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Guidelines on the Operation Phases of Manual Material Handling Tasks Through Literature Reviews

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Objective: The purpose of this study is to suggest the guidelines of operation phases to minimize injuries and musculoskeletal disorders in manual material handling (MMH) tasks through literature reviews. The guidelines are presented as the preparing phase, lifting phase, carrying phase, and lowering phase. Also, we summarized the non-numerical general guidelines for MMH tasks.

Background: Manual material handling is still a main cause to musculoskeletal disorders.

Method: Procedures of a literature review are classified into database selection, keyword search, title review, abstract review related to literature selection, guideline review and arrangement. A total 48 papers and books were analyzed in detail by title and abstract reviews.

Results: In the preparing phase, we suggested the basic conditions in MMH, preparing procedure, clothing and protective equipment, and education. In the lifting and carrying phases, we recommended maximal acceptable weight by frequency and body posture. In the lowering phase, we suggested the lowest weight and safety body postures. Finally, we recommended general guidelines and guideline items for MMH. General guidelines are presented to suggest worker selection, technical education, and work design parts.

Conclusion: We suggested the guidelines on the four operation phases of MMH tasks such as preparing, lifting, carrying, and lowering phases.

Application: The findings of this study can be utilized as guidelines for proactive recommendations according to workers in MMH tasks.

Keywords: Manual material handling, Preparing, Lifting, Lowering, Carrying, Literature review

1. Introduction

A manual material handling (MMH) task refers to a task carrying materials by lifting, lowering, pulling, or pushing them. Manual material handling tasks include all the tasks including package carrying and supporting in a static posture and throwing materials/packages to others from a designated place or a transport vehicle (Kim, 1997). Since differences in MMH tasks are huge according to personal capability in terms of efficiency, the tasks are limited within one's capability. If a MMH task is beyond a worker's capability, physical fatigue increases, work efficiency drops, and a safety accident can be caused (Garg and Saxena, 1979). The accident and injury types in the process of MMH tasks can be lumbago due to the lumbar, and stenosis, fall, and collision, and the most typical injury is lumbago by lumbar sprain (Kim, 1997). Lumbago is one of the typical musculoskeletal disorders, and can occur, when a worker conducts a task transcending his/her capability repetitively and unreasonably for the long-term (Ayoub et al., 1987; Liberty Mutual Insurance, 2004). Upon looking at the occupational injury statistical data in 2016, lumbago accounted for 34.8% of the total disorders, the highest ratio, followed by physically-burdening tasks at 26.6% (Ministry of Employment and Labor, 2016). The representative tasks causing lumbago and burdens to human body are the typical tasks that workers carry out themselves in many cases, despite automation and mechanization due to technological development in many fields (Garg, 1983; Mo et al., 2010).

MMH tasks show differences in physical load according to weight property, worker characteristics, and environment characteristics (Mack et al., 1995). Upon examining the detailed factors by each characteristic, the weight property encompasses size, weight, the center of gravity, shape, and the type of force (lifting, lowering, pulling, etc.). The task characteristics contain repetition, duration, speed, the pressure of work, and the status of assist devices use. The worker characteristics are the factor having the biggest personal differences, and gender, age, anthropometric data, muscle power, education/training and technology, and motivation are included. Compatibility between working space and equipment, spatial restrictions, the status of obstacle existence, topography/floor surface, surface friction force, slope or ramp, the intensity of illumination, and vibration correspond to the environment characteristics.

MMH tasks can be classified into preparing phase, lifting phase, carrying phase, and lowering phase. The preparing phase is to minimize and remove risks that can be caused during the MMH tasks. This phase refers to preparing for worker's safety before carrying out a task. Upon looking at the guidelines of previous studies on the preparing phase, the carrying method, carrying phase decision, gymnastics to prevent lumbago, working environment preparation such as securing safe carrying passage, the provision of clothes and protective equipment, and education/training are included (Ministry of Employment and Labor, 2012).

The lifting phase is the phase in which workers feel physical burden most in MMH tasks, especially heavy load occurs to the back. In the lifting phase, quite a difference in load on the back is shown according to material lifting posture. For example, the load on the lumbar 3 (L3) increases 62% when one lifts a 20kg package in a back-bending posture than lifting it with leg power in a back-erecting posture (Hansson et al., 1980). In addition, many studies research maximal acceptable weight according to lifting frequency and weight.

The carrying phase is the next phase of the lifting phase and refers to the task carrying a material to the designated place or space. The factors affecting workers most in the carrying phase are the weight, width, and height of a material, and carrying frequency and distance (N.C. Department of Labor, 2014). In this phase, heavy load occurs to worker's arm, shoulder, and back. The carrying posture is very important, and the burden to the arm and shoulder can be reduced, when carrying a material by contacting it to worker's body, since 30~40% of weight is supported by worker's body according to a study of Bhambhani et al. (1997).

The lowering phase, the last phase of the MMH tasks, is the phase carried out after the carrying phase, and it refers to the task lowering materials to the place or space concerned. Not many studies on the guidelines concerned with the lowering phase are found than those on the other phases, and there are not many relevant guidelines. Especially, ISO 11228-1 (2003) and British L23 do not distinguish the lower phase and lifting phase. The recommended weight and lifting frequency in the lifting regulations are used together for the lowering phase.

Previous studies on MMH tasks in which lumbago occurs and workers feel lots of burden to human body have been steadily researched for a long time. Therefore, guidelines on some influence factors including acceptable weight and frequency are presented. However, guidelines by operation phase of MMH tasks are not systematically presented, which can be a problem. In this regard, the purpose of this study is to present guidelines by operation phase through literature reviews to minimize musculoskeletal disorders-related injuries and burdens that may occur due to MMH tasks. The guidelines are presented through the preparing phase, lifting phase, carrying phase, and lowering phase, and the regulations on influence factors in each phase and whether the guidelines are included were arranged. This study also summarized the overall operation method on MMH tasks.

2. Literature Review Methods

To suggest the guidelines for MMH tasks by operation phase, we selected papers, books, and reports, and arranged and summarized the details by operation phase. PubMed, Elsevier Science, ScienceDirect databases, and the database search engines including Google Scholar, DBpia, RISS, and KISS providing various functions were selected, and the papers, books, and reports containing the adequately selected keywords in the titles were searched targeting the data registered from 1980 until now. The keywords to search for guideline suggestion were "Manual material handling", "Lifting", "Lowering", "Handling", and "Carrying". We primarily selected the data searched with the keywords which were judged to have high relevance with this study, and then reviewed the abstracts of those selected data (papers). The reason why abstract reviews were conducted is that vast amount of data were searched, and some data having little relevance were included. Based on the abstract reviews, we selected the data to be suggested as the final guidelines. The number of the selected data first through the keyword search was 285. We finally selected 48 papers and books judged to have high relevance with this study through title and abstract reviews and carried out an in-depth analysis (Figure 1).

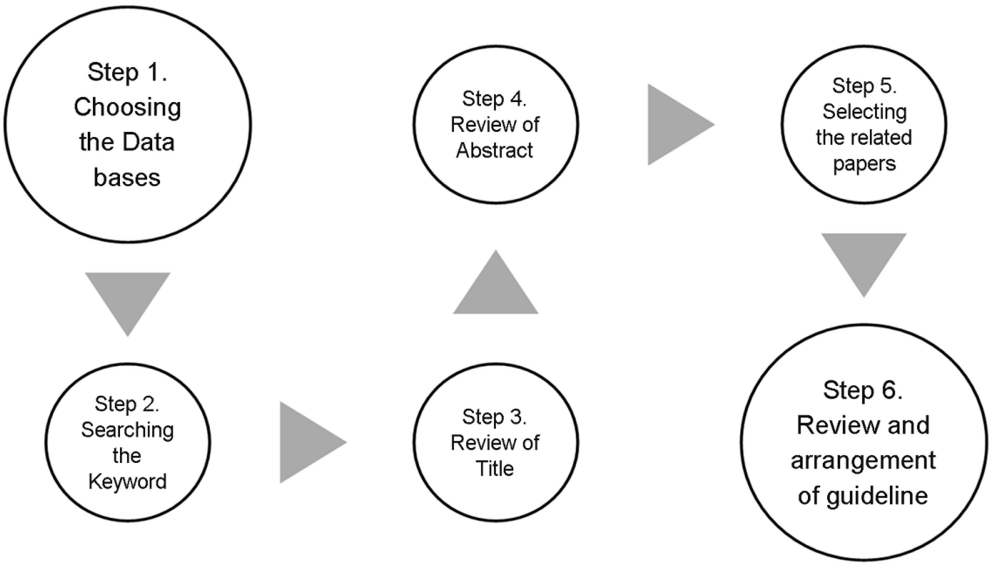

Figure 1. Methodology of literature review

3. Guidelines on the Operation Phases in MMH

3.1 Preparing phase

In the Employment and Labor Ministry Notification No. 2, the details to be carried out for safe work in the preparing phase in the

MMH tasks are arranged. The Notification consists of the following: 1. Basic conditions on MMH tasks, 2. Preparing process for MMH tasks, 3. Clothes and Wearing Protective Equipment, 4. Education/training. The following three are included in the basic conditions for MMH task:

1) An operation method and carrying phases need to be consulted and decided by choosing a skilled and experienced person as the head of the task.
2) When carrying a material together, unified motions need to be taken according to the task head's instructions excluding workers with remarkable differences in consideration of workers' physical strength and height.
3) A material (heavy stuff) having high center of gravity should not be carried manually.

The preparing process of MMH tasks include the following as worker's preparations and environmental preparations:

1) Light exercise is necessary to prevent lumbago centered on the back before a task begins.
2) Secure safe carrying passage by checking the carrying passage and removing obstacles in the passage. A bypass passage needs to be used, if inevitable.
3) Workers should be assigned in consideration of workers' physical strength.

The suggestion on clothes and protective equipment in MMH tasks encompasses the following five details:

1) The sleeves of upper working clothes should be a structure to contact the wrist, and the upper clothes' edge needs to be put into the pants.
2) The pants' edge should be put into safety shoes or should tightly contact the ankle.
3) The safety helmet, safety shoes, and safety gloves should gain safety certification and should be properly worn to fit each worker's body.
4) When handling a material generating dust or when workers handle dust-generating tasks, the workers need to wear a dustproof mask and goggles suitable for working conditions.
5) Protective equipment that can defend from harmful and hazardous substances should be selected and worn.

Lastly, we suggest the operation-related persons, as well as persons in charge of MMH tasks, should complete the following education/training:

1) Education/training of lumbar support equipment and working methods for safe work.
2) Education/training of cautions upon handling heavy stuffs or hazardous materials.
3) Review education/training associated with work paths.

3.2 Lifting phase

In the lifting phase, physical load is heaviest in the operation phases of MMH tasks, and especially load on the back intensively occurs. Concerning the lifting phase, many guidelines on the posture, frequency, and weight of lifting are presented. The working posture in the lifting phase affects load on lumbar 3 (L3). For instance, in comparison of lifting a 20kg material in a posture of erecting the back and bending the knees with lifting it in a posture of stretching the knees and bending the back, 38% of load can be reduced in the case of lifting in a posture of erecting the back and bending the knees (Table 1) (Hansson et al., 1980).

Many studies have presented guidelines on working posture and maximal acceptable weight according to lifting frequency and weight in the lifting phase. Table 2 shows the guidelines on maximal acceptable weight according to lifting frequency. Although

Table 1. Lumbar 3 load by upper and lower body posture

Posture	Load (Kg)
Standing	70
Twisting of upper body (trunk)	90
Lateral-flexion of upper body (trunk)	95
20 degree flexion of upper body (trunk)	120
20 degree flexion of upper body (trunk) in lifting 10kg with each hand	185
No flexion of upper body (trunk) and flexion of knee in lifting 20kg	210
Flexion of upper body (trunk) and no flexion of knee in lifting 20kg	340

some differences existed in each guideline on acceptable weight, the mean weight was 22.7kg, 23.7kg, 22.9kg, 21.1kg, 19.4kg, and 18.4kg in frequency 1, 2, 3, 4, 5, and 6, respectively. Upon looking at the decrease of weight according to frequency, big difference was not shown up to frequency 3 per minute; however, 1.5kg difference was revealed on average from frequency 4. In addition, ISO 11228-1 defined recommended limit weight and maximal lifting frequency. The recommended limit weight was 23.5kg for frequency 1 per minute in a lifting task for an hour or less, and it was 22kg for frequency 1 per minute in a lifting task for 1~2 hours. In the case of a15kg material, the ISO 11228-1 suggested 8 times of lifting per minute maximum in a lifting task for an hour or less, and 5 times of lifting per minute maximum in a lifting task for 1~2 hours.

Table 2. Maximal acceptable weight (MAW) by lifting frequency

Authors	Lifting frequency per min					
	1	2	3	4	5	6
Snook (1971)	23.4		21.1	20.4	20.2	
Garg and Saxena (1979)			20.5			17.5
Mital and Manivasagan (1983)		21		19.4		18.7
Aghazadeh (1985; 1986)		27.4				
Asfour et al. (1985)	27.2		20		18.6	
Mital and Fard (1986)	18.1			19.7		18.6
Mital (1987)		21		19.7		18.6
Garg and Banaag (1988)			28.2			
Mital and Wang (1989)	19.8					
Danz and Ayoub (1991; 1992)				27.5		
Chen et al. (1992)	27.5	25.3		20.2		
Ciriello et al. (1993)	19.7			18.5		
Lee et al. (1995)	23.2			18.5		
Lee and Chen (1996a; 1996b)	23.9			18.7		
Mital and Kumar (1997)	18.6					

Table 2. Maximal acceptable weight (MAW) by lifting frequency (Continued)

Authors	Lifting frequency per min					
	1	2	3	4	5	6
Wu (1997)				27.2		
Boocock et al. (1998)	21.5					
Chen (2000)	25.4			19.9		
Chen (2003)	24.3			18.5		
Min.	18.1	21.0	20.0	18.5	18.6	17.5
Max.	27.5	27.4	28.2	27.5	20.2	18.6
Average	22.7	23.7	22.9	21.1	19.4	18.4
SD	3.2	3.2	4.6	3.6	1.1	0.6

The Korean Employment and Labor Ministry Notification No. 2012-70.7 recommends as follows as the regulations and guidelines for safe work in the lifting phase: 1. The weight of a material must be actually measured in principle, and when the weight of a material is not constant, the mean weight and maximum weight must be actually measured. 2. When the weight of a material is guessed, judge whether it is sufficient in view of individual's competence. 3. The body posture in a lifting task should comply with the following:

1) Safely fix one foot toward the object to lift, and fix the other foot safely behind the foot.
2) Always Keep an upright posture for the back, and make the back a right angle from the floor, if possible.
3) Take a right-angled posture of the knees and lift the object from the front by making worker's body close to the object, if possible.
4) Pull the jaw inwards, and keep the posture to make it a straight line with the spine.
5) Closely contact arms to the body, take a pulling posture, and make the horizontal distance short, if possible.
6) Do not make a pinch grip of the object with only fingers, and grip the entire object with the palm (power grip).
7) Keep balance by making the center of worker's body weight position at the center of both legs.
8) Lift giving force to the foot at the back at first.

Eastman Kodak Company (2004) presents eight items of the guideline in the lifting phase as follows:

1) Make a plan for lifting.
2) Decide the optimal lifting method.
3) Hold the object solidly, and take the two feet apart as much as shoulder width to keep stable state.
4) Lift the object contacting the body as closely as possible, while maintaining power.
5) Lift a heavy object using legs.
6) Do not twist the upper body while lifting the object.
7) As for the lifting task of excessively heavy objects, lift them by dividing the frequency into several times.
8) Exert force using big muscles and carry the object.

The North Carolina (N.C.) Department of Labor presents seven items of the guideline for a safe lifting task (N.C. Department of Labor, 2014) as follows:

1) Check the weight and distribution of the materials in advance, and do not be surprised at weight change or excessive weight.
2) If the material is excessively heavy or lifting has to be conducted in an inappropriate posture, use other workers or an assist device. In the case of working with other workers, coordinate the lifting task through continuous communication during the lifting phase.
3) Check the place where the material needs to be lowered, and also check whether an obstacle or other danger risk exists in the path concerned.
4) Position the body close to the material, and put feet evenly and stably. Make the material close to the body, if possible, so that the center of gravity can come close to the body.
5) Grab the material with both hands, if possible (power grip), and do not conduct a pinch grip, namely do not grip with fingers.
6) Move with natural, gentle, and continuous balanced motions, and do not take fast or sudden motions. Prevent upper body twist by moving feet, and keep balance during the lifting task.
7) The twist, flexion, excessive reaching motions need to be minimized, because they can increase the risk of lumbago.

Lastly, British L23, guidelines on MMH tasks, defines the weight in the lifting phase as shown in Figure 2. The guideline in Figure 2 is about the irregular lifting phase. The guideline suggests the application of reduced weight according to upper body posture, if such a lifting task occurs repeatedly (Health and Safety Executive, 2016) (Table 3).

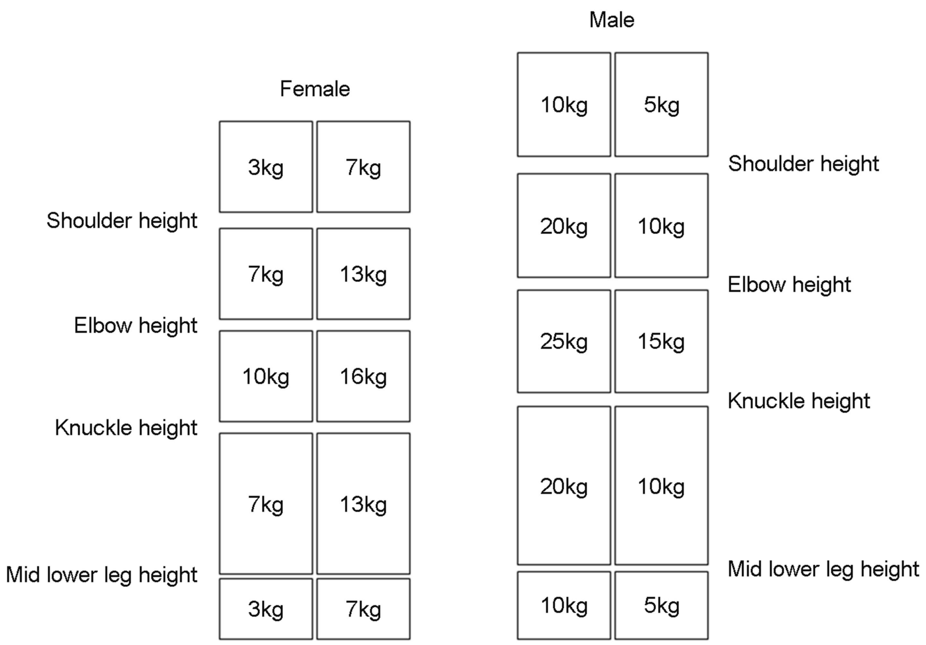

Figure 2. Recommended lifting weight of L23

Table 3. Decrease ratio of recommended lifting weight according to lifting frequency

Frequency per min	Decrease ratio of recommended lifting weight (%)
Standing	30
Twisting of upper body (trunk)	50
Lateral-flexion of upper body (trunk)	80

3.3 Carrying phase

The carrying phase of a heavy stuff gives physical burden to the arm, shoulder, and back. To minimize such physical burden, the body posture handling materials is very important among others. A worker should secure front vision, when lifting a material, and it is desirable to stretch arms straight and lift the material to the height of the waist not to make the material disturb walking (N.C. Department of Labor, 2014). Bhambhani et al. (1997) reported that the burden to the arm and shoulder can be reduced by carrying a material by making it close to the body, when carrying a material, because 30~40% of the weight of the material is supported by the body.

Table 4 shows the Snook Table provided by Liberty Mutual Insurance (2012), and it reveals the recommended weight upon carrying by male workers as far as 8.5m. For example, in case carrying a material 8.5m with one frequency per minute in an arm stretching posture, the table means that there is a possibility that 10 percentile of the total male workers can carry a 44kg material safely. Therefore, the weight of a material for 90 percentile male workers to safely carry 8.5m with one frequency per minute is 17kg.

Table 4. Recommended weight during 8.8m carrying (kg)

Hand height	%tile	Carrying period						
		6 Sec	12 Sec	1 Min	2 Min	5 Min	30 Min	8 Hours
111cm (Bending the Elbow)	90	10	11	13	13	15	17	20
	75	13	15	18	18	20	23	27
	50	17	19	23	24	26	29	35
	25	21	24	29	29	32	36	43
	10	24	28	34	34	38	42	50
79cm (Straight the Elbow)	90	13	15	17	18	20	22	26
	75	17	20	24	24	27	30	35
	50	22	26	31	31	35	39	46
	25	27	32	38	38	42	48	56
	10	32	38	44	45	50	56	65

Likewise, ISO 11228-1 also defines the recommended limit of cumulative weight according to carrying distance and frequency in the carrying phase (Table 5). For instance, carrying 15kg material once is recommended in case carrying 20m once per minute.

The Korean Employment and Labor Ministry Notification No. 2012-70 presents four items and three items of recommendations to comply with, when carrying a general material and a long material, respectively: The recommendations upon carrying a general material are as follows:

1) The carrying of a material should be horizontal distance carrying in principle, and carrying by lifting several times, relay carrying, or repeated carrying are prohibited.
2) A worker should look at the carrying direction, and backward carrying is prohibited.
3) Lifting and carrying a material at the height higher than shoulder height should not be carried out.
4) Taking out from the middle part or lower part, when carrying piled up materials, is prohibited.

Table 5. Cumulative recommended weight by carrying distance and frequency in ISO 11228-1

Carrying distance	Frequency per min	Cumulative weight			Example
		kg/min	kg/h	kg/8h	
20	1	15	750	6000	5kg × 3 times/min 15kg × 1 time/min 25kg × 0,5 time/min
10	2	30	1500	10000	5kg × 6 times/min 15kg × 2 times/min 25kg × 1 time/min
4	4	60	3000	10000	5kg × 12 times/min 15kg × 4 times/min 25kg × 1 time/min
2	5	75	4500	10000	5kg × 15 times/min 15kg × 5 times/min 25kg × 1 time/min
1	8	120	7200	10000	5kg × 15 times/min 15kg × 8 times/min 25kg × 1 time/min

The recommendations upon carrying a long material are as follows:

1) When carrying a material on the shoulder alone, make the front end of the material a bit higher than the worker's height, and be cautious not to collide with its corner or edge.
2) When carrying a material together, the workers need to carry the material on the shoulders of the workers, and work according to the head worker's instruction.
3) When lowering a material, be careful about unexpected situations such as bouncing and rolling down.

3.4 Lowering phase

Although Snook and Ciriello (1991) presents the maximal acceptable weight according to lowering distance, height, and frequency in the lowering phase as shown in Table 6, not many studies on the regulations concerned with the lowering task are found. The ISO 11228-1 and British L23 do not classify the lowering phase and lifting phase and apply the recommended weight and frequency of the lifting regulations together. The work practices guide for manual lifting (1981) and application manual for the revised NIOSH lifting equation (1984) of the U.S. (National Institute for Occupational Safety and Health: NIOSH) regard lowering phase as the same as lifting phase (Kim, 2010). Upon looking at the recommended weight of Snook Table, slightly higher recommended weight is presented in the lowering phase than in the lifting phase.

The Korean Employment and Labor Ministry Notification No. 2012-70 presents the three items of the regulations on the lowering phase in brief as follows:

1) Keep the erecting position of the back, bend legs into a low posture, if possible, with the no movement of feet, and lower one side to the floor first, and then the other side.
2) Do not unload the material in a hasty manner.

Table 6. Maximal lowering weight in U.S. workers (kg)

Width	Distance	Percent	Height	Sec			Min				Hour
				5	9	14	1	2	5	30	8
Males 34	51	90	Knuckle height to floor level (One lower every)	10	13	14	17	20	22	22	29
		75		14	18	20	25	28	30	32	40
		50		19	24	26	33	37	40	42	53
Females 34	51	90		7	9	9	11	12	13	14	18
		75		9	11	11	13	15	16	17	22
		50		10	13	14	16	18	19	20	27
Males 34	51	90	Shoulder height to knuckle height (One lower every)	11	13	15	17	20	20	20	24
		75		15	18	21	23	27	27	27	33
		50		20	23	27	30	35	35	35	43
Females 34	51	90		8	9	9	10	11	12	12	15
		75		9	11	11	12	14	15	15	19
		50		11	13	13	14	16	18	18	22
Males 34	51	90	Overhead reach to shoulder height (One lower every)	9	10	12	14	16	16	16	20
		75		12	14	17	19	22	22	22	27
		50		16	19	22	24	28	28	28	35
Females 34	51	90		7	8	8	8	10	11	11	13
		75		8	9	10	10	12	13	13	16
		50		10	11	11	12	14	15	15	19

3) When lowering a material at the shoulder or waist height, unload it safely with another person's help.

3.5 General guidelines and guideline items for MMH

Konz and Johnson (2008) presented 10 items of the general guideline on MMH tasks, not the guideline based on acceptable weight suggested by NIOSH guidelines and previous studies. The 10 items of the guideline are divided into 1. Selection of workers, 2. Technical education/training on MMH tasks, and 3. Task design.

As for the guideline on the selectin of workers, it is selecting workers suitable for MMH tasks based on job capacity evaluation. To select workers, job severity index can be used (Liles, 1986; Ayoub et al., 1987; Herrin et al., 1986). The job severity index is calculated using the following equation:

JSI (Job Severity Index) = f (Weight/Capacity)

where, weight indicates the lifted or carried weight, and capacity means worker's capacity on the task. Worker's capacity means the function of mainly fat-free body weight. A study of Jackson et al. (1997) reported that lifting capacity can be predicted by the sum of the isometric tests of the arm, shoulder, leg, and trunk or by fat-free body weight.

Regarding technical education/training on MMH tasks, the following were presented: 1. Bend knees, 2. Do not slip or do not move suddenly, 3. Do not twist body when carrying a material. According to a study of Burgess-Limerick et al. (1995), it was reported that bending knees can make coordination of the inter-joint between the knee and hip better and can reduce the muscular effort of the hamstring, quadriceps, and erector spinae. Slip causes sudden and unexpected load on the back during MMH. In this regard, it is important to enhance friction force between the shoe and sole. It is also important to give information on the weight of a material to be handled by a worker in order to prevent slip or a sudden motion. The reason is that the load on workers' body can be reduced by different use of the motion patterns in advance on the basis of the weight information.

From the task design aspect of MMH tasks, the environment is recommended to be designed through the following: 1. Use machines/instruments/equipment, if possible, 2. Reduce the weight of a material as much as possible and frequently move 3. Provide a handle (or a strap), 4. Reduce spinal torque, 5. Keep the material close to the body, and 6. Work at the knuckle height. It is most desirable to remove or reduce manual handling by using various machines, instruments, and equipment for manual material handling including conveyors, lift trucks, balancers, manipulators, and turntables. Reducing weight is a good method from the perspective of reducing load on the musculoskeletal system in the MMH tasks. The best method in order to reduce weight is to use gravity. Another method is to reduce weight through joint work. However, it is efficient for people with similar height and muscle strength to work together so as to carry out joint MMH tasks (Lee and Lee, 2001). To reduce spinal torque, it is necessary to calculate torque on the spine. The torque on the spine can be calculated using the following equation (Konz and Johnson, 2008).

SPINET = OBJWT (OBMARM)

where, SPINET means torque on the spine, and OBJWT means materials' weight, and OBMARM means material's moment arm. The moment arm can be calculated through the following equation.

DISTO + DISTCG

where, DISTO means distance between the spine and material (coronal plane), and DISTCG means the distance from the close part of the material's center of gravity. To reduce torque on the spine, a material needs to be placed close to the human body or a person should approach a material closely and reduce arm reaching.

It is important to design the position of a MMH task. By installing a pallet or a scaffold, let a material not be placed on the floor. From the human body aspect, the terminal position of lowering a material is more important than the point in time of lifting a material. Therefore, the terminal height should not exceed shoulder height.

Table 7 shows the detailed items and the status of inclusion of the guidelines and regulations by operation phase presented in the previous studies.

Table 7. Guideline items through operation phases in manual material handling tasks

Phase	Item	MEL	Kodak	NCDOL	L23	ISO
Preparing	Discussion/Plan	○				
	Worker selecting	○				
	Limit weight	○	○	○	○	

Table 7. Guideline items through operation phases in manual material handling tasks (Continued)

Phase	Item		MEL	Kodak	NCDOL	L23	ISO
Preparing	Warm-up		○				
	Secure passage		○		○		
	Clothes rule		○				
	Prior education		○				
	Lifting plan establishment			○		○	
	Weight measurement		○		○	○	
Lifting	Posture	Foot position	○	○	○	○	
		Back	○				
		Knee	○				
		Eye position	○				
		Arm	○	○	○	○	
		Hand	○	○	○	○	
		Center of gravity	○				
	Motion	Upper limb twist		○	○	○	
		Using the large muscle		○			
		Sudden motion			○	○	
	Recommended lifting weight		○			○	○
	Recommended lifting frequency		○			○	○
Carrying	Close to the body					○	
	Carrying distance					○	○
	Carrying frequency						○
	Carrying method		○				
	Carrying direction		○				
	Carrying height		○			○	
	Both people		○				
Lowering	Posture		○				
	Speed		○				
	Both people		○				

4. Discussions

The purpose of this study is to present guidelines by operation phase through literature reviews in order to minimize musculoskeletal injuries and burdens that may occur due to manual material handling tasks. The guidelines were presented in four phases: preparing phase, lifting phase, carrying phase, and lowering phase, and the major regulations on influence factors by each phase and whether each guideline is included have been arranged. In addition, this study summarized conceptual MMH task's guidelines, not based on numeric values.

In the guideline on the preparing phase of MMH tasks, the establishment of plans on operation and preparation were included. The suggestions for the operation method, operation phase consultation, and motions are mainly included, also the environment preparation for safe MMH and worker's preparation are included. The guideline on clothes and protective equipment for MMH tasks and the guideline on education/training on cautions and handling method were presented. Upon synthesizing the guidelines corresponding to the preparing phase of MMH tasks, the guidelines from the managerial aspect were generally presented.

Upon synthesizing the guidelines in the lifting phase, the lifting phase is defined as the task having the heaviest physical load. Especially, lifting is a task accompanying load on the back intensively, and the guideline on the lifting posture, frequency, and weight is presented. The load on the back becomes different according to lifting posture, and the lifting posture by erecting the back and bending knees is suggested to be the most proper posture (Hansson et al., 1980). The maximal acceptable weight becomes different according to lifting frequency. Upon calculating the mean value by synthesizing the previous studies' results, 22.7kg upon frequency 1 lifting per minute, 23.7kg upon frequency 2, 22.9kg upon frequency 3, 21.1kg upon frequency 4, 19.4kg upon frequency 5, and 18.4kg upon frequency 6 on average are presented, respectively. As a result of analyzing the mean values numerically, the difference in maximal acceptable weight was not large from frequency 1 to frequency 3; however, the maximal acceptable weight fell proactively from frequency 4 (Table 2). In the case of frequency 5 to 8, it was reported that the recommended weight fell by 50% in the lifting task, compared to frequency 1, and 80%, when frequency exceeds 12 (Health and Safety Executive). As the important guideline in the lifting task, offering the weight of a material to a worker and the lifting posture are suggested. In conclusion, reducing lifting frequency, decreasing weight, and keeping proper handling posture are the best method to reduce physical load.

In the carrying phase, the major factors affecting worker's physical load are weight, the width and height of a material, carrying frequency, and carrying distance (N. C. Department of Labor, 2014). In the carrying phase, the carrying posture is most important. Upon synthesizing the results in Table 4, the recommended weight that can be carried maximum shows 3 to 16kg difference according to the height of the hand in carrying a material. The recommended weight gradually decreases, as carrying distance becomes longer or carrying frequency becomes more. The important factors in the carrying phase are the variables related with the size of a material to be carried (package), and the recommended weight shows a big difference according to whether a handle or a strap exists. Workplace design to reduce carrying distance is important above all, and it is also important to provide packing that can reduce the width of a material or a package and a handle (or a strap).

In the lowering phase, not many studies offering the guidelines are found in comparison with other operation phases. The reason is that most studies regard the lowering phase as similar to the lifting phase, and therefore the recommended weight and handling frequency in the lifting phase are applied together. A study of Snook and Ciriello (1991) presents maximal lowering weight based on distance, height, and frequency. Upon looking at recommended lowering weight, the recommended weight increases, as the lowering distance is shorter. To minimize load on human body in the lowering phase, it is most important to minimize lowering distance, and it is also desirable to minimize lowering frequency, if possible.

This study organized the guideline items of previous studies by operation phase in MMH tasks as shown in Table 7. Upon putting the results mentioned above together, there were no previous studies encompassing all the various items of the guidelines, and the items of qualitative guidelines took up more than the items of quantitative numerical value-based guidelines. Concerning posture, for example, it is difficult to find a guideline dealing with detailed information on the posture angle recommended to each joint area. In most studies, recommended weight by operation phase is suggested; however, the data are not suitable for the reality of Korean workers. The reason is that the anthropometric data of Korean workers show huge differences from the anthropometric data of foreign workers. For this reason, it will be slightly unreasonable to apply the recommendation guidelines to Korean workers.

A further study to suggest guidelines on the recommendation limit suitable for Koreans are judged to be necessary by revising and complementing the findings of the previous studies through the task competence evaluation or anthropometric information of Korean workers.

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