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Original Article

# Effectiveness of home training program to improve health and physical fitness of individuals with spinal cord injury

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*ABSTRACT*

**Objectives:** This study aimed to evaluate the effectiveness of a home training program using web-based services to manage obesity and improve functional independence in individuals with spinal cord injury (SCI).

**Patients and methods:** Fifteen individuals (12 males, 3 females; mean age: 40.7±10.8 years; range, 28 to 60 years) with SCI paraplegia were included in the study conducted between August 2020 and December 2020. All participants remotely completed a six-week resistance program using Thera-Band with the aid of training videos. The program comprised chest press, lateral raise, front raise, shoulder press, and arm curl exercises, performed for five sets of 8 to 10 repetitions, and exercise intensity was increased by 5% each week.

**Results:** Lean body mass (p=0.042) and high-density lipoprotein cholesterol levels (p=0.038) increased, and C-reactive protein levels decreased without significance. Significant improvements were observed in the 6-min push test (p=0.009), peak oxygen uptake ($VO_2$ peak; p<0.001), $VO_2$ peak/kg (p<0.001), $VO_2$ (p=0.004), $VO_2$/kg (p=0.002), and ventilation (p=0.019), while statistically insignificant increases were observed in the respiratory exchange ratio, maximum inspiratory pressure/mean, maximum inspiratory pressure, maximum expiratory pressure/mean, maximum expiratory pressure, and shoulder and chest press weights. Heart rate values decreased without significance. Arm curl repetitions (left, p=0.008; right, p=0.032) and lateral pull weight increased (p=0.038).

**Conclusion:** Home training using Thera-Band is feasible for persons with SCI to manage obesity and improve cardiopulmonary function, muscle strength, and endurance. It can facilitate the maintenance of physical activity in individuals with SCI who have limited mobility and access to training facilities.

***Keywords:*** Exercise, obesity, paraplegia, spinal cord injuries.

Although the rate of increase in the incidence of spinal cord injury (SCI) has declined, approximately 40 to 80 new cases of SCI occur per million population annually.[1] Unfortunately, the majority of individuals with SCI are not provided adequate opportunities to continuously engage in physical activities upon return to the community following hospital-based acute care. As a result, individuals with SCI experience dramatic alterations in body composition, including reductions in muscle mass and bone mineral density and increases in body fat percentage (%BF).[2,3]

Physical inactivity among individuals with SCI leads to flaccidity of skeletal muscles and osteopenia,[4] which eventually reduces cardiopulmonary functions and hinders activities of daily living. Moreover, increased sedentary time increases the prevalence of central obesity, with fat accumulating in the abdominal area, predominantly around the visceral organs.[5] The majority of individuals with SCI are overweight or obese, which elevates their risk for metabolic syndrome.[3] Obesity increases the incidence of cardiovascular disease (CVD) in individuals with SCI because increased

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%BF affects total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) levels[6] and is strongly associated with increased C-reactive protein (CRP), an independent risk factor for CVD.[7]

Despite the tremendous impact of obesity on the overall health of individuals with SCI, obesity management strategies for this population are limited. Individuals with SCI are often deprived of opportunities to exercise, which is the most effective and efficient obesity management approach, with a lack of specialized exercise programs being the greatest barrier.[8] Studies developing exercise programs to prevent obesity and the consequent changes in body composition and studies investigating feasible health management strategies for community-dwelling individuals with SCI are rare. The lack of exercise-based health management practices is further compounded by the limited number of facilities providing exercise programs geared toward this population.

The Korea Consumer Agency recently reported that exercise patterns in daily living are shifting in most populations due to increased internet- and smartphone-based communications, with increased utilization of “home training” content uploaded on social media to save money and time.[9]

A study reported that home training produces positive changes in health-related fitness and psychological stability.[10] Thus, research on web-based home training offers an opportunity to alter the exercise paradigm not only for the nondisabled but also for individuals with SCI. Continuous engagement in physical activity through mobile home healthcare may be a more practical and effective means of obesity management than instructor-led exercise training at exercise facilities, particularly for individuals with SCI due to their challenges with mobility and accessibility. However, more research is required to ensure the applicability of exercise programs using various forms of media among those with SCI, as only limited data are currently available on home training approaches for this population.

Therefore, this study aimed to develop and validate a web-based home training program geared toward individuals with SCI to promote regular exercise, manage obesity, and lower the risk for metabolic syndrome and coronary artery disease. Ultimately, we aim to enhance the physical capability of this population by diversifying exercise approaches and improving functional independence and activities of daily living, thereby aiding with health management and improving quality of life (QoL).[11]

## PATIENTS AND METHODS

Fifteen individuals (12 males, 3 females; mean age: 40.7±10.8 years; range, 28 to 60 years) with paraplegia were enrolled in this one group pretest-posttest study conducted at a rehabilitation center in South Korea between August 2020 and December 2020. The inclusion criteria were as follows: age 19 to 65 years, diagnosis of SCI paraplegia, capability of using a manual wheelchair, and ability to understand the researcher’s instructions. The exclusion criteria were as follows: inability to routinely use a wheelchair, past or recent onset (previous three months) of chronic or acute heart disease or respiratory disease, cardiovascular abnormality (uncontrolled CVD or frequent autonomic dysreflexia), musculoskeletal disorders (severe shoulder pain) that could affect physical activity, severe rigidity (Modified Ashworth Scale ≥3), susceptibility to potential adverse medical effects from physical activity, taking of drugs that could affect obesity, and participations otherwise deemed to have difficulty in communication or were unable to provide informed consent. Twenty eligible individuals were initially recruited. Four of these individuals were quarantined due to COVID-19 (coronavirus disease 2019) exposure, and one withdrew due to adverse symptoms, including chills. As a result, a total of 15 individuals participated in the study. Written informed consent was obtained from each patient. The study protocol was approved by the National Rehabilitation Center Ethics Committee (date: 17.04.2020, no: NRC-2020-02-020). The study was conducted in accordance with the principles of the Declaration of Helsinki.

### Experimental design

Specific exercise training videos were created for individuals with SCI to enable participants to exercise without temporal and spatial restrictions. While home training videos for the nondisabled are typically filmed at a single angle (front), we filmed the videos from two angles (front and side) to aid accurate performance of each exercise, considering that individuals with SCI may have little experience or be unfamiliar with home training.

Participants with paraplegia caused by SCI were recruited in this study. All participants visited the rehabilitation center to complete the pretest.

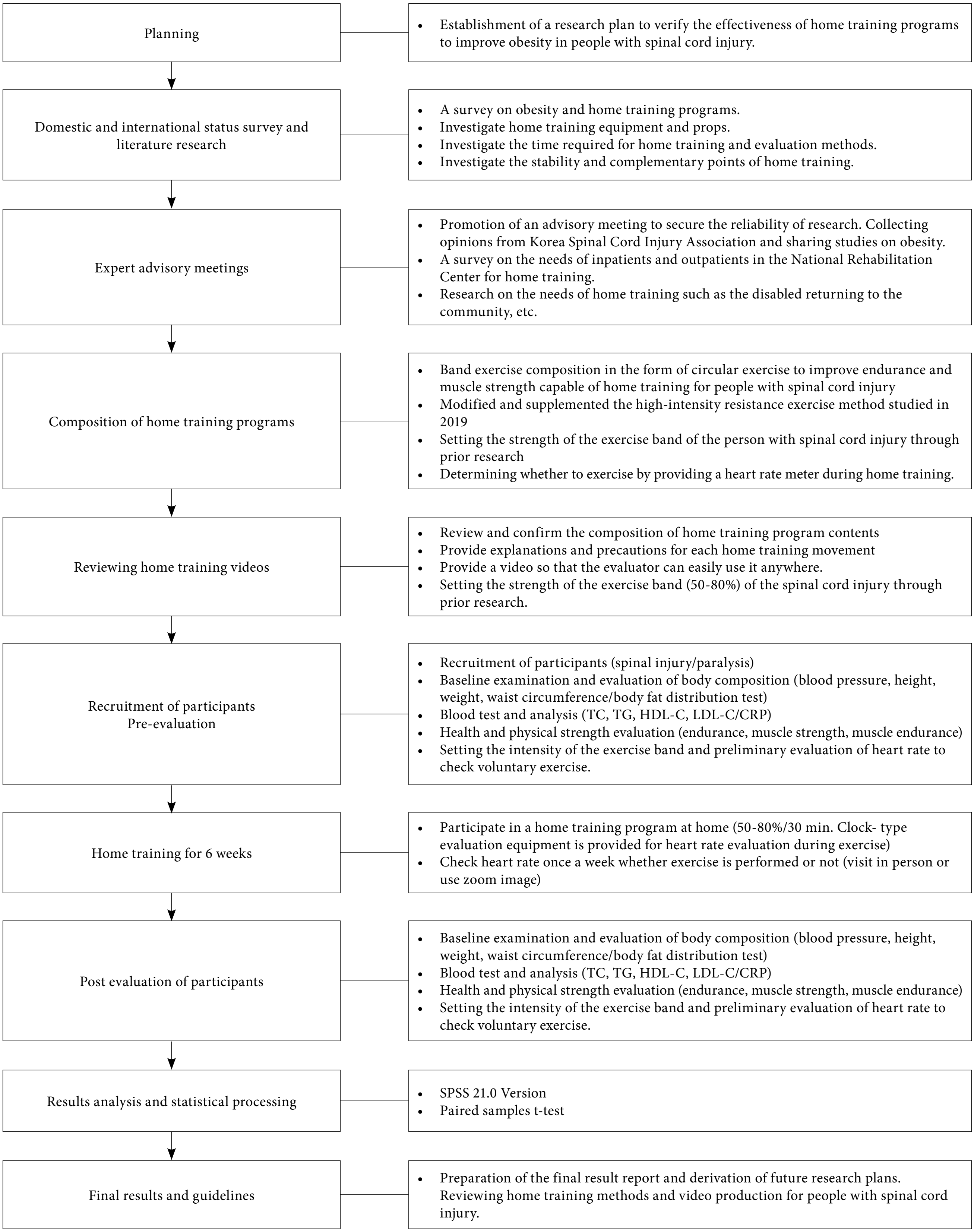


**Figure 1.** Flowchart of the study.

TC: Total cholesterol; TG: Triglyceride; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; CRP: C-reactive protein.

Subsequently, home training was performed four times per week for six weeks, after which the posttest was performed at the same venue (Figure 1).

## Training intervention

All exercise training performed as a part of this study was completed remotely. The study protocol for home training was explained using social media. Participants were instructed to use devices of their own choosing (desktop computer, laptop, tablet computer, or cell phone). First, ZOOM video conferencing (Zoom Video Communications, Inc., San Jose, CA, USA) was used to explain the correct exercise techniques, breathing methods, and precautions during home training and provide guidance on checking heart rate (HR) during exercise using an HR monitor (Mi Band; Xiaomi, Beijing, China) to ensure that exercises were performed at the appropriate intensity. After providing instructions about exercise training videos and other announcements, the same information was repeated via social media within a day to minimize errors during remote exercise training.

Participants performed a resistance circuit training program using Thera-Band four days per week for six weeks with the aid of exercise training videos. The videos demonstrated the correct exercise postures while specific information about each exercise (name of the exercise, number of repetitions, and tips for performance) was presented on the screen.

Weeks 1 and 2 proceeded as remote sessions, during which we provided information regarding the order of exercises, the exercise method, and the use of equipment for data collection over ZOOM. During Weeks 3 to 6, the participants performed the exercises on their own while watching the exercise training videos and reported whether they completed the exercises using social media. Furthermore, during Weeks 3 to 6, we explained the exercise method and encouraged participation via video conference once per week to minimize errors in the data required to evaluate the effectiveness of the program. As the participants' health could not be directly examined during the remote program, they were instructed to immediately notify the principal investigator of any changes in their health to review the eligibility for continued participation in the study.

The home circuit training program comprised warm-up (10 min), main (15 min), and cool-down (5 min) exercises (Table 1). The main exercises consisted of five activities: chest press, lateral raise, front raise, shoulder (military) press, and arm curl (Figure 2). Five sets of eight to 10 repetitions were performed for each exercise. Exercise intensity was set at 50 to 80% of one-repetition maximum (1RM), with a 10-sec break between sets. To prevent resistance training injuries, the participants were instructed to perform the warm-up and cool-down exercises at an intensity of 10 to 20% of maximum HR.

Exercise intensity was set based on HR and Borg rating of perceived exertion (RPE). Target HR values were calculated using the Karvonen equation. Exercise intensity was increased by 5% each week, and the decision to continue with the program was determined based on RPE and discussion among the researchers. Participants were instructed not to exceed an exercise intensity of 11 to 13 RPE due to the risk of autonomic dysregulation.

**TABLE 1**
Components of the circuit resistance training program

| | Exercise | Intensity (%HRmax) | Volume | Time (min) | Duration (weeks) |
|---|---|---|---|---|---|
| Warm-up | | 10-20% | 1 set | 10 | |
| | Chest press | | | | |
| | Lateral raise | | | | |
| Main exercise | Front raise | >50% | 5 sets of 8-10 reps | 15 | 6 |
| | Shoulder press | | | | |
| | Arm curl | | | | |
| Cool down | | 10-20% | 1 set | 5 min | |

HR: Heart rate.

**Figure 2.** Main exercises of circuit resistance training program. **(a)** Chest press; **(b)** Lateral raise; **(c)** Front raise; **(d)** Shoulder press; **(e)** Arm curl.

## Assessment

An assessment of each study variable was conducted at the rehabilitation center before and after the six-week exercise program. Skeletal muscle mass, %BF, and body mass index were measured using bioimpedance analysis (Inbody S10; Biospace, Seoul, South Korea). Blood lipid profiles (TC, TG, HDL-C, and LDL-C) and CRP were evaluated using blood tests.

Cardiopulmonary endurance and function were measured using the 6-min push test (6MPT) and respiratory gas analysis (K5; COSMED, Rome, Italy). The 6MPT was conducted along the line drawn on the floor of the gym, and the maximum distance participant pushing the wheelchair (MS-1, Miki-Korea medical, Paju, South Korea) for 6 min was measured. Peak oxygen uptake ($VO_2$ peak), $VO_2$ peak per weight ($VO_2$ peak/kg), oxygen uptake ($VO_2$), oxygen uptake per weight ($VO_2$/kg), ventilation (VE), and respiratory exchange ratio (RER) during 6MPT. Cardiopulmonary function (maximum inspiratory pressure [MIP] and maximum expiratory pressure [MEP]) was also assessed to analyze oxygen usage during exercise. Systolic blood pressure and diastolic blood pressure were measured at rest.

The participant's HR during exercise was measured using a wireless MIO GO (59p; MIO, Vancouver, Canada) worn around the wrist. Heart rate was automatically saved at 15-sec intervals, and the saved data were relayed to a computer upon completion of the exercise.

A compressed air machine (p50/24 AL; HUR, Kokkola, Finland) was used to measure the strength of the shoulder girdle muscles, pectoralis major (left and right), and latissimus dorsi. Muscular endurance was measured using an arm curl stand for persons with disabilities (Upper body resistance machine NXF; Kaesun Sports, Paju, South Korea). The participant was seated on the machine with the correct posture while their 1RM was measured. The weight of the machine was then set to 60% of 1RM, and elbow flexion and extension were performed for 1 min at this load intensity. The maximum number of elbow flexion and extension repetitions performed before and after the intervention were compared.

### Statistical analyses

The effect sizes were calculated using G*Power version 3.1.9.6 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). Statistical analyses were performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). The normality of the distributions was assessed by the Kolmogorov-Smirnov test. The means and standard deviations were calculated for all variables. The effectiveness of the home training program was analyzed using a paired-samples t-test. The level of statistical significance was set at $p<0.05$. Prior to the study, the minimum required sample size was determined to be 54, with an effect size of 0.5, an alpha level of 0.05, and a power of 0.95.

## RESULTS

Participants' characteristics are presented in Table 2. Changes in study variables are shown in Table 3. Changes in lean body mass (LBM), body fat mass (BFM), and %BF were examined. Lean body mass significantly increased ($p=0.042$), but BFM and %BF did not significantly change ($p=0.941$ and $p=0.215$, respectively). Changes in blood TC, TG, LDL-C, and HDL-C levels were examined. The HDL-C level significantly increased ($p=0.038$), but TC, TG, and LDL-C levels did not significantly change ($p=0.418$, $p=0.308$, and $p=0.117$, respectively). CRP level decreased, although the change was not significant ($p=0.990$).

The mean 6MPT distance, mean $VO_2$ peak, mean $VO_2$ peak/kg, mean $VO_2$, mean $VO_2$/kg, and VE all significantly increased ($p=0.009$, $p<0.001$, $p<0.001$, $p=0.004$, $p=0.002$, and 0.019 respectively). The RER, MIP/mean, MIP, MEP/mean, and MEP increased; however, the changes were not significant ($p=0.251$, $p=0.308$, $p=0.233$, $p=0.632$, and $p=0.151$, respectively). Resting systolic blood pressure and diastolic blood pressure did not significantly change after exercise ($p=0.288$ and $p=0.460$, respectively). Resting HR before the 6MPT decreased, although the change was not significant ($p=0.174$).

**TABLE 2**
General characteristics of participants (n=15)

| Characteristics | n | % | Mean±SD | Median | Min-Max |
|---|---|---|---|---|---|
| Age (year) | | | 40.7±10.8 | | |
| Sex | | | | | |
| Male | 12 | 80 | | | |
| Female | 3 | 20 | | | |
| Height (cm) | | | 168.00±10.88 | | |
| Weight (kg) | | | 72.30±16.55 | | |
| Duration of injury (year) | | | | 8 | 1-60 |
| ASIA impairment scale | | | | | |
| A | 15 | 100 | | | |
| Level of injury | | | | | |
| Thoracic | 10 | 66.7 | | | |
| Lumbar | 5 | 33.3 | | | |

SD: Standard deviation; ASIA: American Spinal Injury Association.

**TABLE 3**
Comparison of changes in study variables before and after the 6-week training intervention

| | Pre | Post | | | |
|---|---|---|---|---|---|
| Variables | Mean±SD | Mean±SD | t | *p* | Effect size $d_z$ |
| Body composition | | | | | |
| Lean body mass (g) | 42,757.88±9822.64 | 43,511.26±9442.87 | -2.236 | **0.042*** | 0.577 |
| Body fat mass (g) | 28,477.97±9021.62 | 28,502.99±9099.87 | -0.076 | 0.941 | 0.020 |
| % body fat (%) | 38.41±6.87 | 37.99±6.94 | 1.299 | 0.215 | 0.335 |
| Blood lipid profile | | | | | |
| TC (mg/dL) | 189.33±26.35 | 194.20±31.22 | -0.835 | 0.418 | 0.216 |
| TG (mg/dL) | 219.73±94.01 | 205.33±76.85 | 1.058 | 0.308 | 0.273 |
| LDL-C (mg/dL) | 114.13±19.81 | 121.07±32.04 | -1.671 | 0.117 | 0.431 |
| HDL-C (mg/dL) | 46.92±12.60 | 49.05±12.05 | -2.296 | **0.038*** | 0.593 |
| CRP (mg/dL) | 0.83±1.93 | 0.55±0.99 | 0.990 | 0.990 | 0.256 |
| Cardiopulmonary endurance and function | | | | | |
| 6MPT (m) | 546.13±142.17 | 607.80±147.75 | -3.016 | **0.009*** | 0.779 |
| $VO_2$ peak (mL/min) | 1,247.08±435.67 | 1,580.21±420.72 | -4.834 | **<0.001**** | 1.248 |
| $VO_2$ peak/kg (mL/min/kg) | 17.50±4.99 | 22.28±5.01 | -4.698 | **<0.001**** | 1.213 |
| $VO_2$ (mL/min) | 890.84±349.24 | 1,081.56±300.13 | -3.463 | **0.004*** | 0.894 |
| $VO_2$/kg (mL/min/kg) | 13.25±3.61 | 15.43±3.67 | -3.724 | **0.002*** | 0.962 |
| VE (L/min) | 29.45±9.31 | 35.58±12.42 | -2.642 | **0.019*** | 0.682 |
| RER | 0.94±0.12 | 0.99±0.14 | -1.197 | 0.251 | 0.309 |
| MIP/mean ($cmH_2O$) | 77.57±28.20 | 82.17±32.31 | -1.038 | 0.308 | 0.295 |
| MIP ($cmH_2O$) | 94.73±36.05 | 105.80±38.56 | -1.248 | 0.233 | 0.322 |
| MEP/mean ($cmH_2O$) | 86.67±24.51 | 73.77±28.68 | -0.490 | 0.632 | 0.127 |
| MEP ($cmH_2O$) | 70.20±24.29 | 76.93±28.59 | -1.520 | 0.151 | 0.392 |
| SBP (mmHg) | 121.93±18.44 | 124.33±16.57 | -1.104 | 0.288 | 0.285 |
| DBP (mmHg) | 79.40±11.60 | 77.47±10.93 | 0.759 | 0.460 | 0.196 |
| HR (bpm) | 81.00±14.12 | 77.87±10.79 | 1.432 | 0.174 | 0.370 |
| Muscle endurance and strength | | | | | |
| Arm curl, left (reps) | 41.73±12.53 | 51.87±12.89 | -3.120 | **0.008*** | 0.805 |
| Arm curl, right (reps) | 42.87±11.65 | 51.53±15.46 | -2.384 | **0.032*** | 0.616 |
| Chest press, left (kg) | 42.91±15.08 | 49.04±18.25 | -1.812 | 0.092 | 0.468 |
| Chest press, right (kg) | 46.15±16.38 | 48.36±15.09 | -0.806 | 0.434 | 0.208 |
| Shoulder press (kg) | 56.45±20.20 | 59.82±19.63 | -0.877 | 0.395 | 0.227 |
| Lateral pull (kg) | 46.69±17.74 | 59.82±19.63 | -2.293 | **0.038*** | 0.592 |

SD: Standard deviation; TC: Total cholesterol; TG: Triglyceride; LDL-C: Low-density lipoprotein cholesterol; HDL-C: High density lipoprotein cholesterol; CRP: C-reactive protein; 6MPT: 6-min push test; $VO_2$: oxygen uptake; VE: Ventilation; RER: Respiratory exchange ratio; MIP: Maximum inspiratory pressure; MEP: Maximum expiratory pressure; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HR: Heart rate; * p-value <0.05; ** p-value <0.001.

The number of arm curl repetitions significantly increased in both left and right arms (p=0.008 and p=0.032, respectively). The mean chest press weight increased in both left and right, although the change was not significant (p=0.092 and p=0.434, respectively). The mean shoulder press weight increased without significance (p=0.395). The mean lateral pull weight significantly increased (p=0.038).

## DISCUSSION

The COVID-19 pandemic has brought tremendous societal changes, impacting the lives of both nondisabled and disabled people. Even before the COVID-19 pandemic, physical inactivity was shown to inversely impact the QOL of individuals with SCI compared to preinjury state, reducing basic fitness and impeding return to society. As a result of inactivity, individuals with SCI are more likely to develop secondary diseases, including obesity, hypertension, diabetes mellitus, and heart disease, compared to their nondisabled counterparts. In addition, those who are wheelchair-dependent are at increased risk of developing muscle or joint injuries due to the excessive use of their arms and shoulders, while those who are bedridden are at increased risk of developing chronic pressure ulcers.[12] These phenomena highlight the importance of exercise for individuals with SCI to maintain and improve QOL, as well as to counteract the negative effects of sustained postures/positions. Furthermore, exercise plays an important role in obesity management, thereby aiding in the prevention of additional diseases. Therefore, this study aimed to develop and validate a home training program for individuals with SCI.

A study involving a 12-week resistance band exercise program in older women reported a significant reduction in %BF and a significant increase in LBM.[13] In this study, a six-week home training program utilizing training videos for individuals with SCI led to significant changes only in LBM. Increased LBM is associated with increased basal metabolic rate,[14] thereby helping to prevent calorie imbalance and ultimately contributing to weight management. In our study, %BF tended to decrease but not at a statistically significant level. This suggests that the resistance exercise regimen did not result in significant changes in body composition. However, altering body composition requires dietary adjustment; thus, the absence of a concurrent dietary intervention may have contributed to the failure in achieving adequate improvements. As studies report that the amount of exercise is more important than exercise intensity to adequately reduce BFM,[15] subsequent studies should develop a holistic program involving exercise of adequate amount and intensity and a dietary regimen.

Regarding blood lipid profiles, significant changes were observed in HDL-C levels ($p=0.038$) but not in other variables (TC, TG, and LDL-C). Blood lipid profiles exert diverse metabolic effects; therefore, maintaining normal blood lipid levels is crucial. Exercise training has been reported to reduce TC, TG, and LDL-C levels and increase HDL-C levels. A previous study involving a 12-week resistance band program in older women reported significant changes in HDL-C, TC, and TG levels,[16] which was partially consistent with our results. High-density lipoprotein cholesterol can be increased by regular exercise, but more intense exercise regimens are required to lower LDL-C and TG,[17] which could be the reason why significant changes were not observed in all blood lipid variables in our study. Thus, we recommend increasing physical activity as much as possible and adding moderate-intensity resistance training for people with dyslipidemia and limited mobility to lower LDL-C and TG while increasing HDL-C.

Total cholesterol, a parameter influenced by duration and intensity of exercise, is used as an index of intestinal nutritional absorption, lipid metabolism disorder, hyperlipidemia, and arteriosclerosis. Total cholesterol concentration declines with prolonged or high-intensity exercise,[18] and physical activity slows the rate of TG secretion, enabling metabolic regulation in response to stimulated activation of oxidative enzymes and increased myoglobin concentration in the mitochondria. In this way, regular exercise is reported to reduce TG levels.[19]

Other variables must be considered to achieve significant changes in blood lipid variables. Diet is one of the major factors influencing blood lipid profiles.[20] Although we used a short exercise regimen (six weeks) without dietary adjustment, TC and LDL-C were both within the normal ranges before and after exercise, although there were no significant changes after the intervention. High-density lipoprotein cholesterol concentration increased significantly, showing that home resistance training had some impact in altering blood lipid variables.

C-reactive protein is an acute-phase reactant that becomes elevated in a nonspecific response to tissue injury and inflammation. C-reactive protein concentration is dramatically elevated in obese individuals, confirming a strong association between CRP and obesity.[7] Old age, smoking, hypertension, and hyperlipidemia are also positively correlated with increased CRP concentrations, and because adipocytes secrete CRP, CRP concentration increases with increasing adipocyte count, leading to reduced muscle mass.[21] In our study, CRP levels tended to decrease after the six-week resistance exercise regimen, although the results were not statistically significant. In light of previous reports showing effective reductions in CRP levels after 10 weeks of resistance exercise[22] and after seven months of resistance exercise in obese women,[23] the finding that CRP concentration was reduced in our study after a short-term exercise regimen suggests that resistance exercise using Thera-Band has positive effects in individuals with SCI. Thus, the home training program developed in this study has the potential to be highly beneficial for the health of individuals with SCI if lifestyle factors (e.g., diet) are controlled and the duration of the program is increased.

In individuals with SCI, reduced cardiopulmonary function has a wide-ranging impact on sarcopenia and physical disability.[24] Poor cardiopulmonary fitness is associated with increased CVD risk factors.[25] A 12-week resistance band exercise program in older women produced significant changes in cardiopulmonary variables, similar to the improvement in cardiopulmonary endurance that was observed in our study.[26] Moreover, our exercise program was designed to allow individuals to exercise at home using Thera-Band instead of having to visit an exercise facility. Our results highlight the potential of this program as an alternative training method to boost cardiopulmonary fitness in individuals with SCI.

In this study, respiratory muscle function tended to improve after intervention, although the changes were not statistically significant. A previous study that administered an eight-week normocapnic hyperpnea training program in 14 individuals with SCI reported that the participants exhibited increased maximum voluntary VE and improved MIP and MEP after the program.[27] Additionally, Liaw et al.[28] reported that inspiratory muscle training increased vital capacity by 67% in individuals with SCI. Another study involving individuals without disabilities reported that high-frequency breathing training significantly increased peak expiratory flow, forced expiratory volume at 1 sec, MIP, MEP, and inspiratory power.[29] The difference between these results and ours may be because past studies focused on the respiratory muscles, whereas our study focused on improving obesity in individuals with SCI. However, as respiratory muscle function did improve in our study, albeit not significantly, strength increases in the pectoralis and accessory muscles, rather than the respiratory muscles, may have contributed to this improvement. This is supported by previous findings indicating that intensive exercise results in significant respiratory-related improvements compared to regular exercise and breathing exercise ($p<0.01$), both of which exhibited no significant improvements.[30]

Spinal cord injury negatively impacts neurological regulation of respiratory muscles, which substantially impairs respiratory functions. Despite a significant improvement in survival rate through acute and chronic phase management, individuals with SCI still exhibit higher mortality (47%) than those without SCI.[31] Hence, our findings may serve as baseline data to develop programs to improve respiratory muscle function in this population.

There were no statistically significant changes in HR values after the exercise program. However, there was a reduction in HR, which is a positive result as elevated HR is associated with a higher risk of hypertension and atherosclerosis and is, therefore, a potent risk factor for CVD morbidity and mortality.[32] In a previous study involving 13 individuals with thoracic SCI, a 16-week exercise program (three 120-min sessions per week) resulted in decreases in HR 6 min after the exercise test.[33] In light of these results, the reduction in HR with a shorter exercise program in our study shows that a home resistance training regimen using Thera-band may positively impact individuals with SCI.

Significant changes were observed in the arm curl (left, $p=0.008$; right, $p=0.032$) and lateral pull ($p=0.038$) exercises. A previous study involving wheelchair athletes with SCI also reported that an eight-week bench press regimen (five sets, 10 to 12 repetitions/set, twice a week) using a Smith machine significantly increased muscle strength and power.[34] A South Korean study using an elastic resistance band, as in our study, reported positive changes in the elbow and shoulder joints in individuals with SCI,[35] which was partially consistent with our findings. These results suggest that the main goals of resistance training were achieved. Resistance training increases the cross-sectional area of muscles by thickening muscle fibers and by stimulating protein synthesis in skeletal muscles.[36] Another South Korean study on individuals with SCI reported that endocrine activities involving growth hormones, insulin-like growth factor-1, and testosterone can influence muscle protein synthesis.[37] Hence, resistance exercise using Thera-Band can help to improve muscle strength and endurance required for daily living in individuals with SCI. Moreover, another study reported that resistance training using an elastic resistance band is appropriate for muscle strengthening since the resistance is generated depending on the length of the pull, as opposed to gravity, and thus resistance can be applied at all points of the performed exercise.[38] Simple home training using Thera-band was as effective as gym-based muscle training in improving muscle strength and endurance in individuals with SCI in our study. Accordingly, this exercise program can help to address barriers to regular exercise participation, such as restricted access to exercise facilities, among this population.

This study has some limitations. Despite implementing anti-COVID-19 measures and adequately informing the participants about the anti-COVID-19 protocols at the rehabilitation center, some individuals declined to participate in the study and others withdrew from the study due to the rapid spread of COVID-19 during the study period. Second, this study used a one-group pretest-posttest design; hence, external influences could not be controlled. Furthermore, we used a short exercise regimen and a small sample size. However, meeting the target sample size was challenging due to COVID-19. Hence, we had to proceed with a small sample and add the effect sizes to the results to calculate post hoc power. Subsequent longer-term studies involving larger cohorts would be required to confirm these results. Although diet is an important factor in improving obesity, we could not control diet in this study. Thus, future studies could potentially obtain more positive outcomes by coupling the exercise program with dietary adjustment.

In conclusion, as special circumstances such as COVID-19 further restrict activities of daily living and physical activity in individuals with SCI, a shift in the perception of exercise is required. In this regard, home-based training may play a pivotal role. Our results confirm that web-based home training provided significant improvements in LBM, HDL-C, cardiopulmonary endurance, muscle endurance, and muscle strength in individuals with SCI. These findings suggest that the remote administration of a home resistance training program using Thera-Band has the potential to promote physical activity participation and improve obesity rates and fitness levels among individuals with SCI. Future randomized, case-control studies are required for further objective assessment of the effectiveness of this exercise program.

**Data Sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

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