3.560*
Depression	−3.990	1441	−22.658*	−0.450	169	−1.116
Anxiety	−3.966	1463	−23.621*	−0.778	167	−1.904
Stress	−5.572	1808	−32.153*	−1.160	169	−2.659*

* Significant at 5%

Table 3. Mean difference in DASS and VAS scores for successful and unsuccessful return to work.

difference was statistically significant for all 10 components suggesting that the rehabilitation had improved the injured workers' psychosocial and psychological wellbeing.

Subsequently, separate analyses were performed on the DASS and VAS mean scores among injured workers who participated in the rehabilitation and successfully returned to work and among those who did not return to work. The results shown in **Table 3** indicates significant mean difference is observed in all 10 components of DASS and VAS scores among injured workers who successfully returned to work. Among those who did not return to work, significant difference is observed in all but one VAS scores while for the DASS, only stress showed significant improvement in the workers' stress level after rehabilitation.

5. Discussion

Workers who experience work related injuries and illnesses do not only suffer from physical health problems but to some extent also suffer from psychological and mental health problems. This study examined the impact of a case management rehabilitation program through a biopsychosocial approach on the psychological wellbeing of injured workers as measured by the VAS and DASS assessments containing seven and three components, respectively, before and after rehabilitation.

The findings showed statistically significant difference between the mean scores before and after rehabilitation for all the seven components of VAS and three components of DASS. This suggests that the rehabilitation had improved the level of the workers' skills, career goal, independence, self-esteem, confidence, health condition and pain tolerance, as well as reduced the level of depression, anxiety and stress. The improvement in the VAS and DASS scores after rehabilitation is an indication of the improvement in psychological wellbeing and quality of life which in turn improve the workers' motivation and readiness to return to work.

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Substantial difference in the improvement in psychological wellbeing was observed between injured workers who successfully returned to work after completion of the rehabilitation program and those who did not return to work. It could very well be that workers with larger improvement in the VAS and DASS assessments were more likely to succeed in returning to work. Majority of SOCSO's insured workers who returned to work actually went back to the same employer and the improvement in their psychological wellbeing could be motivated by their former employers' interest to accept them back while they were undergoing rehabilitation. Work itself is a form of therapy which would further improve the workers' overall wellbeing. For workers who did not return to work, there could be other hindering factors such as the severity of the injury and the nature of their jobs prior to the injury that restricts them from returning to a suitable job after rehabilitation. However, substantial improvement was also observed in their VAS and DASS scores.

6. Conclusion

In conclusion the findings from this study suggest that a structured intervention program such as a case management rehabilitation program had significant qualitative impacts in improving several aspects of the workers' psychological wellbeing and quality of life. This will provide the motivation to not only prepare injured workers to return to work but more importantly to help them to adjust better and ensure sustainability in their post-rehabilitation work life.

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Conflict of interest

The authors have no conflicts of interest to declare.

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Chapter 5

Socio-Cultural Practices and Health and Safety Behaviors Among Ghanaian Employees

Kwesi Amponsah-Tawiah

Additional information is available at the end of the chapter

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Abstract

This paper highlights some pertinent issues regarding the effects of socio-cultural practices on the health and safety behavior of Ghanaian workers. These practices tend to unimaginably flout occupational safety rules in organizations but are unfortunately given little attention. Employers must therefore take cognizance of the fact that any attempt at controlling and eradicating the negative effects of occupational hazards or accidents would prove futile if the issues of socio-cultural values that control workers' behavior are trivialized. Thus, it is incumbent on managers and policy makers to focus their attention on the socio-cultural environment of developing countries if strategies aimed at improving work practices are to be successful.

Keywords: socio-cultural practices, occupational health and safety, Ghana

1. Introduction

The conflict between bureaucratic processes and socio-cultural practices among Ghanaian workers poses a challenge to effective management of health and safety of employees. This follows from the point that, the welfare of the human resources in every organization is of primary importance and thus, "in so far as people are employed, the concern for people exists, however inarticulate it may be" (Lyons, 1971: 143 cited in [2]). Tyson and Feli [32] and Annan [7] further emphasize the need for employers and Human Resource Managers to rethink their roles, in order to overcome the difficulties inherent in their positions—workers' safety being the ultimate.

The rate of industrialization in Ghana is on the ascendancy and this has predisposed a large percentage of the Ghanaian workforce to physical (i.e. noise, fall from heights, equipment/material falls, vibration and barometric pressures from drilling and boring equipments, etc.) chemical (i.e. toxic chemical spills, wielding fumes, asbestos dust, lead fumes and particles, etc.) biological (bacterial infections from sharing PPEs, allergic reactions from building materials, lung infections caused by soil fungi, etc.) and psychological stressors (i.e. abuse from supervisors, effects of depression, anxiety and sleep disorders etc.) at the workplace [22, 34]. Unfortunately, there seem to be inadequate systems for anticipating, monitoring, controlling and preventing such exposures to the workforce. Between 2012 and 2016, various parts of Accra has seen massive fire accidents across various gas and fuel stations leading to the loss of hundreds of lives and damage to property to sums running into millions of Ghana cedis, mainly due to human error and negligence. Asumeng et al. [8] attributes this to the appalling safety culture in the country which leaves the country to the devastating effects of major disaster and accident which could have been anticipated and addressed earlier.

Employers in Ghana are required by the Labour Act [18], (Act 651) to ensure that their employees are not exposed to conditions that would lead to work related injuries or illnesses. Employees on the other hand are required to execute their roles as per their employers' standard operating procedures which employers are mandated to incorporate safety and health requirement in the organization [23].

However, employees, individually and collectively can also compromise their own safety by acting unsafely. This is inherently due to a combination of the 'macho culture' exhibited by many Ghanaian workers, the collectivitist nature of the Ghanaian society and the lack of enforcement of health and safety laws and policies by management [17]. Many companies lack health and safety facilities, and although there are laws binding Occupational Health and Safety (OHS) across various Acts and Legislative Instruments (LI), the environment and sanctions regime make their enforcement difficult [6, 4]. Adei and Kunfaa [1] and WIEGO [34] point to some of these challenges in Ghana, including the lack of commitment by managements and government to implement and enforce OHS laws and policies; lack of OHS education by management leading to the lack of awareness levels of laws and regulations among employees. This assertion is further corroborated by Kheni et al. [17] who identified the Factory Inspectorate lacked personnel, resources and the enabling environment to effectively enforce OHS laws, and investments in OHS education for employees was very low.

In addition to the above, socio-cultural practices can also be an impediment to attaining healthy living conditions among workers. Akuoku [2] defines socio-cultural practices as the distinctive, spiritual, material, intellectual and emotional features that characterize a society or a social group. Individuals generally hold onto these at all times irrespective of the environment they find themselves. This, perhaps, explains why socio-cultural issues remain dominant in the behavior of most employees in Ghana. These practices include a tendency to ignore conventional organizational safety rules, hence have become one of the major problems in Ghanaian organizations, and which can threaten health and safety of workers [8]. Consequently, employees who find their socio-cultural values to be overruled by new organizational rules try to defend their already held beliefs at the expense of organizational rules. Though there has been rapid rate of modernization in the twenty-first century global economy, the rigid nature of Ghana's socio-cultural and traditional values still remain a setback. Ghanaian workers, whose socio-cultural values and traditional norms contravene the organizational code of conduct face the dilemma of accepting OHS rules that are in direct contrast with their belief systems [2, 3]. These attitudes result in increased OHS problems for organizations. Lahey [19] investigated health and safety issues existing in construction sites in Ghana and found that only three (3) of the twenty three (23) investigated areas recorded marks above the 50% in relation to standard health and safety procedures measured, especially in the wearing of safety equipment. He found that these procedures are trivialized in Ghana and many developing countries. This could contribute to the increased occupational accidents and incidents in the country. These accidents have generally been associated with unsafe work environment in most cases [10, 13, 22]. However, little attention has been given in extant literature to the socio-cultural context and the role they play in OHS. This chapter is our attempt to address this gap.

It is our argument that the problems of OHS in developing countries cannot be considered in isolation of the external environments within which workplace practices are embedded. It has therefore become expedient to probe into the area of socio-cultural practice and OSH to illuminate some negative effects of practices that emanate from these values in the workplaces in developing countries, especially Ghana.

2. Literature review

2.1. Socio-cultural factors that affect OHS behaviors of employees in Ghana

Given the importance of the external environment of businesses, research into OHS should also focus on the issues in the external environment that has the potential of affecting employee behavior in addition to the over-reliant internal work environment. Indeed, there is a link between culture and the external environment as clearly postulated Hofstede's [15] definition: "*Culture is the interactive aggregate of common characteristics that influence a human group's response to its environment*" (p. 10). Other studies conducted by sociologists such as Hofstede [14] and Schein [28] show that organizations are inherently culture bound. This supports the view that the cultural environment (especially, external) is an important aspect which cannot be overlooked when developing safety policies for the workplace, primarily because every organization is a microcosm of the society in which the find themselves and thus their internal processes are likely to be significantly impacted by the societies norms and values. Rwelamila et al. [26] study of poor project performance in Southern African countries found that failure to consider both national and organizational culture in procurement was a key contributor. Casio [9] cited in Akuoku [2] noted that machines and work environment have been the major causes of safety hazards. However, most employees were less concerned about safety precautions at work, their cost, effect and benefit to themselves and the organization [24]. This indicates ignorance and negligence to safety measures and regulations instituted by organizations.

According to Schulte et al. [29], socio-cultural factors predisposed workers to an array of occupational ill-health which could lead to occupational diseases. Sense of community, organizational cultural differences, and traditional beliefs in death and the power of the talisman tend to be some of the critical socio-cultural issues that are mostly overlooked by most employers and poses serious negative consequences for the individual, colleagues and the organization as a whole [35].

2.1.1. Sense of community

Socio-cultural diversity concerns aspects of culture that can influence an individual's interactions with others of different backgrounds. Furthermore, it can influence how individuals respond to management demands, operational requirements and company policies, or what could be summed up as the organization's culture. Diversity will exist between employees' ethnicities, religious beliefs, social backgrounds, training experiences, and union membership, to mention a few. Thus employees belong to the same social background or union membership hold on to beliefs and practices without caring much about organizational rules that seem to contradict their belief about oneness. Zohar [36] cited in Cudjoe [10], explained that group-level climate perceptions reflected shared patterns of practices rather than isolated supervisory actions. This may explain how some workers flouted safety rules that affected their group behavior. For instance, it is a common practice to find workers at a construction site in Ghana sharing the same drinking cup and going in turns for water while working. This behavior illustrates a sense of community that makes them feel accepted by that group of workers. They feel some sense of belongingness doing all these together, not taking cognizance of the associated biological hazard [10]. Those who refuse to follow such examples can be regarded as outcasts and individualistic. Some workers, in their attempt to appear as team players, compromise their health, by joining in group actions in order to feel belonged, irrespective of the health issues.

These behaviors are more prevalent in industries such as the mining, construction, manufacturing, energy, transport and food processing, noted for occupational incidents and accidents. For instance, Asumeng et al. [8] noted that it is common to see male commercial drivers refusing to wear their seat belts because of the simple belief in acting like 'men' – a cultural presumption that a man should be fearless despite looming dangers; unlike their female counterparts who drive with trepidation on the road with the fear of encountering accidents. The same applies to those who drive and ride in pickup trucks especially may think that their large vehicles will shield them from road accident, unlike the smaller cars. This false sense of security may lead them into not wearing their seat belts. However, the statistics shows that this perceived bravado is misplaced and usually followed by the occurrence of fatal injuries during road accidents [8].

2.1.2. Traditional beliefs

Some traditional beliefs such as belief in the power of the talisman mostly upheld by some workers who would not allow for the erosion of their cultural identities, some of which being the belief in the potential power that emanates from their locally produced talismans may serve as an impediment to OHS policies that serve to substitute their previously known protection equipment [2]. These workers, some of whose cultural heritage lead them to believe in the power of these talismans can find it difficult altering their states of thinking into believing otherwise (such as protection from the adherence to OHS policies). The rigid nature of some cultural values in Ghana contribute to low compliance with the safety management procedures in organizations. Beads, talismans and some jewelleries are believed by some societies to offer protection to individuals in their day to day activities [2]. Some workers prefer wearing these artifacts to wearing protective equipment at the workplace. The artifacts are believed to enhance the spiritual powers, bring luck and protect the wearer from danger and harm, and also to strengthen the connection with the spiritual world (Doney, 1996:4). In so far as the wearer holds onto this belief, he/she sees no need in seeking necessary protection from the personal protective equipment provided by the organization. This attitude is a major cause of many accidents and incidents among workers, especially in developing countries such as Ghana.

Another traditional value desperately held onto by some worker is the simple belief in death being predestined. The simple thought that death is preordained, and the fact that one cannot fight fate, heightens the nonchalant attitude concerning safety precautions at the workplace [27]. Individuals believe one's destiny (good or bad), occurs at different alternate timelines; and therefore unwise for anyone to attempt changing fate, since fate does not take kindly to having it's hand forced; it should operate freely without any interference. Why then should a worker use protective equipment to avert any unforeseen calamities they have been destined to meet? As a result of this belief, majority of Africans (especially Ghanaians) see death as an inevitable incident when one's 'number comes up'; thereby trivializing OHS issues. For instance, in the Akan dialect, a commonly held adage that "Se Nyame ennkuwo a wo nwu", to wit 'one is not destined to die until God kills him/her', seems to dictate the behavior of some workers. When prompted by other colleague workers about the unsafe work practices, some go to the extent of asking "who am I to change fate when God says I will be dying or having accident tomorrow?" They believe no behavior or practices are likely to kill or harm them unless their time is "ripe". Many Ghanaian workers hold on desperately to this belief, unaware of the likely consequences of these thoughts that lead to unsafe work behaviors. These are the people, who according to Lahey [19], 'need to be forced before adhering to safety rules and procedures in organizations'.

2.1.3. Organizational cultural differences

Employees who have experienced working with different organizations in the past, and their ways of doing things influenced by their past will usually "carry" with them values, beliefs and practices that may differ from those shared by their current employers. In terms of occasional variations in the application of skills and/or procedures, this can happen habitually from learned behavior. Reversion to past practices can endanger safety at moments of critical stress and importance. The same process can occur with how much an employee values certain tasks and the factors they use to prioritize as well as importance placed on those tasks. This organizational cultural baggage, from a person's past, can be an invisible socio-cultural latent trap for employees, which may have serious health and safety repercussions.

Organizations that fail to identify cultural differences of new employees are exposed to high risk of work place incidents and accidents.

2.2. Theoretical backbone

The work of the sociocultural theory amply explains how individual mental functioning is related to cultural, institutional, and historical context; hence, the focus of the sociocultural perspective is on the roles that participation in social interactions and culturally organized activities play in influencing the individual.

2.2.1. Cultural-historical activity theory

The Activity theory or cultural-historical activity theory propounded by Vygotsky [33] is a cross-disciplinary framework for studying how humans purposefully transform natural and social reality, including themselves, as an ongoing culturally and historically situated, materially and socially mediated process. Rooted in the dialectical psychology of Vygotsky [33] and Leontiev [21], this perspective transcends traditional dichotomies of micro and macro, individual and social, as well as agency and structure by integrating three perspectives: the objective, the ecological, and the socio-cultural [11].

An essential feature of activity theory is the recognition of subject, community, and other features of cultural practice as constitutive moments of activity. According to Vygotsky [33], a human individual never reacts directly (or merely with inborn reflects) to environment. The relationship between human agent and objects of environment is mediated by cultural means, tools and signs.

Development as a self-regulated meaning making process driven by goals and motives in which individuals or groups of individuals choose to participate [20], includes both mental and physical enactments of the activities that are interlaced throughout an individual's meaning making process. Within an activity, the events that occur and the consequences the participants experience can qualitatively change the participant's goals and motives for participation, the environment, and the activity itself [16]. It is further believed that the activity performed, holds cultural formations with its own structures (Engestrom & Miettinen, 1999; [20]). Thus, individuals who find themselves as participants of any cultural formation process find it binding on them, and therefore failure in adhering to this cultural norm is seen as despicable.

The above explains why employees who have previously accepted and embraced specific cultural beliefs in their societies feel reluctant giving up those practices for any organizational safety rules that seem to contravene these beliefs and practices. Cole and Engestrom [11] agreed that as an activity is institutionalized, it becomes a robust and enduring tool within the culture. Hence, workers who see the act of drinking from same cup with others as a sign of love and unity, are more likely to resist organizational rules that frown on this act. They therefore will prefer acting according to their belief systems no matter what. They believe in the assumption that an individual who calls him/herself as part of a group or society must act according to the society's code of conduct in order to fit into that group. Hence, the implication of the common phrase "walk your talk", where their actions prove their belief systems, instead of blurting out loudly to belief but no proof in actions. Same applies to those who prefer wearing religious artifacts to any protective equipment. These individuals, due to their cultural beliefs embrace the fact that wearing the artifacts better protect them than any protective equipment provided by the employer. They find these practices as binding on them, provided they still find themselves as recognized members of that group or society. These practices confirm Vygotsky's [33] assertion that the relationship between human agent and objects of environment is mediated by cultural means. One's behavior or attitude is mediated by these cultural factors embraced.

Interestingly, workers refuse to change their socio-cultural beliefs and practices even after the repercussions of their actions. They simply believe it was bound to happen, and no amount of protective equipment or occupational rules could have stopped that incidence from occurring. They refuse giving in to those practices, forget the incident or accident and move on, believing it was for the best. Changing these strongly held beliefs and assumptions according to Cole and Engestrom [11] is a very difficult and daunting task as a result of the group behavior explicated above by Vygotsky's [33] activity theory.

3. Discussion

Human behaviors to a large extent determine the rate of occupational accidents at the work place. These behaviors result from the cultural and social values and norms that an individual wishes to uphold irrespective of the health and safety repercussions at the workplace. Safety is directly influenced by individual's perception and/or attitude towards risk which is impacted by differences in language and culture; and that language, education and cultural differences may be factors that preclude safety activities such as instructions for safe work practices, effective safety meetings and training, and/or correct operations of equipment needed to perform their job [12]. Sociological and anthropological studies according to Slovic [30], have been able to show that the root of risk perception and acceptance of risk at any place form from social and cultural settings. Due to the cultural differences between workers, risk perception on a particular work differs from one worker to the other, which seems to impede the integration of OHS policies into the work environment. Thus, an attitude which one worker may perceive as harmful to one's health may not be the case for another of the same work environment, making the successful incorporation of health and safety policies very challenging.

Consequently, the importance of the cultural environment of developing countries to the practice of safety among workers cannot be over emphasized when analyzing the safety behavior of employees. Indeed, the living and working environments of most workers are mutually inclusive with happenings from the living environment creeping into the working environment and vice versa. However, since the individual's behavior (an embodiment of socio-cultural values) is largely molded by his living environment where he/she acquires a lot of the values that tend to shape human behavior before attaining the formal working age, the values from living environment pre-dominate the individual's behavior even within the working environment. Thus any attempt at devising an answer to the health and safety problems in developing countries is bound to fail if the influence of the socio-cultural environment is not well understood [17]. It is therefore imperative to consider these factors which play very critical roles in the health and safety of workers.

The traditional approach to safety in the workplace used the 'careless worker' model [35]. This is where most organizations and accident prevention bodies postulate that the occurrence of accidents are mainly caused by employees' failure to take safety precautions seriously while on the job [5] These unsafe behaviors are inadvertently informed by the socio-cultural beliefs of employees, which influence their ways of thinking and acting. Yankson [35] posits that these socio-cultural practices expose employees to safety issues such as slipping or tripping on the work floors, machine related issues, exposure to noise, odor, and dust as well as exposure to various chemicals all of which have serious debilitating effect on the health of the worker and productivity of the organization as a whole. Indeed, the socio-cultural beliefs and values of the employee influences his or her safety behavior at work and cannot be ignored in any struggle to maintain sound occupational health and safety practice.

Nuwayhid [24] has argued that health and safety research in developing countries should focus more on the social context of businesses than the businesses themselves. It is therefore an obvious fact that, the workplace can be made safe simply by changing behavior of employees via the integration of socio-cultural beliefs into the health and safety practices and policies of organizations. A simple practice of attaching religious and cultural artifacts on personal protective equipment perhaps will get employees to readily accept the "potency" of the personal protective equipment to indeed protect them against the harsh effects of accidents and incidence. Annan et al. [6] have asserted that effective consultation with relevant organizations will have a positive impact on the successful implementation of the "Expected Ghana National Occupational Health and Safety Policy". These organizations may know and understand the practices and attitudes of their workers, and thereby administering appropriate measures to facilitate the adherence to organizational health and safety management systems in the country without completely reproving of their socio-cultural values. This to some extent can help create peace, understanding and help workers embrace these policies for their own wellbeing, which can help curb the canker of these values that destabilizing the OHS policies of the country.

Managers and policy makers must have a build-in mechanisms in terms of awareness creation to consistently remind workers that the work environment is not different and independent of the living environment. Thus the need to act safely to protect each other and prevent the occurrence of accidents through a sound health and safety practices that takes into consideration the sanctity of the human being.

4. Conclusion

Due to the important role health and safety standards play in occupational accidents and diseases, 'it relies on the cooperation of both employers and employees to ensure a self-generating effort between those who create the risks and those who work with them' [25]. Given the wide range of potential and/or actual undesired events associated with the myriad of work groups in Ghana, there is the need to have a comprehensive provision for occupational health and safety standards and practices enforced in the country. Every business has the legal responsibility of ensuring the health and safety of employees and other people affected by the business activities. Poor health and safety practices lead to illness, accidents and significant cost to the business. Effective health and safety practices pay for themselves and improve the reputation of organizations. It is therefore incumbent on policy makers and law enforcers to highly consider and develop measures to incorporate socio-cultural issues, which appear to be important determinants of health and safety incidents and accidents at the workplace. For instance, the issue of religious fanaticism is one key determinant of workers' behavior in Ghana, which determines their health and safety behaviors of employees. Each group of workers have their own traditions, customs and practices, including dress and behavioral codes determined mainly by religious affiliation. It is very difficult (if not impossible) to persuade the traditional Ghanaian worker to forsake his/her religious code of conduct for occupational health and safety rules.

Morris (2011) asserts that people do not leave their identities, values and sensibilities at the door when they arrive each day at work. They unequivocally preach and practice these values with pride without hesitation. Such workers feel mandated to continually embrace their customs and practices at any place they find themselves. For instance, while workers affiliated to the African Traditional Religions feel mandated to wear religious artifacts for protection, those in the Catholic or Protestant Churches feel inclined to carry Rosaries or Bibles with them for the porous belief of spiritual safety at the workplace [31].

Morris (2011) further posits that in an environment of respect for cultural differences and where work practices and timetables accommodate religious beliefs and activities, there can be discernible benefits for employers and employees. Workers are more likely to cooperate with employers on issues of health and safety since they feel recognized. Though it may be a great challenge for law enforcers or policy makers to try and incorporate socio-cultural values of all workers in their community into the OHS codes of conduct, it is imperative for certain measures to be taken in order not to totally rebuff all these socio-cultural values of workers for the sake of OHS rules; which workers may deliberately flout with impunity. However, inasmuch as possible, OHS policies must be enacted in a way to suit the social and cultural settings within which a worker lives—in this case, Ghana, scholars and experts in the field of OHS must engage stakeholders particularly employers and employees in a form of social dialog to help fashion out policies that take into account the socio-cultural elements of the employees living environment, which inadvertently tend to have a hold on their safety behaviors particularly safety compliance and safety participation.

Indeed, it is of little worth to have a law that no one knows about and no one complies with even when it's known. It is therefore paramount that the laws be made simple and to resonate with the values of the critical stakeholder (employees). The full scale importation of health and safety legislations and practices without recourse to the socio-cultural values of employees will only amount to a "white elephant" with little or no impact on health and safety behaviors.

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The Utility of M-31000 for Managing Health and Safety Risks: A Pilot Investigation

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Additional information is available at the end of the chapter

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Abstract

The management of occupational health and safety (OHS) risks is an important part of any business. ISO 31000 risk management has been suggested to represent the natural standard for integrating OHS risk management into business operations. However, published research on this standard is very limited, so its ability to influence the management of OHS risks is unknown. The aim of this chapter is to report on the first part of the findings of a pilot study aimed at investigating the utility of the ISO 31000 risk management standard for managing occupational health and safety (OHS) risks. A review of the published literature on ISO 31000 is presented first. This is followed by a modified theoretical framework, M-31000, taking into account OHS risk management practice. The results of 42/149 key informants selected as part of a purposive sampling strategy identified three main advantages of ISO 31000, including acting as a good starting point for risk management, supplementing other risk management strategies, and allowing for easier integration with other similar strategies. The two main shortfalls identified in this pilot included the standard being vague and difficult to implement. The study also revealed that M-31000 was much simpler and more consistent with safety management practice.

Keywords: risk management, health and safety risk management, ISO 31000, M-31000, pilot studies, safety management practice

1. Introduction

The effective management of occupational health and safety (OHS) is an integral part of risk management in organisations. More than 2.7 million workers die from work-related accidents and diseases and over 374 million people suffer from non-fatal accidents and injuries [1]. These have increased by 17% compared to a decade ago and are expected to increase further as organisations are challenged by globalisation, advanced technologies, and their increasing complexity [2, 3]. A number of institutional, regulatory, and structural arrangements have been developed and implemented to address the impact of these developments. These include, for example, a strategy for sustainable prevention [4], visions of zero accidents [5], or healthy, safe, and productive working lives [6]. These underpinned a key principle of the United Nation's Universal Declaration of Human Rights, that all workers, regardless of their occupation, have the right to a healthy and safe working environment. At the same time many safety practitioners charged with managing OHS risks are being asked to draw on strategies and measures for achieving simultaneous business objectives of environmental protection, finance, and quality management. The international standard for risk management, ISO 31000: 2009, has also been suggested as providing the necessary mechanism for such integration [7]. However, apart from the guidance notes and supporting documentation, published research on ISO 31000 is limited, so its utility for managing OHS risks remains questionable [8]. A framework for implementing risk management based on ISO 31000 has been proposed for construction projects [9]. However, this has been suggested to be suitable for construction organisations which have a relatively mature approach to risk management, has not been empirically tested outside of construction, and does not take into account practices and approaches used for managing OHS risks [8].

To overcome this, another framework based on ISO 31000 has been proposed [8]. This framework, M-31000, takes into account the key process common to OHS practice. However, it has not been empirically tested or validated. The present chapter reports on the first stage of a research project aimed at investigating the utility of ISO 31000 and M-31000 for managing OHS risks in the Australian industry.

2. Literature review

2.1. The ISO 31000 risk management standard

The International Organisation for Standardisation (ISO) published ISO 31000 in 2009. Titled *'Risk management—principles and guidelines'*, it represented the concerted efforts by a dedicated group of international technical advisors from a range of industries and backgrounds [10]. One of the key aims behind ISO 31000 was to ensure consistency through one vocabulary, a set of performance criteria, a common process, and guidance on how such processes could be integrated in decision-making [11]. As such it has been regarded the gold standard in risk management [12]. Lalonde and Boiral [7] argued that ISO 31000 offered a number of advantages over previously established standards. These included a comprehensive and multi-risk approach to reinforce commitment from leaders in the advance of decisions, ability to integrate the risk management framework into an organisation's existing practices, principles and guidelines to manage poorly understood complex risks, and the ability to adapt the risk management system to specific contexts. However, authors such as Leitch [13] have argued that the terminology used in ISO 31000 was vague or ambiguous, offered minor guidance to managers, and was impossible to comply with. Purdy [11] proposed that some compromise and change was required to address the differences in terminology and its application across different regions and sectors.

ISO 31000 includes five main chapters [14], of interest to this project are the last two: framework and process. These are briefly discussed below.

2.1.1. Framework

ISO 31000 provides a structured framework for managing organisational risks. This includes five main stages, so is an expanded version of the Plan-Do-Study-Act (PDSA) cycle [15]. These stages include (i) mandate and commitment, (ii) the design of framework for managing risks, (iii) implementing risk management, (iv) the monitoring and review of framework, and (v) the continual review of framework [14]. A common framework provides an assurance that proposed organisation-wide processes for managing risks are supported and iterative, have continued to remain effective, and provide the necessary mechanism for integration, reporting, and accountability [10, 11]. It also includes the core supporting organisational structure, mandates, policies, and procedures [16]. The 'framework is not intended to prescribe a management system, but to assist organisations integrate risk management into its overall management system' [14]. Many organisations already have established management systems, such as ISO 9001 (Quality), ISO 14001 (Environmental Protection) or OHSAS 18001 (Safety), so there is an expectation that the key processes used for these can be integrated into a company's risk management framework [8, 17].

2.1.2. Process

Risk management involves a series of integrated and coordinated activities aimed at directing and guiding an organisation in relation to risk; ISO 31000 has summarised these into five main ones, including (i) communication and consultation, (ii) establishment of the context, (iii) risk assessment, (iv) risk treatment, and (v) monitoring and review [8, 11, 14]. Steps (i) (communicate and consult) and (v) (monitoring and review) have been suggested to be continually acting and hence have been suggested to be part of the other three activities [11].

2.2. Published research on ISO 31000

Ciocoiu and Dobrea [18] examined standardisations in improving the effectiveness of an integrated risk management strategy and concluded that ISO 31000 was an appropriate tool for formalising the process and harmonising best practice. Gjerdrum and Salen [19] explored the basics of ISO 31000 and argued that it made risk management a central part of organisational success. Oehmen et al. [20] examined the adoption and application of ISO 31000 in product design and concluded that, while the suggested process was relevant, the published literature addressed different aspects of them to varying degrees, and there was generally a lack of integration between the suggested standards and processes. Gjedrum and Peter [21] compared ISO 31000 with the enterprise risk management (ERM) framework and found that 'establishing the context' and continuous 'communication and consultation' were major differences between the traditional processes of managing risks between the two frameworks. The authors concluded that the main strengths of ISO 31000 were in the identification of risk owners. In construction, Liu et al. [22] examined the practices and challenges of implementing enterprise risk management (ERM) modelled on ISO 31000. This research revealed that the construction organisations generally had a basic understanding of risk management and a relatively clear focus on market and financial risks; most had an established risk management system, and the main means of managing risks involved behavioural control. Dali and Lajtha [12] reviewed how the field of risk management had progressed and used this to compare the strengths and weaknesses of guidance provided on ISO 31000. Sousa et al. [9] integrated operational and organisational strategies to propose an ISO 31000 framework for managing risks in construction projects. Luko [16] reviewed the terminology and language and used the new guidelines as adopted in the United States as ANSI/ASSE Z690.2-2011 and concluded that ISO 31000 provided a good framework for managing quality and business risks through integration. Scannell et al. [23] investigated the supply chain risk management (SCRM) approaches and determined that ISO 31000 included the core steps used in SCRM but included two additional steps and so this was more comprehensive. This research also revealed that companies recognised the importance of SCRM but lacked skills and the ability to integrate these into ISO 31000. And Ariff et al. [24] proposed a framework which integrated the enterprise risk management with ISO 31000 to improve organisational performance in the Malaysian public university system. Collectively, these studies point towards a gradual adoption of ISO 31000 into different sectors and aspects of business risk management.

A few studies have also sought to investigate and/or link ISO 31000 with OHS risk management.

Haddad et al. [25] proposed a risk assessment method, hazard matrix, and demonstrated how this could be applied to health, safety and environment management by integrating it with the risk management process suggested in ISO 31000. The method suggested by the authors is useful for prioritising risks, which is one part of an overall risk management process. The authors contended a difficulty with their method, which was in prioritising both environmental and occupational risks in the same hazard matrix. Moraru [26] identified effective practices, processes, and structures in OHS risk management and demonstrated how these could be integrated in the ISO 31000 framework. The authors argued their framework provided a step forward to managing safety compared to a decade ago, but there was a need to adopt a more systematic approach for managing safety risks as part of their journey towards a culture of prevention. Poplin et al. [27] demonstrated how the ISO 31000 risk management process could be used to prioritise and manage injury risks in the Tucson fire department using a systematic approach. The authors contend that a significant amount of resources was required for conducting the key stages of their approach, which included scoping, risk assessment, and implementation, and that their approach was suitable for one or two key tasks. And a more recent study described the process, outputs, and lessons learnt from a proactive application of the ISO 31000 risk management process to reduce emergency service vehicle crashes in the US fire departments [28].

These studies point to a move towards some levels of adoption. Most of the above studies, however, concentrated on some aspects of the risk management process. None of these took into account safety management practices, so the utility of ISO 31000 for managing safety risks remains questionable [8]. This is an important issue from the perspective of safety management scholars and practitioners.

2.3. Key differences between ISO 31000 and OHS management process

There are four main differences between ISO 31000 and OHS management practice.

The first is the inclusion of 'establishing the context', a concept which is not featured in health and safety management practice [8]. According to Sousa et al. [9], this involves evaluating and understanding the internal and external contexts, the challenges faced by the organisation, factors which can impact on the achievement of goals, and the broader risk management strategy. Flaus [29] suggested distilling this stage into four key inputs, including (i) external environment; (ii) internal environment; (iii) risk management framework; and (iv) risk criteria [8]. The closest reference to 'context' in the OHS management process comes from safety cases in the major hazard regime, in the form of facility descriptions [30]. In effect, this is equivalent to the 'background' of any major undertaking or project and is deemed important because

a. risk management takes place in the context of the broader organisational objectives and

b. the objectives and performance criteria for any specific project, process, or activity need to be considered alongside other related objectives.

The second is the notion of 'risk identification', which is suggested to be the first part of the risk assessment process under ISO 31000 [8]. This is confusing, something previously identified by others [31]. Moreover, it represents a significant point of departure from existing OSH literature and practice, which associated risk with *a 'degree of harm, injury or disease'*. Being able to determine *degree* involves making some level of determination based on two aspects, consequence and severity, so risk is an outcome of an assessment process. OHS regulations, practitioners, professionals, and academics relate more to the notion of identifying *hazards*, not risks! Manuele [32] makes this point more precisely, that hazards provide the generic base and justification of the practice of safety. The term 'hazard identification' instead of 'risk identification' is more common. Related to the notion of risks in the standard form are the terms risk analysis and risk evaluation, each of which have a different meaning. According to ISO 31000, risk analysis involves a 'process for comprehending the nature of risk to determine the level of risk', while risk evaluation involves a 'process of comparing the results of risk analysis with risk criteria to determine whether the level of risk is acceptable or not' [14]. In this regard there are two different outcomes of analysis and the evaluation of risks:

i. from risk analysis—the *level of risk*

ii. from evaluation—the decision whether the level of risk is acceptable or not.

Again, in OHS practice, the simpler process of 'risk assessment', which accounts for analysis and evaluation is more common [8]. This is summarised by Rausand [33], 'the overall process of risk analysis and risk evaluation'. Combining these two ideas gives us the main difference the way risk is conceptualised. In OHS practice *risk includes determining the level of risk* (hence the process of risk analysis) *and a decision about whether this level of risk is acceptable or not* (risk evaluation). Most importantly, it is also a separate process from hazard identification [8].

The third difference is the notion of 'risk treatment'. The use of the term treatment seeks to suggest that an adverse outcome is a normal expectation of risk management, a philosophical problem when applied to OHS which has, at its core, the main objective of preventing harm, illness, injury, or diseases [8, 34]. For these reasons, OHS practice refers to risk control rather than risk treatment [35]. Hence, the process that follows risk assessment is *risk control* instead of risk treatment [8].

The fourth difference is in the range of approaches suggested for dealing with risks [8]. ISO 31000 posits that this can be done by avoiding the risks altogether, taking or increasing the risk to pursue an opportunity, removing the source, changing likelihood, changing consequences, sharing (outsourcing) through contracts and risk financing, and retaining the risks through informed decision-making [14]. However, in Australia, the suggested approaches of transferring and retaining OHS are illegal under safety law [36]. This is because the primary responsibility for management and control of OHS hazards remains with the person conducting or undertaking a business [35], irrespective of any efforts to engage with contractors or insure it off. Safety practitioners will therefore find it difficult to implement these specific controls.

2.4. A modified ISO 31000 OHS risk management process

In order to make ISO 31000 more user-friendly to safety managers, practitioners and scholars, a modified ISO 31000 OHS risk management process (herein called in M-31000) has been suggested [8]. This addresses some of the differences identified in Section 2.4 and includes a set of six iterative stages. It retains communicating and consulting, establishing the context, and monitoring and reviewing suggested by ISO 31000. However, it introduces the identification of hazards (instead of risk), the assessment of risk, and control of risks, as illustrated in **Figure 1**. The authors provided that M-31000 was theoretical in nature and had yet to be tested for its application in the general industry. The present study aims to address this by investigating the utility of M-31000 for managing OHS hazards and risks. In doing so it seeks to stimulate safety managers, leaders, practitioners and scholars to think more laterally before implementing ISO 31000 [7], by starting with careful listening to the practice of risk management [37].

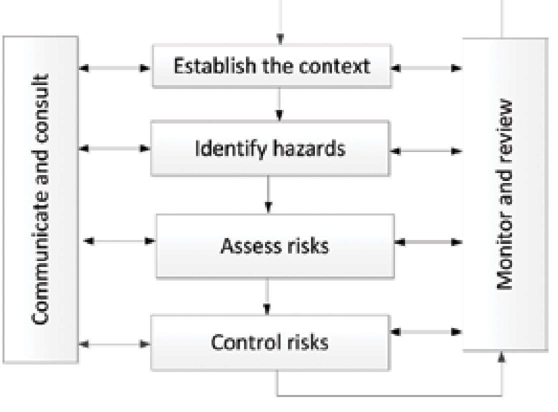

Figure 1. M-31000 OHS risk management process [8].

3. Research method

A pilot study was undertaken in order to examine the efficacy of ISO 31000 and M-31000 for managing OHS risks in Australia. Pilot studies guide the design and implementation of larger-scale studies and the collection of credible data and hence are an integral part of any social research [38, 39]. An exploratory research design [40] using purposive sampling [41] was utilised for this pilot. The informants included graduate students completing two postgraduate courses in OHS who were interviewed in 2016 and 2017. Apart from demographic information, the informants were asked to share their experiences and comment on two specific questions around:

i. the usefulness (or otherwise) of ISO 31000 and M-31000 for managing OHS risks in their organisations and/or roles and

ii. any other approaches they had used, or were familiar with, for managing OHS risks in their work and organisations.

This chapter presents and discusses the findings for the first part.

The main data collected included free-flowing texts of responses to the above open-ended questions [42]. Comments were collated into a word document and pseudonyms used to code each comment to de-identify the personal details of the informants. Each comment was read twice, first to get a general overview of the data and the second for in-depth information to identify common themes and/or any sub-themes located in large blocks of texts [42, 43]. The aim here was to capture the surface meanings of the data as explicitly stated by the informants in order to maintain the original meaning of the key message(s) conveyed. In order to be regarded as a theme, the core message needed to be expressed by at least three different informants.

4. Findings and discussion

A total of 42 informants responded to the questions from a class size of 149, with a response rate of 28%. The informants included a relatively diverse group—risk managers, project managers, safety managers and/or coordinators, engineering managers and human resources. Most worked for large companies or projects and had between 2 and 18 years of experience in the field. Many chose not to divulge their sex, while a number chose to remain silent on their specific roles, industries in which they had worked for.

4.1. Utility of ISO 31000 for managing risks

The respondents raised a wide range of views regarding ISO 31000. Those relating to its positives centred around three main themes. These included:

a. a useful starting point for risk management,

b. supplementing other risk management strategies, and

c. the ease of integration with/into other management systems.

4.1.1. ISO 31000 as a useful starting point for risk management

The first finding was that ISO 31000 provided a useful starting point for risk management. Examples of this theme are illustrated in the following excerpts:

> *'The risk management process …is a useful starting point for those seeking to establish risk management process'* MG-01.
>
> *'…is considered a starting point for initiating and obtaining further knowledge about risk…'* DA-25.
>
> *'ISO 31000 is considered a good starting point for any company…'* RK-27.

This finding is consistent with the ISO's position that ISO 31000 is a generic process [14]. Previous authors have argued that risk management is a strategy that managers take up [7]. This needs to start from somewhere, and the above finding suggests that ISO 31000 acts as a starting point for the doing part of risk management—establishing the process and obtaining knowledge about risks. This is also supported by Gjerdrum and Peter [10], who argued that it acted as a vehicle to make risk management central to successful performance and therefore an integral part of other business processes such as planning, management, and governance.

4.1.2. ISO 31000 supplemented other risk management strategies

The second finding was that ISO 31000 supplemented other risk management strategies. Examples of this theme are indicated in the excerpts below:

> *'… used in parallel with other risk management strategies…'* JC-08.
>
> *'ISO 3100 is… domain neutral for all types of risks'* GP-22.
>
> *'…works well when applied…to holistically manage business risks…'* MH-30.
>
> *'…consistent with other ISO standards in that it promotes a "plan, do, check, act"'*…DC-37.
>
> *'… ISO 31000 support … rather than replace those standards'* MC-39.

ISO 31000 is built around a three-tiered structure incorporating principles, framework, and process [12], so the above finding provides some support for this claim. It has previously been asserted that ISO 31000 be used in conjunction with, or takes into account, other similar strategies [24, 26, 31, 44]. Some authors have argued against the creation of any addition, parallel management system [12], while others have made the case for ISO 31000 to complement other conventional risk management systems [7, 23, 24]. This includes systems-based approaches.

4.1.3. ISO 31000 allowed for easier integration

A third common finding was that ISO 31000 allowed for an easier integration of risk management strategies. The following excerpts illustrate examples of this theme:

> *'…and one of them is the ISO31000 can easily integrate into organisation existing practice… Companies with ISO 9001 and ISO 14001 certifications could incorporate into their management system'* MR-11.

> *'ISO 31000 used as a set standard would allow for integration of …risk management practices'* MG-19.

> *'…. It provides an important framework for integrating OHS into an organizations broader objective'* DA-25.

> *'ISO 31000 … provides the necessary framework for integrating OHS into an organisations broader objectives'* MS-35.

ISO 31000 has been suggested to provide a structured framework to meet the needs of any type of organisation [7]. Moreover, it has been suggested to act as an umbrella for over 60 standards and guidelines for risk management and is more user-friendly to many other ones [12]. So the above finding is in tandem with the expectations of the risk management standard with respect to integration into an organisation's risk management decision-making processes [11, 14]. The ease of integrating ISO 31000 into existing approaches for managing different risks (environmental, business, political) has been argued to be one of its key strengths [9, 12, 23, 26]. The results from this study provide support for this argument, with examples for quality and environmental protection. In addition, the results also provide support for integrating practices (MG-19) and objectives (DA-25 and MS-35). It is possible this takes into account different models and theoretical frameworks [26] to enable risk managers to take a more holistic view.

4.2. Concerns and issues with ISO 31000

A number of informants also saw a number of problems with ISO 31000. The two main ones included it being vague and lacking consistency and being difficult to implement.

4.2.1. ISO 31000 was vague and lacked consistency

A number of informants provided comments about ISO 31000 being vague. Some examples of this are illustrated in the excerpts below:

> *'the standard is quite vague'* KW-14.

'The intended meaning … is frustratingly hard to pin down. Key words and phrases are either vague, have meanings different from those of ordinary language, or even change their meaning from one place to another' RH-06.

'a number of concerns … relate to the process, terminology and its interpretation …' SV-07.

'…contains steps that are not necessary or particularly accurate in the risk management process' JB-17.

One of the aims behind the development of ISO 31000 was to provide a common language and process for risk management specialists, auditors, and assurance providers, thereby enhancing the communication between the various stakeholders [14]. However, the findings above suggest this is not necessarily the case. This has also been identified previously by authors such as Leitch [13] and Purdy [11], who argued that there remained some elements which needed to be simplified to enable the framework to be better understood and implemented and appear less onerous. In this instance the respondents raised a similar opinion. Future full-scale investigations should explore whether this was a broader issue. Moreover, while terminology, process, and steps were identified as potential areas of confusion in this pilot, further studies should investigate which specific terms, process, and steps required more clarity.

4.2.2. ISO 31000 was difficult to implement

Another common finding was that ISO 31000 was difficult to implement, as the following excerpts demonstrate:

'A risk management system is more easily applicable … if it is simplified. An over complicated risk management system can end up being demanding on time and company resources with more going in to the administration of the management system than the management of risks' BH-18.

'Impractical aspects are that (ISO 31000)… leads to illogical decisions if followed; is impossible to comply…' MG-19.

'whilst this standard is quite succinct, it is…lax in nature and offers little direction … as to how the processes of management risk should actually be implemented' DG-21.

'The negative aspects of the risk management process … are that it is difficult to use in industries…' PG-24.

'… it would prove challenging to incorporate….' DV-29.

The ability to design or revise the components of its risk management system to suit a company's key processes, structure, and risk profile has been suggested to be one of the main strengths of ISO 31000 [11]. The above findings indicate that this is not necessarily the case. This is not uncommon and possible reasons may be due to the changing nature of risk [45] or their management [46]. In the previous finding one of the informants suggested that ISO 31000 contained unnecessary steps, and this could make it difficult if the suggested process was used as a prescribed approach to managing risks. Risk management needs to make sense and should not be used for bureaucratic back covering, scaring people, or generating useless mountains of paperwork [47]. Some ways in which aspects of ISO 31000 could be improved have also been suggested, including:

i. minimising use of labels,

ii. simplifying the risk assessment process,

iii. adopting an existing risk assessment process,

iv. accepting subjective assessments during risk assessment, and

v. accepting uncertainty [26].

These improvements are associated with risk, or its assessment, which is an area of contention raised previously [8, 31]. Some authors have attempted to simplify the adoption and use of hazard matrixes [25] but whether this simplifies the overall process of risk management is unknown. Future full-scale investigations should enable an understanding of which specific aspects of the overall process were difficult, including any specific examples and/or cases.

4.3. Utility of M-31000 for OHS risk management

The respondents also raised positive views regarding M-31000. The two main themes are centred around its

a. simplicity and

b. consistency with safety management practice.

4.3.1. M-31000 was simple

A common understanding regarding M-31000 was that it was a simple approach. Examples of this are reflected in the following excerpts:

> *'…The adapted version supports new, simple way of thinking…'* FB-05.
>
> *'I would recommend the use of the simplified HSRM process'* SV-07.
>
> *'…focus on health and safety make the simplified model…appealing as a practical, hazard management process'* JB-17.
>
> *'…reducing the process from seven items to six…'* AM-10.
>
> *'The adaptive version … allows the framework to be more understandable…'* MRA-11.
>
> *'the adapted version of ISO 31000 provides a more concise and clear risk management process, …. By summarising into 5 key points, primary objectives for an organisation are better understood'* KW-14.

'The adapted version … simplifies the ISO 31000 risk management process, by combining and eliminating certain steps…' BT-26.

The need to keep the process of risk management simple and sensible has also been previously raised [12]. The informants in this instance believed M-31000 allowed this to occur by reducing the number of steps, making it more understandable and combining and eliminating certain steps. In some ways this may address the issue of reducing bureaucracy, paperwork, and making it a more sensible approach [47]. While this may indicate that M-31000 is easier to adopt, future studies should focus on actual experiences of implementing the revised version to identify if this is supported across small, medium, and large organisations across different industries and different hazards. This is necessary to identify which parts of the process are working as presented and which ones require further adaptation.

4.3.2. M-31000 is consistent with safety management practice

Another common theme was that M-31000 was consistent with safety management practice. Some examples of this are included in the following excerpts:

'…seeks to better represent WHS by… retaining historical WHS language…' AM-10.

'Safety practitioners and professionals would be more likely to identify with a more relevant process of assessing hazards to health & safety' BT-26.

'…, alignment with in-the-field understanding and practice is required. We should speak of "hazard identification" rather than "risk identification" because "risk" implies predicting consequences by jumping to conclusions. Likewise 'Risk treatment' incorrectly implies a risk as something negative rather than an opportunity…' DM-36.

'The simplified HSRM process is more practical for OHS risk management whilst being harmonious with the standards principles…' FD-38.

' …the adapted version … is more closely aligned to the terminology utilised in this jurisdiction' MG-01.

'…the adapted version of risk management is more closely aligned with other health and safety management framework (e.g. OHSAS 18001). …' RK-27.

One of the criticisms of ISO 31000 was that it failed to account for OHS management practice, including steps such as risk identification and risk treatment [8]. In this instance the informants felt M-31000 addressed this shortfall through a mix of retaining historical language, the process for assessing health and safety hazards, and closer alignment with safety management, while retaining the essence of the ISO 31000 principles. Again, while consistency of safety management practice has been suggested to be one of the main reasons for M-31000, future studies should investigate which aspects of the process are consistent and/or closely align with safety management practice and actual experiences of integrating it safety management systems such as AS/NZS 4801, ILO-OSH 2001, OHSAS 18001 and/or ISO 45001.

5. Limitations and conclusions

5.1. Limitations

Any pilot study will have its limitations, and this study is no exception. The use of a purposive sampling strategy is one. This is a subjective and non-probabilistic approach and can lead to errors in judgement by researchers and high levels of bias [38, 39]. Future researchers investigating this issue should consider quota, cluster, or more systematic sampling methods. A second limitation is the issue of quality in the research process. There is a wide diversity of methods and approaches used for conducting qualitative research [48] and an equally large set of quality indicators [49]. Future studies should make the quality criteria clear.

5.2. Conclusions

In spite of these limitations, this study is one of the first to shed some light on the utility of ISO 31000 and M-31000 for managing health and safety risks. The findings of this pilot investigation suggest that ISO 31000 provided a useful starting point for risk management, supplemented other risk management strategies, and allowed for ease of integration with or into other management systems used by organisations. The two main disadvantages included it being vague and difficult to implement, and these could restrict its uptake and/or adoption. Future full-scale investigations should investigate those aspects of the overall process deemed to be difficult and which specific terms, process, and steps required more clarity. With respect to M-31000, the findings suggest it was simple, more consistent with safety management practice, and could enable closer alignment with other safety management systems. Future studies should consider actual experiences of implementing M-31000 to identify if this is supported across small, medium, and large organisations or across different industries and different hazards in order to identify which parts of the process are working as presented and which ones require further adaptation. In addition, studies investigating aspects of M-31000 which are consistent and/or closely align with safety management practice and actual experiences of integrating it with safety management systems such as AS/NZS 4801, ILO-OSH 2001, OHSAS 18001 and/or ISO 45001 will also be useful to advance research and practice in OHS risk management.

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Occupational health and safety (OHS) is an important focus of governments and organizations throughout the world because there are over 2.78 million fatal and 374 million nonfatal work-related injuries and illnesses experienced by employees every year. Addressing these requires paying attention to the physical organizational, cultural, and social contexts amidst which work is undertaken. A multidisciplinary approach is also necessary in finding effective solutions. Interestingly, countries and regions address different aspects of OHS depending on what OHS hazards and risks are important to them. This book, based on research from Australia, Belgium, Ghana, Malaysia, Turkey, and Slovakia, examines how a range of OHS hazards are addressed in these contexts. We believe that this is an important first step in addressing an age-old OHS problem through a multiregional collaboration.

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