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Effects of Personal Health Record based Lower Cross Muscle Exercise Programs on Muscle strength, Endurance, Flexibility, Balance, and Cardiopulmonary endurance Function: A Randomized Controlled Trial

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Abstract

The purpose of this study was to research the effects of the lower cross syndrome (LCS) muscle exercise program based on Personal Health Record (PHR) on muscle strength, muscle endurance, flexibility, balance, and cardiopulmonary endurance of the general public. The 42 adult men and women who voluntarily participated in the study were randomized into 2 groups, consisting of an experimental group of the Personal Health Record (PHR) exercise program and a control group of existing exercise protocol. Muscle strength, muscular endurance, flexibility, balance, and cardiopulmonary endurance in each group were measured using hand-held dynamometry (HHD), endurance test, stand and reach test (SRT), Y-balance, and cooper's test, respectively. The statistical methods of all measurements were analyzed using paired t-test and independent t-test. Both the experimental group and the control group had significant differences after exercise in terms of muscle strength, muscle endurance, balance, flexibility, and cardiopulmonary endurance through intervention(p<.05). When comparing the degree of difference between the groups before and after, there was a significant difference in muscle strength and cardiopulmonary endurance, and there was no significant difference in muscle endurance, balance, and flexibility. PHR exercise was more efficient than protocol exercise when performing exercise intervention under the same conditions, and studies on PHR exercise intervention and PHR for various diseases, including LCS, are needed.

Keywords: *PHR; LCS; muscle strength; endurance; flexibility; balance; cardiopulmonary endurance.*

1. Introduction

Recently, as the use of smartphones in modern society has increased and access to health has improved, it has also been used in clinical circles as a convenient tool by using apps aimed at lifestyle management for personal health records of the general public[1]. The Personal Health Record (PHR) system is an electronic application that allows patients to maintain and manage their own health information (and other authorized health

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information). And a personal health and disease management tool for individual patients, and a communication tool with medical staff[2]. In fact, PHR is sometimes used for health care from infectious diseases such as COVID-19[3], Hongxuan X has recently successfully demonstrated the feasibility of PHR involving digital changes in the behavior of people with chronic diseases[1].

As we enter the era of the 4th Industrial Revolution, the awareness of the health of modern people using mobile is increasing, and many apps using various PHRs are emerging. PHR-based exercise programs allow patients to approach treatment in a way that can positively affect their health through interactions with their health data[4,5]. PHR allows patients to efficiently manage information about their medical status, medications, and behaviors related to self-care and health self-monitoring[6]. However, although the barriers to access to personal health records of modern people have been lowered, objective self-judgment on the patient's own health is required in order to use it correctly, and the lack of training of therapists has been a limitation[7]. So, to compensate for this, Mashi Rabbi said that AR algorithms are useful for providing personalized programs for users[8]. The AR algorithm is a program that recommends individual exercises to the subjects by calculating the algorithm that sets the intensity and exercise based on the evaluation data collected after the motion evaluation of the subjects. Through this, the AR system can maximize the benefits of the PHR program by quantifying the subject's movement and providing an optimal exercise program[9].

With the increasing sedentary lifestyle of modern people these days, and the increasing number of patients with Lower Cross Syndrome (LCS), a patient-centered approach to treatment is needed, and O'Lenick, D. E. have shown that a patient-centered, evidence-based approach leads to the best interventions in the clinic[10]. LCS is a musculoskeletal disease associated with muscle imbalances caused by the weakness and tightness of the muscles connecting the dorsal and ventral sides of the body as a result of a lower muscle imbalance[11]. According to Priyanka Sahu, LCS is caused by an excess of pressure, such as hip flexion and lumbar extension, which results in anterior tilt of the pelvis, increased hip flexion, and lordosis of the lumbar spine. Janda suggested LCS as the cause of many low back pains[11].

LCS needs exercises to strengthen the muscle strength of rectus abdominals and hamstrings. Accordingly, IMAI proposed a core stabilization exercise consisting of front plank, back bridge, quadruped exercise, side bridge, and back extension as a protocol for trunk stabilization exercises[12]. Continuous core stabilization exercises have been reported to strengthen weakened muscle strength and strengthen muscle endurance[13,15]. Lower back pain (LBP) caused by LCS requires stretching exercises[14]. It has been reported that stretching on hip flexor to address muscle imbalances caused by muscle stiffness has an effect on reducing muscle imbalances[15].

These exercise protocol has been applied as an essential therapeutic approach to LCS, but there are limitations to the expectation of therapeutic effects by applying the formalized protocol to all patients, and it is not known whether exercise protocol is more effective than personalized exercises[16]. Therefore, a patient-centered approach to LCS treatment needs to be studied as an approachable approach to applicable treatment. Sanjog S et al. have shown that a health system that provides evidence-based updates for the diagnosis and treatment of back pain has a significant impact on patient care. Therefore, the optimal treatment method for LCS is to find the best evidence for cure using evidence-based practice and to say that care with correct diagnosis is effective[17]. However, research into access and diagnosis using evidence-based practice is ongoing, and while many exercise programs have been studied to prevent LCS, there is no research on PHR-based exercise programs. In addition, it has been reported that using PHR still lacks PHR-based health care because patients need to build their own health data, and because it plays a negative role in PHR when the therapist fails to perform health direction and education properly[18].

Therefore, this study is divided into a control group that implements the existing exercise protocol and an experimental group that conducts an exercise program based on PHR in general people who have experienced LCS. By conducting experiments in previous studies, we complement the limitations of previous papers that do not affect muscle strength and muscle endurance generated using the original protocol without using a PHR-based exercise program, and apply a PHR-based exercise program to analyze the effects on LCS's muscle strength, muscle endurance, flexibility, balance, and cardiopulmonary endurance. The purpose of this study is to demonstrate the need for PHR exercise programs in clinical practice when physiotherapists treat patients by drawing results on whether PHR-based LCS exercise therapy methods are more effective when compared to existing exercise protocols.

2. Materials and Methods

The process of this study is as follows (Figure 1).

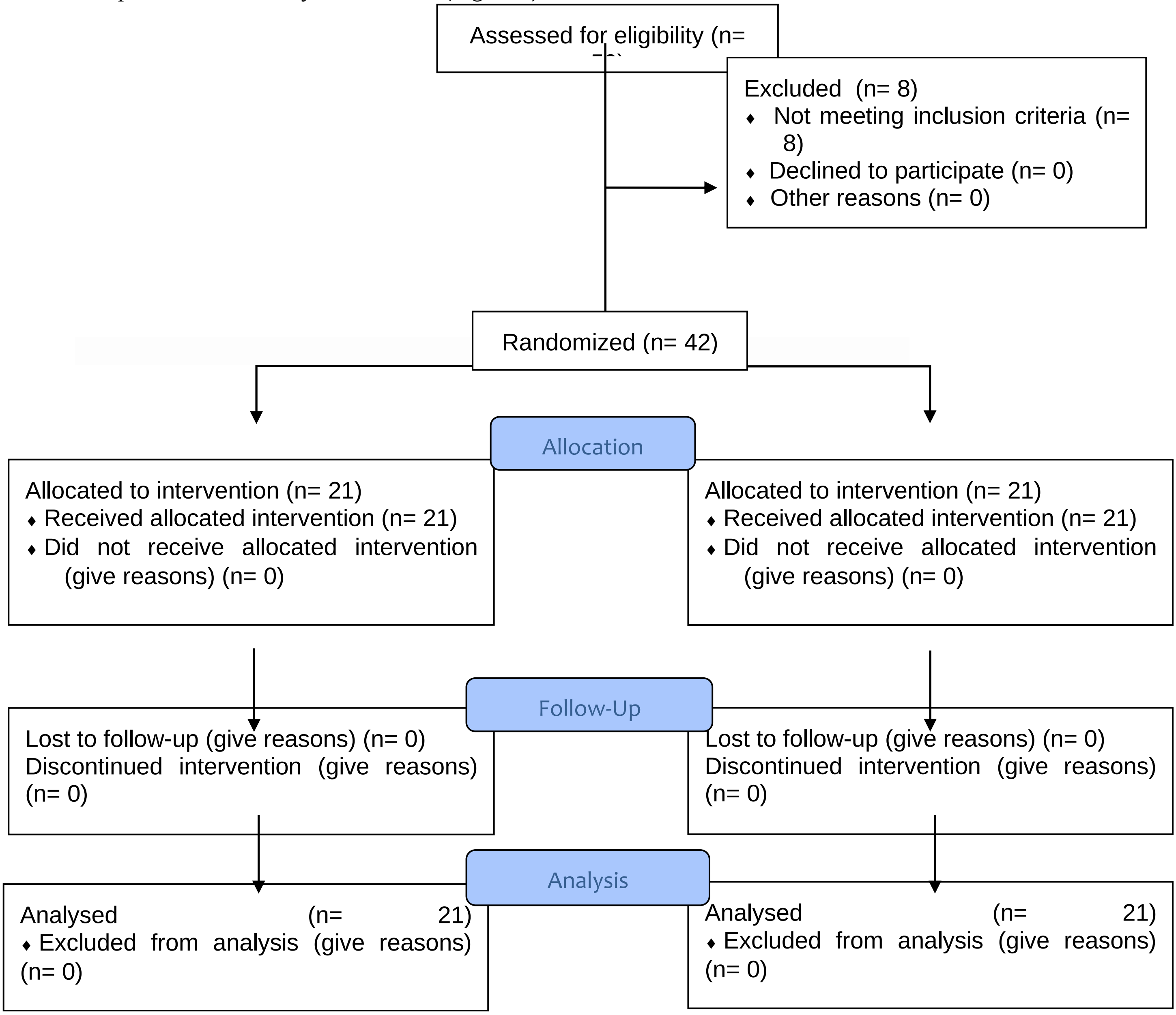

Figure 1. Experiment Procedures.

2.1. Research design

This study was a randomized controlled trial pretest-posttest with two groups conducted in the Department of Physical Therapy at Sunmoon University, Korea. Participants were randomly assigned to one of two groups, and the intervention lasted for four weeks. Written informed consent was acquired from each participant. The study followed the principles of the Declaration of Helsinki and was approved by the Institutional Review Board of Sunmoon University (SM-202204-014-3) .

2.2. Participants

In this study, 42 male and female college students in their 20s and 30s attending S University in A city were selected as subjects. This study was controlled on 42 regular adults. The study subjects obtained the number of samples using the sample count calculation program ‘GPOWER, 3.1.9.7’. The subject of this study is called LCS group, which has a history of low back pain in the past, complained of discomfort due to lordosis, or suspected symptoms. The selection criteria for this study are those who have a past history of low back pain, who have complained of discomfort due to anterior inclination, or who have suspected symptoms are called LCS group, and those who do not have pain or disease caused by damage to the lower extremities, and those who do not have a diagnosis, medical history, or family history related to anemia such as orthostatic hypotension (Table 1).

Table 1. General characteristics of participants.

	PHR Exercise (N=21)	Protocol Exercise(N=21)
Sex (male/female)	11/10	11/10
Age (years)	21.95 ± 1.95	22.09 ± 2.09
Height (cm)	168.63± 16.63	167.61 ± 17.38
Weight (Kg)	64.72 ± 19.72	65.66 ± 20.66
Leg length (cm)	85.21±7.91	86.71±8.71

2.3. Randomization

Participants were randomly allocated to one of the two groups: the PHR exercise group, the Protocol exercise group. The allocation was conducted by excel spread sheet. The subjects were randomly divided into two groups, and then a group of subjects and controls were randomly placed within each group as well. At this time, the subject group was applied to the AR algorithm. It is a group that conducts an exercise program customized for each individual by the experimental group, and the control group is a group that proceeds according to the previously set exercise protocol. The study subjects were randomized and conducted without knowing which group they belonged to.

2.4. Intervention

2.4.1. PHR(personal health record)Exercise

The experimental group conducted a motion evaluation of five movements: Front Plank, Back Bridge, Side Plank, Quadruped Exercise, and Back extension. Motion assessment was evaluated and analyzed through AR. Based on this, the subject's frequency of exercise, the intensity of the exercise, the break time, and the time of exercise were selected as customized exercise according to the AR algorithm. The five exercises selected based on PHR were adjusted by applying a deviation of ±10%. Also, The stretching program was applied for 2 or 3 minutes depending on the results of the subject's motion evaluation according to the AR algorithm.

2.4.2. Protocol Exercise

(1) Strength exercise

The first exercise program of the LCS Protocol is as follows: Imai Trunk Stabilize Protocol[14]. (A) Front Plank,(3 sets of 50s) (B) Back Bridge(3 x 50s), (C) Side Plank (3 x 30s L,R), (4) Quadruped Exercise(3 x 2 x 15s A,B), (E) Back Extension(3 x 50s)[16]. Perform a total of 5 different exercises and gave yourself a 30-second break between each set. In the case of Front Plank, participants were instructed to maintain a prone position supporting the body with their forearms and toes (Figure 2-A). In the case of the Back Bridge, participants began by placing their feet flat on the floor, bending their knees at 90°, and lying with their hands folded across their chests. They raised their pelvis to achieve and maintain a neutral hip flexion angle. In the next step, lift one leg from the floor, straighten the knee, and maintain this position (Figure 2-B). Side Bridge was performed in a sideline position with elbows and feet supporting the body (Figure 2-C). The Quadruped Exercise was performed by lifting the right arm and left leg or the left arm and right leg in the position(Figure 2-D). The Back Extension was held up by lifting the body and held it up, while the shoulder was lifted backwards (Figure 2-E).

(2) Stretching exercise

The second exercise program performed self-stretching in the order of Quadratus Lumborum (QL), Gluteus, and hip flexor as stretching[19]. Stretching for 2 minutes each was performed for a total of 6 minutes. For this QL 90-90 stretch, choose a hip to place behind you and form a 90-degree angle at the knee. Place the other foot in front of the experimenter at a 90-degree angle. You stretch your left hand forward, push your left hip away with your outstretched hand. Try to elongate the area of the quadratus lumborum. Tilt forward to strengthen stretching (Figure 2-F) Gluteus stretching crosses the legs of the buttocks that you want to stretch across the knees of the other leg while lying on your back with your knees bent. Grab a hamstring that is not across the leg. Gently pull back and stretch (Figure 2-G). Hip flexion stretching is carried out in a lunge position. Assist with the core and glute so that the pelvis is aligned throughout the stretch and is not deflected to the front or posterior pelvic tilt. Now lean forward and stretch your hip flexion. You can place your hands behind your head and tilt your knees away from the side below to strengthen your stretch by rotating your arms on the same side with your arms (Figure 2-H-1,2).

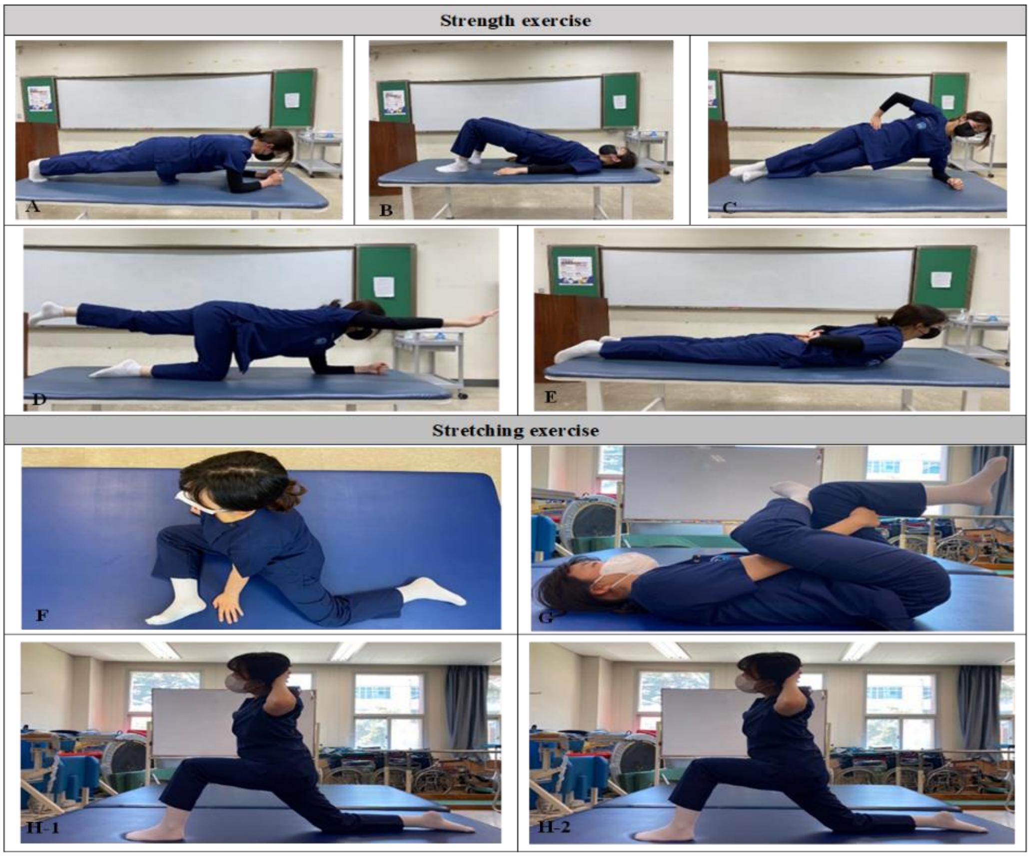

Figure 2. Strength exercise. (A) Front Plank; (B) Back Bridge; (C) Side Plank; (D) Quadruped Exer cise; (E) Back extension; (F) Quadratus lumborum stretching; (G) Gluteus muscle stretching; (H-1), (H-2) Hip flexor stretching.

2.5.1. Measuring Muscle strength

HHD (hand-held dynamometry)(MicorFET2, 2002, Hoggan) was used to measure the muscle strength of the subject. The subjects did not use their hands in a straight lying position, but asked them to bend the trunk to stop each person's eyes from aiming at the navel for three seconds. After 15 seconds of rest, the measurements were re-measured and the best of the two measurements was utilized[20]

2.5.2. Measuring Muscle endurance

To measure the subject's muscular endurance, Tosikazulto, RPT, was referred to the study[23]. Both hip and knee were bent 90 degrees to measure flexibility(Figure 3-A). For Extension endurance measurements, the tester was placed face down and kept the sternum away from the floor (Figure 3-B). At this time, a small pillow is placed on the lower side of the target person's belly to reduce lumbar lordosis. During the two procedures, the subjects maintained pelvic stabilization by maximal flexion of the cervical spine and muscle contraction of the hip The tester was then asked to maintain the posture for as long as possible, and not to exceed a maximum of 5 minutes. The tester measured the time to maintain the subjects' posture and used it for further statistical analysis[21].

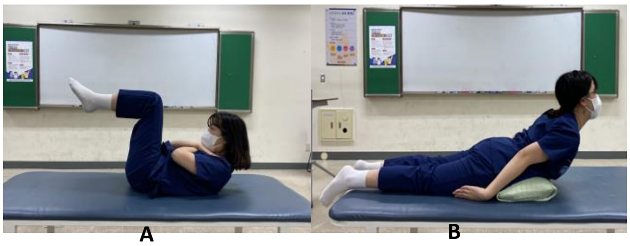

Figure 3. Muscle Endurance measurement posture: (A) Flexor Endurance; (B) Extension Endurance

2.5.3. Measuring Flexibility

The subject's flexibility was measured using SRT. The subjects put their feet on the crate, stretches their feet, and puts their toes on the test panel. Subjects were encouraged to maintain the posture reached by bending forward as much as possible for 2 seconds while touching the test panel with their fingers. The data on the toe line was recorded as negative and the data below was recorded as positive. After two practice opportunities, two actual measurements were made and the best values were used for additional statistical analysis[22]

2.5.4. Measuring Dynamic Balance(Y-balance test)

Dynamic balance was evaluated using Y-Balance. The measurements were based on what was done in the previous study. In order to calculate the result value, the leg length was measured before the Y-balancing test (YBT) was performed[23]. For actual leg length measurement, the length from the Anterior Superior iliac spin (ASIS) to the medial malleolus on the upper leg of the subject was measured in centimeters using a tape measure in the lying position. Subjects were instructed to balance barefoot in the middle of the Y-balance board and push the board forward, backward, and backward as far as possible with their hands against the hip ridge. The subjects were given two practice opportunities in each direction, and then two actual tests were conducted in each direction. Furthermore, the distance (cm) measured from each direction was converted to 100% (%) of the leg length and applied to the analysis {Sum of Composite Score(%)={(ANT+PM+PL)÷(leg length×3)}×100}[23].

2.5.5. Measuring Cardiopulmonary Endurance

Cooper's test is used to measure cardiopulmonary endurance. Participants instructed to run as many laps as possible on the treadmill(treadmill NR30XA, 2016 , DRAX) for 12 minutes. Researchers measured a total of 12 minutes of rap and used distance values of how many distances they ran for additional analysis[24].

2.6. Statistical Analysis

In this study, all statistical analysis used SPSS statistical software (version 28.0.1; IBM Corp, Armonk, NY). Descriptive statistics were used to calculate the mean (M) and standard deviation (SD) of each group and to compare and analyze them. To ensure that the collected data followed a normal distribution, a normality test was performed. Since the test results follow a normal distribution, a parametric statistical method was used($p<.05$). Paired t-test was used to compare the changes in Muscle Strength, Muscle Endurance, Flexibility, Balance, and Cardiopulmonary endurance function before and after the intervention application of the experimental group that performed the PHR exercise and the control group that performed the protocol exercise, and an independent t-test was used to compare the degree of difference in results between each group. All statistical significance levels (α) were set to 0.05 or less.

3. Results

In this study, when an exercise program for the LCS group based on PHR was administered to the experimental group, the effects on strength, muscle endurance, flexibility, balance, and cardiopulmonary endurance after 4 weeks were measured and compared with the control group. Paired t-test was performed to compare the differences before and after intervention within the group. Muscle strength measured through HHD, muscular endurance measured by Flexion and Extension postures, flexibility measured through SRT, balance analyzed through YBT composite score, and cardiopulmonary endurance measured through Cooper's test were also significantly different between the experimental and control groups. Also, It can be seen that the post-value increased compared to the pre-value for all variables in the parent group($p<.05$), (Table 2). ($p<.05$), (Table 2). An independent t-test was performed to compare the degree of before and after differences according to intergroup interventions. When the two groups were compared, all 5 variables showed a difference before and after. However, there was no significant difference in muscle endurance, flexibility and balance($p<.05$). On the other hand, muscle strength and cardiopulmonary endurance showed a greater difference in the experimental group and a significant increase in the degree of difference than that of the control group($p<.05$), (Table 3). The chart presented below also confirms that there is a big difference between muscular endurance and cardiorespiratory endurance (Table 4).

Table 2. Comparison of interventions PHR and Protocol.

		Intervention							
		PHR exercise				Protocol exercise			
		Pre	Post	T	P	Pre	Post	T	P
Strength (N)		4.27 ±0.67	6.08 ±1.35	-7.073	.012*	4.19 ±0.64	5.05 ±0.92	-4.054	.001*
Muscle endurance (sec)	Flexor	53.62 ±5.56	94.19 ±45.08	-5.751	.001*	78.67 ±33.14	110.14 ±63.97	-3.569	.001*
	Extensor	88.29 ±54.85	168.24 ±72.12	-6.451	.001*	93.86 ±49.39	156.81 ±86.07	-5.545	.001*
Flexibility (cm)		9.11 ±11.41	13.12 ±10.43	-6.453	.001*	8.59 ±7.03	11.29 ±6.38	-2.558	.009*
Balance (%)	composite score	96.88 ±6.12	106.23 ±7.12	-6.588	.007*	92.82 ±9.89	100.32 ±8.94	-5.412	.001*

Values are presented as mean ± SD, *p < .05, PHR: Personal health record.

Table 3. Differences in between pre and post interventions.

	Intervention			
	PHR	Protocol	T	P
Muscle Strength (N)	1.81±1.17	0.86±0.97	2.853	.003*

Differences					
Muscle endurance(sec) Differences	Flexor	40.57±32.32	31.48±40.41	0.805	.213
	Extensor	79.95±56.79	62.95±52.02	1.011	.159
Flexibility(cm) Differences		4.00±2.84	2.70±4.84	1.067	.146
Balance(%) Differences	Composite score	8.92±6.92	7.58±6.23	0.663	.256
Cardiopulmonary Endurance(M) Differences		323.86±282.58	174.29±168.76	2.082	.022*

Mean(M) ± Standard Deviation(SD), *p < .05 , PHR: Personal health record.

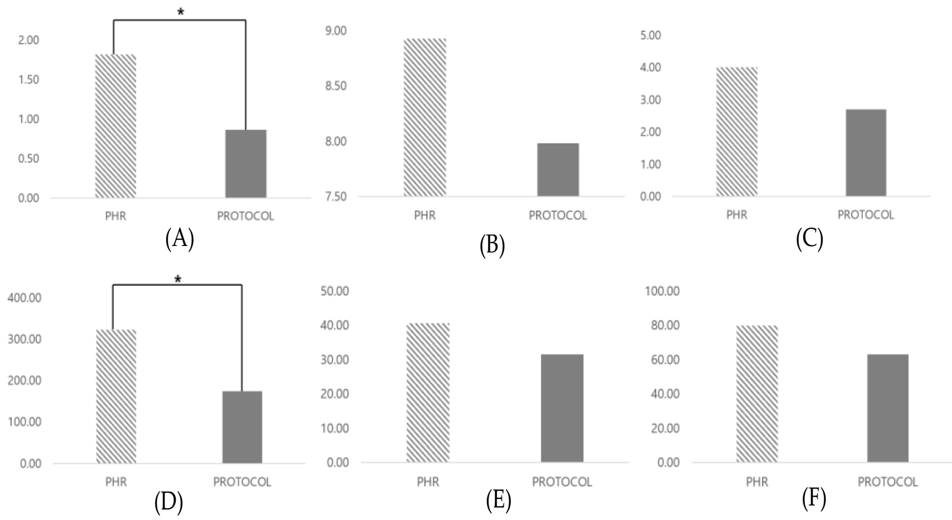

Figure 4. Comparison chart by Differences in between pre and post interventions: (A) muscle Strength; (B) Balance; (C) Flexibility; (D) Cardiopulmonary Endurance; (E) Flexor muscle Endur-ance; (F) Extensor muscle Endurance.

4. Discussion

This study compared the effects of PHR-based exercise programs and protocol exercise on muscle strength, muscle endurance, flexibility, balance, and cardiopulmonary endurance. This study compared PHR-based exercise programs with protocol exercise with LCS group based on Imai's exercise program centered on core exercise. Pardis studies have also demonstrated that LBP decreases by adjusting the stability of the lumbar vertebrae during core muscle movement[25]. In addition, Daniel's previous study of increased muscle strength and endurance during core exercise revealed that our study also showed increased muscle strength and endurance in both experimental and control groups. Also, flexibility and balance were compared by performing stretching and muscle exercises separate[26]. But our study was conducted simultaneously with post-muscle core stability and stretching to produce more positive results. So, we guessed that this established body alignment and significantly increased flexibility and balance. In addition, we measured Cardiopulmonary endurance, which was not mentioned in existing studies, was significantly increased in both the experimental and control groups. Previous studies have shown that if core exercises to improve muscle strength and muscle endurance are carried out, cardiopulmonary endurance can also be improved by core stabilization[27].

In the comparison results between groups in this study, significant differences were found only in muscle strength and cardiopulmonary endurance. We infer that this is because we provided the experimental and control groups with exercise programs aimed at strengthening core muscle strength for LCS prevention. Malar showed that core muscle stabilization programs are effective in increasing and maintaining students' muscle strength and cardiopulmonary endurance[28]. Furthermore, a study by Stutz has shown that core muscle training increases the role of respiratory systems through strengthening respiratory muscles and increases cardiopulmonary endurance[29]. This was advantageous to increase the core muscle strength of the subjects by adjusting the time and frequency of exercise twice a week and adjusting it to the patient. Furthermore, through research that the PHR-based exercise program helped improve muscle and cardiopulmonary endurance, our research supports the results of increased muscle strength and cardiopulmonary endurance[30]. Lang once mentioned the effectiveness of a customized exercise program that meets the patient's needs to maximize treatment for a particular individual because each individual has different lumbar muscles. However, the comparison group to which the existing exercise protocol was applied was not individualized due to the subject's motor ability and posture changes, so the exercise did not appear to have a greater effect[31]. On the other hand, the number and frequency of respiratory muscle exercises in the experimental group were different depending on each cardiopulmonary ability, so it is thought that there was a significant difference in cardiopulmonary endurance. Accordingly, the intensity level of exercise is individualized according to the characteristics of each subject, Since exercise focused on core muscle strengthening was provided as a customized exercise program based on PHR, the effect of exercise can be maximized and the muscle strength and cardiopulmonary endurance of the experimental group can be derived more significantly. Therefore, the intensity level of exercise was individualized according to the characteristics of each subject, Since exercise focused on core muscle strengthening was provided as a customized exercise program based on PHR, the effect of exercise can be maximized and the muscle strength and cardiopulmonary endurance of the experimental group can be derived more significant[32].

In this study balance, flexibility, and muscle endurance showed no significant differences in the comparison results between groups. Although the muscles that enhance balance are located in the front of the body in hip flexor and quadriceps, it can be inferred that our movements did not show significant differences because our study did not focus on the front of the hips and feet[33]. For SRTs measuring flexibility, it is mainly used to measure the degree of stretching of hamstring muscles[34]. However, our stretching exercise was less relevant to hamstrings, so there was no significant difference. Elvis has established that muscle training programs to boost muscle endurance require 10 weeks of exercise[34]. However, we find that our study was conducted for four weeks and was not sufficient to promote a significant increase[35].

PHR-based exercise programs can be exercised in a direction that is more tailored to the patient's condition. In fact, according to Lee, the efficiency of an active exercise-based treatment approach can provide individuals with customized exercise, which has been shown to help people suffering from chronic back pain by allowing them to resume daily life activities[36]. Takashi reported that based on individualized programs exercise has a positive effect on enhancing the self-esteem and confidence in performing exercise education[37]. These studies show that specialized and individualized exercise programs are essential for the development and maintenance of exercise habits to increase the exercise efficacy of subjects. However, the number of sets and repetitions during exercise is often made without considering symptoms such as age or pain, and such unindividualized exercise programs prevent you from starting or continuing exercise. In response, Michalowski reported that customized interventions considering individual differences are more important for behavioral changes related to physical activity than general interventions[38]. Therefore, exercise programs should consider individual differences based on PHR so that they can be useful for behavioral changes.

In our study, a customized exercise program based on PHR to prevent LBP in subjects was applied to the subjects as a suitable exercise by modifying the change in posture and time during exercise through the AR algorithm. However, since a four-week exercise algorithm was formed based on the initial evaluation, it is believed that if a new algorithm is formed through weekly re-evaluation, it will show better and more effective results. Both the existing exercise protocol and the PHR exercise program were considered to be good exercises because there was a difference between before and after exercise. However, this study revealed that PHR-based exercise programs can more efficiently exercise muscle strength and cardiopulmonary endurance for busy modern people. Just as PHR can be a useful tool to help patients communicate and treat with medical staff in clinical practice, it is thought that through this study, physical therapists will also be able to show more enhanced effects through PHR-based treatment[39].

5. Conclusions

This study compared the changes in muscle strength, muscle endurance, flexibility, balance, and cardiopulmonary endurance when performing PHR-based exercise programs and existing exercise protocol, and obtained the following results. First, Both of the experimental group and the control group showed significant differences in muscle strength, muscle endurance, balance, flexibility, and cardiopulmonary endurance before and after exercise through intervention. Second, when comparing the before and after differences between groups, there was a significant difference in muscle strength and cardiopulmonary endurance, and there was no significant difference in muscle endurance, balance, and flexibility. Based on this, it can be seen that PHR-based exercise programs are more efficient in improving muscle strength and cardiopulmonary endurance than conventional exercise protocol. Therefore, in order to maximize the effectiveness of exercise for LBP prevention when given the same space and time, it is considered that we use PHR-based exercise programs, and studies on various exercise programs based on various PHRs will be needed in the future

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Institutional Review Board Statement: Informed consent was obtained from all subjects involved in the study. The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Sunmoon University (SM-202204-014-3).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this study.

Data Availability Statement: The data used to support the findings of this study are available from the corresponding author upon request.

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