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The Effects of Various Bag-Carrying Styles on the Muscle Tone and Stiffness and the Spinal Alignment of Adults with Rounded Shoulder Posture during Treadmill Walking

Background : There is lack of studies on the effects of the bag–carrying style on the shoulder muscles and body alignment in adults with rounded shoulder posture (RSP).
Objective: The purpose of this study was to investigate the effects of various bag–carrying styles on muscle tone, muscle stiffness and spinal alignment in 20 adults with RSP as they were walking on a treadmill.
Design : Crossover Study Design.
Methods: A subject performed treadmill walking for 15 minutes at a speed of 4 ㎞/h while carrying three different types of bags: a backpack, a cross bag, and a shoulder bag.
Results : The results showed that the main effect of timing was observed in the muscle tone for all the variables and in muscle stiffness only for the upper and lower trapezius muscles. As for the main effect of timing, the muscle tone of the upper trapezius and the pectoralis major significantly increased in all conditions, while the muscle tone of the lower trapezius significantly decreased in all conditions. The muscle stiffness of the upper trapezius significantly increased in all conditions, while the muscle stiffness of the lower trapezius significantly decreased in all conditions. As for the spinal alignment, the dimple distance data values significantly decreased for the cross–bag style.
Conclusions : This study demonstrated that walking with a heavy bag, regardless of the bag–carrying style, increased muscle stiffness around the shoulders in adults with rounded shoulder posture, and walking with a cross–bag also induced changes in spinal alignment.

Key words: *Bag, Rounded Shoulder Posture, Muscle Stiffness, Spinal Alignment*

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INTRODUCTION

In general, it is common to carry a bag, especially for those with careers who are advancing in society [1]. In everyday life, different bag types are used to efficiently transport items that are necessary for daily life in a variety of ways, such as backpacks for carrying things on one's back, cross bags that are worn across the body, and shoulder bags that are worn on a shoulder [2]. When walking while carrying a bag, the physical stress associated with the weight of the bag is applied to the human body, inducing physiological or mechanical impact on the body and leading to changes in the dynamic balance and posture of the body [3]. Also, If the shape of the bag, the bag– carrying style, or the position of the bag is not good enough to disperse the weight, it may cause an abnormal posture and affect the musculoskeletal system, causing pain and spinal impairment [4].

The rounded shoulder posture (RSP), which is a body alignment disorder, is defined as a posture where the acromion protrudes forward compared to the body's gravity line [5]. This increases the forward head posture (FHP), lordosis of the cervical spine and kyphosis of the thoracic vertebrae. It also changes the position of the scapula and causes the scapula to protraction, downward rotation, anterior tilt. This increases stress and muscle tone in the muscles of the neck and shoulders [6, 7, 8, 9]. These changes in the muscle tone of the neck and shoulder muscles, in turn, leads to various skeletal muscle-related disorders, such as pain, functional impairment, and reduced upward rotation of the scapula [10].

A previous study reported that improper bag-carrying methods caused inadequate postures, leading to various problems in the musculoskeletal system, including lower back pain, shoulder pain, neck pain, and an increase in the incidence of spinal deformations, such as scoliosis, kyphosis, and lordosis [11]. These changes have been reported to increase muscle tone in the neck area, causing headache or neck pain [12] and to increase the muscle tone of the erector spinae muscles around the lumbar vertebrae, causing lower back pain or pelvic pain [13].

As shown above, previous studies have investigated the effects of the bag type or the bag-carrying method on pain, abnormal body alignment, and muscle tone, but most of these studies have been focused on healthy people without postural deformation, in spite of the recent increase in the prevalence of RSP in modern society due to the development of mobile phones and the increase of computer usage [14, 15]. As a result, there is lack of studies on the effects of the bag-carrying style on the shoulder muscles and body alignment in adults with RSP. Therefore, this study aimed to investigate the effects of various bag-carrying styles during treadmill walking on the muscle tone and stiffness of the muscles around the shoulders and spinal alignment in adults in their 20s with RSP.

It is thought that there will be a change in muscle tone and stiffness and the spine alignment depending on various bag-carrying styles in adults with round shoulder posture.

SUBJECTS AND METHODS

Subjects

Among the college students who were enrolled in N university located in Chungcheongnam-do, 20 adults (10 males and 10 females) with RSP were included in this study. RSP was defined as a condition in which the distance between the backside of the acromion of the subject and the table was at least 2.5 cm in a supine position [6, 16]. The participants voluntarily agreed to participate after being provided information about the purpose of the study. This study was approved by the Institutional Ethics Committee of Namseoul University (No. NSUIRB-201809-002). Those with a severe disease, a history of injury in the shoulder or vertebrae, congenital anomalies on the extremities, and with other conditions that could affect the experiment were excluded.

Experimental procedures

The experiment in this study was designed as a single-sample repeated test, in which a subject performed treadmill walking while carrying three different types of bags. It was conducted as a randomized cross-over trial, in which all subjects randomly participated in every experimental condition. RSP was measured using a digital caliper to select the subject of the round shoulder posture. Before subjects performed treadmill walking, spinal alignment and muscle tone and stiffness of upper trapezius, pectoralis major, and lower trapezius were measured.

The subjects randomly wore one the three types of bags: a backpack, a cross bag, or a shoulder bag, and started treadmill walking for 15 minutes [17] at an average adult walking speed of 4km/h [18]. To prevent the fatigue effect of treadmill walking while carrying different bag types, at least 24 hours of rest time was set between each treadmill walking [19]. The weight of the bag was set to 15% of the body weight for treadmill walking [20], and the bag weight was adjusted using books. A square bag (with a width of 30 cm and a height of 34 cm) equipped with a shoulder strap with a width of 12 cm was used [21]. The bag could be carried in three different ways by adjusting the strap, and the subjects were divided into a backpack condition wearing the bag on both shoulders, a shoulder bag condition wearing the bag on one shoulder, and a cross-bag condition wearing the bag across the body on one shoulder. The conditions carrying the shoulder bag and the cross bag had the bag strap placed on the right shoulder to make the position of the bag the same [22]. In addition, the length of the bag strap was adjusted so that the lowest part of the bag was at the level of the iliac crest of the subject's back [23]. Immediately after the treadmill walking was finished, the subject's muscle tone, stiffness, and spinal alignment were measured.

Measurement of muscle tone and stiffness

A muscle elasticity meter (MyotonPRO, MyotonAS, Estonia) was used to measure the muscle tone and stiffness of the upper trapezius, pectoralis major, and lower trapezius muscles before and after treadmill walking according to the bag-carrying style. The instrument, which was equipped with a three-axis acceleration sensor, is highly reliable for measuring muscle tone, elasticity, and stiffness. [24] The measurements were taken by placing a polycarbonate probe (3 mm) perpendicular to the muscle to be measured and setting the number of repetitions of the oscillation tap to 5 times. The frequency (㎐) represented the muscle tone characteristics; this involved calculating the duration of the last stimulation during the muscle measurement. Muscle tone refers to vibrations in a steady state without voluntary muscle contractions. For stiffness, muscle resistance was expressed in N/m. In general, when the muscle is stiff, the muscle tone and stiffness increase; when elasticity decreases, muscle fatigue increases; and when elasticity is low, the movement velocity becomes limited [25]. In this study, the overall stiffness of the muscles was measured and expressed as data values for muscle tone (Frequency [㎐], F) and stiffness (Stiffness [N / m], S).

In a supine position, the subject was marked with a harmless marker on their body, and then the measurement tool was placed in the vertical direction to make a measurement. The mechanical impulse transmission time (tap time) during the 5 repetitions of the oscillation taps was set to 15 ms, and the interval between the muscles to be measured was set to 10 seconds. The initial measurement was taken after the subject was resting in a supine position for 10 minutes. If the coefficient of variation was less than 3% during the measurement, the measured value was used for the analysis, while if it was 3% or greater, the measurement was repeated [26]. In addition, the belly region of each muscle was selected as a specified measurement site, and the measurements were performed by a single examiner to control and increase the internal reliability of the examiner in the repetitive measurements before and after walking training [27] .

Spinal alignment

A spinal structure analysis system (Formetric 4D, Diers International GmbH, Germany) was used to measure the spinal alignment of the subjects. The spinal structure analysis system analyzes and diagnoses the structure of the vertebrae in a four-dimensional manner in the static and dynamic states without radiation exposure. Markers are attached to both shoulders to compare and analyze the slopes of the shoulders and pelvises, and this machine can be used for the analysis of spinal changes after exercise therapy and for the analysis of musculoskeletal disorders [28]. Also, the instrument has been proven to be highly reliable and feasible when compared to radiation measurements [29].

For scanning, the subjects were instructed to take off their top garments, to turn their backs toward the camera of the measuring instrument, and then to lower their bottom garments until the tail bone was exposed. The distance between the spinal structure analysis system and the subject was set to 2 m, and the subject was told to relax the body with both arms naturally lowered and to look straight ahead during the measurement. The feet were fixed horizontally on the foot plate, and the knees were kept unbent. The error range of the model formed by the scanning is only about 0.05 mm, so the shape of the back surface could be accurately analyzed [30]. After analyzing the

Table 1. Arrangement of terms

Acronym	Terminology	Description
CP	Cervical Point	Intermediate location of C4 and C5 of the cervical vertebra
VP	Vertebra Prominens	C7 of the cervical vertebra
DL	Dimple Left	Left posterior superior iliac spine(PSIS)
DR	Dimple Right	Right posterior superior iliac spine(PSIS)
DM	Dimple Middle	Intermediate position of PSIS (DL-DR)
SP	Sacrum Point	Lower position of sacrum
CA	Cervical Apex	Vertex of cervical lordotic curve
KA	Kyphotic Apex	Vertex of thoracic kyphotic curve
LA	Lordotic Apex	Vertex of lumbar lordotic curve
ITL	Inflection Point Thoracic Lumbar	Inflection point of thoracic vertebra and lumbar vertebra
ILS	Inflection Point Lumbar Sacral	Inflection point of lumbar vertebra and sacrum

back surface, four anatomical points were automatically set. The anatomical results are obtained based on the morphology of the vertebrae and the pelvis according to the set values of the two dimples (left lumbar dimple: DL, right lumbar dimple: DR), the vertebra prominens (VP), and the sacrum Point (SP)(Table 1).

Data analysis

The data collected in this study were analyzed using SPSS Version 20.0 for Windows. The K-S test was used to prove normal distribution. A two-way repeated ANOVA was performed to compare the differences in the variables of muscle stiffness and spinal alignment according to the bag-carrying style and the timing. The significant differences between the pretests and posttests were examined by a paired sample T-test. Statistical significance was set at α = .05.

RESULTS

General characteristics of the subjects

The general characteristics of the subjects in this study are as follows (Table 2).

Table 2. General characteristics of the subjects

General characteristic	
Age (years)	21.30±2.96
Sex (Male/Female)	10/10
Height (cm)	167.20±6.61
Weight (kg)	64.92±9.65
RSP (cm)	5.54±.73

Values are shown as mean ± SD

Changes in muscle tone and stiffness

Table 3 shows the changes in muscle tone and stiffness of the upper trapezius muscle.

In the comparison of the frequency data obtained before and after walking with a bag, significant increases ($p < .05$) in muscle tone were found according to the timing in all three conditions, but no statistically significant difference was found in the interactions between the condition and the timing and between the conditions. In the comparison of the stiffness data obtained before and after walking with a bag, significant increases ($p < .05$) in muscle stiffness were found according to the timing in all three conditions, but no statistically significant difference was found in the interactions between the condition and the timing and between the conditions.

Table 4 shows the changes in muscle tone and stiffness of the pectoralis major muscle.

In the comparison of the frequency data obtained before and after walking with a bag, significant increases ($p < .05$) in muscle tone were found in all three conditions, but no statistically significant difference was found in the interactions between the condition and the timing and between the conditions. In the comparison of the stiffness data obtained before and after walking with a bag, none of the three conditions showed statistically significant differences in the interactions between the condition and the timing, according to the timing, and between the conditions.

Table 5 shows the changes in muscle tone and stiffness of the lower trapezius muscle.

In the comparison of the frequency data obtained before and after walking with a bag, significant increases ($p < .05$) in muscle tone were found according to the timing in all three conditions, but no statistically significant difference was found in the interactions between the condition and the timing and

Table 3. Changes in upper trapezius muscle frequency and stiffness

	Condition	Pre-test	Post-test		F	p
Frequency (Hz)	Backpack	15.77±3.09	16.95±3.19	condition	0.120	.887
	Shoulder bag	15.52±2.96	16.52±3.19	time	4.019	.047*
	Cross bag	15.60±3.13	16.85±3.15	condition*time	0.016	.984
Stiffness (N/m)	Backpack	291.85±85.11	324.65±85.75	condition	0.062	.940
	Shoulder bag	288.30±82.83	315.20±81.79	time	4.005	.048*
	Cross bag	288.25±79.78	319.93±82.80	condition*time	0.014	.986

Values are shown as mean ± SD
*$p < .05$; significant difference between pre- and post-test

Table 4. Changes in pectoralis muscle frequency and stiffness

	Condition	Pre-est	Post-test		F	p
Frequency (Hz)	Backpack	13.38±1.56	14.12±1.83	condition	0.140	.870
	Shoulder bag	13.65±1.69	14.21±1.77	time	4.281	.041*
	Cross bag	13.59±1.75	14.26±1.83	condition*time	0.029	.987
Stiffness (N/m)	Backpack	221.90±56.84	238.10±62.06	condition	0.077	.926
	Shoulder bag	226.40±57.17	235.95±60.77	time	1.371	.244
	Cross bag	228.65±59.94	241.45±62.98	condition*time	0.031	.970

Values are shown as mean ± SD
*p<.05: significant difference between pre- and post-test

Table 5. Changes in lower trapezius muscle frequency and stiffness

	Condition	Pre-test	Post-test		F	p
Frequency (Hz)	Backpack	16.81±2.78	15.47±2.67	condition	0.115	.891
	Shoulder bag	17.11±3.42	15.77±2.77	time	5.381	.022*
	Cross bag	16.71±2.96	15.71±2.68	condition*time	0.045	.956
Stiffness (N/m)	Backpack	320.70±84.66	287.35±75.65	condition	0.069	.933
	Shoulder bag	323.70±82.95	297.70±76.36	time	4.186	.043*
	Cross bag	324.70±93.52	292.48±74.82	condition*time	0.024	.977

Values are shown as mean ± SD
*p<.05: significant difference between pre- and post-test

between the conditions. In the comparison of the stiffness data obtained before and after walking with a bag, significant decreases ($p < .05$) in muscle stiffness were found according to the timing in all three conditions, but no statistically significant difference was found in the interactions between the condition and the timing and between the conditions.

Changes in spinal alignment

(Table 6) shows the changes in spinal alignment before and after the treadmill training with a bag by condition.

No significant effect was found in the interactions between the condition and the timing for all bag types, and no main effect of the condition appeared in any of the variables either. For the main effect of timing, the dimple distance in the cross-bag condition was significantly reduced in the posttest compared to that in the pretest ($p < .05$).

DISCUSSION

This study aimed to investigate the effects of various bag-carrying styles on the muscle stiffness and spinal alignment of male and female subjects in their 20s with RSP during treadmill walking.

Muscle fatigue occurs when an extreme muscle strength exercise is continuously performed in daily life, and the accumulation of muscle fatigue induces myotonia, where muscles become hardened. A myotonia-related involuntary contraction occurs in the form of dystonia and myotonic developmental disorder, and muscle stiffness results from the accumulation of such myotonic conditions [31].

In a previous study, the shorter the pectoralis minor muscle length, which is one of the causes of rounded shoulders, reported that the muscle activities of the upper trapezius and the pectoralis major muscles increased [32]. In the present study, significant increases in the muscle tone of the upper trapezius and the pectoralis major muscles were observed in the posttest for all bag types compared to that in the

Table 6. Comparison of spinal alignment changes according to intervention

	Condition	Pre	Post		F	p
TL (mm)	Backpack	464.30±48.67	450.05±42.79	condition	0.545	.581
	Shoulder bag	459.30±50.38	452.65±24.51	time	0.813	.369
	Cross bag	466.30±48.84	464.95±49.49	condition*time	0.207	.813
DD (mm)	Backpack	99.45±12.93	98.00±12.52	condition	1.026	.362
	Shoulder bag	99.60±12.52	96.05±14.89	time	4.174	.043*
	Cross bag	99.80±13.55	89.15±16.94†	condition*time	1.188	.308
TC (°)	Backpack	39.95±10.23	36.35±7.05	condition	0.186	.830
	Shoulder bag	37.60±10.60	39.55±8.61	time	0.022	.883
	Cross bag	38.95±10.53	39.85±8.26	condition*time	1.002	.370
TB (°)	Backpack	9.85±8.37	12.15±11.74	condition	0.715	.491
	Shoulder bag	10.00±8.09	14.85±11.38	time	1.607	.207
	Cross bag	10.30±8.93	9.60±5.87	condition*time	0.895	.412
PT (°)	Backpack	2.70±1.78	2.95±3.54	condition	0.200	.819
	Shoulder bag	2.50±2.39	2.75±3.30	time	1.425	.235
	Cross bag	2.35±2.30	3.70±3.21	condition*time	0.504	.606
KA (°)	Backpack	38.10±9.83	36.35±7.05	condition	0.590	.556
	Shoulder bag	37.60±9.52	39.55±8.61	time	0.049	.825
	Cross bag	38.95±10.53	39.85±8.26	condition*time	0.445	.642
K12 (°)	Backpack	30.90±9.39	28.70±7.99	condition	0.966	.384
	Shoulder bag	32.40±10.38	32.55±7.77	time	0.113	.737
	Cross bag	31.60±10.45	32.00±7.14	condition*time	0.257	.774
LA (°)	Backpack	34.35±9.01	31.95±10.86	condition	0.436	.648
	Shoulder bag	34.30±8.92	33.90±10.58	time	0.279	.598
	Cross bag	35.35±11.09	35.20±10.45	condition*time	0.146	.864
S+ (°)	Backpack	5.45±3.92	4.85±4.04	condition	0.103	.903
	Shoulder bag	6.15±4.14	5.00±4.83	time	1.494	.224
	Cross bag	5.85±4.41	4.75±4.11	condition*time	0.051	.950
S− (°)	Backpack	3.93±2.07	4.05±2.56	condition	0.099	.906
	Shoulder bag	4.30±2.45	4.10±3.07	time	0.067	.797
	Cross bag	4.15±2.32	3.85±2.25	condition*time	0.091	.913
LD (mm)	Backpack	5.20±4.45	5.15±5.85	condition	0.178	.837
	Shoulder bag	5.05±4.55	6.55±6.81	time	0.374	.542
	Cross bag	4.95±4.65	5.35±6.32	condition*time	0.208	.812

Values are shown as Mean ± SD
*p<.05; significant difference between pre– and post–test
TL: trunk length, DD: dimple distance, TC: trunk inclination, TB : trunk imbalance, PT : pelvic tilt, KA: kyphotic angle(°), K12: kyphotic angle, T12(°),
LA: lordotic angle, S+ : surface rotation(max+) S−: surface rotation (max−),
LD: lateral deviation(㎜)

pretest. However, in the comparison of muscle stiffness between the pretest and the posttest, a significant increase in the muscle stiffness of the upper trapezius muscle was observed according to the timing, but not in the pectoralis major muscle. These results suggest that weight itself, regardless of the bag type, induced RSP even further in adults in their 20s with preexisting RSP. Considering that the muscle tone of the pectoralis major muscle increased, but its muscle stiffness was not significantly affected, it appears that the pectoralis major muscle does not have as much of a direct effect on RSP as the pectoralis minor muscle does.

In addition, in the comparison of the data obtained in the pretest and the posttest, significant decreases in the muscle tone and stiffness of the lower trapezius muscle were observed in all bag types according to the timing. The results of the present study showing an increase in the muscle stiffness of the upper trapezius muscle and a decrease in the muscle stiffness of the lower trapezius muscle are consistent with the results of the study by Cools et al. (2007) [33], which showed that shortening of the upper trapezius muscle and weakening of the lower trapezius muscle caused imbalanced scapula muscles.

In the comparison of the changes in spinal alignment according to the bag type, the dimple distance significantly decreased in the cross-bag condition according to the timing. The dimple distance refers to the straight line distance between the two PSISs of the iliac crest; thus, this result indicated that the dimple distance was shorter in the posttest than in the pretest in the cross-bag condition. Ahn (2006) reported no significant difference in the full range of torso and pelvic rotational movements during unilateral weight loading, but a statistically significant difference in the rotational angle was observed. This was interpreted as an indication of no significant difference in the overall amount of joint movement during walking with a unilateral weight load, but more asymmetric posture was induced during walking compared to the normal walking condition [2].

Except for the dimple distance in the cross-bag condition, no significant differences were found in other variables for the interactions between the condition and the timing, the main effect of the condition, and the main effect of the timing. These results are consistent with a previous study showing that when a bag was worn on both shoulders, no change in the side slope of the trunk was seen due to the same load being applied to both shoulders [34]. Im et al. (2009) investigated the effects of the bag type on body alignment in male and female subjects in their 20s and 30s and did not find any significant difference in the trunk angle [35].

The present study showed that when wearing a backpack, the participants adjusted their body's center of gravity forward in response to the weight applied backward, and the spinal alignment was changed accordingly. In the same way, wearing the shoulder bag and the cross bag also changed the spinal alignment corresponding to the center of gravity applied; thus, changes in spinal alignment were similar in all conditions, and as a result, no significant intercondition differences were apparent. Therefore, the results of the present study suggest that the effects of various bag-carrying methods on the spinal alignment of the subjects are not significantly different except for the dimple distance.

With the increased prevalence of RSP in modern people, many suffer from musculoskeletal pain, such as lower back, shoulder, and neck pain. Causes of these symptoms can vary, but improperly worn bags may also be a cause. Long-term or habitually wearing a bag in the wrong way may apply abnormal stress on our bodies, which can lead to musculoskeletal problems, such as scoliosis or myalgia.[36] When weight is applied on one side, humans tend to unconsciously tilt the body toward the other side in an attempt to equilibrate the external load and to position the center line at the center of the basal plane.[37] Therefore, if the shape of the bag, the bag-carrying method, or the position of the bag is incorrect, it may cause abnormal posture and affect the musculoskeletal system, causing pain and spinal disorders [4].

Many previous researchers have reported that proper shoulder posture generates balance in the skeletal system and minimizes upper body stress and tension. Maintaining a neutral position through spinal alignment can reduce the burden of poorly positioned vertebrae, the thoracic spine, and scapular postures and activate deeper postural muscles that help us maintain functional postures [38, 39].

CONCLUSION

This study aimed to investigate the effects of treadmill walking while wearing three widely used types of bags, a backpack, cross bag, and shoulder bag, on the muscle tone and stiffness and spinal alignment on young adults with RSP. These shoulders-area muscles (the upper trapezius, pectoralis major, and lower trapezius) are likely to be affected by bag wearing.

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