THE DIMENSIONS OF A CIRCULAR RAISED BED WITH CONSIDERATION OF BODY SUPPORT AND SPACE TO PUT TOOLS IN A STANDING POSTURE

Assuming Use for Gardening Activities of Senior Citizens' Groups

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Abstract: The objective of the present study is to identify guidelines for the design of a raised bed for gardening activities conducted together by senior citizens. The experiment was planned assuming work in a standing posture. Circular raised beds with rims of three different widths and a height of 76 cm were prepared, and 38 subjects made 6 types of body movements imitating gardening work while in a standing posture. The following results were obtained. (1) It is thought to be desirable to install a rim with a variable width of up to 20cm. (2) Based on their average stature, a rough estimate of the distance up to which work is possible by senior citizens is thought to be about 60 cm from the front edge of the rim of the raised bed. (3) It is desirable to select a material for the rim of the raised bed that is suitable for supporting the body with the hands. Furthermore, the front edge of the rim needs to be shaped such that work can be done while the pelvis or thigh(s) are in contact with it without hurting the body.

Keywords: Raised bed, Senior citizens' groups, Gardening, Wheelchairs

1. Objectives

In a previous study [1], the design requirements of gardening facilities conducive to gardening activities conducted by senior citizens in groups were identified through observation of the behavior of four senior citizens and an assistant engaging in gardening activities at a day service center. A circular raised bed that allows participating senior citizens (hereinafter, participants) and their assistants to position themselves comfortably, and that has a rim suitable for placing tools and supporting the body was presented as a proposed design to fulfill these requirements. A raised bed is a flowerbed or horticultural plot with its soil surface raised higher than usual to allow wheelchair users, senior citizens and others to engage in gardening activities from a high working position in a stress-free manner. As for prior studies on the specific design of raised beds, Oogama, et al., conducted experiments with senior citizens with and without disabilities, identifying the relationship between the elevation of the bed conducive to gardening work in a standing posture and the distance reachable by hand, with the objective of designing a raised bed for horticultural therapy [2]. In the above study, limited in scope to body movements when planting seedlings, the dimensions were derived on the assumption that the participants work alone and do not use the rim to support their bodies. However, observation of behavior in the previously mentioned study indicated that body posture and tools used vary according to the type of gardening work, that the rim is used as a body support while working, and that ease of interaction between participants, etc., should be considered in the case of gardening activities conducted in groups.

Thus, in the present study, the suitable rim width and horizontal dimensions of a circular raised bed were sought by considering the results of experiments using students without disabilities as subjects to simulate recreational gardening activities of senior citizens' groups.
2. Experimental Method

2.1 The Raised Bed used in the Experiment

A raised bed with the shape and dimensions indicated in Figure 1 was used for the experiment. The platform of the raised bed was constructed of a polystyrene foam core covered with glass fiber reinforced plastic (CFRP). The rim of the raised bed was made of laminated lumber. Its height was 76 cm, thought to be a rough estimate of the height suitable for senior citizens to work without stress in a standing posture [2, 3, 4]. The diameter of the working surface was 120 cm to allow ample space for measurement of the distance up to which work is possible. As for the shape of the raised bed, a circular shape was chosen with thought to facilitating exchanges among participants and between the participants and their assistants. A rim was installed in three sections with a width of 15 cm, 20 cm, and 25 cm, respectively, each with a central angle of 120 degrees. These widths were determined on the basis of observation of behavior in the previous study.

2.2 Subjects

Students were chosen as subjects, as the physical stress, etc., from repetitive work would have been problematic if senior citizens were subjects. The basic dimensions of a prototype for usability testing by senior citizens were sought. A total of 38 people (20 men and 18 women) with a stature in the range of 144 cm - 177 cm were selected as subjects in order to identify the effect of stature on evaluation of the width of the rim and on the distance up to which work is possible. The average stature of the subjects was 164.8 cm (144 cm - 177 cm, standard deviation 8.3 cm).

2.3 Experimental Method

The experiments were conducted in a standing posture. It was known from the observation of behavior mentioned in the above section that the posture when supporting the body with the workbench, as well as the location where tools are placed and the distance up to which work is possible vary according to the gardening activity. Therefore, it was thought that data needed to be collected for each type of gardening work. Six types of body movements imitating the typical gardening work of sowing, thinning, watering, transplanting seedlings, harvesting fruit and harvesting root vegetables were studied. Figure 2 shows the gardening tools that were used. In the previous study, these tools had all been found to be utilized without problem by senior citizens using day services. The types of work are explained in detail below.

① Sowing: Pebbles with a diameter of about 5 mm representing seeds were put on a flat plate with a diameter of 13 cm, which was placed on the rim. Subjects were instructed to make small holes on the working surface with their fingers and to plant the seeds 1 cm apart from each other in a horizontal line. This is because in the case of actual sowing, planting at a fixed interval can facilitate subsequent thinning work. The subjects were allowed either to hold the plate in their hand or to place it on the rim, as long as they could work in a posture that was comfortable.

② Thinning: 5 toothpicks, representing plant seedlings, were stood up 1 cm apart from each other in a horizontal line on a styrene foam platform (vertical width 3 cm x horizontal width 6 cm x thickness 1.5 cm), which was placed on the working surface. The subjects were instructed to hold the platform with one hand, to pull out 2 of the 5 "seedlings" so that those remaining would be 2 cm apart from each other, and to place the thinnings (removed seedlings) on the rim. The reason such a platform was provided was that in actual thinning work, the base of the seedling to be left growing is held down to prevent it from being pulled out with the thinnings.

③ Watering: A watering pot 70% full of water (container diameter 10 cm, height 13 cm) was placed on the rim, and the subjects were instructed to water the work surface with it. The spout was sealed with packing tape to prevent the working surface from becoming waterlogged from repetition of this activity.
2. Overview of the body movements imitating gardening work and the tools placed on the rim

4 Transplantation of seedlings: Two nested vinyl pots (diameter 10 cm, height 9 cm), one of which contained soil and represented a seedling, and a transplanting trowel (8 cm x 21 cm) were placed on the rim. The subjects were instructed to use the trowel to dig a hole for transplanting the seedling, to place the trowel on the rim, to remove the outer vinyl pot, and to plant the seedling in the hole that was dug. Subjects were instructed to place the removed vinyl pot on the rim, because it was observed during actual transplanting of seedlings that the removed vinyl pot was often placed on the workbench.

5 Harvesting fruit: Styrene foam balls with a diameter of 4 cm, representing fruit, were held 30 cm above the working surface by hanging them from a 1 cm diameter wooden cylinder with woolen yarn (hereafter referred to as ”the branch”). The subjects were instructed to cut the ”branch” with scissors while holding the ”fruit” with one hand so that it would not fall, and to put the fruit on the rim. This is because it was assumed that fruit-type vegetables such as tomatoes or eggplants would be grown.

6 Harvesting root vegetables: A 12 cm long plastic rod was inserted into a 4 cm diameter styrene foam ball; the resulting object, representing a root vegetable, was planted into the working surface. The subjects were instructed to pull the ball out while holding the rod, making sure that it is not dislodged from the ball. This is because during actual harvesting of root vegetables, the base of the stem is held firmly to prevent the stem from becoming dislodged from the root.

Furthermore, the subjects were instructed to assume the posture in which they could work most comfortably, and to use the rim as a body support if they wanted.

The six types of gardening work shown in Figure 2 were conducted in random order in standing posture next to three types of rims with a width of 15 cm, 20 cm and 25 cm, respectively. The experiment was conducted in the following order.

1) Measurement of the distance up to which work is possible

The subjects were instructed to make body movements imitating gardening work at a position that their hands could reach without physical strain. The distance from the front edge of the rim of the raised bed to the point where the work was done was measured. The subjects were instructed to assume a posture that felt comfortable, and to use the rim as a body support if necessary for this.

2) Recording the posture at the time of working

The posture at the time of working was recorded with a digital camera. Photographs were taken at the following moments: ① sowing: while seeds were being sown, ② thinning: while the seedlings were being thinned, ③ watering: when the watering pot was being held over the place to be watered, ④ transplanting seedlings: immediately after the hole was dug with the trowel in the place where the seedling was to be planted, ⑤ harvesting fruit: immediately before the fruit was harvested, ⑥ harvesting root vegetables: immediately before the root vegetable was harvested.
3) Evaluation of the rim width

For each type of gardening work conducted, the subjects evaluated the width of the rim adjacent to them. Specifically, they were asked to choose one of the following seven ratings regarding the width of the rim as (1) a body support and as (2) a place to put tools: “very narrow (-3)”, “narrow (-2)”, “somewhat narrow (-1)”, “optimal (0)”, “somewhat too wide (+1)”, “too wide (+2)”, “much too wide (+3)”.

4) Collection of additional information

The subjects were asked to note down freely anything that they noticed regarding the rim width while working.

3. Results and Discussion

3.1 Rim Width

Figure 3 and 4 show the evaluations of the width of the rim as a body support and as a place to put tools, respectively, with the rim width and work type on the horizontal axis and with the average rating and standard deviation on the vertical axis, in order to show their relationship. The rim width suitable for body support is thought to be between 15 cm and 20 cm. It is evident that the rim width suitable for placing tools is about 20 cm.

Looking at the evaluation trends per work type, one notes that during the thinning work, a rim width of 25 cm was considered too wide for body support as well as for placing tools.

From the above results, it was found that the optimal width of the rim is 15-20 cm for use as a support for the body, and about 20 cm for use as a place to put tools. Therefore, if the raised bed is to have a rim of fixed width, that satisfying both requirements is thought to be about 20 cm.

The following trends were identified from the observations noted down freely regarding the rims. The narrower the rim is, the further the hand can reach on the working surface, but conversely, the more difficult it is to place tools on it and the more likely it is for the clothes to get dirty if the rim is used for body support. On the other hand, the wider the rim is, the easier it is to put tools on it and the more stable the body support feels, but the harder it is to work due to the greater distance to the working surface.

From the above results, it was confirmed that the narrower the rim is, the further away work can be done on the working surface whereas the wider the rim is, the easier it is to place tools on it. One solution might be to install a rim with multiple segments of different widths of up to 20 cm. In such a case, it would be possible to get closer to the working surface from where the rim is narrower, and to use the rim for body support and for placing tools where it is wider.
3.2 The Relationship between Stature and the Distance up to which Work is Possible

The relationship between stature and the distance up to which work is possible is shown per work type in Figure 5. In order to study the effects of stature on the distance up to which work is possible, one-way analysis of variance of the distance up to which work is possible was conducted with stature as the factor. The subjects were divided into three groups of roughly equal number on the basis of stature in ascending order to define three block factors as follows: H155 (13 people, average stature 155.1 cm), H166 (13 people, average stature 165.8 cm) and H173 (12 people, average stature 173.3 cm).

Table 1 shows the results of one-way analysis of variance of the distance up to which work is possible with stature as the factor. The distance up to which work is possible was found to differ significantly according to stature, there is a need to extend both arms toward the working surface and thus the hands cannot be placed on the rim to support the body. It

<table>
<thead>
<tr>
<th>Work Type</th>
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<th>SD</th>
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<tr>
<td>Sowing</td>
<td>61.2</td>
<td>7.4</td>
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<tr>
<td>H155</td>
<td>63.5</td>
<td>7.7</td>
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<td>H166</td>
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<tr>
<td>H173</td>
<td>66.8</td>
<td>8.3</td>
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<tr>
<td>Thinning</td>
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<td>7.4</td>
</tr>
<tr>
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<td>68.8</td>
<td>9.8</td>
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<tr>
<td>H166</td>
<td>76.8</td>
<td>9.6</td>
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<tr>
<td>H173</td>
<td>83.3</td>
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<td>Transplantation of seedlings</td>
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<td>H155</td>
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<td>H173</td>
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<td>H173</td>
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*P < 0.01, *P < 0.05, Multiple comparison: Bonferroni correction

In order to identify differences in posture according to the type of work, the silhouettes of 35 subjects who had been photographed (H155: 12 people, H166: 12 people, H173: 11 people) were traced from image data showing their posture while working, and the composite image for each stature group was overlaid to obtain Figure 6. How many subjects were touching the raised bed with which part of their body is shown in Table 2. It is evident from these results that in the case of thinning and harvesting fruits, in which the distance up to which work is possible does not differ significantly according to stature, there is a need to extend both arms toward the working surface and thus the hands cannot be placed on the rim to support the body. It
was apparent that almost all subjects had either their pelvis or their thigh(s) in contact with the rim to support their body; subjects of low stature had their waist and those with high stature had their thigh(s) in contact with it. It was apparent from comparison of the posture silhouettes of the stature groups that in the case of work using the rim as body support, the taller the subjects were, the deeper they tended to lean forward, and the further their arms could reach on the working surface.

The regression line of the distance up to which work is possible according to stature was calculated in order to estimate the distance up to which work is possible by senior citizens, but the coefficient of determination was less than 0.3 for all work types, so its use for such estimation was not felt to be suitable. Thus, the results for H155 were referred to in light of senior citizens' average stature [6]. It was evident from these results that a rough estimate of the distance up to which work is possible by senior citizens is about 60 cm from the front edge of the rim of the raised bed.

In the present experiment, thinning and harvesting of fruit were types of work in which the rim could not be used as a body support. It is thought that plants requiring such work can be placed toward the periphery of the working surface to enable trouble-free work. Furthermore, as the rim of the raised bed is useful for supporting the body with the hand, it is desirable to select a material for it that does not easily get dirty, does not get extremely hot or cold, and is pleasant to the touch. Furthermore, as work is often done with the pelvis or thigh(s) in contact with the front edge of the rim, it is necessary to take care, for instance, to give it a rounded design so that contact does not cause physical injury. An example of a raised bed design that fulfills the above design guidelines is shown in Figure 7.

4. Conclusion

The present study identified guidelines for the design of a raised bed for gardening activities conducted together by senior citizens, on the basis of design requirements identified in a previous study. The following specific guidelines were identified as a result of experiments with students as subjects.

(1) It was found that the optimal width of the rim of the raised bed is 15-20 cm for use as a support for the body, and about 20 cm for use as a place to put tools. The narrower the rim is, the further away work can be done on the working surface whereas the wider the rim is, the easier it is to place tools on it; for these reasons, it is thought to be desirable to install a rim with a variable width of up to 20 cm.

(2) In the case of work in which the rim can be used as a body support, the distance up to which work is possible was found to differ significantly depending on stature. Based on their average stature, a rough estimate of the distance up to which work is possible by senior citizens is thought to be about 60 cm from the front edge of the rim of the raised bed.

(3) It is desirable to select a material for the rim of the raised bed that is suitable for supporting the body with the hands. Furthermore, the front edge of the rim needs to be shaped such that work can be done while the pelvis or thigh(s) are in contact with it without hurting the body.

References


