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Upper and Lower Limb Muscle Activation during Green Care: An Electromyographic Analysis

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Abstract. **Green care activities are associated with lower intensity and a lower risk of injury than agricultural activities aimed at producing agricultural and livestock products; however, the risk of health problems cannot be completely ruled out. To implement green care interventions to improve physical health, it is essential to identify the green care activity levels and biomechanical characteristics of the movements that are appropriate for each subject's physical functions and goals. Thus, this study was conducted to determine the muscle activation of the upper and lower limbs during 19 green care farming activities. We used electromyography signals, which are biomedical signals that measure the action potentials generated in the muscles and nervous system when the muscles contract, to evaluate the muscle activation. Twenty adults (aged 29.9 ± 9.6 years) participated in this study. Participants performed 19 green care farming activities, including horticultural activity, animal-mediated, and off-farming activities. The participants performed each activity three times. The electromyography data were assessed using surface electromyography during activities to measure muscle activation. As a result, 16 upper and lower limb muscles were activated during the green care farming activities, which showed significantly different muscle activation by care farming activity. As a result of the comparison of muscle activity according to each muscle, many of the muscles of the upper and lower limbs were most activated during organizing a garden plot, transplanting plants, and collecting natural objects. In conclusion, the electromyography data obtained during this study suggest that green care farming interventions may be effective for training specific muscles of the upper and lower limbs.**

Green care refers to the utilization of a farm's natural resources, such as animals, plants, gardens, and forests, to improve the mental health, physical health, and quality of life of humans (Hassink and Van Dijk 2006). Green care participants take care of living things and, at the same time, take care of themselves in the natural environment. Types of green care activities include gardening, horticultural activities, caring for farm animals, and outdoor activities such as walking and other physical activities (Garcia-Llorente et al. 2018). Green care in agriculture, also called care farming, is an innovative intervention at the intersection of agriculture and healthcare that actively provides therapeutic benefits to a variety of participants through the medium of agriculture (Hassink et al. 2017). Compared with medical environments, care farms provide an alternative and promising environment where people can interact with various living things, including plants and animals. Interactions with nature through farming activities conducted during green care provide various benefits to participants, and these activities give rise to a variety of physical movements. Park et al. (2014) reported that gardening activities, such as hoeing and troweling, include full-body movements that activate the upper and lower limb muscles. Lee et al. (2016) reported that horticultural activities, such as seed sowing and planting activities, use the upper limb muscles, including the anterior deltoid, upper trapezius, and flexor carpi radialis, and that these kinematic and kinetic characteristics are similar to those of exercise training during rehabilitation.

Green care activities are associated with lower intensity and a lower risk of injury than agricultural activities aimed at producing agricultural and livestock products; however, the risk of health problems cannot be completely ruled out because of the low skill level of the participants. In particular, a higher risk of musculoskeletal health problems, including shoulder, wrist, and back problems, has been observed among agricultural workers than among workers in other industries (Lee et al. 2014; Osborne et al. 2012; Walker-Bone and Palmer 2002). Unskilled participants who working while positioned in incorrect postures for long periods can develop musculoskeletal disorders and injuries to various muscles (Kumari et al. 2023).

Based on these circumstances, studies have been conducted to measure biomechanical factors using different methods during specific agricultural tasks, such as pruning (Balaguier et al. 2017) and milking parlor work (Kuta et al. 2015). Among these methods, electromyography (EMG) is used to analyze biomechanical characteristics. It is an ergonomic technology that measures electrical activity when muscles contract and relax (Ayoub 2000) and can assess muscle function and activity for various movements. The EMG analysis methods are used in various fields of sports and rehabilitation medicine to identify safe movements for physical health promotion and rehabilitation by analyzing muscle activation patterns during various movements (Ekstrom et al. 2007; Hug and Dorel 2009). Muscle activation refers to the degree of the load that a muscle undergoes through movement, and a load of less than 45% of one repetition at maximum effort is considered most beneficial for motor control training or endurance of previously untrained individuals (Anderson and Kearney 1982; Ekstrom et al. 2007; Escamilla et al. 2006). Therefore, to implement green care interventions to improve physical health, it is essential to identify the green care activity levels and biomechanical characteristics of the movements that are appropriate for each subject's physical functions and goals.

However, to our knowledge, no studies have measured muscle activity while performing various green care activities on actual care farms to understand the magnitude and pattern of activation of each muscle. Collecting quantitative data regarding the biomechanical factors of various upper and lower limb muscles throughout green care activities is important for reducing the risk of injury of participants and improving physical exercise effectiveness. We hypothesized that there would be differences in the characteristics of upper and lower limb muscle activities while participating in various green care activities. Consequently, the aim of this study was to measure the muscle activation in the upper and lower limbs of adults participating in green care during various farm activities.

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Materials and Methods

Participants. Twenty adults between 20 and 40 years of age (12 female and 8 male participants; aged 29.9 years ± 5.6 years) volunteered to participate in this study (Table 1). Participants were limited to those who agreed to participate after receiving an explanation of this study from researchers. The inclusion criterion was no personal history of extremity injuries or bone or joint disorders within the previous year (Wallmann et al. 2005). A comprehensive explanation of the purpose of the study, specifics of green care farming activities, and clinical implications of the study were provided to the participants. Before starting the experiment, the participants were instructed to not engage in strenuous physical activity. All the participants were right-hand-dominant.

After completion of the study, the participants received $10 as a reward. The Institutional Review Board of Konkuk University approved this study (no. 7001355-202106-HR-442).

Experimental procedure and condition. The experiment was conducted at a P-care farm in Sejong, South Korea (https://www.sejong.go.kr/prog/nongjang/adtc/sub02_02/55/view.do; accessed 20 Mar 2023), which has a variety of plant resources, such as vegetable gardens and greenhouses, animal resources, such as chickens, dogs, peacocks, and rabbits, and facility resources, such as cooking spaces and indoor classrooms. All participants performed 19 green care farming activities (Table 2). The selected green care farming activities performed during the experiment were those that appropriately used the agricultural and rural resources of the P-care farm and were used in the green care farming program actually operated by the farm.

During this crossover study, each participant performed the experimental procedure as shown in Fig. 1. Participants first measured the maximum voluntary contraction (MVC) of a reference contraction for each investigated muscle separately and in random order (Table 3) after an initial warm-up stretch for 5 min. The MVC value of each muscle was measured three times; after measuring one muscle, the MVC value of the next muscle was measured after a rest period of 1 min. After measuring all MVC values, the researchers explained and demonstrated the green care farming activities before the participants performed each activity. Subsequently, the participants performed each green care farming activity twice, sat in a chair, and rested for 5 min without moving or talking. The EMG values of the upper and lower limb muscles were recorded during green care farming activities using a telemetry EMG unit (Ultium; Noraxon, Scottsdale, AZ, USA). The placement of the EMG surface electrodes is shown in Fig. 2.

The experiment was conducted for a total of 4 weeks with one participant at a time and a maximum of two participants participating per day. According to the observations of the Korea Meteorological Administration, the average temperature of the farm area was 23.3 °C (±2.5 °C), and the average relative humidity was 81.7% (±12.3%) during the experiment. According to Tucker and Gilliland (2007), physical activity levels vary depending on the season, and the effects of extremely hot or cold weather have been identified as barriers to participation in physical activity.

Measurements. The Ultium EMG sensor system (Noraxon) was used to measure muscle activation during green care farming. This device noninvasively measures the electrical activity evoked by nerve stimulation in muscles by EMG electrodes. Before attaching the EMG electrodes to the skin, an alcohol swab was used to remove dead skin cells, dirt, and sweat, which could cause high impedance at the electrode site. Additionally, the device measures EMG in real time, has 16 channels, and is wireless; therefore, it is easy to wear during outdoor activities.

Data processing. Amplitude data can be affected by the detection conditions, which differ depending on the electrode site, subject, and measurement conditions (Konrad 2005). To overcome this limitation, the MVC value of the reference contraction was used to normalize the data. The percentage of the maximum innervation capacity of muscle activity for each farming activity was calculated using the MVC value.

The measured EMG data were sampled at 1000 Hz and then bandpass-filtered at 10 to 500 Hz. The MVC data were rectified and smoothed by applying a 50-ms root mean square. Then, the MVC data were amplitude-normalized to yield peak values at 500-ms intervals. The EMG data measured during green care farming activities were also rectified and smoothed by applying a 50-ms root mean square. The EMG data were normalized to the ratio of processed MVC values for each muscle (%MVC).

Statistical analysis. To compare the EMG data according to each activity, the Kruskal–Wallis test was performed using SPSS (version 25 for Windows; IBM, Armonk, NY, USA); $P < 0.05$ was considered statistically significant. Regarding demographic information, descriptive statistics of means, *SD*s, and percentages were obtained using Microsoft Excel (Office 2007; Microsoft Corp., Redmond, WA, USA).

Results

Demographic characteristics. Twenty participants 29.90 ± 9.59 years of age participated in the experiment. There were 8 male and 12 female participants (age of the male participants, 27.13 ± 7.70 years; age of the female participants, 30.91 ± 10.65 years) (Table 1). The average body mass index was 22.66 ± 4.49 kg/m^2, which was within normal range.

Electromyographic muscle activity. The activities (%MVC) of the upper and lower limb muscles for each green care farming activity are shown in Tables 4 and 5 and Supplemental Fig. 1. The 16 upper and lower limb muscles showed significantly different muscle activation attributable to the green care farming activities. Muscle activation of the upper limbs showed that the anterior deltoid of the shoulder and flexor carpi radialis of the lower arm were significantly more activated than other muscles during green care farming activities. As a result of the comparison of muscle activity according to each muscle, most of the upper limb muscles were activated when organizing the garden plot, especially during digging.

Muscle activation of the lower limb showed that the gastrocnemius muscle activity of the calf was the highest when raking, digging, fertilizing, washing, and walking with a dog; however, during other agricultural activities, the muscle activities of the vastus lateralis, vastus medialis, and biceps femoris of the thigh were high. The comparison of muscle activity according to each muscle showed that most of the lower limb muscles were most activated when organizing garden plots, which involved activities such as digging, raking, fertilizing, planting, and collecting natural objects.

Discussion

The purpose of this study was to measure the activity of the upper and lower limb muscles used during 19 agricultural green care farming activities. The following 16 upper and lower limb muscles were selected for this study: the anterior deltoid of the shoulders; biceps brachialis of the upper arms; brachioradialis and flexor carpi ulnaris of the lower arms; vastus lateralis and vastus medialis of the anterior thighs; biceps femoris of the back thighs; and gastrocnemius of the calves. The results of this study showed that 16 upper and lower limb muscles were activated during the green care farming activities and showed significantly different muscle activation by green care farming activity.

Table 1. Descriptive information of participants who participated in the study.

Variable	Male (n = 8)	Female (n = 12)	Total (N = 20)
	Mean ± *SD*		
Age (years)	27.13 ± 7.70	30.91 ± 10.65	29.90 ± 9.59
Height[i] (cm)	175.90 ± 3.13	163.45 ± 6.65	168.69 ± 8.26
Body weight[ii] (kg)	74.21 ± 17.66	58.07 ± 9.48	64.87 ± 15.43
Body mass index[iii] (kg/m^2)	24.03 ± 6.00	21.66 ± 2.94	22.66 ± 4.49
Body composition			
Fat (kg)	14.04 ± 10.83	17.97 ± 7.56	16.35 ± 8.95
Lean (kg)	54.14 ± 6.85	38.89 ± 4.10	45.17 ± 9.32

[i] Height was measured without shoes using an anthropometer (Ok7979; Samhwa, Seoul, South Korea).
[ii] Body weight was measured using a body fat analyzer (ioi 353; Jawon Medical, Seoul, South Korea).
[iii] Body mass index was calculated using the following formula: [weight (kg)]/[height (m)^2].

Table 2. Descriptions of green care farming activities performed by participants.

Activities	Descriptions
Digging	1) Holding the handle of a shovel (1.3 kg) with the right hand and standing with feet shoulder-width apart. 2) Stepping the left foot in front of the right foot and holding the middle part of the shovel with the left hand. 3) Inserting the blade into the designated position with a shovel. 4) Digging the soil and piling it on the right side. 5) Stepping back with the left foot and returning to the standing position and repeating the procedures three times.
Raking	1) Standing with feet shoulder-width apart and holding the tip of the garden rake with the right hand. 2) Placing the left foot in front of the right foot and holding one-third of the tip of the rake (0.9 kg) with the left hand. 3) Inserting the blade of the rake into the designated position. 4) Scraping soil with the front of the body. 5) Stepping back with the left foot and returning to the standing position and repeating the procedures three times.
Fertilizing	1) Standing with feet shoulder-width apart and holding the basin containing fertilizer with the left hand. 2) Holding a handful of fertilizer in the right hand. 3) Bending forward and extending the right arm forward to spread fertilizer in the designated area (area of 1.5 m × 2.0 m). 4) Returning to the standing position and repeating the procedures three times.
Planting	1) Standing with feet shoulder-width apart while holding the handle of the trowel with the right hand. 2) Squatting (bending both legs horizontally). 3) Placing a trowel in the designated position. 4) Digging the soil and piling it on the left side. 5) Planting plants with both hands. 6) Standing up. 7) Moving one step to the right and repeating the procedures three times.
Mulching	1) Standing with feet shoulder-width apart. 2) Squatting (bending both legs horizontally). 3) Grabbing the rice straw in the basin with the right hand. 4) Covering straw around the seedlings in front with both hands. 5) Standing up. 6) Moving one step to the right and repeating the procedures three times.
Setting-up plant stakes	1) Standing with feet shoulder-width apart. 2) Squatting (bending both legs horizontally). 3) Inserting the plant stake into the soil near the base of the plant using both hands. 4) Tying the stake and plant stem with a strap at the midpoint of the plant height using both hands. 5) Standing up. 6) Moving one step to the right and repeating the procedures three times.
Harvesting crops	1) Standing with feet shoulder-width apart with a basin in the left hand. 2) Checking peppers (*Capsicum annuum* L.) that have reached the harvest stage and moving. 3) Bending the back toward the pepper to be harvested and extending the right hand. 4) Picking one pepper. 5) Bringing the outstretched hand toward the body and putting it in the basin. 6) Straightening the back and repeating the procedures three times.
Washing crops	1) Standing in front of a table with feet shoulder-width apart while holding a basket of sesame (*Perilla frutescens*) leaves with both hands. 2) Reaching the right hand to a basket of harvested peppers on the table and picking a pepper. 3) Washing the pepper with water with both hands and repeating the procedures three times.
Packing crops	1) Standing in front of a table with feet shoulder-width apart. 2) Opening the lid of the packaging container on the table with both hands. 3) Putting the washed pepper (*Capsicum annuum* L.) into the packaging container with the right hand. 4) Sealing the packaging container using both hands (closing the lid) and repeating the procedures three times.
Cutting crops	1) Standing with feet shoulder-width apart. 2) Holding five sesame (*Perilla frutescens*) leaves with both hands. 3) Shredding it five times and repeating the procedures three times.
Trimming crops	1) Standing in front of a table with feet shoulder-width apart. 2) Putting shredded sesame (*Perilla frutescens*) leaves in a mortar on the table. 3) Grasping the pestle with right hand. 4) Pounding shredded sesame leaves in the mortar and repeating the procedures three times.
Making mojitos	1) Standing in front of a table with feet shoulder-width apart. 2) Putting the crushed sesame (*Perilla frutescens*) leaves into a cup with a drink on the table from a mortar with a spoon. 3) Stirring the inside of the cup with a spoon to mix it well and repeating the procedures three times.
Collecting natural objects	1) Standing with feet shoulder-width apart and holding a basket with the left hand. 2) Checking a natural object on the ground and moving (2.0 m distance). 3) Bending the back toward the object and extending the right hand to pick it up. 4) Bringing the outstretched hand toward the body and straightening the back. 5) Putting the object that was picked up into the basket held in the left hand and repeating the procedures three times.
Creating art	1) Extending the left hand and picking up a natural object in a basket on the table while sitting on a chair in front of the table. 2) Extending the right hand and grabbing the glue on the table. 3) Applying glue to the natural object. 4) Attaching the object to the ornament and repeating the procedures three times.
Interacting with a dog	1) Placing the pet on the lap and holding the dog with both arms while sitting in a chair. 2) Petting the dog with the right hand. 3) Repeating the procedures three times.
Walking with a dog	1) Standing while holding the dog leash with the left hand. 2) Squatting. 3) Putting a leash on the dog with both hands. 4) Standing up. 5) Taking a walk. 6) Continuing the procedures three times.
Feeding rabbits	1) Standing with feet shoulder-width apart while holding a basket of clovers with the left hand. 2) Bending the back and holding clovers in the basket with the right hand. 3) Extending the right hand holding the clovers to feed the rabbit. 4) Straightening the back and repeating the procedures three times.
Cleaning-up the farm	1) Standing with feet shoulder-width apart while holding the broom with the right hand and the dustpan with the left hand. 2) Bending the back to sweep the floor. 3) Sweeping the waste with the broom and putting it in the dustpan and continuing the procedures three times.
Maintaining a garden	1) Standing with feet shoulder-width apart with a basket in the left hand. 2) Checking withered leaves and moving. 3) Bending the back toward the withered leaves and extending the right hand. 4) Cutting a leafstalk of the withered leave. 5) Bringing the outstretched hand toward the body and putting it in the basket. 6) Straightening the back and repeating the procedures three times.

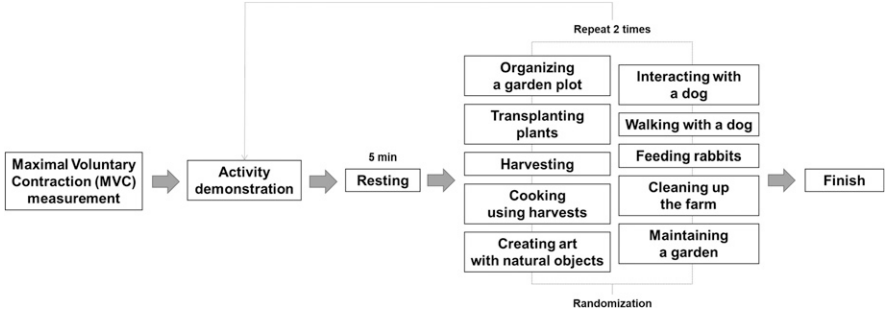

Fig. 1. The experimental protocol used for this study. MVC = maximum voluntary contraction.

The green care farming activities performed during this study consisted of the following movements and postures using small tools, such as trowels and plant stakes, and large tools, such as shovels and rakes: squatting, standing, sitting on a chair, walking, and grasping. Farming activities performed using various postures and tools are weight-bearing exercises that use the entire body and apply stimulation and load to the bones and muscles based on one's own body weight. A previous study showed that a weight-bearing posture is highly correlated with muscle activity (Uhl

Table 3. Maximum voluntary contraction (MVC) positions for upper and lower muscles in this study (Konrad 2005).

Activities	Descriptions
Upper limb	
Anterior deltoid	Participants sit in a chair with a backrest fixed on the back and then spread both arms 90° in both directions. The researcher presses the participants' upper arms, and the participants hold the arm in a horizontal state. Repeat this action three times at 5-s intervals.
Biceps brachialis	Participants sit in a chair with a backrest fixed on the back. The participants place their elbows on a support in front of their body so that their arms are at 90° to the body. They bend the lower arm at 90° to the upper arm. The researcher pulls the participants' arms from the body, and the participants brace to maintain the angle of the arm. Repeat this action three times at 5-s intervals.
Brachioradialis	Participants sit in a chair and support the lower arm on a support in front of the body, with the palms facing up. The researcher presses the participants' lower arms downward, and the participant tries to lift the lower arm. Repeat this action three times at 5-s intervals.
Flexor carpi ulnaris	Participants sit in a chair and support the lower arm on a support in front of the body, with the palms facing down. The researcher presses the participants' lower arms downward, and the participant tries to lift the lower arm. Repeat this action three times at 5-s intervals.
Lower limb	
Vastus lateralis and vastus medialis	Participants sit in a chair with a backrest fixed on the back. The researcher firmly fixes the participants' ankles to the chair leg with a band so that the participants can maintain a 90° knee flexion position. Participants perform a single leg extension. Repeat this action three times at 5-s intervals.
Biceps femoris	Participants lie prone on the floor, maintaining ∼30° of knee flexion. The researcher grabs the participants' ankles and pulls toward the floor while the participants bend the knees. Repeat this action three times at 5-s intervals.
Gastrocnemius	Participants sit in a chair with a backrest fixed on the back. The participants spread the legs horizontally and place the toes on a firmly fixed pedestal at the 90° ankle position. The participants push the toes toward the pedestal while the chair and pedestal are fixed. Repeat this action three times at 5-s intervals.

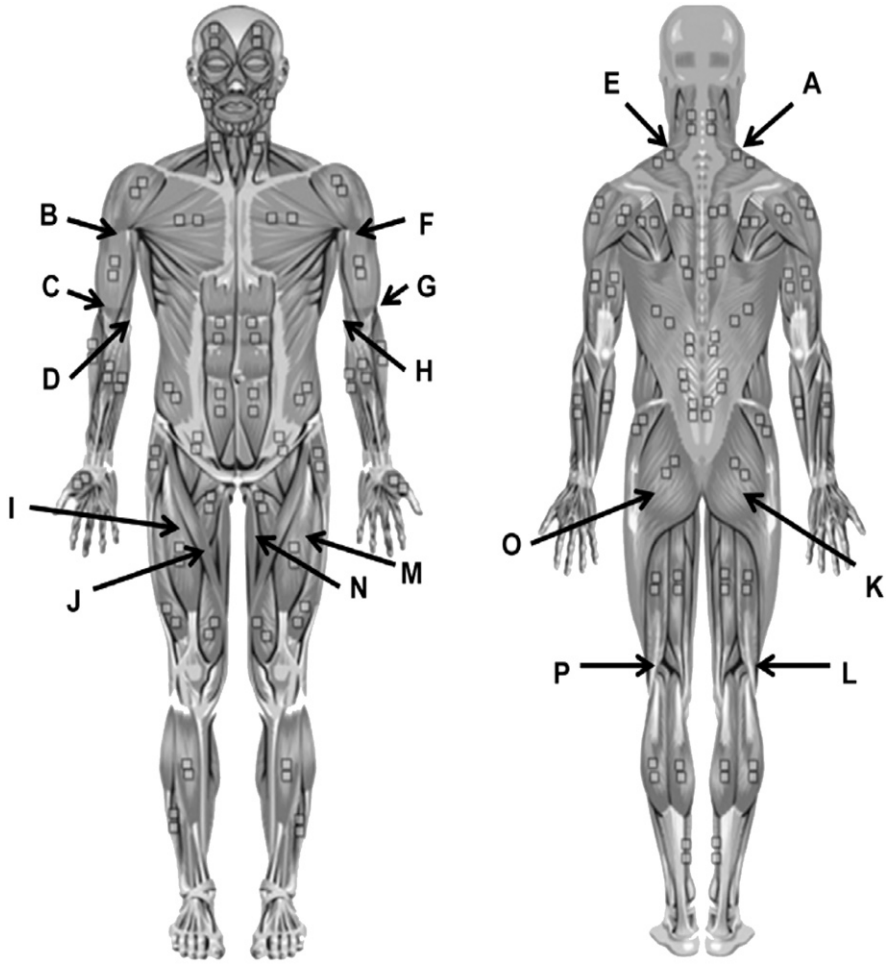

Fig. 2. Upper and lower limb muscles measured by electromyography (MyoMUSCLE Software Module; Noraxon, Scottsdale, AZ, USA) during green care farming activities: (**A**) right anterior deltoid; (**B**) right biceps brachialis; (**C**) right brachioradialis; (**D**) right flexor carpi ulnaris; (**E**) left anterior deltoid; (**F**) left biceps brachialis; (**G**) left brachioradialis; (**H**) left flexor carpi ulnaris; (**I**) right vastus lateralis; (**J**) right vastus medialis; (**K**) right biceps femoris; (**L**) right gastrocnemius; (**M**) left vastus lateralis; (**N**) left vastus medialis; (**O**) left biceps femoris; and (**P**) left gastrocnemius (Park et al. 2014).

et al. 2003), which is also effective in relieving osteoarthritis symptoms and improving position sense (Jan et al. 2009; Yõlmaz et al. 2010).

Muscle activation of the upper limb showed that the anterior deltoid and flexor carpi radialis of the shoulder were significantly more activated than other muscles during green care farming activities (Table 4). The anterior deltoid is the main horizontal flexor responsible for arm elevation (Hoffmann et al. 2022). During this study, the muscle activity was higher during the following activities involving lifting and extending the arm than during other activities: fertilization, harvesting, cooking using harvests, creating art with natural objects, interacting with a dog, feeding rabbits, and maintaining a garden. The flexor carpi radialis is a forearm muscle that is mainly activated during handgrip activities (Montagna et al. 2005). During this study, it was also highly activated during the following activities that involved grasping objects such as gardening tools, plants, and dog leashes: raking, digging, transplanting plants, washing, packing, trimming, walking with a dog, and cleaning-up the farm.

A comparison of muscle activity according to each muscle showed that most of the upper limb muscles were most activated when organizing the garden plot, which involved digging, raking, and fertilizing, and especially during digging activities (Table 4). During a previous study that compared upper limb muscle activity during five horticultural activities, the digging activity activated upper limb muscles more than the raking, troweling, weeding, and hoeing activities (Park et al. 2014). These activities involve the movements of lifting the shovel, inserting the head of the shovel into the soil, and scooping up the soil with the shovel, which require greater strength of the upper arm muscles than other green care farming activities.

Muscle activation of the lower limb showed that the gastrocnemius muscle activity of the calf was the highest when organizing a garden

Table 4. Muscle activation data of eight upper limb muscles during 10 green care farming activities obtained using electromyography.

	Maximum voluntary contraction integrated electromyography (mean ± *SD*)								
	Right (%)				Left (%)				
Care farming activities	Anterior deltoid	Biceps brachialis	Brachioradialis	Flexor carpi radialis	Anterior deltoid	Biceps brachialis	Brachioradialis	Flexor carpi radialis	Significance[i]
Raking	12.69 ± 10.51	6.87 ± 4.09	9.65 ± 6.10	25.82 ± 14.32	10.97 ± 6.86	9.09 ± 6.72	13.19 ± 6.84	27.79 ± 9.52	0.000***
Digging	19.65 ± 11.65	8.74 ± 6.44	15.56 ± 15.31	21.53 ± 9.03	11.97 ± 7.79	11.09 ± 8.63	13.46 ± 8.69	28.00 ± 12.04	0.000***
Fertilizing	12.15 ± 7.53	5.59 ± 3.19	6.52 ± 4.74	12.13 ± 6.40	5.60 ± 4.08	5.51 ± 4.12	5.86 ± 5.09	10.64 ± 6.38	0.000***
Planting	11.63 ± 7.62	5.58 ± 3.85	8.36 ± 8.39	19.34 ± 10.96	8.83 ± 6.12	4.71 ± 6.17	4.65 ± 3.32	11.00 ± 6.78	0.000***
Mulching	14.45 ± 8.14	6.17 ± 3.62	7.60 ± 5.41	17.35 ± 9.52	12.73 ± 8.04	6.62 ± 5.76	7.22 ± 4.30	15.85 ± 6.00	0.000***
Setting-up plant stakes	11.72 ± 6.31	6.06 ± 3.73	7.08 ± 4.97	14.76 ± 8.12	8.27 ± 4.48	5.44 ± 5.61	5.24 ± 3.38	11.14 ± 5.55	0.000***
Harvesting crops	10.16 ± 7.12	4.83 ± 2.48	4.02 ± 2.53	7.43 ± 3.86	3.76 ± 2.46	3.10 ± 2.04	3.49 ± 2.87	5.77 ± 5.52	0.000***
Washing crops	12.49 ± 8.22	4.29 ± 2.72	4.53 ± 3.22	10.42 ± 6.00	8.69 ± 5.48	4.46 ± 2.28	5.18 ± 3.73	14.49 ± 9.87	0.000***
Packing crops	10.14 ± 7.30	4.10 ± 2.24	4.83 ± 2.76	9.63 ± 4.66	7.04 ± 4.79	4.09 ± 2.57	4.44 ± 3.09	11.56 ± 8.28	0.000***
Cutting crops	16.00 ± 12.78	4.12 ± 2.42	3.10 ± 1.98	8.89 ± 4.61	10.87 ± 8.55	4.17 ± 1.98	3.73 ± 2.51	10.93 ± 4.81	0.000***
Trimming crops	15.86 ± 10.67	6.97 ± 4.15	7.43 ± 4.29	18.01 ± 10.31	8.37 ± 5.83	2.79 ± 1.60	5.14 ± 3.68	13.41 ± 7.53	0.000***
Making mojitos	13.61 ± 10.04	5.11 ± 2.57	4.34 ± 2.15	11.62 ± 6.03	10.10 ± 7.43	5.08 ± 3.28	4.97 ± 3.08	11.32 ± 5.40	0.000***
Collecting natural objects	6.11 ± 4.23	2.54 ± 1.43	3.94 ± 2.74	5.16 ± 2.86	4.26 ± 2.55	2.46 ± 1.42	3.46 ± 2.34	5.53 ± 4.64	0.000***
Creating art	11.15 ± 8.51	4.32 ± 2.24	3.95 ± 2.42	11.10 ± 4.92	9.40 ± 5.72	4.36 ± 2.95	4.38 ± 2.95	10.27 ± 4.42	0.000***
Interacting with a dog	11.42 ± 9.18	6.15 ± 4.86	5.08 ± 4.37	11.16 ± 8.48	9.72 ± 10.21	5.94 ± 5.32	6.09 ± 5.48	10.33 ± 6.67	0.006**
Walking with a dog	6.24 ± 2.89	3.73 ± 2.24	3.94 ± 2.75	8.62 ± 4.04	9.01 ± 9.96	3.14 ± 1.71	4.28 ± 3.76	9.37 ± 5.74	0.000***
Feeding rabbits	10.92 ± 8.26	4.39 ± 2.95	3.59 ± 2.51	5.44 ± 3.73	3.83 ± 4.10	3.05 ± 3.08	2.96 ± 2.27	4.11 ± 2.97	0.000***
Cleaning-up the farm	6.09 ± 4.11	4.13 ± 2.49	5.10 ± 4.09	20.77 ± 9.77	4.88 ± 4.81	2.33 ± 2.23	3.32 ± 1.52	12.34 ± 7.72	0.000***
Maintaining a garden	7.93 ± 4.46	4.30 ± 2.97	4.01 ± 2.92	6.25 ± 3.23	4.75 ± 3.98	2.82 ± 2.27	3.18 ± 2.74	4.57 ± 3.42	0.000***
Significance	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	

[i] **, ***Significant at $P < 0.01$ or 0.001 using the Kruskal–Wallis test, respectively.

plot, which involved activities such as digging, raking, and fertilizing, and walking with a dog; however, during other agricultural activities, the muscle activity of the vastus lateralis, vastus medialis, and biceps femoris of the thigh was high (Table 5). The gastrocnemius muscle is important for generating and transmitting power and force (Jacobs et al. 1996; Neptune et al. 2001) and shows high activity during weight-bearing activities (Hébert-Losier and Holmberg 2013). During the present study, high gastrocnemius muscle activity was observed during the following activities that mainly involved standing and supporting body weight: digging, raking, fertilizing, washing, interacting with a dog,

Table 5. Muscle activation data of eight lower limb muscles during 10 green care farming activities obtained using electromyography.

	Maximum voluntary contraction integrated electromyography (mean ± *SD*)								
	Right (%)				Left (%)				
Care farming activities	Vastus lateralis	Vastus medialis	Biceps femoris	Gastrocnemius	Vastus lateralis	Vastus medialis	Biceps femoris	Gastrocnemius	Significance[i]
Raking	12.23 ± 10.25	11.50 ± 8.29	8.83 ± 4.39	13.92 ± 8.27	13.33 ± 5.46	10.25 ± 5.50	12.06 ± 4.98	18.61 ± 11.63	0.004**
Digging	15.25 ± 9.36	18.82 ± 14.34	13.54 ± 3.82	15.42 ± 8.06	19.24 ± 11.24	17.79 ± 14.97	16.21 ± 6.23	20.13 ± 12.58	0.618^{NS}
Fertilizing	11.79 ± 9.71	8.14 ± 6.71	11.64 ± 3.99	16.26 ± 8.80	9.70 ± 6.64	10.78 ± 9.19	10.84 ± 4.89	16.17 ± 9.97	0.003**
Planting	27.28 ± 19.22	20.24 ± 14.54	6.72 ± 4.84	11.28 ± 6.88	23.66 ± 14.18	28.20 ± 20.47	6.88 ± 5.06	11.14 ± 10.09	0.000***
Mulching	23.39 ± 18.55	21.25 ± 22.55	6.06 ± 4.27	11.07 ± 7.40	18.06 ± 13.27	23.29 ± 18.00	7.58 ± 5.48	11.13 ± 8.38	0.000***
Setting-up plant stakes	20.52 ± 15.94	19.27 ± 19.45	8.90 ± 9.38	12.95 ± 9.35	15.27 ± 10.50	25.04 ± 22.74	6.86 ± 4.79	8.54 ± 8.32	0.001**
Harvesting crops	8.05 ± 6.21	10.12 ± 13.41	12.25 ± 4.29	11.66 ± 7.29	10.06 ± 10.69	9.78 ± 10.10	12.08 ± 5.11	12.20 ± 6.56	0.001**
Washing crops	10.39 ± 13.93	8.47 ± 9.73	13.52 ± 5.49	14.85 ± 10.22	9.08 ± 9.54	9.30 ± 10.70	13.25 ± 5.34	12.55 ± 8.14	0.000***
Packing crops	7.20 ± 7.98	5.91 ± 4.97	12.65 ± 4.93	12.97 ± 9.18	6.71 ± 4.91	6.53 ± 5.59	14.12 ± 5.27	14.54 ± 6.36	0.000***
Cutting crops	2.82 ± 2.37	2.59 ± 2.70	4.85 ± 3.46	4.17 ± 3.90	2.64 ± 2.31	2.77 ±± 2.39	4.29 ± 4.07	4.92 ± 6.59	0.404^{NS}
Trimming crops	2.37 ± 2.14	2.21 ± 2.18	5.51 ± 3.85	4.19 ±5.71	2.25 ± 1.63	2.33 ± 1.98	4.78 ± 4.20	5.83 ± 8.32	0.034*
Making mojitos	2.46 ± 2.24	2.55 ± 2.59	5.53 ± 3.10	6.84 ± 7.50	2.75 ± 2.15	2.64 ± 2.50	5.38 ± 4.40	6.05 ± 8.70	0.006**
Collecting natural objects	19.82 ± 11.50	23.37 ± 16.52	10.30 ± 2.99	13.81 ± 8.61	24.20 ± 13.27	22.48 ± 12.31	11.75 ± 4.90	14.27 ± 6.53	0.000***
Creating art	6.25 ± 5.74	5.46 ± 3.63	3.56 ± 2.18	4.52 ± 3.73	5.53 ± 3.28	5.88 ± 3.53	3.10 ± 1.87	4.73 ± 4.12	0.027*
Interacting with a dog	3.06 ± 3.99	3.97 ± 5.71	2.74 ± 6.37	3.67 ± 3.81	2.49 ± 2.76	2.63 ± 2.62	1.25 ± 0.72	3.22 ± 3.70	0.136^{NS}
Walking with a dog	18.95 ± 18.38	19.12 ± 18.69	11.03 ± 5.80	13.82 ± 7.67	18.37 ± 13.95	18.49 ± 13.13	10.90 ± 5.10	15.65 ± 8.33	0.197^{NS}
Feeding rabbits	8.23 ± 6.82	8.26 ± 14.74	11.20 ± 5.38	10.27 ± 7.26	8.30 ± 9.41	9.34 ± 10.61	11.28 ± 4.81	9.61 ± 5.34	0.007**
Cleaning-up the farm	7.59 ± 5.45	7.83 ± 7.58	11.46 ± 5.03	13.72 ± 7.76	8.37 ± 5.53	7.74 ± 5.24	12.37 ± 4.59	12.79 ± 5.63	0.000***
Maintaining a garden	12.89 ± 12.17	8.68 ± 8.40	12.82 ± 4.37	12.43 ± 7.71	10.93 ± 8.94	15.45 ± 13.68	10.47 ± 5.64	11.55 ± 4.89	0.107^{NS}
Significance	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	

[i] NS, *, **, ***Nonsignificant or significant at $P < 0.05$, 0.01, or 0.001 using the Kruskal–Wallis test, respectively.

and maintaining a garden. The vastus lateralis, vastus medialis, and biceps femoris are the main muscles activated during squat exercises with up to 90° of knee flexion without resistance (Caterisano et al. 2002; Schaub and Worrell 1995). The results of our study also showed that the activities of these three muscles were high during knee bending or squatting, transplanting plants, harvesting, creating art with natural objects, and feeding rabbits.

As a result of the comparison of muscle activity according to each muscle, most of the lower limb muscles were most activated when organizing garden plots, which involved activities such as digging, raking, and fertilizing, planting, and collecting natural objects (Table 5). A similar previous study that measured lower limb muscle activity during five gardening activities also showed high lower limb muscle activity during raking and digging activities (Park et al. 2014).

Green care farming activities include various functional movements used in the field of upper-limb and lower-limb muscle strength, conditioning, and rehabilitation, such as weight-bearing exercises, squats, walking exercises, and reaching–grasping exercises (Coluccini et al. 2007; Escamilla et al. 2012; Schoenfeld 2010). However, one of the differences between these exercise interventions and green care farming is that the intervention in green care farming activities is conducted in a natural environment using living organisms. The potentially positive health-promoting effects of contact with nature can be explained by the biophilia and attention restoration theories (Kaplan 1995; Ulrich 1993). Nature provides a rewarding and supportive environment, and the diverse living organisms within it provide a unique experience of acceptance (Steigen et al. 2016). The positive effects of nature in green care farming interventions may provide psychological and social benefits in addition to the physical effects of exercise interventions. Care farms can offer a variety of activities to clients, depending on their specific needs and capabilities and the types of farms and interventions available (Murray et al. 2019). Care farming activities can be designed and provided as a number of interventions using various natural resources, environmental resources, and activity resources. It is essential to identify the therapeutic mechanism for each activity before providing a care farming program tailored to the participation purpose of each client. In this context, this study provided basic data for the development of an evidence-based care farming program; therefore, it is possible to design care farming interventions for each client and purpose.

In conclusion, this study evaluated the muscle activation during activities in a program operated at an actual green care farm and collected the basic data necessary for the development of a green care farm program for the improvement of the physical function of adults. However, limitations of this study include the small sample size and the inability to measure various biomechanical effects (for example, by performing motion analyses and evaluating the joint range of motion). In the future, various physical effects of green care farming activities should be organized using measurements that can be used to evaluate physical effects as well as muscle activation. Green care farming programs suitable for the participants' goals of care should be developed and disseminated to improve physical health. In addition, studies of the health benefits of the effects of other natural resources such as the landscape, sounds, and climate of the farm environment that are encountered during green care farming activities are necessary.

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