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Effects of Backward Walking Training with a Weighted Bag Carried on the Front on Craniocervical Alignment and Gait Parameters in Young Adults with Forward Head Posture: A case series

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Abstract

Purpose : This case study aimed to investigate the effects of backward walking exercises with a front-loaded bag on craniovertebral angle (CVA), craniorotational angle (CRA), and gait variables in subjects with forward head posture (FHP).

Methods : Two individuals in their twenties with FHP performed backward walking exercises on a treadmill while carrying a front-loaded bag with a load equivalent to 20 % of their body weight, for 30 minutes per day, three times a week, over two weeks. CVA and CRA were measured before and after the intervention using side view photographs taken from 1.5 meters away. CVA was calculated by marking C7, the tragus of the ear, and the outer canthus of the eye, and CRA was determined using the same landmarks. Image J software was used for angle analysis, with measurements taken three times and averaged. Gait variables such as step length and cadence were recorded using a step analysis treadmill and analyzed with the software included with the equipment, with measurements taken at baseline and after the two-week intervention.

Results : Both participants demonstrated notable improvements in the CVA, indicating enhanced head alignment relative to the cervical spine. There was also a marked decrease in the CRA, suggesting a reduction in rotational misalignment. Although differences were observed in gait variables, such as step length and cadence, these changes were not consistent across measurements. The results suggest that backward walking exercises with a load carried in front can positively influence postural adjustments by aligning the cervical spine in individuals with FHP.

Conclusion : The findings of this case study indicate that backward walking exercises with a front-loaded bag can effectively improve cervical spine alignment in individuals with FHP. Differences were observed in gait variables, such as step length and cadence, but these changes were not consistent across measurements. Future studies should explore these effects more comprehensively and consider optimizing the exercise protocol for better therapeutic outcomes.

Key Words : backward walking, craniorotational angle, craniovertebral angle, forward head posture

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Ⅰ. Introduction

Among musculoskeletal disorders, it is said that neck fatigue due to a lack of exercise, stress caused by continuous overload, incorrect posture, and lesions caused by occupational characteristics are mainly found in the neck (Moreira et al., 2022). In particular, a forward head posture (FHP) occurs frequently in people in their 10s to 30s due to the use of smartphones (Ahmadi & Razeghian Jahromi, 2017). In a FHP, the center line of the head's gravity moves ahead of the human body's line of gravity, increasing the load on the neck muscles that support the head (Park et al., 2020). The upper cervical vertebrae are hyperextended, causing excessive tension in the extensor muscles and excessive bending of the lower cervical vertebrae, resulting in weakness in the deep neck flexors and extensor muscles of the spine and the loss of the normal anterior bending of the cervical spine (Jun & Kim, 2013). In addition, Kim et al. (2018) defined FHP as a typical posture caused by incorrect spinal alignment, as the head vertebral angle decreases and the head rotation angle increases.

Many studies have been conducted to correct this FHP, and most apply direct interventions to the neck. A comparison between the sling exercise and McKenzie exercise for adults in their 20s diagnosed with FHP and complaining of neck pain showed that the sling exercise produced significantly greater improvements in pain and neck alignment (Jang, 2017). Neck exercises supported spinal self joint mobilization training, and an increase was confirmed in the alignment and range of motion of the cervical vertebrae (Oh, 2018). In addition, treatments such as chiropractic are being applied as interventions for improving FHP (Sheikhhoseini et al., 2018).

Among the indirect intervention methods used to mediate FHP, postural control methods using walking exercises have also been widely reported. Backward walking exercises are recommended to correct the walking pattern that occurs due to the forward movement of the head and changes in FHP (Hoogkamer et al., 2014; Jansen et al., 2012; Park et al., 2020). Moreover, backward walking exercises targeting elementary school children diagnosed with FHP reported significant changes in the gravitational center line of the cervical vertebrae and the curvature of the cervical vertebrae (Jo, 2018). Wearing a bag is also known to relate to FHP.

Backpack use, particularly when worn on the front, has significant effects on posture and gait. According to Kim et al. (2019), wearing a backpack in this manner reduces lumbar lordosis by flexing the lumbar region, thereby shifting the load into the base of support. This adjustment involves thoracic changes that contribute to reduced lumbar lordosis and influence cervical alignment, often resulting in a FHP. Additionally, Lehnen et al. (2017) found that carrying a backpack in the front affects several gait variables: it reduces step length, increases step frequency, prolongs the double stance phase, increases the stance phase duration, and shortens the swing phase. Goswami et al. (2017) studied elementary school children and observed that carrying backpacks with weights ranging from 0 % to 20 % of their body weight led to trunk forward lean and head forward inclination, adversely affecting posture and gait.

Abaraogu et al. (2017) reported a significant decrease in the head spine angle when walking forward while wearing a bag weight more than 15 % of one's body weight, and Barbosa et al. (2021) found a significant correlation between the head spine angle and backpack weight. In addition, it is said that when walking while carrying a load such as a bag, the center of gravity shifts (Oh & Choi, 2007). Changes in speed, stride length, and step length occur depending on the weight of the load (Simpkins et al., 2022).

Previous studies have confirmed that walking backward and carrying a bag affect changes in postural control and gait variables. However, a lack of research confirms changes in FHP and gait variables by carrying a bag forward and walking backward. Therefore, this study was conducted to determine changes in FHP and the effects on walking variables by applying a backward walking exercise while carrying a bag forward with a load of 20 % of one's body weight applied to adults in their 20s with FHP.

Ⅱ. Methods

1. **Case description**

1) Subjects

The subjects of this study were college students in their 20s attending B University in Busan for two weeks from May 30, 2023, to June 9, 2023. Those who voluntarily agreed to participate after receiving an explanation of the purpose and methods of this study were selected. Among 20 subjects whose center of gravity was more than 2.5 ㎝ before the coracoid process of the shoulder, 2 subjects with a craniovertebral angle of 52 ° or less were finally chosen (Park et al., 2020). The subjects were picked as those who had no previous surgical experience, were not infected with the coronavirus, and could walk backward on a treadmill. This study complied with the research ethics of the Declaration of Helsinki. The general characteristics of the subjects are as follows (Table 1).

Table 1. General characteristic of subjects (n= 2)

	Age (year)	Height (㎝)	Weight (㎏)	Gender (male/female)
A	21	166.85	65.52	Female
B	21	180.51	78.97	Male

2. **Outcome measures**

1) Gait variables

A step analysis treadmill (Zebris FDM-Treadmill AP1171, Apsun Iic, Germany) (Fig 1) checked the walking parameters of the subjects before the backward walking exercise intervention. This step training device helps recover and improve the walking ability of patients with walking disorders. This analytic device is equipped with a step analyzer and medical pressure gauge to objectively determine the decline in walking ability and functional recovery following treatment. It comprises a system that can calculate and output the results of information on changes in pressure and walking variables that occur while standing or walking on a device using Zebris FDM software. Foot pressure was checked in a static state when standing on a recycled treadmill for 10 seconds, and sole pressure was assessed in a dynamic state when walking for 30 seconds alongside step length and stride length (stance phase, swing phase, and step time). When measuring walking variables, the walking speed was set to 2.5 ㎞/h for each subject according to the equipment manual due to preliminary experiments to confirm the most comfortable walking speed for each subject. The results of all walking variables were measured three times, and the average value was adopted. After 2 weeks of a backward walking exercise intervention, walking variables were remeasured using the same method. Step variables and sole pressure measurements were all measured barefoot to eliminate variables caused by shoes (Park & Park, 2021).

Fig 1. Zebris FDM−treadmill

2) Craniovertebral angle (CVA) and craniorotational angle (CRA)

Before measuring the CVA and CRA (Fig 2) before the backward walking exercise intervention, a self-balancing posture was performed to start the natural head posture. A self balance posture was achieved by having the subject perform maximum flexion or extension of the cervical spine and gradually reduce the degree of flexion or extension. With the head in the most comfortable position, the subject’s cervical shoulder and upper extremity muscles were relaxed, and the subject stood comfortably. The side view was photographed using a digital camera. The distance between the camera and the measuring device was set at 1.5 m, and the CVA was measured by marking C7, the tragus of the ear, and the outer canthus of the eye in the video taken from the experimenter. Subsequently, a horizontal line was drawn passing through C7, which forms a right angle to the vertical line. The angle formed by the line connecting C7 and the tragus of the ear and the horizontal line, CVA, was measured. Next, the CRA was determined by measuring the angle formed by the line connecting C7 and the tragus of the ear and the line connecting the tragus of the ear and the outer canthus of the eye.

A CVA of 40˚ or less indicates a severe FHP. A score between 48˚ and 55˚ means a light FHP, and a score over 55˚ refers to a normal state. The head rotation angle is formed by the line connecting the spinous process of the seventh cervical vertebra and the ear canal and the line connecting the ear canal and the lateral eye corner. This angle indicates the degree of extension of the superior cervical vertebra. In the case of FHP, the CRA is found to be over 145˚ (Park, 2015; Salahzadeh et al., 2014; Silva et al., 2010).

Filming and photo analysis were each conducted by the same surveyor. To analyze the angle of the photograph taken, the head’s spine and rotation angles were measured three times using the freeware program Image J (Image J version 1.51, National Institutes of Health, USA) (Rueden et al., 2017; Sun et al., 2015). The average value was adopted. Image J is a program first used by Wayne Rasband at the NIH in 1997. This program is frequently used to analyze images in various ways (Rueden et al., 2017). After 2 weeks of backward walking exercises, CVA and CRA were remeasured using the same method.

Fig 2. Image (A; CVA, B; CRA)

3) Weight of bag

During the backward walking exercise intervention, the subject’s weight was considered. A weight plate was placed in the bag, and the subject was placed in front of the bag and walked backward. Using a typical backpack with two straps carried it side by side on both shoulders. A 1 ㎏ to 5 ㎏ weight plate created a load of 20 % of the body weight (Kim et al., 2015). Subject A's weight was 65.52 ㎏, and 20 % of the weight (including bag weight) was applied to make the test 13 ㎏. Subject B's weight was 78.97 ㎏, and 20 % of the weight (including bag weight) was applied to make it 16 ㎏ (Fig 3). All of which was combined and placed in a bag to control the weight.

Fig 3. Back pack and weight plate

3. **Intervention**

The backward walking exercise program in this study was conducted by modifying and supplementing the exercise method of Park et al. (2020), an existing study. Backward walking exercises were performed for 30 minutes a day, 3 times a week for a total of 2 weeks. As for the exercise program, the subjects performed barefoot exercises on a treadmill (Goldstone GST-8000, SAMHYUNG, Korea) for 5 minutes at a previously set speed of 1.5 ㎞/h as a warm-up exercise. This exercise was performed for 20 minutes at 2.5 ㎞/h in the first week. In the second week, this exercise was performed for 20 minutes at 2.5 ㎞/h. The finishing exercise was performed for 5 minutes at 1.5 ㎞/h. The 20 minutes of this exercise were set as 10 minutes of exercise, 1 minute of rest, and 10 minutes of exercise. When the subjects complained of dizziness or paresthesia while walking backward on the treadmill, the exercise was stopped immediately.

Ⅲ. Results

Table 2 shows notable differences in the CVA and CRA before and after the 2-week backward walking exercise. Subject A walked backward after wearing the bag forward. The CVA increased from 45 ° before the exercise to 49 ° after the exercise. The CRA decreased from 155 ° to 147 °.

Subject B also walked backward after wearing the bag forward. The CVA increased from 52 ° before exercise to 55 ° after exercise, and the CRA decreased from 156 ° to 138 °.

Table 2. Comparison of CVA and CRA before and after backward walking exercise (n= 2)

Parameters	Subjects	Pre exercise	Post exercise
CVA (°)	A	45	49
	B	52	55
CRA (°)	A	155	147
	B	156	138

CVA; craniovertebral angle, CRA; craniorotational angle

Table 3. Comparison of gait parameters before and after backward walking exercise (n= 2)

Subject		A		B	
		Pre	Post	Pre	Post
Left	Forefoot (%)	32.00	34.67	32.67	31.67
	Backfoot (%)	68.0	65.33	67.33	68.33
Right	Forefoot (%)	30.33	34.67	36.33	28.67
	Backfoot (%)	69.67	65.33	63.67	71.33
Left step length (㎝)		42.50	40.67	44.33	42.67
Right step length (㎝)		41.50	39.67	42.33	41.00
Stride length (㎝)		84.00	76.67	86.33	83.67
Left stance (%)		71.57	69.43	72.33	71.87
Right stance (%)		70.93	71.13	70.83	71.90
Left swing (%)		29.03	30.57	27.67	28.13
Right swing (%)		29.07	29.07	29.17	28.10
Left step time (sec)		.82	.78	.85	.86
Right step time (sec)		.88	.83	.90	.84
Stride time (sec)		1.71	1.61	1.76	1.70

CVA; craniovertebral angle, CRA; craniorotational angle

Table 3 compares changes in walking variables according to walking backward after wearing the bag forward. Such variables include pressure in the front and back of the left and right feet before and after 2 weeks of the backward walking exercise, step distance on the left and right, step distance on the left and right step, left and right sway, left and right step time, and step length on the left and right. There was no notable difference in time for either subject.

Ⅳ. Discussion

This study examined changes in the CVA and CRA in subjects with FHP by having them carry a bag forward with a load of 20 % of their body weight while walking backward. The results showed notable improvements in both CVA and CRA, suggesting that this exercise intervention can effectively improve cervical spine alignment. These findings align with previous research indicating that backward walking exercises can positively influence postural control and spinal alignment.

Previous studies have shown that carrying a bag forward induces a compensatory mechanism where the head and trunk tilt forward to counterbalance the backward-applied weight. This mechanism results in a FHP, characterized by increased flexion of the lower cervical spine and upper thoracic region, and increased extension of the upper cervical vertebrae. Prolonged standing or walking with this posture can lead to postural and alignment imbalances, potentially causing neck and upper back pain (Park, 2015; Park et al., 2020; Park & Park, 2021).

The notable improvements in CVA and CRA observed in both subjects indicate that backward walking with a front load can enhance cervical spine alignment. The increase in CVA suggests that the head's position relative to the cervical spine becomes more aligned with the body's midline, reducing the anterior tilt commonly seen in FHP. This aligns with findings from previous studies, such as Jo (2018) and Park et al. (2020) which reported similar improvements through backward walking exercises. The decrease in CRA further supports the idea that backward walking with a load can correct rotational misalignments, potentially reducing strain on cervical muscles and improving overall neck posture.

Changes in gait variables included a reduction in step length and stride length, as well as alterations in foot pressure for both subjects. These results are consistent with the findings of Kim et al. (2019). When carrying a backpack in the frontal position, several gait variables are affected: step length is reduced, step frequency is increased, the double stance phase is prolonged, the stance phase duration is increased, and the swing phase is shortened. These changes collectively indicate that the body adopts compensatory mechanisms to maintain balance and stability while carrying the load, but they may lead to less efficient gait patterns and increased muscle fatigue over time. Changes in step length, stride length, and foot pressure distribution suggest that carrying a load while walking backward may alter gait mechanics. These alterations could have implications for balance and stability, as suggested by Kim et al. (2015), who found that load carriage affects gait parameters.

Carrying a bag forward shifts the body's center of gravity forward, causing adjustments in gait mechanics. This includes increased pressure on the forefoot and reduced pressure on the heel, leading to changes in foot pressure distribution. Furthermore, the need to maintain balance may result in increased activation of stabilizing muscles, which could explain the observed changes in step and stride length. These gait adaptations are crucial for maintaining stability and preventing falls but might lead to increased muscle fatigue and less efficient movement patterns over extended periods (Abdelraouf et al., 2016; Mosaad & Abdel-aziem, 2018; Verma et al., 2018).

In previous studies, such as those by Krishnan and Pithadia (2021) backward walking was found to reduce knee joint reaction forces and improve muscle activity, suggesting its suitability for rehabilitation programs. Cranage et al. (2019) also reported higher muscle activity in the legs during backward walking compared to forward walking, indicating its potential for gait training. Further studies with larger sample sizes are needed to explore these trends in more detail and determine their significance.

The practical implications of this study are significant for individuals with FHP and healthcare professionals. Backward walking exercises with a front load could be integrated into rehabilitation programs to address FHP effectively. The simplicity and accessibility of this exercise make it a viable option for individuals seeking to improve their posture without the need for specialized equipment. However, it is important to tailor the load and exercise duration to individual capabilities to prevent overexertion or injury.

This study has several limitations. Firstly, generalizing the results is challenging due to its nature as a case report study. Secondly, the intervention period was relatively short. Thirdly, there was insufficient control over other variables that might influence posture and gait, such as physical activity levels and ergonomic factors. Therefore, additional research should be conducted to address these limitations and provide a more comprehensive understanding of the topic.

Ⅴ. Conclusion

In conclusion, this study suggests that backward walking exercises with a load carried in the front can significantly improve cervical spine alignment in individuals with FHP posture. While the changes in gait variables were not statistically significant, the observed trends warrant further investigation. Integrating this exercise into rehabilitation programs could offer a simple and effective strategy for addressing FHP.

Future research should focus on larger, more diverse populations and longer intervention periods to validate these findings. Investigating the underlying mechanisms through which backward walking with a load affects cervical spine alignment and gait could provide deeper insights into its therapeutic potential. Exploring the effects of different load weights and distributions could help optimize the exercise protocol for various populations.

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