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Application and Effectiveness of a Program to Promote Adolescent Musculoskeletal Health: A Pilot Study*

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Ⅰ. Introduction

Adolescence is a critical period in human development that forms the basis for lifelong health, particularly as the musculoskeletal system undergoes rapid growth. Thus, it is important to maintain correct posture during this period. A recent study reported that the level of physical activity among adolescents decreased with an increase in academic grades (Kim, 2013). Such a decrease in physical activity increases the incidence of musculoskeletal diseases, including spinal deformity (Edwards, 2005). The rate of musculoskeletal and spinal abnormalities in national elementary, middle, and high school students reported by the Korean Educational Development Institute in 2016 was 1.4% overall, showing a gradual increase over five years from 0.7% in 2012 (Korean Ministry of Education, 2017).

Scoliosis is a growth-related disorder that develops rapidly before skeletal maturity and is one of the most common musculoskeletal diseases in adolescence (Konieczny, Senyurt, & Krauspe, 2013). The prevalence of childhood scoliosis ranges from 0.5% to 5.2% (Konieczny, Senyurt, & Krauspe, 2013). Idiopathic scoliosis—the cause of which is unclear—develops primarily in late childhood or early adolescence (at around the age of 10), as bone or muscular mass grows quickly during this period (Burns, Dunn, Brady, Starr, & Bloasser, 2009). Previous studies have shown that various approaches combining medications, complementary therapy, rehabilitation,

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and psychological counseling can be adopted as interventions to address pain of unknown causes in adolescents (Friedrichsdorf et al., 2016; Jolly et al., 2021). Although the actual etiology of adolescent idiopathic scoliosis (AIS) is unknown, low bone density has been associated with scoliosis in adolescent girls, resulting from prolonged use of computers, desks, and chairs inappropriate for their bodies; heavy backpacks; and a lack of exercise and physical activity during the growth period (Giampietro et al., 2013; Lee et al., 2005; Reamy, & Slakey, 2001). Because spinal deformity may be caused by a lack of exercise, a decline in physical activity, or a negative daily habit; systematic programs are required to prevent it.

Exercise intervention programs provided in adulthood and adolescence can improve lifelong musculoskeletal health (Province et al., 1995). Moderate-intensity strength training, such as walking and swimming to balance the body, along with steady stretching, is recommended for the prevention and improvement of scoliosis (SNU HQ Center, 2019). In addition, scoliosis was reported to be relieved after a posture management program for elementary school students (Park & Park, 2003). A study that evaluated the effectiveness of a posture management program for adolescents with AIS also reported a decrease in the Cobb angle (Choi, 2012). Nevertheless, there is still a scarcity of programs that promote spinal health and awareness of the musculoskeletal system among adolescents, and the majority of research has focused on intervention programs delivered through treatment clinics centered on healthcare providers (Jeon et al., 2011; Negrini et al., 2008). As existing research has not implemented real-time monitoring via wearable devices, there are few intervention programs utilizing this approach.

Wearable devices are electronic wearable tools that continually gather comprehensive information about the surrounding environment or bodily changes of the wearer in real time (Kim, 2013). Currently, wearable devices include wristbands, glasses, shoes, and clothing, which collect information about the body in three main ways: (1) factors such as number of steps, exercise distance, and sleep time are measured using an accelerometer; (2) factors such as pulse, respiration, and oxygen saturation are measured using an optical sensor; (3) and factors such as electrocardiogram, body composition, and perspiration are measured using electrodes (Jo, 2016). Smart insoles assess walking habits using an acceleration sensor and pressure sensor to help correct posture (Park & Park, 2016).

This study aimed to develop a musculoskeletal health promotion program for adolescents using a smart insole and evaluate the effectiveness of the program through a pilot study for its application. The study is expected to provide helpful data for improving the musculoskeletal health of students.

Ⅱ. Method

1. Study Design and participant

This quasi-experimental pilot study applied a musculoskeletal health promotion program for adolescents and evaluated its effectiveness. This study was conducted after obtaining approval from the Bioethics Review Committee (IRB No. HIRB-2019-091) of the institutional affiliation of one of the researchers. Convenience sampling was used to recruit study participants. A recruitment notice was posted on the bulletin board of a health room with the cooperation of nursing teachers in middle and high schools in C city, Gangwon-do, which was close to the research site. The researcher fully explained the purpose of the study and the possible psychological and physical harm during participation in the study. Students who voluntarily agreed to participate in the study (with parental consent) were selected as study participants. The number of participants required was calculated with a significance level of 0.05, power of 0.80, median effective size of 0.5, and number of groups set as one, based on a paired t-test using G*Power 3.1.2 software. Accordingly, 33 participants were required; a total of 36 participants were included, with a dropout rate of 10%. One participant withdrew due to personal reasons after attending the first study session, and two participants were excluded after being absent for more than three out of a total of seven sessions. Consequently, 33 participants were included in the final analysis.

2. Instruments and Scales

The survey items consisted of participants' general characteristics, including their grade, age, and gender, and usual lifestyle habits, such as their physical activity and postural habits. Body composition, bone mineral density, and body shape (exbody) were calculated using physical measurements.

1) Physical Activity

Physical activity level was assessed using the International Physical Activity Questionnaire (IPAQ). This scale consists of seven items; the results were classified as highly active, moderately active, and low active based on the IPAQ scoring method (IPAQ Research Committee, 2005).

2) Postural Habits

The Questionnaire on Body Awareness of Postural Habits in Young People (Q-BAPHYP), translated into Korean, was used to investigate the postural habits of adolescents (Schwertner, Oliveira, Beltrame, Capistrano, & Alexandre, 2018). The Q-BAPHYP consists of four sub-domains with a total of 35 items, including 11 items on postural habits in the classroom, 17 on postural habits at home, four on postural habits for carrying objects, and three on posture guidance by teachers. All items were answered on a five-point Likert scale (-2 = not at all, -1 = almost never, 1 = often, 2 = always, and 0 = do not know/do not remember), where a higher score represents better postural habits. In addition, the Q-BAPHYP included inverse questions. The intraclass correlation coefficient (ICC) value for the test-retest for the original tool was 0.59 to 0.74, indicating acceptable reliability, and Cronbach's alpha, indicating internal consistency, was 0.80. In this study, Cronbach's alpha was 0.754.

3) Body Composition

To measure body composition, such as muscle mass and body fat, which can affect the musculoskeletal system, height was measured using a stadiometer (seca 213, seca Deutschland, Hamburg, Germany). After inputting the body composition analyzer (Inbody270, Inbody Inc., Seoul, Korea), body weight was measured, and body mass index (BMI), muscle mass, body fat mass, and skeletal muscle mass were calculated using a body composition analyzer.

4) Bone Mineral Density

The average bone quality index (BQI) for the calcaneus on both sides were measured using a portable bone mineral density meter (SONOST 3000, OsteoSys Inc., Seoul, Korea), which is a quantitative ultrasound imaging method. To

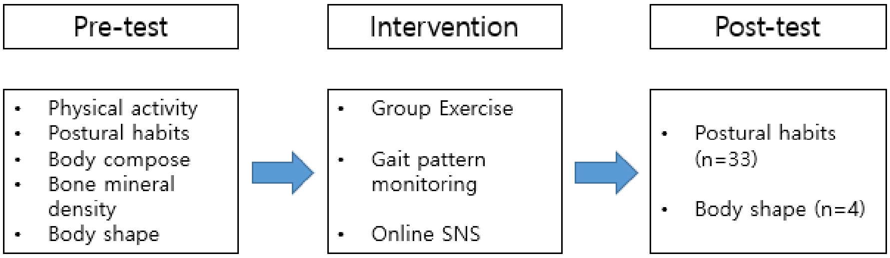

Figure 1. Study Flow

minimize the measurement error range, bone mineral density was measured after calibrating the machine using the phantom once per day based on the manufacturer's instructions.

5) Body Shape

A body shape test was conducted using a postural analyzer (exbody 550, exbody Inc., Seoul, Korea). The exbody 550 system is a device that performs musculoskeletal imbalance and body malalignment tests conveniently and quickly, without the risk of radiation exposure, using an infrared camera. The test measures the body shape in the order of front posture, side posture, and rear posture, and measurements proceed in the order of posture measurement and posture assessment. Using front and rear posture measurements, the left and right balance of the entire body, head, shoulders, pelvis, and knees were measured. Using side posture measurement, cervical spine inclination, shoulder inclination, pelvic inclination, and knee flexion were measured. Using these body measurements, exbody 550 was used to obtain a musculoskeletal index and guide the test cycle to properly maintain body shape. A higher musculoskeletal index indicates more severe musculoskeletal deformation.

3. Procedure

To investigate the effects of stretching, breathing, and muscle exercise in the spinal region on the promotion of musculoskeletal health, surveys were conducted, and posture variables were measured before and after the exercise program (Figure 1).

1) Preliminary Survey

A preliminary survey on the musculoskeletal exercise program was conducted on January 2, 2020 with two middle school students. First, an exercise expert demonstrated the movements of the exercise program in sequence, which the participants followed slowly. Posture education was provided by the research team to help the participants easily understand the aspects that are easily overlooked in daily life. After the preliminary survey, problems such as the movements that were difficult to reproduce were discussed during interviews with the participants, and rest time between motions and the order and frequency of exercise were adjusted.

2) Pre-test

The participants were asked to visit the research office, which was easily accessible, from January 8 to 9, 2020, to fill out questionnaires and undergo body measurements, including body composition, bone mineral density, and body shape. Two research assistants who were trained nurses conducted the body measurements.

3) Intervention Program

Social cognitive theory is a framework that can be used when constructing a program intended to induce changes in physical activity behavior (Young, Plotnikoff, Collins, Callister, & Morgan, 2014). In particular, it has been reported to be more effective when self-efficacy or self-regulation strategies, such as goal setting, planning, self-monitoring, and reward provision are included. In this study, an exercise program for the posture correction of adolescents was constructed based on the social cognitive theory (Table 1).

4) Construction of Exercise Program

To develop an intervention program for this study, a consultative body was formed with one physical education expert and one professional trainer (exercise prescriber). Primarily, effective movements for spine and posture correction were constructed by referring to the scoliosis exercise methods developed by the Orthopedic Surgery Department of Korea University Guro Hospital, the scoliosis prevention exercise methods of Seoul National University, and previous studies (Jeon et al., 2011; Korea University Guro Hospital, orthopedic surgery department, Scoliosis center, 2019; SNU HQ Center, 2019). Following this, information on posture correction necessary to maintain musculoskeletal health, basic lifestyle habits, and appropriate exercise types and sequences was collected, advice was obtained from one nursing professor, one nursing teacher, and one physical education teacher, and the program was designed considering the number of movements, difficulty of exercise, and total exercise time.

5) Implementation of Exercise Program

Education on correct posture and the necessity of maintaining correct posture for maintaining musculoskeletal health was conducted by the

Table 1. Intervention Methods and Application

Methods	Application	On/offline	Time period
Feedback & goal setting	The body shape result sheet (exbody) was provided, and the results were explained. Participants were allowed to set their own goals.	Offline	1 week
Planning	Based on the preliminary survey results, participants selected Wednesdays or Thursdays to participate in the exercise program.	Offline	1–7 weeks
Modeling	Health trainers, who exercised with the right posture, lead the exercise education class.	Offline	1–7 weeks (1 time/week)
	Participants watched videos of trainers exercising with correct posture.	Online	8–32 weeks
Self- monitoring	Checklist with pictures of exercise movements.		1—32 weeks
	Participants checked their gait habits when walking outdoors using the mobile application.		1–32 weeks
Verbal persuasion	Participants were reminded to exercise through SNS group chat. Message included: “Don’t forget, tomorrow is exercise day,”; “It’s the weekend, but you should still exercise at home!”; and “Due to COVID-19, outdoor activities are restricted. In times like these, do upright posture exercises every day at home.”	Online	1—32 weeks
Reward	Rewards were given for participating in the “take a picture of yourself exercising’ event.”	online	8–32 weeks

research team in the first week of the program through demonstrations and handouts. The exercise program was led by two exercise experts for 60 min, once per week. The research team remained with the participants during the program and assisted with the exercise. The exercise program was conducted face-to-face from the first to seventh sessions; however, from the eighth session, it was conducted individually at home due to restrictions imposed because of the Coronavirus disease 2019 (COVID-19) pandemic. A video of the exercise was produced and distributed to allow the participants to practice it easily at home. A checklist with the exercise movement images was distributed to the participants in the first week of the program to encourage them to exercise at home. Furthermore, to make participation convenient, participants were allowed to attend the program on any day of the week.

At the start of each session of the exercise program, explanations of the type and sequence of each exercise were provided with demonstration along with precautions. Each session proceeded in the following order: warm-up (10 min), main exercise (40 min), and wrap-up (10 min). The exercise program was conducted in a rented fitness center, considering participants' accessibility, and all programs were provided by exercise experts. The movements of this program exercise proceeded from the spine toward both sides, and each movement was performed twice consecutively. The rest time between sessions was the same as the duration of the movement. For the first to third weeks, the focus was on learning the movements, while the rest of the sessions were aimed at enhancing proficiency by repeating the learned movements. To avoid boredom with repetitive movements, the participants were encouraged to exercise while listening to music popular among their age group in a comfortable atmosphere. A foam roller was used as an exercise device to facilitate stretching. Specific exercise movements are described in Appendix 1.

6) Gait Pattern Monitoring

The gait habits of the participants were monitored using a smart insole (Prospecs Smart Insole, TLi Inc., Gyeonggi, Korea). The insole has a three-axis acceleration sensor and four pressure sensors to gather information such as gait habits, including left and right balance, foot angle (normal gait/out-toeing gait/in-toeing gait), triple time ratio, and support distribution (inner/outer), activity level, and number of steps. These data were transmitted via Bluetooth and displayed on the application provided by TLi Inc. During the intervention program, the participants installed a smart insole in the shoes they usually wear to continuously monitor their gait habits through an application installed on their smartphones.

7) Online Communication

To enhance the effectiveness of the exercise, the demonstration of movements performed by a professional trainer (exercise prescriber) was included in a video, which could be easily followed at home. The video was uploaded on an online website for easy access. To promote participation, an exercise photo contest event was conducted, in which participants could send a photo of their exercise to the research team via a social network service (SNS); the research team provided a reward (culture voucher) for the participants, in return, based on the identified frequency. In addition, group chats on the SNS were conducted once or twice per week to motivate and encourage exercise.

8) Post-test

The post-test was temporarily postponed due to the COVID-19 pandemic. The post-test questionnaires were mailed to the participants in August. A research assistant visited the participants' homes to collect the questionnaires on August 21. Bone density and body composition tests planned for the post-test were not conducted to reduce the possibility of infection. However, the body shape test was conducted in a fitness center on participants who wanted this to be assessed. Four participants wished to receive a body shape test, and they were asked to visit at different times.

4. Data Analysis

The general characteristics, lifestyle, and posture of the participants were analyzed using descriptive statistics, including percentages and averages. A t-test and analysis of variance (ANOVA) were performed to analyze the differences in musculoskeletal indices based on participant characteristics. Pearson correlation analysis was performed to examine the relationship between body composition and musculoskeletal indices. For body composition values with non-normal distribution, the Mann-Whitney U test and Spearman correlation test were conducted. A paired t-test was conducted to analyze the effect of the intervention program. The Wilcoxon signed-rank test, a nonparametric method, was used for data that did not follow a normal distribution. All analyses were performed using IBM SPSS Statistics for Windows (Version 25.0, IBM Corp., Armonk(NY), USA).

Ⅲ. Results

The participants included 13 male and 20

Table 2. Differences in Total Musculoskeletal Index by Demographic Characteristics of Adolescents (N=33)

Characteristics	Categories	n (%) or Mean±SD	MSI Mean±SD	MSI t/F	MSI *p*
General characteristics					
Sex	Male	13 (39.4)	28.77±5.97	0.73	.469
	Female	20 (60.6)	27.20±6.02		
Age		15.39±1.82		1.87	.071
	12–15	15 (45.5)	29.87±6.23		
	16–18	18 (54.5)	26.11±5.30		
Activity habits					
Physical activity	Low active	15 (46.9)	28.67±5.90	0.76	.479
	Moderate active	9 (28.1)	27.11±6.41		
	High active	8 (25.0)	25.63±4.50		
Sitting time (hour/day)	<8	15 (55.6)	27.53±6.07	−0.09	.932
	≥8	12 (44.4)	27.75±7.07		
Sleeping time (hour/day)	<7	15 (45.5)	26.73±4.27	None	.290*
	≥7	18 (54.5)	28.72±7.07		
Outdoor activity time (min/day)	<40	26 (78.8)	27.27±5.89	−1.02	.315
	≥40	7 (21.2)	29.86±6.23		

* Mann-Whitney U test,
† MSI = Musculoskeletal index.

female students, with a mean age of 15.39 years (Table 2). There were no significant differences in the musculoskeletal index based on general characteristics and physical activity. The mean BQI of the participants was 75.38, and the correlation of BQI and body composition with the musculoskeletal index was not statistically significant (Table 3).

Tables 4 shows the results concerning the effects of the posture correction exercise program. The total score of postural habits increased from -0.39 to 0.03 points; however, this was not statistically significant. The musculoskeletal index measured by Exbody was compared with the non-parametric Wilcoxon signed rank test using the pre- and post-test values for four participants, as only four participants underwent post-test measurements. The overall musculoskeletal index decreased from 31 to 25 points, indicating an improvement in the level of musculoskeletal imbalance. The P value was 0.068, which was not statistically significant at the 0.05 level but was significant at the 0.1 level (Table 4).

Ⅳ. Discussion

This study aimed to identify the effects of a musculoskeletal health promotion program for healthy adolescents on overall posture habits and overall musculoskeletal index. The musculoskeletal health promotion program developed in this study was implemented for middle and high school students after examining participants' physical activity, usual posture habits, body composition, bone mineral density, and body shape. The exercise program consisted of stretching, breathing, and spinal muscle exercises and was conducted for 60 min, once per week, for seven weeks.

The results indicated that the musculoskeletal health promotion program was effective in improving postural and musculoskeletal imbalances by increasing the overall posture habit score and decreasing the overall musculoskeletal index score. This was in line with previous studies that reported that posture and musculoskeletal health were improved by applying an exercise program for adolescents with AIS. An integrated exercise program that included Schroth exercise, manual

Table 3. Correlations Between Body Composition and MSI (N=33)

Characteristics	Mean±SD	Range	MSI§	
			r/rho*	*p*
BQI †	75.38±12.14	54.4~104.5	.26	.141
Height (㎝)	164.08±7.35	152.0~181.0	.24	.188
Weight (㎏)	57.56±9.25	42.5~79.6	.13	.464
BMI ‡ (㎏/㎡)	21.35±2.83	16.6~27.5	.01	.970
Body water (ℓ)	30.25±6.12	21.8~44.0	.22*	.228
Protein (㎏)	8.14±1.69	5.8~12.0	.22*	.223
Minerals (㎏)	2.95±0.55	2.2~4.2	.19*	.308
Body fat mass (㎏)	16.20±5.78	5.7~27.7	−.12	.496
Skeletal muscle mass (㎏)	22.56±5.10	15.6~34.2	.21*	.243
Percent body fat (%)	28.10±8.72	10.0~42.9	−.20	.258

* Spearman correlation coefficients,
† BQI = bone quality index, ‡ BMI = body mass index, § MSI = musculoskeletal index

therapy, muscle relaxation training, and core stability exercise twice per week for six months on average, conducted with 10 female adolescents with AIS, with a mean age of 14.6 years, demonstrated that their posture significantly improved (Aly, Amin, & Negm, 2019). This suggests that appropriate musculoskeletal health promotion programs for modern adolescents with poor postural habits due to prolonged computer use and lack of exercise are effective in maintaining correct posture.

Correct posture is important for adolescents, as changes in body shape due to incorrect posture can lead to psychological and physical disabilities. A study on the psychological and emotional stress of 92 adolescents (12 to 18 years of age) with AIS found that 32% of adolescents experienced clinically significant emotional problems, with 66% of parents unaware of the problems (Sanders et al., 2018). In addition, incorrect posture can cause pain. A study that investigated the relationship between habitual sitting posture and neck and shoulder pain among 1,593 14-year-old adolescents found that 5.3% of adolescents reported neck and shoulder pain (Straker, O'Sullivan, Smith, & Perry, 2009). Lumbar lordosis was found to be associated with long-term neck and shoulder

Table 4. Change in Outcomes Among Program Completers

Variables	Baseline	After	t/ Z*	*p*
	Mean±SD	Mean±SD		
Q-BAPHYP† (n=33)				
Total	−0.39±13.73	0.03±16.78	−0.17	.865
Classroom	−0.15±6.86	0.18±7.86	−0.34	.734
At home	−0.70±7.89	−0.36±9.37	−0.28	.822
Carrying objects	1.73±2.31	1.58±3.08	0.23	.821
Teachers	−1.27±1.84	−1.36±2.13	0.21	.836
Body Shape (exbody) (n=4)*				
Total musculoskeletal index	31.00±7.30	25.00±6.78	−1.83*	.068
Musculoskeletal malalignment deviation index	23.75±5.85	19.50±5.80	−1.84*	.066
Musculoskeletal unbalance deviation index	6.75±0.96	5.50±1.00	−1.63*	.102
Musculoskeletal alignment test results				
Shoulder angle (°)	2.00±1.16	1.75±0.96	−0.27*	.785
Neck inclination - forward head Posture (°)	12.75±3.86	11.50±5.92	−0.92*	.357
PCMT‡ (kg)	5.03±1.89	4.03±2.36	−1.60*	.109
Pelvic tilt angle (°)	7.25±2.22	4.50±2.08	−1.60*	.109
Knee flexion (°)	180.25±2.22	179.25±2.06	−1.00*	.317
Musculoskeletal balance test results				
Body inclination	0.75±0.50	0.75±0.50	0.00*	1.000
Incline angle of head	1.25±0.50	1.00±0.00	−1.00*	.317
Incline angle of shoulder	2.00±0.82	1.25±0.50	−1.73*	.083
Incline angle of pelvic	1.25±0.50	1.00±.00	−1.00*	.317
Incline angle of knee	2.00±0.82	1.50±0.58	−0.82*	.414

* Wilcoxon signed-rank test;
† Q-BAPHYP: Questionnaire on Body Awareness of Postural Habits in Young People; ‡ PCMT: posterior cervical muscle tension.

pain (Straker et al., 2009). These types of pain are commonly found among adolescents in South Korea (Koh et al., 2014). A survey of 912 students from two high schools revealed that approximately 82.5% of students had neck and shoulder pain and that providing these students with problem awareness and posture correction education for three months reduced the pain by approximately 19.5%; this suggests that maintaining correct posture is an effective way to reduce neck and shoulder pain among adolescents (Koh et al., 2014).

The exercise program applied in this study was easily accessible and practical for adolescents, since it was based on stretching and was cost-effective and non-invasive, requiring no complex equipment. A systematic literature review of 20 randomized controlled trials on the effects of physical activity on AIS demonstrated that people who engaged in physical activity for six months showed an improvement, where the progression of scoliosis slowed down in early puberty and the Cobb angle improved after growth stopped; this indicates the effectiveness of physical activity (Fusco et al., 2011), which has been shown to improve the Cobb angle, strength, mobility, and balance and appears to be an important factor in preventing AIS in adolescents and promoting healthy growth (Aly et al., 2019; Fusco et al., 2011).

This study demonstrated the effectiveness of an exercise program, which included stretching, in alleviating body imbalances. Such exercises should be organized and implemented as regular school curriculum, although this may be challenging for high school students because of their large academic burden. Therefore, school health policies should establish methods to encourage stretching every day during lunch or in the afternoon. The World Health Organization (WHO) recommends that children from 5 to 17 years of age engage in aerobic exercise for at least 60 min per day and activities to strengthen muscles and bones at least three days a week (World Health Organization, 2021). South Korea established a national goal of achieving at least 60 min of aerobic exercise every day among teenagers; however, this did not cover strengthening muscles and bones (Korean Ministry of Health and Welfare, 2021). To promote musculoskeletal health among adolescents, national goals should be established to promote muscle and bone strength based on the WHO recommendations, and adolescents should be encouraged to engage in stretching, even for a short period, every day.

However, this study could not assert effectiveness, as only about 12% (n=4) of the participants completed the post-test due to restrictions imposed by COVID-19. The present results demonstrated a positive effect of the program on overall score improvement; however, the amount of data was insufficient to provide statistical evidence. The participants directly met and interacted with exercise experts from the first to seventh sessions and attended the exercise program before the pandemic. Meeting an exercise expert has been reported to increase the effectiveness of exercise programs (Kuru et al., 2016). However, this study continued non-face-to-face education through SNS as it became difficult to conduct face-to-face exercise programs due to COVID-19. In other words, exercise was encouraged through exercise photo contests and chatting. In addition, a questionnaire survey that can be conducted in a non-face -to-face way was used for the post-test, but the body shape measure was not conducted remotely because the method was different from the previous survey. A case study examining the effects of an integrated exercise program on posture in patients with AIS assessed the effect of exercise on participants using a mobile application before and after the treatment; however, the 2D presentation in mobile applications was noted as a limitation (Aly et al., 2019). Studies on self-reported measures of exercise effectiveness are rare, and there are cases where exercise programs must be conducted non-face-to-face, such as during the COVID-19 pandemic. Therefore, it is necessary to develop a mobile application that can measure the effect of exercise, and studies should be conducted to evaluate its effect.

This study had some limitations. First, the study was conducted with middle and high school students in a single province; therefore, generalization of the results to the entire adolescent population should be done with caution. Second, due to COVID-19, in the post-test, both non-face-to-face and face-to-face data collection were performed concurrently, and only four people participated in the final body shape analysis. Therefore, the effectiveness of the program cannot be asserted. In addition, this was a single-group pre- and post-test study without a control group. Therefore, to confirm the effectiveness of the musculoskeletal health promotion program for adolescents in the future, repeated verifications should be conducted through single-group pre- and post-test studies with sufficiently large samples and the same data collection method, and non-equivalence pre- and post-test studies with control groups. Third, this study did not examine the long-term effects of the exercise program, as the pre- and post-test were conducted only once. Future research should examine the long-term effects of the exercise program by conducting longer investigations.

V. Conclusions

The results indicated that the developed musculoskeletal health promotion program was effective in improving postural and musculoskeletal imbalances by increasing the overall posture habit score and decreasing the overall musculoskeletal index score. Therefore, healthcare managers should develop effective programs to help adolescents maintain correct posture and encourage and support them to continue participating in exercise programs. In addition, national goals should be established to promote the muscle and bone strength of adolescents. Furthermore, a strategy that allows adolescents to continue exercising at home without attending face-to-face sessions should be devised, and software enabling remote assessment of correct posture should be developed and validated.

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ABSTRACT

Application and Effectiveness of a Program to Promote Adolescent Musculoskeletal Health: A Pilot Study*

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Purpose: Adolescence is a developmental period characterized by the rapid growth of the musculoskeletal system, which is important for maintaining correct posture. Incorrect posture, lack of exercise, and reduced physical activity can cause spine deformities and affect lifelong health. This study was designed to evaluate the application and effect of a program for improving adolescents' musculoskeletal health. **Methods:** A quasi-experimental pilot study was conducted with 13 male and 20 female middle and high school students, with an average age of 15.39 years. Their general characteristics and physical measurements were obtained. The program consisted of group exercises (60 minutes, once per week), gait pattern monitoring, and online communication. A paired t-test and Wilcoxon signed-rank test were used to examine the program's effect. **Results:** Overall posture habits improved, and the total musculoskeletal index decreased; however, these results were not statistically significant. **Conclusions:** The devised program was effective in improving musculoskeletal imbalance. Therefore, effective programs and health devices should be developed to help adolescents maintain correct posture and encourage and support continuous participation in such programs.

Key words : Adolescent, Posture, Musculoskeletal abnormalities, Health promotion

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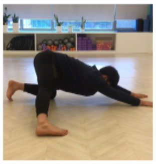
Appendix 1. Exercise program details

Type	Exercise	Motion
Stretching	Thoracolumbar stretch  	- Lie on your back with the foam roller behind your chest. - Put your hands together and support the back of your head. - Slowly lower your elbows and crown toward the floor, stretching out your chest and shoulders. - Hold your breath for 30 seconds. - Lie down with the foam roller on your back (above the pelvis). - Fix the foam roller in place by holding both ends of the foam roller with your hands. - Bend your knees, lift your legs, and move your knees to the left and right to stretch the muscles on your back (10 seconds).
	Gluteus muscle stretch  	- Sit with your legs straight and place your right foot on top of your left thigh. - With your right hand, slowly press your right knee toward the floor (hold for 10 seconds). - Put your left hand behind your head. - Slowly lower your right elbow to the floor. - Stretch your left elbow backwards (hold for 10 seconds).
Respiration	Schroth respiration  	- Lie on your side with a foam roller on your right side. - Rest your head on your right arm, extend your left arm in the direction of the crown, and breathe through your left chest (30 reps). - In a quadruped position, place your right elbow on the floor. - Slide the left hand forward to stretch out the left side of the body. - Breathe in and out 30 times.
	Pectoralis minor, intercostal muscle stretch 	- Lie on your side and bring your knees together to prevent your pelvis from turning. - Rotate your left arm greatly and put it on the floor behind your back. - Keep breathing for 20 seconds.
Strengthening exercise the muscles around the spine	Adductor Stretch  	- Bend your right knee and extend your left foot. - Push the floor with your fingertips and straighten your back. - Push the left heel away and feel the deep stimulation (hold for 10 seconds). - Place your right knee on the floor and straighten your upper body. - Keep your left knee straight. - Hold it while pushing your fingertips away. - Feel the stimulation on the inner side of the left thigh (hold for 10 seconds).

Type	Exercise	Motion
	Gluteus muscle strengthening exercise 	- Lie on your back. - Bend both knees up. - Pull your right knee toward your chest. - Press the floor with your right heel and lift your hips (hold for 10 seconds). - Lie on your side with your right knee slightly bent. - Stretch the left knee and raise the left foot. - As you lift your leg, stretch it slightly backward for a deeper stimulation. - Be careful not to turn the pelvis to the back (hold for 10 seconds).
	Core strengthening exercise 	- With your left hand on the floor, take a side plank position. - Extend the right hand toward the ceiling. - Breathe in and gain balance. - If possible, gaze toward the tip of the right hand (hold for 10 seconds). - Lie on your side with your left elbow on the floor and fold your knees. - Hold your pelvis with your right hand while keeping the pelvis from turning. - Lift your hips by pushing the floor with your left hand and elbow (hold for 10 seconds).