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Analysis of Farm Work in a Vertical Farm

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ABSTRACT

Background and objective: Farm work involves a range of postures depending on the type of work, and repeated farm work performed in an uncomfortable posture can cause serious functional disorders affecting the lower back, shoulders, joints, and muscles. For the physically disabled to participate in farm work, it is essential to analyze farm work based on their individual levels of physical ability. This study analyzed farm work in vertical smart farms to develop care farming services for the purpose of vocational rehabilitation of the physically handicapped.
Methods: Farm work was analyzed through a field survey in a vertical farm located in P-si, Gyeonggi-do. Based on the analysis, major farm work was classified into duties and tasks.
Results: Through a filed survey, farm work in a vertical farm was categorized into six duties, and all tasks were mainly performed within the same workplace. The six duties were analyzed as sowing, raising seedlings, transplanting, planting, harvesting (including sorting and packaging), and post-harvest cleaning, which were further classified into 28 tasks as sub-areas.
Conclusion: The result of this farm work analysis in a vertical farm will provide useful basic data for the development of care farming services for the vocational rehabilitation of the physically handicapped.

Keywords: care farming (social farming), green care, smart farm, socio-horticulture, vocational rehabilitation

Introduction

Work is one of the essential elements for the physical and mental well-being of people, regardless of whether they are disabled or are able-bodied (Chan et al., 2005). However, as people with functional limitations resulting from physical disabilities have difficulty participating smoothly in training and work, continuous support and consideration for their social security and care are required (Achterberg et al., 2009; Nieuwenhuijsen et al., 2008; Prins, 2013; Van Mechelen et al., 2008).

Agriculture's healing functions have been verified in many domestic and overseas findings, which have shown that it has positive effects on physical and mental health for a wide range of people, including the chronically ill, the disabled and the able-bodied (Care Farming UK, 2017; Kim et al., 2020; RDA, 2020). In Europe, which is advanced in the field of care farming, social agriculture has already been used as a medium to provide welfare services to the handicapped, including care, employment, and education (Kim and Na, 2019). In Japan as well, agriculture has been actively utilized by the Ministry of Agriculture, Forestry and Fisheries and the Ministry of Health, Labor and Welfare in employment, health promotion, job training, and improved quality of life for the disabled through "social welfare projects linked to agriculture" (Lim, 2017).

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In South Korea, social farming is defined as an industry that creates social and economic added value through agricultural activities using various agricultural and rural resources in order to recover, maintain, and improve the health of the public. Depending on the form or content provided, it can be divided into horticultural care, forest care, animal-assisted therapy, and farm work care (Jung et al., 2022; RDA, 2020). Based on this, policy projects have been implemented by Korea's central and local governments to support care, employment, and education services for the health vulnerable. A small number of farms based on agricultural cooperative corporations, social cooperatives, and non-profit private organizations have actually offered farm work jobs to the health vulnerable, including the handicapped and the elderly (Kim and Na., 2019). However, conventional farming in open fields not only provides somewhat unstable work due to the agricultural off-season, but also imposes many physical limitations, such as lifting heavy objects or bending over, posing a challenge to the physically handicapped who require mobility aids. Farm work involves a variety of work postures, such as squatting and bending over, and repetitive work performed in uncomfortable postures can cause serious functional impairment in joints and muscles including the lower back, shoulders, and knees, in both the disabled and the able-bodied (Park and Kim, 2013). The imbalance in working postures may cause musculoskeletal disorder, as well as negative emotions including stress and unhappiness. These health hazard factors can have a negative impact on people with diseases or handicaps, damaging their health and quality of life (Law et al., 2017).

For the handicapped, health means living a healthy life rather than completely being cured or overcoming their disability (Krahn, 2003). As such, their participation in physical activities can involve diverse health effects, while being expected to improve their health in a multifaceted manner (Williams and Smith, 2018). Participation in social and physical activities is necessary to improve the health of people with disabilities (Carroll et al., 2014). It is important to provide opportunities to improve self-esteem through their participation in economic activities by pursuing social welfare policies that can offer the disabled steady jobs (Moon et al., 2017). For social minorities, such as the disabled, the social perception of them and their social roles play an important role; the experience of social achievement, along with their economic activity, helps handicapped people improve their personal health (Moon et al., 2017). For people with disabilities, "work" has great value and plays a key role in helping them escape from the vulnerable worker or underprivileged classes, to become self-reliant members of society (Ji et al., 2019). According to the Ministry of Health and Welfare (2021), the number of disabled people registered in South Korea reaches 2.51 million, equivalent to 5% of the total population, and is continuously increasing due to diseases and industrial accidents. The rates of participation in economic activities and of employment among people with disabilities are low, at 37% and 34%, respectively. To successfully promote the employment of and job creation for people with disabilities, comprehensive support for them throughout society is required, along with policy and institutional changes (Kim et al., 2021). Vocational rehabilitation experts have recognized the importance of labor, and have consistently argued that labor is a basic human right for the handicapped (Marrone and Golowka, 2000).

Individuals with physical disadvantages have a higher success rate in landing jobs in professional and technical fields than those with intellectual disadvantages. However, as they have significant limitations in physical function (Dutta et al., 2008), it is necessary to support them through a vocational rehabilitation system, which can include appropriate aids and facilities that take into account their physical function (Frank, 2016). Recently, agriculture has evolved into various types of industries, including smart farming that integrates information and communication technologies, farm produce processing industries, farm experiences, and care farming, creating new steady jobs (Lim, 2020). Notably, smart farming in the form of vertical farms allows us to escape from labor-intensive farming and remotely and automatically control the growth environment of plants, enabling year-round production of agricultural products and the automation of certain parts of the growing process as needed. This can provide an optimal working environment for the physically handicapped who use mobility aids. Labor and employment are very important for people with physical disabilities in promoting their social par-

ticipation, satisfying their psychosocial needs, and forming individuals' identity, social role, and social status (Waddell and Burton, 2006). In supporting the labor and employment of the physically disabled, that is, vocational rehabilitation, in this field, it is necessary to establish a working environment that is suitable for the characteristics of their disabilities, to subdivide the work process, and to develop an optimal cultivation system.

Therefore, this study was conducted to analyze the types of farm work in smart farming and use them as basic data for the development of a smart farm system suitable for the functional abilities of the physically handicapped participating in agricultural activities for future vocational rehabilitation and health promotion.

Research methods

Research design

In this study, for a systematic field survey, the observational method (OM) was used based on a hierarchical task analysis (HTA), one of the task-oriented techniques, to classify tasks according to the scope and duties of farm work in a vertical smart farm and present the order of specific tasks. OM is a method of analyzing work by directly visiting the workplace when the work to be analyzed includes only simple and repetitive tasks (Ju et al., 2011). The analysis process of farm work is shown in Fig. 1 below.

Survey target and data collection method

For this study, a field survey of farm work and an interview with farm workers at P Smart Farm located in Pyeongtaek, Gyeonggi-do were conducted. Through the field survey, the working environment and conditions were investigated, and detailed task units of farm work in vertical smart farms were derived by analyzing repetitive tasks, time taken for each task, and the relationships between and procedures of detailed tasks. The unit of work analysis was set as job, duty, and task. A job is a task that must be vocationally taken on with responsibility, and refers to a specific unit within the work system that a worker performs (Lee and Won, 2000). A duty is defined as a unit in which a job is classified based on a systematic method. A task is a unit of a scope of action that can be measured (Lee and Won, 2000). During the field survey, the researchers were accompanied by a work manager capable of explaining the farm work, and data on farm work were collected by directly observing the workplace. The types of farm

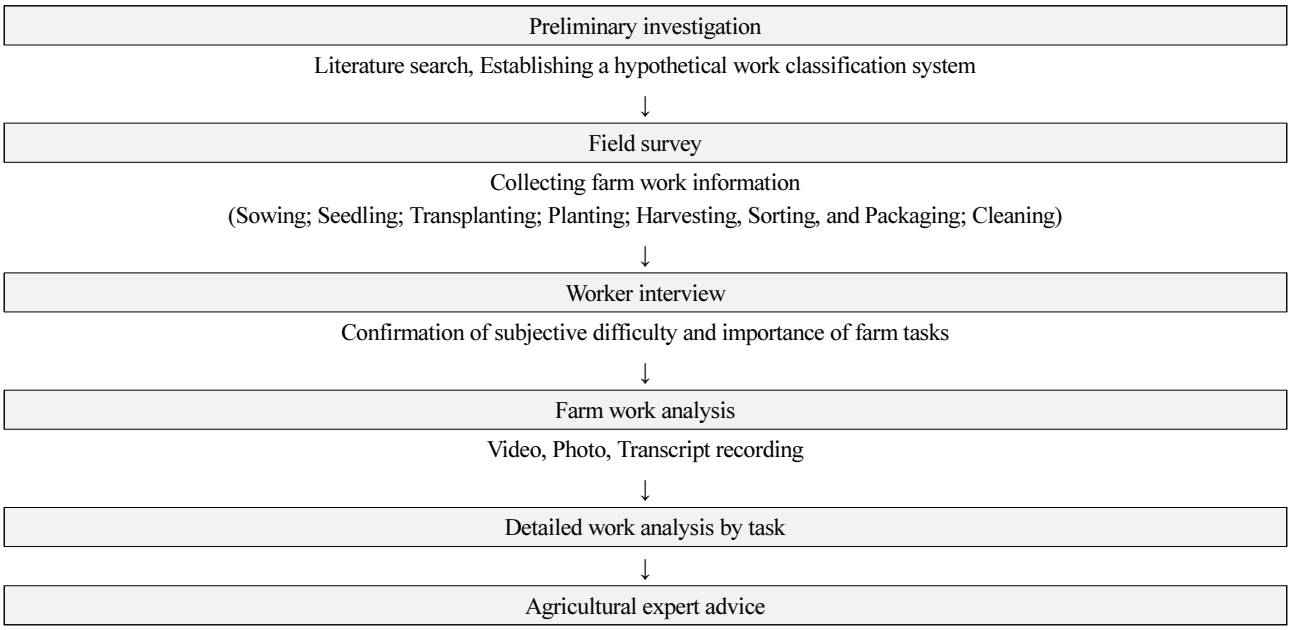

Fig. 1. Farm work analysis process.

work were subdivided and analyzed repeatedly based on the collected data, which were recorded in the form of photos, videos, and documentation. They were analyzed and derived based on the legal working hours of 8 hours per day. The types of farm work analyzed were consulted on with two care farming experts, an agricultural expert, and a vertical-farm manager. Vertical farm work jobs were classified into 6 duties and 28 tasks and categorized based on task procedures.

Results

Categorization of farm work

The farm work within the smart farm was categorized into the following 6 duties, which could be subdivided into 28 tasks based on work procedures: sowing (8 tasks), raising seedlings (3 tasks), transplanting (4 tasks), planting (4 tasks), harvesting, sorting and packaging (5 tasks), postharvest cleaning (4 tasks). The order of farm work may vary depending on the shipping time of crops harvested each day, and all 6 duties were completed within the working hours of 8 hours per day (Table 1; Fig. 2).

Sowing included 8 tasks: donning sanitary work-clothes before work, taking an air shower, selecting seeds to be sown, briefly soaking seed trays in water, sowing seeds on growing media, sowing inspection, attaching name tags with sowing date and seed name to seed starting racks, sprouting, and cleaning up around the workplace. It took an average of 2 days for the seeds to sprout after being sown. Sowing was performed by one skilled worker alone. Raising seedlings consisted of 3 tasks: moving seed trays from seed starting racks to seedling racks and loading them, attaching name tags with the date of movement and seed name to seedling racks, and managing cultivation. It took an average of 10 days to cultivate and manage the seedlings.

For sowing and raising seedlings, since task importance affects the quality of crops, it was found that the higher the worker's proficiency level, the more it contributes to improving the quality of the harvest. Transplanting consisted of 4 tasks: selecting and transplanting seedlings from seed trays to transplanting trays in the planting workbench, moving and loading transplanting trays to transplanting racks, and attaching name tags with the date of movement and the name of crops to transplanting racks. It took an average of 10-12 days to cultivate and manage the transplanted seedlings. Planting included 4 tasks: selecting the crops from transplanting trays and planting them to planting trays in the planting workbench, moving planting trays to planting racks from transplanting racks and loading them, and attaching name tags with sowing and planting dates to planting racks. It took an average of 16-18 days to grow and manage the planted crops. Harvesting, sorting, and packaging included 5 tasks: moving planting trays from planting racks to harvesting workbenches, harvesting crops by separating them from planting trays; sorting crops (removing the roots and weighing crops); packing harvests in boxes, attaching barcode stickers to packing boxes, and cleaning up around the workplace. Post-harvest cleaning consisted of 4 tasks: cleaning planting trays with a high-pressure water hose after harvesting, draining the nutrient solution from the planting racks, cleaning the filter units of planting racks, and cleaning workbenches and floors. With the exception of sowing and raising seedlings, all farm work was performed in teams of two, such as moving the transplanting/planting trays, or moving harvests to the workbenches, and was further divided into direct work and support work depending on the workers' proficiency level. The frequency of farm work in the smart farm was found to be high for transplanting, planting, harvesting, and post-harvest cleaning, but workers' proficiency level and task importance were found to be high for sowing and raising seedlings (Fig. 3).

Working postures in the vertical farm were performed repeatedly with the following movements: "lifting" in which objects are raised or lowered from a given height to another

Table 1. Farm work analysis process

No.	Duty	Task
A	Sowing	8
B	Raising seedlings	3
C	Transplanting	4
D	Planting	4
E	Harvesting, Sorting, and Packaging	5
F	Postharvest cleaning	4
Total	6 duties	28 tasks

Duty	A Sowing	B Raising seedlings	C Transplanting	D Planting	E Harvesting, Sorting, and Packaging	F Post-harvest cleaning
Task 1	Wearing sanitation work clothes and going through the air shower room	Moving and loading from seed starting racks to seedling racks	Transplanting seedlings from seed trays to transplanting trays in the planting workbench	Planting crops from transplanting trays to planting trays in the planting workbench	Moving planting trays from planting racks to harvesting workbenches	Cleaning planting trays
Task 2	Pre-sowing treatment 1 (Seed selection)	Attaching name tags to seedling racks	Moving and loading transplanting trays from seedling racks to transplanting racks	Moving and loading them from transplanting racks to planting racks	Harvesting crops from planting trays	Draining the nutrient solution from planting racks
Task 3	Pre-sowing treatment 2 (Briefly soaking seed trays in water)	Managing cultivation (10 days)	Attaching name tags to transplanting racks	Attaching name tags to planting racks (sowing and planting dates)	Sorting crops, removing roots with a work knife, and weighing crops	Cleaning the filter units of the planting rack
Task 4	Sowing 1 (Sowing plate)		Managing cultivation (10~12 days)	Managing cultivation (16~18 days)	Packing harvests into boxes and attaching barcode stickers	Cleaning workbenches and floors
Task 5	Sowing 2 (Sowing inspection)				Cleaning up around the workplace	
Task 6	Attaching name tags to seed starting racks					
Task 7	Sprouting (2 days)					
Task 8	Cleaning up around the workplace					

Fig. 2. Farm work in a vertical farm (6 duties and 28 tasks).

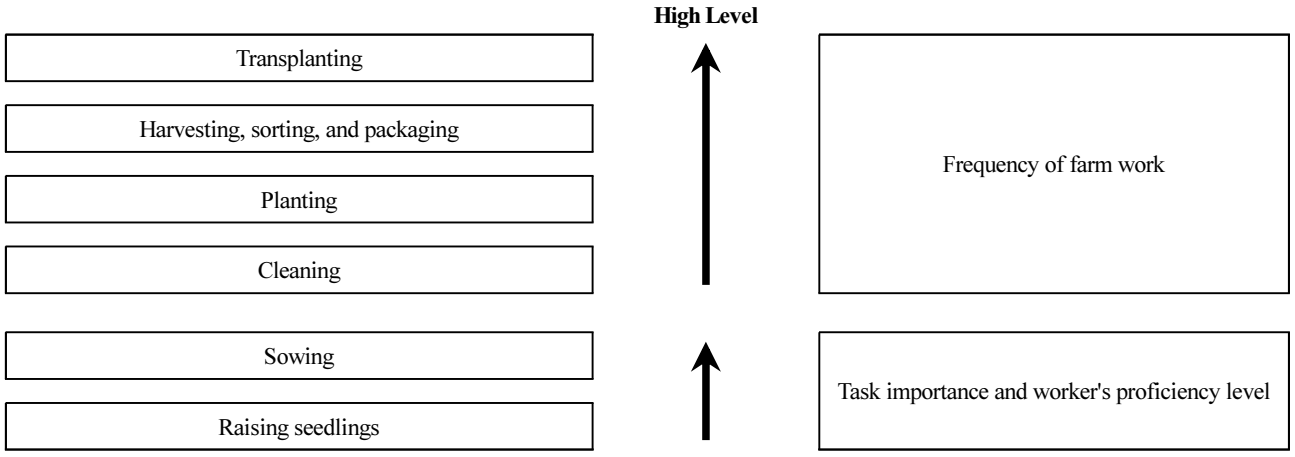

Fig. 3. Task frequency and importance in a vertical smart farm.

Table 2. Work intensity (Korea Dictionary of Occupations, 2019)

Title	Definition
Very low-intensity task	• Lifting up to 4 kg of stuff. • Sometimes lifting or carrying books, props, etc. • A sedentary task. There are times when it is necessary to stand or do something on the job.
Low-intensity task	• Frequent lifting or transportation of items from 4 kg to up to 8 kg. • A walking or standing job. • Even sedentary work involves pushing and pulling arms and legs.
Moderate-intensity task	• Lift up to 20 kg of items and carry 10 kg of items frequently.
High-intensity task	• Lift up to 40 kg of items and carry 20 kg of items frequently.
Very high-intensity task	• Lifting more than 40 kg of goods and carrying 10 kg of goods frequently.

height; "carrying" in which objects are moved from one place to another by holding them in the hands, hanging them on the arm, or carrying them on the shoulder; "pushing" in which a force is applied to objects to cause them to move in the direction opposite to the force applied; and "pulling" in which a force is applied to objects to cause them to move in the direction of the applied force. "Lifting" was performed repeatedly for the tasks of selecting crops in seed/transplanting trays and transplanting/planting them into transplanting/planting trays; "carrying" crops was performed for the task of moving transplanting/planting trays to transplanting/planting racks and loading them; and "pushing" and "pulling" were performed for the task of moving transplanting/planting trays to transplanting/planting racks and loading them, and separating crops from planting trays. Most of the farm work in the smart farm consisted of "low-intensity tasks" in terms of work intensity, which involved lifting or carrying objects weighing up to 8 kg, and working while walking or standing, based on lifting, carrying, lifting and pulling movements. Work intensity represents the intensity of physical input required to perform the duties of a job, and is classified into 5 levels (very low, low, moderate, high, and very high). It does not take into account the psychological and mental input workers put into their work (Table 2).

Discussion

Depending on their individual conditions, there will be limits to the range of occupations available to handicapped individuals. Appropriate education and training are needed to help them choose a job according to their vocational aptitude and interests. Vocational training not only improves the occupational and social adaptability of the handicapped but is also effective in helping them integrate with the local community and find employment (Joo et al., 2012).

As for care farming programs utilized in all or part of a care farm, it is necessary to develop an operating model for each service provider as they can be operated in various forms including individual farms, corporations, public institutions, and private organizations (Moon et al., 2022). The work intensity of farm work as a care program for physical activity is an important factor that affects the selection and maintenance of relevant jobs by the physically disabled, who have lower strength and muscular endurance compared to the able-bodied. Therefore, it is necessary to ensure that people with disabilities can safely participate in the farm work of care farm programs for vocational rehabilitation and health promotion according to their functional level considering the type and degree of disability, through an evaluation of farm work at the workplace.

Working is one of the basic human rights, and regardless of whether or not one has a disability, or the degree of one's disability, having the opportunity to work has important social value. Yet currently, people with disabilities have difficulty obtaining work opportunities on their own with their occupational abilities. Until now, many have been limited to performing simple, repetitive tasks in manufacturing and other industries. This allows them to lead a normal life, but may also impose limitations on the extent to which work supports their pursuit of a healthy life, both physically and mentally. For the therapeutic use of farming practices to recover, maintain, and improve the health of the physically disabled, it is necessary to evaluate the risk

factors of farm work that cause musculoskeletal diseases, and improve the farming environment to reduce the physical burden on people with disabilities who participate in care farming programs.

It was found that appropriate vocational training is associated with positive attitudes toward work proficiency (Truitt, 2011), and is a key factor in improving task performance (Campbell, 1990). In evaluating the effectiveness of a horticultural therapy program to improve the job competency of the intellectually disabled, Son et al. (2022) reported that a low-to-moderate intensity horticultural therapy program using the upper body and hands was found to be significantly effective on job performance, including hand dexterity and grip. Significantly positive results were also found in the areas of interpersonal negotiation skills and functional and adaptive behaviors. A horticultural therapy program developed to improve upper limb function and balance ability in stroke patients was found to have a significant effect on improving upper limb and hand function, balance ability, daily living skills, and fall efficacy (Lee et al., 2018). By establishing smart farm and plant factory models as social job models for people with disabilities, Lim (2020) found that beyond therapeutic- and care-centered agricultural experiences, it is possible to provide the disabled with opportunities to get sustainable agricultural jobs through continuous agricultural education and activities. Work in agricultural activities will be a good job that allows them to gain psychological and emotional stability and satisfaction from labor through contact with nature (Lim, 2020).

The physically handicapped who use mobility aids have different required workbench heights, working radius, and subjective work intensity compared to people without disabilities. To improve working posture and tasks of lifting and carrying heavy objects, prevent injuries, and improve overall work efficiency, agricultural equipment that takes into account the characteristics of both people with physical disabilities and farm work should be developed (RDA 2020). The introduction of care farming services for the vocational rehabilitation of the physically disabled requires continuous research on education and the development of farm work activities (Knoke and Kalleberg, 1994; Cheng and Ho, 2001). Farm work is performed according to the relationships and procedures between tasks at each work step, and requires repetitive work and a variety of work postures over a long period of time. Most agricultural work in a smart farm consists of tasks with low work intensity performed while walking or standing. However, the physically handicapped who use mobility aids such as wheelchairs or canes may face significant limitations in performing farm work depending on the location and height of the workbench, the height of transplanting/planting racks, the size of transplanting/planting trays, the movement line and so on.

To enhance the therapeutic effect on the physically handicapped who participate in agricultural activities for vocational rehabilitation and health promotion, it seems that safe care farming programs suitable for their functional level should be developed. This study aimed to determine the difference in the intensity of farm work between the disabled and able-bodied, and to derive work data on the level of difficulty, importance, and frequency of farm tasks at the workplace. It is expected to provide useful basic data for the development of a universal system-based care farming program that takes into account the physical and functional characteristics of the physically handicapped.

Conclusion

This study categorized farm work in a vertical smart farm. Through a field survey, details of farm work at each work step were determined, and relationships between and procedures of work tasks, repetitive tasks, and time taken for each task were analyzed. Farm work was mainly carried out in each work zone within the same workplace. Farm work in a smart farm was categorized into 6 duties and 28 tasks, including sowing (8 tasks), raising seedlings (3 tasks), transplanting (4 tasks), planting (4 tasks), harvesting (including sorting and packaging; 5 tasks); and post-harvest cleaning (4 tasks). By analyzing these 6 duties, and 28 tasks based on work procedures, details of farm work at each work step in a smart farm were determined. Data on the level of difficulty, importance, and frequency of farm tasks at the workplace derived in this study can provide useful basic data for the development of a universal system-based care farm-

ing program that takes into account the physical and functional characteristics of the physically handicapped.

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