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Review Article

Status of resource recycling stations in Taiwan and recycling work-related health effects

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Abstract

Resource recycling has become an integral part of environmental protection efforts. At present, the development of Taiwan's resource recovery and related works are quite mature. However, laborers or volunteers working in resource recycling stations may be exposed to different types of hazards during the recycling process. These hazards can be divided into biological, chemical, and musculoskeletal problems. These hazards are usually related to the work environment and work habits; therefore, a related control strategy is needed. Tzu Chi's recycling business has been running for over 30 years. In addition to leading the trend of resource recycling in Taiwan, many elderly people have also participated in Tzu Chi recycling stations as volunteers. These older volunteers may be more sensitive to exposure to hazards, and thus the focus of this review is to illustrate the possible hazards and health impacts of resource recovery work and to recommend relevant interventions to improve occupational health during resource recovery work.

Keywords: *Environmental hazards, Musculoskeletal problems, Occupational health, Resource recycling*

Introduction

Resource recycling is a necessary direction for sustainable development. Currently, Taiwan is implementing the 6R policy, which includes reduction, reuse, recycling, energy recovery, land reclamation, and design change (redesign). If material utilization can achieve the concept of sustainable material management, it will be very helpful for resource recycling, and the utilization of resources can also be more efficient.

The history of resource recycling in Taiwan can be traced back to 1988, and a resource recycling system has been established since 1997. The participating members include the community, recyclers, local governments, and recycling funds. Resource recycling is not only the work of the government but also encourages the participation of all people. At the same time, the government announced that 33 items or containers, such as vehicles, electronic waste, containers, batteries, and lighting sources, are recyclable items. In addition, Taiwan has implemented garbage classification since 2005. The public needs to classify domestic waste into three categories: resources, kitchen waste, and garbage; those that need to be recycled must be sent to a recycling plant for reuse. The follow-up important relevant policies also include restricting excessive packaging of products, promoting mercury-containing battery recycling and control measures, prohibiting cosmetics and personal cleaning products containing plastic particles, and restricting the use of plastic straws. These policies not only implement waste reduction but also consider ecological conservation and public health.

According to the Taiwan Environmental Protection Agency in 2020, Taiwan's garbage recycling rate reached 61.4%, and the general waste recycling rate reached 57.7% [1]. The daily garbage removal volume per person dropped from 1.1 kg in 1997 to 0.4 kg [1]. For electronic appliances and waste information items, the recovered volume reached 159,000 metric tons, and the recycling rate of resources after treatment was approximately 85.6% [1]. In the future, the recycling of waste resources is expected to promote a circular economy, and with the sustainable material management system, the efficiency of resource use will be further improved.

The importance of resource recovery work is undeniable, but working in a resource recovery plant can expose workers to many potential contaminants. Although some of these

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wastes may not be hazardous or toxic at low concentrations, workers may still be exposed to these physical, chemical, or biological substances through ingestion, inhalation, or skin contact during long-term work. Some of the higher-risk wastes include electronic waste (e-waste) containing heavy metals, and the disposal process may release metal dust into the environment, creating further possible health risks. According to relevant literature, workers who handle waste may have related health hazards after exposure to hazardous waste, including respiratory problems, infectious diseases, gastrointestinal issues, irritation of eyes and skins, mechanical trauma, pulmonary problems, chronic bronchitis, musculoskeletal damage, hearing loss, and other specific types of injuries [2,3]. Workers have health hazards related to the property of the waste they handle. This problem is even more serious in low-income countries [3]. When they process e-waste [2], except for the potential health risks mentioned above, there may be burns or cuts, which may be related to the lack of proper waste handling standard procedures and the lack of wearing of personal protective equipment.

Compared with other resource recycling stations in Taiwan, the Tzu Chi Foundation's environmental volunteers tend to be older. The 2020 study shows that the average age of Tzu Chi environmental volunteers is approximately 73 years [4]. For other resource recycling stations from 2014 to 2018, the maximum age group for volunteers was 60–69 years old [5,6], while the major age group of environmental protection volunteers in Hsinchu County was 50–59 years old [7]. In terms of demographic characteristics, Tzu Chi resource recycling station volunteers also suffer from frailty, weakness or sarcopenia, similar to the general elderly population. Therefore, from the perspective of ecological health promotion, it is necessary to pay attention to the skeletal and muscular health status of Tzu Chi volunteers working in the recycling station.

The purpose of this literature review is to categorize the potential hazards to workers or volunteers working in resource recycling stations. In addition, we also illustrate the health effects currently shown in the literature that may result from such exposures. As a part of the Tzu Chi group, we were also concerned about whether older volunteers had musculoskeletal health problems at work. Therefore, in addition to biological and chemical hazards, we have also sorted out some of the physical hazards that the elderly may have in the workplace. It is expected that this literature review can increase the attention of relevant government departments to the health of workers in resource recycling stations and promote the public health of workers in the workplace.

Methods

This literature review was carried out using the major scientific database sources, including MEDLINE (via PubMed), Web of Science, Scopus, and Google Scholar. The search terms included information regarding recycling work-related health effects from 1995 to 2021. The keywords used for searching were "occupational health," "health effects," "ergonometric damages," "musculoskeletal problems," "phthalates," "phthalic acid esters," and "dynapenia." Related studies, including systematic reviews and observational, cross-sectional, and longitudinal studies, were included. Case reports, letters to the editor, and opinion articles were excluded. Finally, 58 references [including Supplementary Table 1] were collected from the selection criteria.

Hazards in waste recycling plant

Biological risks

As long as there is waste, there will be microorganisms. Studies have confirmed that there are various microorganisms or their derivatives in waste storage sites or resource recovery sites. These biological contaminants include bacteria, fungi, endotoxins, and fungal β-glucans. In some waste storage sites, their concentration may be even 10–20 times higher than the common concentrations found in the waste facility [8]. Therefore, workers handling wastes without proper protection may be exposed to these biological hazards of varying risk levels but at high concentrations through inhalation. Such problems not only occur in waste sorting and recycling workers but can also spread to other indoor environments, such as truck cabins, through contaminated clothing [9]. In addition to contact transmission, airborne bioaerosols also have potential health risks, and some air samples also found that these bioaerosols have a small size that makes them settle on the alveoli [10].

Some of the wastes in the sites would be sorted or recycled. Light packaging materials were found to have fewer biological contaminants [11]. Conversely, some household wastes have high concentrations of bacteria and fungi if they are not sorted [12]. The environmental parameters of the waste site are also very important. Some studies have found that the bacterial concentration in the plant is related to the temperature and relative humidity [10-12]. In terms of humidity, it was found that the concentration of bacteria and fungi in high humidity was relatively low [13]. To date, global warming is an important issue, and changes in environmental conditions will also change the composition and concentration of biological substances in waste storage sites. In addition, the storage time of waste at the site also affects the concentration distribution of microorganisms. A longer storage time is associated with higher fungal concentrations, but this correlation is not obvious for bacteria and endotoxins [8].

Due to the high concentration of bioaerosols in waste storage plants, the main exposure is from inhalation, and the health effects caused are mostly respiratory diseases. These bioaerosols may cause infections, allergy-related diseases, or mucous membrane irritation. For example, the fungal metabolite β-glucans or endotoxin from Gram-negative bacteria can often cause membrane irritation syndrome [8]. Other health effects associated with mucosal irritation include rhinitis, increased phlegm production, or shortness of breath. In addition, lung function-related diseases, including allergic bronchopulmonary aspergillosis, chronic obstructive pulmonary disease, allergic asthma, and hypersensitivity pneumonitis, have also been found to be associated with bioaerosol exposure in workers [8,14]. Because there are many indicators of lung function tests, these indicators are

also used to assess the correlation between workers' lung function and bioaerosol exposure. The peak expiratory flow (PEF) of workers was lower when they were exposed to *Aspergillus fumigatus* at concentrations higher than 2×10^3 CFU/m^3. Another study also showed that workers had lower forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1) than service workers and that such correlations were related to employment time (>15 years) [15]. When compared to truck drivers with lower exposures, waste-handling workers all had lower lung function indicators (FVC, FEV1, PEF, and FEF) [16]. However, there are also studies showing different results. Biological exposure is not significantly related to its pulmonary function index FEV1, which may be related to the number of samples and the type of waste [17].

In addition, some proinflammatory cytokines in respiratory or blood biomarkers are also correlated with bioaerosol concentrations obtained from environmental monitoring. The endotoxin concentrations were significantly correlated with interleukin 8 (IL-8) concentrations and MPO (enzyme myeloperoxidase) levels [18]. There was a significant correlation between fungal spores and neutrophils as well as (1 → 3)-β-D-glucans and IL-8 levels [18]. The immunoglobulins IgG and IgA in blood have also been shown to be significantly associated with exposure to environmental bacterial endotoxins [19]. Several studies have also explored the association of other bioaerosols with respiratory and gastrointestinal symptoms. For example, the concentration of rod-shaped bacteria at the plant site was significantly associated with eye and nose irritation [20]; the concentration of fungal spores was associated with symptoms of headache; and endotoxin exposure was associated with nausea and diarrhea [21]. Exactly how diarrhea is related to airborne bioaerosol concentrations is still uncertain, but it should be related to other routes of exposure (e.g., exposure) than inhalation. Some workers even eat and drink on site, which may also increase the risk of diarrhea. In addition, studies have demonstrated that minor effects, such as allergic symptoms, are relatively rare among waste workers [8]. This may be caused by the healthy worker effect.

Health risks related to phthalate esters or phthalate exposure

Phthalic acid esters or phthalates (PAEs), used as plasticizers and additives, are commonly present in many commercial products. Because they are not covalently bonded to the materials of products, PAEs are bound to be released into the surrounding environment, especially when the products become old and turn into waste. It can be imagined that the concentrations of PAEs are very high in junkyards or recycling grounds. A recent Vietnamese study indicated a concentration range of 9210–153,000 ng/g in waste processing workshops, higher than that found in household dust [22], suggesting high exposure sources of PAEs in recycling grounds. Among the PAEs found in the study, di-(2-ethyl) hexyl phthalate (DEHP) was unsurprisingly the most predominant congener, followed by benzyl butyl phthalate (BzBP), di-n-butyl phthalate, di-n-octyl phthalate, and diisobutyl phthalate. These are commonly seen PAE congeners, which have also been found in several relevant studies performed in Taiwan [23,24].

In the work of Hoang *et al.,* [22] previous results from other countries were gathered and compared, showing that PAE concentrations were one to two orders of magnitude higher than theirs. For instance, a Chinese study discovered a PAE concentration profile ranging from 170 to 5,300 μg/g in a typical e-waste junkyard with high-molecular-weight PAEs (e.g., DEHP and BzBP) being dominant [25]. Another example in Thailand found high concentrations of PAEs along with flame retardants from a manual e-waste dismantling facility, showing approximately 86,000–790,000 ng/g for total PAEs [26]. Despite the low toxicity and mild endocrine-disrupting effects of PAEs, the high concentrations in those recycling facilities are of concern in terms of exposure on a daily basis. In addition, recycling workers or volunteers could easily carry significant contents of PAEs home with their clothes and/or shoes to expose susceptible family members, such as young children, should they not change clothes/shoes for work. This potential hazard of PAE exposure should be addressed in a timely manner.

Along with the wide use of phthalates in the world, there has been public concern raised about the potential health effects of phthalate exposure, especially for susceptible populations (pregnant women and children). The potential health effects of different populations on different health effects were found by previous studies. For pregnant women, higher levels of urinary MBP, MEHP, MEHHP, and MEOHP were significantly associated with an increased risk of spontaneous pregnancy loss [27]. However, the relationship between prenatal phthalate exposure and pregnancy outcomes (preterm birth and gestational age) was inconsistent [28]. The potential health effects on children were mainly neurobehavioral outcomes, including cognition, motor effects, and behavior, including attention-deficit hyperactivity disorder, infant behavior, and social behavior. Higher gestational period phthalate exposure may contribute to adverse neurobehavioral outcomes [29], especially the effect of BBP on motor effects [30]. Moreover, sex-specific effects were found to be related to maternal phthalate exposure and children's neurobehavioral outcomes [31]. Studies have suggested a significant association between MBzP and the risk of atopic dermatitis development, but not MEHP, MEP, MiBP, MnBP, or DEHP [32]. Urinary MBzP and MiBP exposure was significantly negatively associated with breast cancer [33]. In conclusion, more consistent findings were found for DEHP exposure in decreasing sperm quality in males and increasing the risk of ADHD in children. Other outcomes were less consistent [34].

Ergonometric damage and musculoskeletal disorder symptoms

Ergonometric damage results from repeated movements, heavy loads, and abnormal postures. Ergonometric damages are frequently reported in studies of waste workers and recyclers. Musculoskeletal disorder (MSD) symptoms, such as low back pain, shoulder pain, and knee pain, are the most common complaints about discomfort in ergonometric damages. In

this section, we reviewed six studies that investigated MSD symptoms in waste workers and recyclers in six different cities and discussed the assessment tools, prevalence, and risk factors for MSD symptoms.

Characteristics of the included articles

We reviewed six articles that investigated MSD symptoms in waste workers and recyclers in developing countries, including Brazil [35], Egypt [36], Iran [37], Ghana [38], and two cities in India [39,40]. These six studies were all cross-sectional in design, and three were case–control studies [36,38,40]. The participants were recruited from different waste industries, including e-waste dumpsite workers [38], municipal solid waste workers [36,37,39], waste pickers in dumps [40], and so on.

All studies measured MSD symptoms by self-report questionnaires. There were different tools used to assess MSD symptoms, including the Nordic Musculoskeletal Questionnaire, Cornell Musculoskeletal Discomfort Questionnaire, and other self-developed questionnaires. The overall period prevalence (any discomfort in the last 12 months) was reported in 4 of 6 studies [36,37,39,40]. The period prevalence of MSD ranged from 60.8% to 92.5%. The overall point prevalence (any discomfort in the last 7 days) was reported in 1 of 6 studies, which was 91.8% [39]. The period and point prevalence of MSD in specific body parts were reported in 4 [36,37,39,40] and 2 [38,39] of 6 studies, respectively. The most common MSD symptoms were related to the lower back, knees, and shoulders in most of the studies. The period prevalence and point prevalence of knee pain ranged from 60% to 60.5% and from 24% to 84.5%, respectively. The period prevalence and point prevalence of lower back pain ranged from 22.5% to 63% and from 41.0% to 67%, respectively. The period prevalence and point prevalence of shoulder pain ranged from 15.8% to 39% and from 18% to 74.5%, respectively. MSD symptoms occur in other body parts, including the upper back [40], neck [35,36], hips/thighs [36], and ankle [35].

Despite the high prevalence of MSD symptoms reported in waste workers and recyclers, it should be noted that the difference was not consistently significant among studies when compared with the reference groups whose socioeconomic status was matched with the waste workers and recyclers [36,38,40]. The risk factor can be categorized into three aspects: individual factors, physical demands, and organizational demands [37]. In individual factors, the higher odds ratio and number of MSD symptoms were related to age, body weight, education level, work duration, financial status, and smoking [36,37,39,40]. In physical demands, repeated movement with heavy loads, such as lifting, pulling, pushing, or carrying loads >20 kg and sitting and walking for long periods of time significantly increased the risk of MSD symptoms [36,37]. In organizational demands, low vacation and high decision authority were associated with a high risk of MSD symptoms [36,37].

Definition and risk factors for dynapenia

In resource recovery work, older workers may have dynapenia, which is the age-associated loss of muscle strength not caused by neurologic or muscular diseases. Dynapenia may make older workers have a higher chance of unintentional injuries such as MSDs or falls during work. In 2008, the concept of dynapenia that was proposed by Manini and Clark [41] and indicated a decline in muscle strength with aging highlighted the significance of this condition for assessing muscle strength [42,43]. An algorithm for dynapenia was proposed by Manini and Clark, [44] and reports comparing sarcopenia with dynapenia have begun to appear. A more specific definition of dynapenia was defined as low muscle strength (<27 kg for men and <16 kg for women) in the studies [45,46]. Dynapenia also predisposes older adults to an increased risk for functional limitations and mortality compared to other factors. Early detection of dynapenia can effectively prevent frailty and promote healthy quality of life by increasing muscle strength rather than simply increasing muscle mass in elderly individuals [45-48]. For older workers with more severe symptoms of dynapenia, moderate rehabilitation and exercise are recommended before they start resource recovery work.

The strength and limitations of the study

The strength of this study is the combination of all possible health hazards when working in a resource recovery site. Previous studies have only identified physical, chemical, or biological hazards. Because workers or volunteers working at the recycling site come into contact with these hazards through ingestion, inhalation, or skin contact, it is possible that these health effects are caused by a combination of hazardous substances with different properties. In addition, this review also specifically considers the potentially vulnerable aspects of the elderly in resource recovery, such as those who may suffer from dynapenia. This has been less mentioned in previous reviews. The limitation of this study is that only descriptive integration is performed, and no quantitative integration of data in the literature (meta-analysis) is conducted.

Conclusions

Overall, we can conclude that workers in resource recycling stations can be exposed to a variety of hazards, including biological, chemical, and MSDs. Consequently, the government or the owner of the station needs to implement strategies such as improving ventilation, better sorting, and storage of waste; reducing the time spent on site for recycling; promoting health education; and using the appropriate tools to reduce musculoskeletal problems. The volunteers participating in resource recycling in the Tzu Chi Foundation are older and may be more sensitive to exposure to many hazards. Therefore, we need to pay more attention to their working environment and health status, so that these volunteers can do their best to protect the environment in a relatively safe and healthy environment.

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Conflicts of interest

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Supplementary Material

Supplementary Table 1: Related studies of exposures and health outcome in resource or waste recycling stations

Study	Location	Exposure or health outcome	Summary of finding
[9]	Denmark	Microbial exposure	Microorganisms may accumulate on workers' clothes in the recycling site, and these microbes may be transported with the clothes and subsequently re-suspended to the indoor air
[10]	Denmark	Fungal exposure	As a reduced waste collection frequency, fungal exposure would increase. Collection of cardboard may cause exposures to food-related microbes
[11]	Germany	Microbial exposure	Total bacteria concentrations during refuse collections were ranged from 10^4-10^5 CFU/m^3. Endotoxin levels were high in the summer whereas normally low in autumn and winter
[12]	Denmark	Implementation of interventions for microbial exposures	Implementation of interventions reduced bioaerosol exposure as well as lower the inflammatory exposures
[13]	Korea	Bioaerosol exposure during waste collection and sorting	During waste collection and sorting may expose to dust, endotoxin, and viable bacteria, Gram-negative bacteria, and fungi
[14]	UK	Occupational illness in the waste and recycling sector	Some adverse health effects have been identified to be correlated with waste and recycling works, but the true prevalence still need more studies
[15]	Egypt	Respiratory disorders among municipal waste collectors	The prevalence of respiratory complaints was higher among waste collectors than the control group
[16]	Turkey	The microbiologic flora in the garbage collectors' environment	The respiratory functions showed that the garbage collectors' FVC%, FEV1%, PEF% and FEF25%-75% were below 80% compared to the control group
[17]	Sweden	Airways inflammation and glucan exposure	The waste collectors demonstrated higher proportion of diarrhea, congested nose, and tiredness as compared to controls
[18]	Norway	Waste handlers exposed to bioaerosols with upper airway inflammation	During waste handling, workers may expose to fungal spores, endotoxins, and β(1→3)-glucans associated with upper airway inflammation
[19]	Denmark	Evaluate the effect of low levels of bioaerosol exposure	Peak expiratory flow variability was significantly correlated to *Aspergillus fumigatus* exposure
[27]	China, pregnant women	Spontaneous pregnancy loss	Higher levels of urinary MBP, MEHP, MEHHP and MEOHP were significantly associated with increased risk of spontaneous pregnancy loss, but MMP, MEP, MiBP, MBzP or MECPP were not associated with spontaneous pregnancy loss
[28]	China, pregnant women and infants	Preterm birth and gestational age	A positive but not statistically significant relation between prenatal exposure to phthalates and preterm birth, and negatively associated with gestational age
[30]	USA, children	Neurobehavioral outcomes	The association between six phthalates (DEHP, DINP, DBP, DIBP, BBP and DEP) and neurodevelopmental effects (cognition, motor effects, behavior, including attention-deficit hyperactivity disorder, infant behavior, and social behavior) were generally not a clear pattern of associations. Only the effect of BBP on motor effects in girls having moderate evidence
[29]	Japan, children	Neurobehavioral outcomes	Higher gestational period phthalate exposure may contribute to adverse neurobehavioral outcomes (Bayley Scales of Infant Development, executive function, behavior problems, patterns of play, and social impairment) in children, but findings of low phthalate exposure were not consistent. There was constant association with prenatal DBP exposure to phthalates with language, verbal, mental and psychomotor development. Moreover, Sex specific effects were found in the relation with prenatal phthalates exposure and cognitive intelligence and language development
[31]	Spain, children	Cognitive and motor functions	There was adverse effect on maternal phthalate exposure on children's cognitive and motor scales. In addition, sex differences were found. The effect was more The boys were more susceptible than the girls
[49]	Korea, children	Atopic dermatitis	Results showed a positive association between MBzP exposure and early childhood atopic dermatitis. Studies suggested no significant association between MEHP, MEP, MiBP, MnBP and DEHP and the risk of atopic dermatitis development
[33]	China, women	Breast cancer	Urinary MBzP (OR=0.73) and MiBP (OR=0.75) exposure was significantly negatively associated with breast cancer. In contrast, there were no significant associations between other urinary phthalate metabolites (MEP, MEHHP, MEHP, MEOHP, MCPP and MBP) with breast cancer
[34]	Taiwan, All age	Human health	Review the potential health effect of phthalate exposure, including reproductive system diseases, cardiovascular diseases, thyroid disorders, respiratory diseases, diabetes, obesity, kidney diseases and neurological disorders. More consist findings were found for DEHP exposure in decreasing sperm quality in males, higher the risk of ADHD in children. Other outcomes were less consistency

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Supplementary Table 1: Contd...

Study	Location	Exposure or health outcome	Summary of finding
[35]	Brazil	Nordic musculoskeletal	Musculoskeletal symptoms were highly prevalent for the low back (49%), shoulders (28%), neck (23%), ankles (23%), wrist and hands (21%) in the last 12 months. For the last 7 days, low back still remains as the most affected body part (41%), followed by the shoulders (18%), knees (15%) and neck (15%). Low back symptom was also the most prevalent for the restrictions in activities of daily life (10%) and seeks for health care (31%)
[36]	Egypt	The percentage of musculoskeletal complaints, and the independent risk factors for having the disorders	The percentage of musculoskeletal complaints during the past 12 months was higher among MSW collectors (60.8%) than the comparison group (43.6%)
			The independent risk factors for musculoskeletal symptoms among MSW collectors were the longer duration of employment (OR=0.4, 95% CI=0.1–0.9); low decision latitude (OR=0.3, 95% CI=0.1-0.7); lifting, pulling; pushing/carrying loads >20 kg (OR=5.5, 95% CI=1.8-17.0) and walking for long periods of time (OR=2.6, 95% CI=1.1-6.6)
[40]	Mumbai, India	Instrument adopted from a standardised nordic questionnaire	The 12-months prevalence of MSDs was higher among waste pickers (79%) compared to controls (55%) particularly in the lower back (54%-36%), knee (48%-35%), upper back (40%-21%) and shoulder (32%-12%)
			Older age and longer duration of work are significant risk factors for MSDs
[37]	Shiraz, Iran	Occupation-specific physical and organizational demands nordic musculoskeletal	92.5% of waste collectors reported MSDs symptom at least in one body region during the last 12 months
			The most prevalent MSDs were related to lower back (63%), knee (60.5%), ankle/foot (45%), and shoulder (39%) regions
			Based on Body Map Scale, the lower back (mean±SD; 4.08±3.51) and knee (mean±SD; 3.61±3.32) had the most severe pain/discomfort among nine body regions
[39]	Chennai City, India	Nordic musculoskeletal questionnaire	70% of waste collectors reported MSDs symptom at least in one body region during the last 12 months 91.8% had pain during the last 7 days
			Prevalence of symptoms in knees, shoulders, and lower back was found to be 84.5%, 74.5%, and 50.9% respectively
[38]	Agbogbloshie, Ghana	Cornell musculoskeletal discomfort questionnaire	A 1-week discomfort prevalence was highest for collectors (91.8%) followed by dismantlers (89%), burners (81%), and the reference group (70.7%). The discomfort prevalence for e-waste workers was highest in the lower back (65.9%), shoulders (37.5%), and knees (37.5%)
[50]	USA	Dynapenia	Sarcopenia be limited to its original definition of an age-related loss in skeletal muscle mass, and that the term dynapenia be applied to describe the age-related loss of strength
[51]	UK	Dynapenia	Studies that assessed changes in mass and strength in the same sample report a loss of strength 2-5 times faster than loss of mass. Loss of strength is a more consistent risk for disability and death than is loss of muscle mass
[52]	São Paulo Brazil	Dynapenia	A population-based, crosssectional study was conducted with 1168 older adults. Men and women with skeletal muscle mass ≤8.90 and ≤6.37 kg/m^2, respectively, were considered sarcopenic. Men and women with grip strength <30 and<20 kg, respectively, were considered dynapenic. Those with both conditions were considered sarcodynapenic. Sociodemographic, behavioral, clinical, nutritional, and biochemical characteristics were investigated as factors associated with each of the three conditions using multinomial logistic regression. The prevalence of sarcopenia, dynapenia, and sarcodynapenia was 4.8%, 30.9% and 9.0%, respectively
[53]	Brazil	Dynapenia	This study aimed to assess the prevalence and factors associated with dynapenia in a nationally representative sample of Brazilians aged 50 years and older. Dynapenia was defined as low muscle strength (<27 kg for men and <16 kg for women). Among the 8396 participants, the prevalence of dynapenia was 17.2%; for those aged 65 years and older, the prevalence was 28.2%. Dynapenia was positively associated with age, low gait speed, limitations in performing two or more basic daily activities, falls and self-reported chronic diseases; and negatively associated with education level, physical activity and body mass index. Educational skills and physical activity improvement present greater potential to reduce dynapenia in this population
[54]	USA	Dynapenia	Dynapenia with obesity is associated with adverse objective and self-reported functional outcomes and reduced physical functioning and self-reported health
[55]	Japan	Dynapenia	Dynapenia was associated with classifications of both frailty and sarcopenia. In addition, sarcopenia had a sensitivity and specificity for dynapenia of 33 and 89%, respectively. Frailty had a sensitivity and specificity for dynapenia of 17 and 98%, respectively. Dynapenia was a significant independent related factor for the TMIG-IC (β=−0.21, P<0.05)

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Supplementary Table 1: Contd...

Study	Location	Exposure or health outcome	Summary of finding
[56]	USA	Dynapenia	Recent epidemiological findings from longitudinal aging studies suggest that dynapenia is highly associated with both mortality and physical disability even when adjusting for sarcopenia, indicating that sarcopenia may be secondary to the effects of dynapenia
[57]	USA	Dynapenia	The term "muscle quality" to describe the relationship between voluntary muscle strength and muscle size. In this review article, we discuss the age-associated changes in the neuromuscular system-starting at the level of the brain and proceeding down to the subcellular level of individual muscle fibers-that are potentially influential in the etiology of dynapenia (age-related loss of muscle strength and power)
[58]	USA	Dynapenia	A definition for a single risk factor such as dynapenia will provide information in building a risk profile for the complex etiology of physical disability. As such, this approach mimics the development of risk profiles for cardiovascular disease that include such factors as hypercholesterolemia, hypertension, hyperglycemia, etc.

FVC: Forced vital capacity, FEV 1: Forced expiratory volume in 1 s, FEF: Forced expiratory flow, PEF: Peak expiratory flow, MBP: Mono-n-butyl, MEHP: Mono-2-ethylhexyl, MEHHP: Mono-2-ethyl-5-hydroxyhexyl, MEOHP: Mono-2-ethyl-5-oxohexyl, MMP: Monomethyl phthalate, MEP: Monoethyl phthalate, MIBP: Mono-isobutyl phthalate, MBzP: Monobenzyl phthalate, MECPP: Mono (2-ethyl-5-carboxypentyl) phthalate, DEHP: Di-2-ethylhexyl phthalate, DINP: Di-isononylphthalate, DIBP: Di-isobutyl phthalate, DEP: Butyl-benzyl-phthalate, DBP: Di-butylphthalate, ADHD: Attention-deficit/hyperactivity disorder, MSW: Municipal solid waste, MSD: Musculoskeletal disorder, OR: Odds ratio, CI: Confident interval, SD: Standard deviation, TMIG-IC: Tokyo Metropolitan Institute of Gerontology Index of Competence

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