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Study on the Content Development of the Exercise Programs for Rehabilitation using the Motion Recognition Technology

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Abstract

This study was conducted to present the development direction of the contents of rehabilitation exercise program for person with disabilities using motion recognition technology. Through the literature review, we selected for those who needed rehabilitation service focusing on exercise. They have difficulties in an exercise for the upper extremity, learning and mobility within a community due to physical and mental disability, brain injury and autism. To set a goal for rehabilitation exercise program, we analyzed preceding literature related to the needs of the disabled persons and 17 evaluation tools for daily living skills in occupational therapy. Accordingly, the goal was set for improving activities of daily living and the goal activities specifically focused on dressing/taking off clothes, eating and personal hygiene. Then, the functional motion elements consisting of each activity and their levels were defined and analyzed. In the rehabilitation program, the motion elements of the goal activity that could be measured by motion recognition sensor were presented. The motion elements of the goal activity involved muscle strength and range of motion that could be measured, so that the development direction of rehabilitation exercise program contents was specifically presented for improving daily living skills. The study presented the possibility that virtual reality program contents developed for rehabilitation for the disabled could attribute to not only simple physical and/or cognitive improvement but also to the actual daily living skills.

Keywords: Activities of Daily Living, Motion Recognition Technology, Rehabilitation Exercise,Virtual Reality Program

1. Introduction

With an increase in disabled persons in recent years, there are steadily growing demands for rehabilitation. At present, the registered people with disability in Korea increased by 163% in compared with 2000, 90% of total disabled population was acquired disabilities due to a posterioricause[1]. According to the Act on Welfare of Persons with Disabilities in Korea, "the state and local government shall take necessary measures for supplying persons with disabilities with rehabilitation medical services such as functional treatment and psychological treatment, in order for them to learn or restore their living abilities"[2]. In addition, people with disabilities reported to be preferentially expanded welfare programs in National survey on Persons with Disabilities, that is 'support of medical expenses and medical rehabilitation service for children withdisabilities'[3]. These results show that the high demands for disabled to rehabilitation services. In spite of various efforts to expand the support according to these requirements, penetration rate of rehabilitation facility is significantly lower in Korea. Also, the burden of treatment costs increases the access restrictions on rehabilitation. In addition, people with disabilities may have no choice because they are difficult to access in rehabilitation facilities focused medical service due to physical or psychosocial reasons.

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As there were many reports on the effects of rehabilitation exercise using virtual reality such as cost-effectiveness, usability, motor skills and physical improvement after the simple application and motivation for self-directed learning, rehabilitation exercise has advantages in the practical aspect[4-7]. In particular, home game devices, such as the Nintendo Wii and Microsoft Kinect™ X-box 360 have been noted as a simple way to measure the user's posture and motion without building expensive facilities or purchasing equipment separately.

Depending on the expanded possibilities of use, many control systems and contents have been developed in various ways related to exercise program for rehabilitation. It is important to identify that the needs of disabled people and reflect it in the product as well as technical implementation when developing rehabilitation programs. Considering the user's needs product in the development process can be useful to achieve the goal of both developers and users. Therefore we have to predict the major target groups and identify the characteristics of them before developing motion centered exercise program for rehabilitation. We need to determine the direction for content development based on these data.

In this study, preceding literature was reviewed to select the disabled group likely to receive significant effectiveness from rehabilitation exercise program using motion recognition sensor. As a result, the main target involved persons with physical dysfunction or brain lesions who have difficulties in performing daily living skills because of their limited function of the upper extremities. Furthermore, the potential group specifically included persons with autism and mental retardation who have retarded cognitive development and the resulting underdeveloped motor function or difficulties in the learning skills for activities of daily living. More specifically, the main targets that are most likely to receive significant effectiveness from rehabilitation exercise program include musculoskeletal diseases (such as spinal cord injury, progressive muscular dystrophy), degenerative diseases of the nervous system (arthritis, multiple sclerosis, amyotrophic lateral sclerosis), brain lesion (stroke, cerebral palsy, traumatic brain injury, etc.).

People with disabilities registered as the four types of disability of the main and potential targets account for 70.5% of the total disabled population in Korea, which make totally 1,770,091 people. In recent years, rehabilitation exercise program for those disabled persons are developed in variousways[8]. However, there is yet no objective verification of the effectiveness of the program and no clear proof for the design basis of specific exercise motions in the process of development. Accordingly, the study was carried out to present the development direction of contents based on the disabled persons' exercise motion necessary to achieve their needs when making rehabilitation program for the disabled using motion recognition technology. The goal of rehabilitation was to focus on the participation and the improvement of function of the disabled in daily living. To this end, the goal activity was selected for the improvement of function of the main demand group in daily living necessary for rehabilitation program based on exercise. In the selected goal activity, the functional motion elements and the levels were identified and the targeted motions were defined. Then, the direction of contents was presented to make use of the target motion for recognition sensor.

2. Research Methods

2.1 The Needs of Main Target and Goal Activity

To obtain the objective of this study, the demand group needed for motion-centered rehabilitation exercise program was specifically selected. Based on the characteristics of the group, preceding literature and data were analyzed as bottom-up approach to present target motion in which the contents consisting of rehabilitation program will result.

First of all, through the review of areas of human occupation presented in the Occupational Therapy Practice Framework (OTPF) as well as the classification of activities of daily living, the characteristics of the demand group were analyzed[9]. Additionally, the evaluation tools of daily living skills often used in occupational therapy was analyzed and then items were divided into Basic Activities of Daily Living (BADL) and Instrumental Activities of Daily Living (IADL) to be redefined as the areas of each activity of daily living. Finally the range of goal activities necessary for the improvement of daily living skills was determined. The 17 evaluation tools used in the analysis involve the Functional Independence Measure (FIM), Korean version Modified Barthel Index (K-MBI), Wee Functional Independence Measure (Wee FIM), Katz Index of Independence in Activities of Daily Living (Katz ADL), Spinal Cord Independence Measure (SCIM), Klein-Bell Activities of Daily Living Scale, Kenny self-care evaluation, PULSES Profile, Assessment of Motor and Process Skills (AMPS), Kitchen Task Assessment

(KTA), Canadian Occupational Performance Measure (COPM), Frenchay Activities Index (FAI), Korean Activities of Daily Living (K-ADL) and K-IADL, Lawton IADL evaluation, Arnadottir OT-ADL Neurobehavioral Evaluation (A-ONE) and Kohlman Evaluation of Living Skills (KELS).

Comparing the redefined result with ones by the disabled who responded that 'they largely faced big trouble in daily living' in the '2011 National survey on Persons with Disabilitiesin Korea, the priority of the important level of activities in daily living was determined based on overlapping items[1,3].

2.2 Abstracting Motion Elements

Motion elements consisting of each activity was abstracted by again analyzing goal activities. The level of motion elements for achieving goal activity was objectively made as the range of motion and muscle strength. Movement is one that occurs by joints connected skeleton arising from contraction of muscle, which occurs when muscle fixed on both sides of joint connected to two or more bones alternately contracts[10]. The range of movement measured in the movement of extremities is called "Range of Motion (ROM)" and according to the direction of movement, the ROM represents the range of motion that enables human body to approach it. Depending on types of joints, the direction of motion and the rangevary[11]. The measurement is made using a different size of goniometer according to the size and feature of the body parts.

Muscle strength is defined as the force of muscle as a result of the contraction of muscle; it dynamically moves or exerts its force against a fixed externalobject[12]. The measurement of muscle strength requires instruments such as back strength tool and pinch meter according to the part of body. This study employed the level of muscle strength that was used in 'Manual Muscle Testing (MMT)' to display the grade of muscle strength. The manual muscle strength test is to measure muscle strength of patients by a therapist directly exerting his/her force with hand and it consists of the 6 grades: Normal, Good, Fair, Poor, Trace and Zero.

3. Results

3.1 Decision of Goal Activities

As a result of the study, the goal activities were finally decided as daily living activity relevant to 'dressing/ taking off clothes, eating and personal hygiene (washing face, washing hair, bath). The evaluation tools of daily living skills reviewed in the process of the study mutually included: 1. Mobility (walking or wheelchair mobility → transfer from one place to another; between bed-chair-wheelchair-bathtub-toilets→ going up stairs→ activities within bed; e.g. changes in position). 2. Dressing and taking off clothes. 3. Eating. 4. Toileting, personal hygiene, grooming and bathing. First of all, main activities of daily living were specifically decided: 'mobility, dressing and off clothes, eating, personal hygiene and grooming (including dealing with personal hygiene, controlling urine and feces), taking a bath' that were overlapped with results of the '2011 disability survey in Korea. However, some items were excluded as follows: items hardly possible to make measurement using motion recognition sensor (e.g. actions done within the inside of mouth, such as 'chewing and eating' among having meals) and mobility and transfer necessary to maintain the balance for users' safety (e.g. walking and transferring, etc.).

3.2 Definition of Motion Elements

Finally, the specific goal activities consist of diverse motion elements. Using motion recognition sensor, the effect of exercise presented in rehabilitation exercise program was measured as the level of goal activities. To this end, motion elements consisting of each goal activity were more specifically defined and analyzed. The level of achievement for motion elements was defined as measurement of range of motion and muscle strength.

Considering the characteristics of the main target group, we focused on the function of upper extremities in functional sitting position. Shoulder, elbow and wrist joints related to exercise of the upper extremity can perform goal activities through the movement of flexion/ extension or abduction, internal/external rotation (only for shoulder joint). In this study, joint range of motion of movement required in activities of dressing/taking off clothes, eating and personal hygiene, which were goal activities, showed their normal range: shoulder jt. flexion 0-90°, abduction 0-90°, internal rotation 080°, external rotation 0-30° and elbow jt. flexion 15-140°, internal rotation 0-42.9°, extension 0-21.9°; wrist jt. flexion 0-9.6°, extension 0-42.6°. The range of motion of knee and hip joints needed for exercise of lower extremities was excluded because it was beyond range of this study. The study was on the assumption that user of rehabilitation program could maintain functional position making it possible to sit or stand. Additionally, each motion was

turned out to require muscle strength equivalent to grade Fair+. This level means that within range of motion, its body has a certain amount of muscle strength in order to perform each motion by resisting against gravity applied on body parts.

In this study, the range of motion required by activities such as dressing/taking off clothes, eating and personal hygiene, defined as main goal activities, is as shown in Figure 1 and Table 1. You can find the minimum to maximum range of motion encompassing each goal activity was described in Table 1.

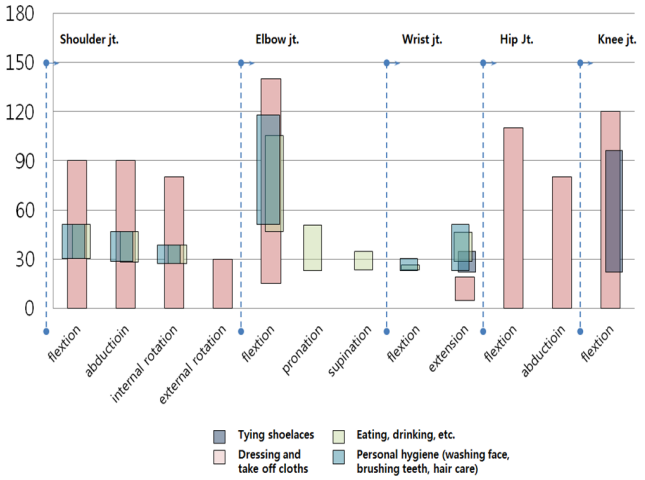

Figure 1. Functional range of motion elements for goal activities.

4. Discussion

In case of persons with physical dysfunction for acquired reasons, there are higher needs for rehabilitation. However, the supply of rehabilitation service far falls short of the demand and rehabilitation services for social participation are not enough in the community. So people with acquired disabilities caused by disease or accidents have a fear of the discharge. In many cases, they did not return into the community such as home or work and become long-stay patients in hospital or admit to the hospital again after discharge. It causes personal and social loss such as excessive medical costs[13,14]. At this juncture, virtual reality technology using household remote control device is considered as a new alternative for rehabilitation exercise for people with disabilities[7]. The development direction of rehabilitation exercise program should be presented according to desires and needs of the disabled. The rehabilitation exercise program based on the demand of the disabled motivates users to participate program consistently[15,16]. Then it contributes to the effective achievement of goals for the use of program in terms of the improvement of daily living skills based on a client-centered approach[8].

The study aimed to define target motions measured by motion recognition sensor in order to develop rehabilitation program based on needs of people with disabilities. Considering users who can maintain sitting position on their own or with positioning device and control of head and neck, target motions were limited to 'function of upper extremities' of full-body movement. If rehabilitation program is used with assistive device for seating and positioning such as wheelchair or inner, when necessary, it will have three advantages: 1. Fully obtaining full-body safety. 2. Effectively facilitating target motions. 3. Reducing risks of accidents during rehabilitation program[8].

Table 1. Distribution of the functional range of motion elements for the goal activities

Motion Elements		The Functional ROM of Elements for the Target Activities(˚)			
		Dressing/take off cloths	*Eating, Drinking, Drinking, etc.*	*Personal Hygiene*	*A Comprehensive range of functional ROM*
Shoulder	flexes.	0.0 ~ 90.00 0.0 ~ 90.0	7.8 ~ 43.2	7.8 ~ 43.2	0.0 ~ 90.0
	Abd.	0.0 ~ 80.0	6.6 ~ 31.2	6.6 ~ 31.2	0.0 ~ 90.0
	IR.	0.0 ~ 30.0	4.8 ~ 23.4	4.8 ~ 23.4	0.0 ~ 80.0
	ER.	15 ~ 140.0			0.0 ~ 30.0
Elbow	flex.		35.6 ~ 123.2	42.8~140.6	15.0 ~ 140.0
	Pronation		0.0 ~ 42.9		0.0 ~ 42.9
	Ext.		0.0 ~ 21.9		0.0 ~ 21.9
Wrists	flex.		0.0 ~ 3.5	0.0~ 9.6	0.0 ~ 9.6
	Ext.	0.0~18.9	8.7~36.5	0.0~42.6	0.0 ~ 42.6

The upper extremity-focused goal motions consist of movements of shoulder, elbow and wrist joints. Such physical movement can be expressed in various ways, but the typical methods examples are joint movement and muscle strength. Therefore, this study employed physical examination results such as range of motion and manual muscle testing to quantificationally show motion elements. The normal range of joint motion slightly varies from person to person[9]. However, the standard range of motion is presented in the various literature or research generally available for reference. To live a daily life, it is not necessary to require full range of motion. Accordingly, motion elements were based on 'functional range of motion', it means the movement necessary for basic activities of daily living[11,17].

In case of muscle strength, there are several findings that if muscle strength of key muscle that produce motion wins against slight resistance including one's own weight (by gravity) and at the same time, joint movement can be possible (fair-good) within partial to full range in the opposite direction of resistance, there is no problem in participating in activities of daily living, for instance, using upper extremities on sitting position[11,17]. These findings substantiate the results of this study.

Such results were reflected in the motions of game contents on rehabilitation exercise program and were used as the basis for embodying rehabilitation exercise program. The level of achievement on the developed contents is measured as a coordinating value, as well as the moving direction, distance and the angle of rotation when users move their upper extremities to perform exercise program for rehabilitation. Each measurement values are collected not only in the middle of the exercise, but also before and after running program and this will serve as an objective index determining the improvement of function. These data may be applied in many ways, for example, the data collected in the first session of the program can be used as reference to set the overall rehabilitation goals to the individual preferentially. Because motion required by exercise program based on finding of our study is essential to perform daily living skills, changes in the level of a game score during a certain period may be also compared to the user's performance level of daily living skills.

Finally, motion centered exercise program for rehabilitation is developed to aim to improve performance of activities of daily living, as well as to recover or promote body function such as the improvement of joint movements or muscle strength. Therefore, we recommend toset target activities based on individual needs and priorities in consultation between the disabled and rehabilitation specialists, then apply rehabilitation program and measure the degree of achievement. If we consider the needs and context throughout life of people with disabilities, i. e., the skills, limitations and characteristic of the disabled and their families, etc., we can provide the services that meet the needs of participants in exercise program for rehabilitation. So, participants can be consistently motivated to perform in a rehabilitation program. In addition, it can be useful to enhance motivation of individual user for participation that the disabled directly choose contents from recommended options as many kinds of type and degree of difficulty related to the rehabilitation goals. Our recommendations are consistent with client-centered approach, that means clients participate in the process todetermine the directions of the program and they are supported for active participation in the rehabilitation program.

This study is meaningful in that it firstly reviews the needs of users before rehabilitation program using motion recognition sensor is developed and to this end, it is the first study in Korea defining the needed goal activities and motion. However, the study was conducted focusing on literature research, so it has the limitation to the needs for collecting and presenting continuous and empirical clinical data after the development of rehabilitation exercise program. Accordingly, further study is needed to determine not only the effectiveness of usage after the development of rehabilitation program but also the general effectiveness contributing to the actual daily living skills.

5. Conclusion

This study aimed to present the development direction of the contents of rehabilitation exercise program in order to improve daily living skills for person with physical dysfunction or brain lesions and autism or mental retardation. As a result of the study, the goal activities of rehabilitation exercise program were specifically

focused on 'dressing/taking off clothes, eating and personal hygiene'. The level of functional motion elements necessary to achieve each activity was analyzed based on muscle strength and range of motion and then it was presented. The findings of this study were reflected in the development direction of rehabilitation exercise program for improving daily living skills of people with disabilities based on their needs. Further research is needed to determine the general effect of the application of rehabilitation program.

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