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Effects of Adjusting Backpack Shoulder Stabilizers on Psychological Responses and Autonomic Nerve Activity in Hiking

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Abstract

Purpose: There have been many studies on the effects of different types of backpacks on posture from a biomechanical perspective and on the center of gravity. Considering the effects of autonomic nervous system activity and mood associated with backpacks in mountaineering and hiking, research is also needed from a psychological perspective. In this study, the effects of adjusting the backpack shoulder stabilizer were preliminarily tested in terms of subjective fatigue and changes in autonomic nervous activity after hiking. **Methods:** The experimental 15 healthy participants hiked the mountain under two conditions: 1) without adjusting the stabilizer, a feature of the backpack (NAH condition), and 2) with the stabilizer adjusted (AH condition). First, all participants hiked the mountain in the NAH condition, and after a 30-minute break, they began the hike in the AH condition after confirming that a) their heart rate had recovered and b) they were in good physical condition. **Results:** HR was significantly lower after each hiking session than during the session. RMSSD was significantly lower pre-AH and post-AH than the NAH condition, but there was no significant difference between the NAH condition and either post-NAH or post-AH. Additionally, RMSSD was significantly lower in the AH condition than pre-AH or post-AH. The shoulders and back were significantly more burdened in the NAH condition than in the AH condition. The pleasure level was significantly higher in the AH condition than in the NAH condition. **Conclusion:** The results showed that also adjusting the position of the waist belt when adjusting the shoulder stabilizer, which is mainly used for the neck and shoulders, has a significant positive effect on the subjective burden on the upper body and parasympathetic nervous system activity after hiking.

Keywords

Shoulder Stabilizer, Autonomic Nervous System, RMSSD, Pleasure Level

1. Introduction

Since the spread of the new coronavirus, an increased number of young and middle-aged individuals have been participating in light- and moderate-intensity hikes. This increase is due to the lifting of behavioral restrictions, increased demand for domestic tourism, reopening of closed mountain lodges, an increasing number of people visiting frequently visited mountains, and a heightened focus on healthy behaviors and exercise. In particular, low mountains and satoyama, which are well-known to many people, are attracting attention and gaining a reputation for being easy to hike. However, the National Police Agency reported that the number of people lost to the mountains in 2022 was a record high at 3506 [1]. For example, while only a few dozen people were lost in 3000-meter summits such as Mt. Fuji (Shizuoka and Yamanashi Prefectures) and Mt. Hotaka (Nagano Prefecture), more than 100 people were lost on Mt. Various reasons exist for increased hiking, such as making meaningful use of leisure time, acquiring exercise habits to prevent lifestyle-related diseases, and maintaining and improving physical and mental health. However, it is important to prevent accidents and disasters by taking care of one's physical condition before climbing (hike), having a climbing (hiking) plan appropriate for one's physical strength, and checking the equipment [2].

Although the size of the equipment varies depending on the height of the mountain and the season, even in low mountains, people carry water, light meals, a change of clothes, and so on. The greater the capacity and weight of the backpack, the greater is the burden on the shoulders. Studies on backpacks have shown that slimmer users are more likely to experience uncomfortable pressures from shoulder straps and hip belts [3]. One method for relieving shoulder strain is to use backpack shoulder stabilizers. In backpacks equipped with top straps and hip belts, the position of the backpack was first secured and constrained with respect to the waist using a hip belt. The load on the backpack was then shifted from the shoulders to the hips by adjusting the shoulder straps and tightening the stabilizers. This shift to the hips improves the stability of the center of gravity and reduces the burden on the body because the stabilizers pull the center of gravity of the backpack toward the body's center of gravity. The importance of these points is introduced by various brands and manufacturers of climbing (hiking) and mountaineering equipment as "How to size and fit a backpack" [4]-[6].

Several studies have been conducted on the effects of different types of backpacks on posture from a biomechanical perspective [7] and on the center of gravity [8] [9].

The neck (midbrain, pons, and medulla oblongata) contains the parasympathetic nervous system, which is an autonomic nervous system [10], while the trapezius muscle, which is a neck muscle that is strained by backpacks, is parasympathetically innervated [11]. The parasympathetic nervous system, which is known as the "relaxation nerve" because it is a network that extends from the neck to the whole body, is a nerve that is activated when the body is recovering. If the neck, which is the base of this network, is strained, it will have a negative effect on the parasympathetic nervous system and cause various physical problems.

Considering the effects of autonomic nervous system activity and mood associated with backpacks, research is also needed from a psychological perspective, and not just a kinematic perspective, even in mountaineering and hiking. Light mountain climbing and forest bathing have positive effects on the body and mind. For example, the acute effects of a 3-hour green exercise intervention (mountain walking) on stress-related physiological responses have been analyzed. The results indicated that 3 hours of hiking indoors (treadmill) or outdoors (green exercise) resulted in decreased salivary cortisol levels and an ameliorative effect on stress. However, no effects on blood pressure or heart rate variability were found [12]. By contrast, Brito (2022) [13] reported that walking sessions conducted in green environments elicited greater benefits for heart rate variability (HRV) than those in suburban environments. However, walking in either a green or suburban environment reduced systolic blood pressure. The HRV results for hikers also differ depending on certain factors. While several studies have shown the psychological effects of light hikes, these studies varied regarding pack carrying and did not adjust for carrying positions or stabilizers. As backpack performance has improved, it has become easier for people who do not regularly hike mountains to engage in light hikes with luggage. When hiking mountains, the effects of adjusting backpacks and stabilizers on psychological and physiological responses must be checked, and basic data must be accumulated to help maintain physical condition and prevent injuries while hiking.

In this study, the luggage weight was controlled at 15% of the body weight [14] [15], and the effects of adjusting the backpack shoulder stabilizer were preliminarily tested in terms of subjective fatigue and changes in autonomic nervous activity after hiking.

2. Methods

2.1. Participants

There were 15 healthy participants in this study, 10 males and 5 females, between the ages of 20 and 55 (mean age 29.9 ± 13.7 years). We excluded participants from taking part in the study if they had an illness or were taking medication. The Medical Research Ethics Review Committee of the Kyoto University of Advanced Science approved the study protocol. Verbal and written informed consent were obtained from each participant.

2.2. Procedures

The experimental participants hiked the mountain under two conditions, 1) without adjusting the stabilizer, a feature of the backpack (NAH condition), 2) with the stabilizer adjusted (AH condition) using Tellus 35 backpack (© THE NORTH FACE, A VF COMPANY). First, all participants hiked the mountain in the NAH condition (50 minutes), and after a 30-minute break, they began the hike in the AH condition (50 minutes) after confirming that 1) their heart rate had recovered and 2) they were in good physical condition (**Figure 1**).

The following is a description of how the backpack was adjusted.

1) All straps were loosened once.

2) The compression straps on the sides of the backpack were tightened so they were not loose.

3) The waist belt strap was tightened so that it wrapped around the hips. The waist belt should carry 70% - 80%—the weight of the backpack weight.

4) The straps on both sides of the backpack were adjusted by gently pulling the straps to fit snugly so that the weight of the backpack did not feel too heavy on the shoulders.

5) The stabilizers (straps at the top of the shoulder harness (shoulder area)) were gently pulled using the thumb and forefinger. Adjusting the stabilizers prevents the backpack from swaying side-to-side and allows the body to make fewer unnecessary balancing adjustments when hiking.

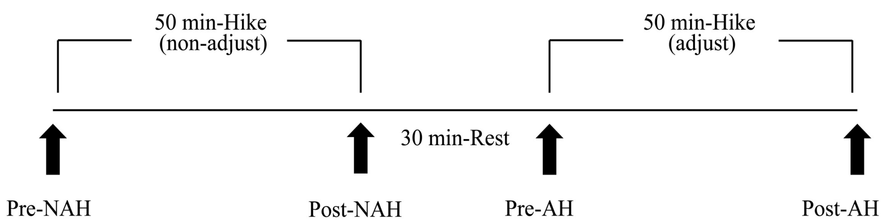

Figure 1. Experimental design in the present study.

2.3. Autonomic Nerve Activity Parameters

The data were transmitted via Bluetooth to an iPhone application (HR Variability Logger) [16] [17]. HRV data were acquired during the experiment using a Polar H10 heart rate sensor, which was placed around the solar plexus. Autonomic nervous system activity was analyzed using Kubios HRV Version 3.5 (Version 2.1, University of Eastern Finland, Kuopio, Finland) based on the RR interval of the ECG. Autonomic nervous system activity was examined based on the parasympathetic nervous system activity, which is measured using the RMSSD value, a widely used statistic that can be calculated reliably and with minimal influence from the respiratory rate [18] [19].

Under each condition, participants measured their resting heart rate for 3 minutes in a seated position before the mountain walk (Pre-NAH, Pre-AH). Data were then measured during 50 minutes of each mountain walk, including the two breaks to rehydrate (5 minutes per break, 10 minutes total) (NAH and AH conditions). The rest period between the conditions was 30 minutes, and participants in the AH condition began the hike after confirming that 1) their heart rate had recovered and 2) they were in good physical condition. After each mountain walk, the resting heart rate was measured in the sitting position for 3 minutes (Post-NAH, Post-AH). Each record was analyzed to detect the possible presence of artifacts and anomalous beats with the corresponding filters applied, if required.

2.4. Psychological Measurements

The participants were asked to record their psychological measurements at the end of each condition (Post-NAH and Post-AH). Psychological measurements included a subjective fatigue assessment, the Borg Rating of Perceived Exertion Scale, and a two-dimensional mood scale. Subjective fatigue was rated on an 11-point scale from 0% to 100% based on how much strain was placed on the shoulders, back, thighs, and calves, and the perceived heaviness of the weight of the backpack. Perceived exertion was measured using the Borg Rating of Perceived Exertion Scale (RPE) [20], which ranges from 6 (very light) to 20 (very hard). Mood was measured using a two-dimensional mood scale (TDMS) [21] [22] comprising four levels: Pleasure, Arousal, Vitality, and Stability. The TDMS comprises eight items that participants rate on a 6-point scale ranging from 1 (not at all) to 6 (extremely).

2.5. Statistical Analysis

A total of 15 participants were included in the analyses. Heart rate was calculated as the average for each condition (for Pre-NAH, NAH, Post-NAH, Pre-AH, AH, and Post-AH). The heart rate for each condition was calculated by subtracting each time point (during the condition minus the pre-NAH measurement). The average salivary cortisol levels were calculated at each time point. The average subjective fatigue, mood factor, and RPE were also calculated for each condition (NAH and AH condition).

We conducted a one-way analysis of variance (ANOVA) with HR and RMSSD as dependent variables (within-subjects design by time point: NAH/Post-NAH/Pre-AH/AH/Post-AH).

We also conducted separate t-tests for each subjective fatigue measure, average mood factor, and RPE as the dependent variables with condition as the within-subjects variable by condition (NAH/AH). SPSS21.0J (IBM Corp., Armonk, NY, USA) was used for the data analysis. Regarding the results of the statistical analysis, a risk ratio of 5% or less was considered a significant difference.

3. Results

3.1. HR and RMSSD

Table 1 shows the differences in HR and RMSSD at each time point. The one-way ANOVA for the HRV showed a significant effect for time point [$F(4, 52) = 19.056$,

$p < 0.001$, $\eta = 0.224$]. Multiple comparisons revealed that the HRV was significantly lower after each hike session than during the session.

Regarding the parasympathetic activity results, the one-way ANOVA for RMSSD showed a significant effect for the time point [$F(4, 52) = 5.781$, $p < 0.001$, $\eta = 0.106$]. Multiple comparisons showed that the RMSSD was significantly lower pre-AH and post-AH than that in the NAH condition, but there was no significant difference between the NAH condition and either post-NAH or post-AH. Additionally, the RMSSD was significantly lower in the AH condition than in the pre-AH or post-AH conditions.

Table 1. Differences in HRV and RMSSD at each time point.

	Time point	Mean N	(SD) = 15	F(df, error), p, η	Multiple comparisons
HR	NAH	38.323	(10.546)	$F(4, 52) = 19.056$, $p < 0.001$, $\eta = 0.224$	NAH vs Post-NAH**, Pre-AH**, Post-AH**
	Post-NAH	15.127	(15.936)		Post-NAH vs Pre-AH***, AH***
	Pre-AH	0.955	(15.852)		Pre-AH vs AH***, Post-AH***
	AH	39.013	(17.665)		AH vs Post-AH***
	Post-AH	17.729	(15.493)		
RMSSD	NAH	38.323	(10.546)	$F(4, 52) = 5.781$, $p < 0.001$, $\eta = 0.106$	NAH vs Pre-AH**, Post-AH***
	Post-NAH	15.127	(15.936)		Post-NAH vs Pre-AH**
	Pre-AH	0.955	(15.852)		Pre-AH vs AH***
	AH	39.013	(17.665)		AH vs Post-AH**
	Post-AH	17.729	(15.493)		

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

3.2. Psychological Responses

Table 2 shows the differences in psychological responses post-NAH and post-AH. Feeling about the weight of the backpack [$t(14) = 3.121$, $p < 0.001$, $d = 0.806$] was significantly heavier in the NAH condition than in the AH condition. Similarly, the shoulders [$t(14) = 3.062$, $p < 0.05$, $d = 0.791$] and back [$t(14) = 2.414$, $p < 0.05$, $d = 0.623$] were significantly more burdened in the NAH condition than in the AH condition. There were no significant differences between the NAH and AH conditions for the thighs, calves, and RPE. Finally, the pleasure level [$t(14) = 2.190$, $p < 0.05$, $d = 0.566$] was significantly higher in the AH condition than in the NAH condition.

4. Discussion

This study examined the effects of a backpack stabilizer on psychological responses and autonomic nervous system activity. Specifically, we set up two hike conditions: one without adjustment of the stabilizer function of the backpack (NAH condition) and one with adjustment (AH condition). We compared and verified psychological indicators (subjective fatigue, mood, and exercise intensity)

Table 2. Differences in psychological responses post-NAH and post-AH.

Scale	Time point	Mean N	(SD) = 15		*t* (df), p, *d*
RPE	Post-NAH	12.60	(4.09)		$t(14) = 1.656$, *n.s.*, $d = 0.428$
	Post-AH	10.53	(3.64)		
Subjective fatigue					
weight of the sack	Post-NAH	50.67	#####		$t(14) = 3.121$, $p < 0.001$, $d = 0.806$
	Post-AH	24.00	#####	***	
shoulders	Post-NAH	46.00	#####		$t(14) = 3.062$, $p < 0.05$, $d = 0.791$
	Post-AH	20.67	#####	*	
back	Post-NAH	40.67	#####		$t(14) = 2.414$, $p < 0.05$, $d = 0.623$
	Post-AH	18.67	#####	*	
thighs	Post-NAH	48.00	#####		$t(14) = 1.340$, *n.s.*, $d = 0.346$
	Post-AH	36.00	#####		
calves	Post-NAH	47.33	#####		$t(14) = 1.019$, *n.s.*, $d = 0.263$
	Post-AH	36.00	#####		
TDMS					
Vitality level	Post-NAH	1.67	(3.18)		$t(14) = 1.372$, *n.s.*, $d = 0.354$
	Post-AH	2.73	(3.58)		
Stability level	Post-NAH	0.93	(2.60)		$t(14) = 1.921$, *n.s.*, $d = 0.496$
	Post-AH	3.00	(4.23)		
Pleasure level	Post-NAH	2.60	(4.15)		$t(14) = 2.190$, $p < 0.05$, $d = 0.566$
	Post-AH	5.73	(7.37)	*	
Arousal level	Post-NAH	0.73	(4.06)		$t(14) = 0.823$, *n.s.*, $d = 0.213$
	Post-AH	−0.27	(2.63)		

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

and physiological indicators (autonomic nervous system activity) during each 50-minute hike. No significant differences were observed between the two conditions in terms of HRV, RMSSD, and RPE. This finding suggests that the exercise intensities in the two conditions were similar. In addition, HRV values during each condition were significantly higher than those before or after each condition. In contrast, the RMSSD values for each condition were significantly lower than those before AH. Furthermore, RMSSD increased significantly during the 30 minutes between after NAH and before AH. This result indicates that regardless of the conditions for adjusting the stabilizer, the heart rate increased during hiking, and the parasympathetic nervous system activity was suppressed. After hiking, the heart rate decreased and the parasympathetic nervous system activity increased. This is a typical response during acute exercise [23]-[25]. Furthermore, the fact that the pre-AH value was very close to 0 suggests that the AH condition performed after pre-NAH was almost the same as that performed post-NAH. In contrast, although RMSSD increased significantly after AH compared to during AH, it did not increase significantly after NAH compared to during NAH. This indicates that the parasympathetic nervous system may recover faster in the AH condition than the NAH condition.

The muscles that hold the luggage remain in a state of tension. In particular, the neck and shoulders, which are home to many nerves, including sympathetic and parasympathetic nerves, can experience symptoms such as depression, dizziness, palpitations, and chronic fatigue. Such symptoms are due to abnormalities in the parasympathetic nervous system caused by poor blood flow [26] [27]. Adjusting the stabilizer increased shoulder range of motion. In addition, because the position of the waist belt was adjusted, balance at the center of gravity of the backpack may have been maintained. This change in balance may have resulted in improved blood flow to the shoulders during hiking and accelerated parasympathetic nervous system activity after hiking in the AH condition compared with the NAH condition.

The fact that fatigue in the upper body, including the shoulders and back, reduced can be attributed to the subjective evaluation of the sense of fatigue in the body. Shoulder strain is known to cause headaches [28]. The fact that shoulder stabilizers distribute part of the load in the direction of the body is thought to reduce subjective fatigue in the upper body because the vertical downward force on the shoulders is also distributed, while the ratio of the load on the lower back is simultaneously increased. In addition, shoulder stabilizers reduce the distance between the shoulders, hips (fulcrum), and backpack (point of force), thereby reducing the force of the backpack's attempt to rotate. Consequently, even when carrying the same weight, the hikers can hike in a more natural posture without having to compensate for the back of the backpack forcing them to lean forward, which is assumed to reduce the load on the hips, shoulders, and back. During physical fatigue, the function of the parasympathetic nervous system, which causes relaxation and healing, decreases [29]. In this study, the feeling the backpack weight was significantly higher in the NAH condition than in the AH condition. In addition, the shoulders and back were significantly more burdened under the NAH condition than under the AH condition. There was no significant difference between the NAH and AH conditions for the thighs and calves. Therefore, although a subjective fatigue-reducing effect was observed in the upper body, it was not observed in the lower body. Based on these results, we believe that adjusting the position of the waist belt when adjusting the stabilizer, which is mainly used for the neck and shoulders, has a significant positive effect on the subjective burden on the upper body and the parasympathetic nervous system after exercise.

Regarding the limitations of this study, although the waistbelt was adjusted while adjusting the stabilizer, the extent to which fatigue was reduced in each area could not be measured objectively. In addition, as this was a pilot study, experiments were conducted on a population of young and middle-aged adults, and the analysis was conducted with the assumption that autonomic nervous system activity is affected by age; however, the statistical significance of age could not be determined by the small sample size. Additionally, this study observed associations between shoulder stabilizer adjustment and subjective/physiological responses, but did not provide a clear physiological mechanism for these effects. Further research is required to confirm these results obtained in this study. In particular, research is needed to obtain objective data on the areas of the backpack that are under significant weight and to further consider confounding factors such as individual muscle strength, physical strength, sex, and age. This study examined only a single hike duration (50 min) and backpack weight (15% of body weight). The effects of subjective fatigue varied under different conditions. Particularly, during mountain hiking, the upper body tends to be more easily reflected in subjective fatigue. Therefore, under conditions of even higher exercise intensity, such as those affected by time, slope, and distance, the lower body may affect subjective fatigue. In addition, stabilizer adjustment did not reduce subjective fatigue in the lower body. The reduction in fatigue in the thigh muscles and calves may be related to other factors such as walking style, shoes, and the use of walking sticks suited to the individual's body. In this study, we did not provide information on walking style or control the use of hike shoes, as the aim was to verify the effects of stabilizers: the more often people hike, the more likely they are to have acquired information about how to walk and use hike shoes. Therefore, it is necessary to control for individual differences in hike experience, fitness level, and walking style, as these factors could influence both subjective fatigue and autonomic nervous system activity. In the future, it will be possible to clarify the effects of shoulder stabilizer adjustment when hiking by setting conditions that include these points in addition to shoulder stabilizer adjustment.

5. Conclusion

We believe that adjusting the position of the waist belt when adjusting the shoulder stabilizer, which is mainly used for the neck and shoulders, has a significant positive effect on the subjective burden on the upper body and parasympathetic nervous system activity after exercise. In particular, adjusting the shoulder stabilizer increased the shoulder range of motion. In addition, because the position of the waist belt was adjusted, balance at the center of gravity of the backpack may have been maintained. This change of balance may have resulted in improved blood flow to the shoulders during hiking and accelerated parasympathetic nervous system activity after hiking in the adjusted condition compared to the non-adjusted condition. However, although the waist belt was adjusted while adjusting the shoulder stabilizer, the extent to which fatigue was reduced in each area could not be objectively measured. Therefore, further research is needed to clarify the results obtained in this study. In particular, research is needed to obtain objective data on the areas of the backpack that are under significant weight and to further consider confounding factors such as individual muscle strength, physical strength, sex, and age.

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Conflicts of Interest

The authors hereby declare no potential conflicts of interest.

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