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Convergence of Comparison of Muscle Activities of Healthy Adults' trunk and Lower Extremities according to wearing/not-wearing and forms of backpack

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백팩 착용 유무 및 형태에 따른 건강한 성인의 몸통과 하지의 근 활성도 비교분석의 융합연구

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Abstract This study aims to compare muscle activities of trunk and lower extremities according to wearing/not-wearing and forms of backpack. Twenti-six healthy adults were participated in the study. In the backpack with 10% body weight, trunk and lower extremities were measured during carrying the no backpack state(NBs), general backpack state(GBs), a decrease moment arm backpack state(DMBs). The muscle activity in a fore muscles(Obilique, Quadriceps, Tibialis anterior, Gastrocnemius) were analyzed with using wireless electromyogram measuring system. DMBs showed significant improvemet in obilique, quadriceps and gastrocnemius muscle RVC

Key Words : Backpack, Convergence, Muscle activity, Lower extremity, Electromyography

요 약 본 연구의 목적은 건강한 대학생을 대상으로 백팩 착용 유무 및 형태에 따른 몸통·하지 근 활성도 변인들의 차이점을 규명하는데 그 목적을 두고 있다. 26명의 건강한 성인이 연구에 참여하였다. 백팩의 무게 10%로 부하된 상태에서, 백팩을 착용하지 않은 상태, 일반적인 백팩을 착용한 상태, 모멘트 팔을 감소시키도록 고안된 백팩을 착용한 상태에서 몸통과 하지의 근활성도를 측정하였다. 배빗근육, 넙다리네갈래근, 앞정강근, 장딴지근의 근 활성도 분석을 위해 무선근전도 시스템을 사용하였다. 모멘트 팔을 감소시키도록 고안된 백팩을 착용한 상태에서 배빗근육, 넙다리네갈래근 그리고 장딴지근의 보행 구간에서 RVC에 변화가 통계학적으로 유의한 차이를 보였다. 그러므로, 백팩을 주로 사용하는 성인들에게 가방끈 조절을 적용하는 방법은 몸통과 다리근육의 활성에 긍정적인 측면을 제공한다는 것을 나타내며, 추후 가방의 디자인과 착용방법에 대한 지속적인 가방융합개발이 필요할 것이다.

주제어 : 백팩, 융합, 근 활성도, 하지, 근전도

1. Introduction

Used as a means of transporting objects, backpack is one of the most comfortable bags for hikers, soldiers and students to move around with their objects[1]. Adhered to spine, backpack's load is

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known to be symmetrical and proper for walking. Recently, however, musculoskeletal system disorders have been shown in students using backpacks[2]. The American Academy of Pediatrics also reported that carrying overloaded backpacks for a longtime can damage muscle and joint, incur pains in back, neck and back, and cause changes in posture[3].

College students usually carry a bag for more than 30 minutes a day[4] with the average shoulder straps of board-loaded backpack weighting 10%[5].

In general, carring methods used by students are a 2 strapped or 1 strapped, a satchel, a shouler back and a handback[6-10].

Wearing backpack incurs a change in a properly aligned body. Walking and moving around with wearing backpack locate a center of gravity to the backside of the body, making the body leaned forward due to the reaction force[11]. Called, it causes muscular problems by incurring stress on trunk muscles. This is resulted from the shortening of upper muscle trapezius and neck extensor, and lengthening of neck hamstring[12]. These alignment changes from muscle imbalance cause pains near neck and increase pressure on spine, resulting in musculoskeletal system disorders[12,13].

In order to complement theses, recent studies are being conducted concerning bags. Li et al (2018), reported critical changes in trunk muscle activation and lumbosacral compression when walking around with backpack weighting 10% of body weight[14]. A test on soldiers showed that backpack weighting more than 34% of their weight incurred musculoskeletal system disorders around knee[15]. In the study of Al-Khabbaz et al, (2008) on 19 male university students, too, it showed an incremental activities of muscle rectus abdominis according to increasing backpack's weight by analyzing muscle activities when they wore backpacks of 0%, 10%, 15%, 20% weight of their body weight[16]. Spine angle, backache, trunk alignment, distribution of weight and reasons of posture change related to wearing backpacks have been reported[17-19].

While many studies on muscle activities, posture change and pains related to using backpack are ongoing, studies on its effects on trunk and lower extremities have been rarely done. In addition, stability and muscle activation of trunk and lower extremities muscle are important to prevent musculoskeletal system disorders caused by wearing backpack. Thus, this study aims to compare muscle activities of trunk and lower extremities according to wearing/not-wearing and forms of backpack.

The hypothesis of this study is that there will be a difference in muscle activities of trunk and lower extremities according to wearing/not-wearing and forms of backpack.

2. Materials and Methods

2.1 Participants

This study conducted an experiment on 26 healthy students of K university located in Gimcheon. The qualifications of subjects are following: 1) one aged from 18 to 28 (20 to 30 in Korean ages), 2) one who has never experienced neurologic and musculoskeletal system disorders or surgeries, 3) one who has no loss in knee and ankle joints and podiatric disorders, 4) one who has no difficulties in walking, and 5) Informed consent was voluntarily obtained from all patients before participating in the study.

The reasons for exclusion are as following: 1) one who has pains in neck, trunk and lower extremities, 2) one who has a severe change in spine, 3) one who has a limitation of wearing backpack, 4) one who is taking drugs that can affect the experiment, 5) one who had an orthopedic and neurologic disorder in lower extremities. The study received approval from the Institutional Review Board of Gimcheon

University(GU-201709-HRa-06-02). Table 1 indicate in the group mean and standard deviations for general characteristics of subject.

Table 1. General characteristics of subject (n=26)

Variables	Mean ± SD / N
Gander(male/female)	12/14
Age(y)	24.08 ± 1.49
Height(cm)	166.96 ± 8.13
Weight(kg)	64.96 ± 10.04

2.2 Outcome Measurements

2.2.1 EMG

This study used a wireless electromyogram measuring system(BTS FREEEMG 300, BTS Bioengineering, Italy) to measure muscle activity. This system stimulates peripheral nerves and detects bioelectrical signals or electric activities induced from nerves. For a display equipment, it used an 8g weight, signal to noise ratio (S/N): 96Db, MRR 110Db and measuring frequency of 1 Khz. When a participant starts to walk, electromyogram collects muscle activity as a sampling rate of 1 Khz per second and transmits it to computer through Wi-Fi. The collected information on various variables is processed with BTS EMG-Analyzer software. Analyzing muscle activity processed raw data to frequency bandwidth of 20-500 Hz[20-22]. For muscle, muscle activities of 1) abdominal oblique externus, 2) rectus femoris, 3) tibialis anterior, 4) gastrocnemius medial side were measured. It recorded means of root mean square, RVC) · symmetric index(SI) of each muscle in stance phase, and means·symmetric index in swing phase.

2.3 Procedure and Experiment Equipment

2.3.1 Procedure

Twenty-six healthy adults were participated in the study. In the backpack with 10% body weight, trunk and lower extremities were measured during carrying the no backpack state(NBs), general backpack state(GBs), a decrease moment arm backpack state(DMBs). This study measured muscle activity of oblique muscle for trunk muscle and quadriceps, Tibialis anterior and gastrocnemius for lower extremities when wearing or not wearing backpack. Using means of RVC which stands for trunk and lower extremities muscles and symmetric index shown in a stance phase and a swing phase, it conducted a comparative analysis by utilizing the means of same variables resulted from three trials. It also recorded common characteristics of the subjects before the experiment. Using a single blind method, this study conducted an experiment without explaining treatments, purposes, effects to participants.

2.3.2 Experiment Equipment

The backpack used in this study is 30cm width, 15cm length, and 45cm height. Straps are attached on the upper and each side of the backpack. Designed to reduce by locating it close to torso, the backpack followed a regular standard of backpack. Its straps are attached on

Table 2. Changes in oblique muscle

	NBs(A)	GBs(B)	DMBs(C)	F(P)	post-hoc
OStR	97.99 ± 35.57	121.01 ± 64.74	137.03 ± 80.98	4.865(0.017)	C>A,B
OStS	0.97 ± 0.23	0.99 ± 0.35	1.01 ± 0.34	0.508(0.608)	
OSwR	101.39 ± 39.88	133.59 ± 79.79	149.26 ± 94.92	6.172(0.007)	B,C>A
OSwS	0.95 ± 0.19	1.02 ± 0.37	1.03 ± 0.29	0.909(0.409)	

Values are Mean ± standard deviation, OStR: Obilique stance phase RVC, OStS: Obilique stance phase symmetry index, OSwR: Obilique swing phase RVC, OSwS: Obilique swing phase symmetry index.

the upper, sides, and the bottom of the backpack, which minimized the distance between backpack and torso.

2.4 Statistical analysis

This study analyzed data with SPSS version 21.0(SPSS Inc. Chicago, Illinois) program. Test of normality was carried by Shapiro-Wilk. For muscle activities according to wearing and not wearing of backpack, and different forms, it used a repeated measure ANOVA, and used a LSD for post-hoc test. The statistical significance level of all data was set under .05.

3. Results

3.1 Changes in oblique muscle

Comparison of RVC and symmetric index of oblique muscle depending on the three types of wearing backpacks while walking is shown in Table 2. DMBs showed a significance level more than NBs and GBs in oblique muscle RVC change in a stance phase, while DMBs and GBs showed a significance level more than NBs in oblique muscle RVC change in a swing phase.

3.2 Changes in quadriceps muscle

Comparison of RVC and symmetric index of quadriceps muscle depending on the three types of wearing backpacks while walking is shown in Table 3. DMBs and GBs showed a significance level more than NBs in quadriceps muscle RVC change in a stance phase, while DMBs showed a significance level more than GBs and NBs in quadriceps muscle RVC change in a swing phase.

Table 3. Changes in quadriceps muscle

	NBs(A)	GBs(B)	DMBs(C)	F(P)	post-hoc
QStR	275.20 ± 166.26	427.85 ± 371.74	479.37 ± 420.96	6.087(0.000)	B,C>A
QStS	0.93 ± 0.40	0.81 ± 0.38	0.86 ± 0.46	1.033(0.363)	
QSwR	212.69 ± 104.26	260.46 ± 172.47	299.09 ± 194.64	3.663(0.041)	C>A,B
QSwS	0.91 ± 0.33	0.93 ± 0.48	0.90 ± 0.46	0.121(0.886)	

Values are Mean ± standard deviation, QStR: Quadriceps stance phase RVC, QStS: Qquadriceps stance phase symmetry index, QSwR: Quadriceps swing phase RVC, QSwS: Quadriceps swing phase symmetry index.

Table 4. Change in Tibialis anterior

	NBs(A)	GBs(B)	DMBs(C)	F(P)	post-hoc
TStR	512.84 ± 197.22	533.86 ± 189.39	573.53 ± 220.04	2.506(0.092)	
TStS	1.00 ± 0.25	0.98 ± 0.28	0.94 ± 0.28	0.611(0.528)	
TSwR	450.55 ± 252.03	489.42 ± 232.03	519.51 ± 269.37	1.451(0.244)	
TSwS	0.95 ± 0.30	1.00 ± 0.23	1.01 ± 0.38	0.306(0.585)	

Values are Mean ± standard deviation, TStR: Tibialis anterior stance phase RVC, TStS: Tibialis anterior stance phase symmetry index, TSwR: Tibialis anterior swing phase RVC, TSwS: Tibialis anterior swing phase symmetry index.

Table 5. Change in gastrocnemius

	NBs(A)	GBs(B)	DMBs(C)	F(P)	post-hoc
GStR	948.56 ± 678.25	1194.47 ± 725.56	1193.27 ± 834.12	7.672(0.001)	B,C>A
GStS	1.36 ± 0.62	1.39 ± 0.81	1.46 ± 0.84	0.586(0.564)	
GSwR	599.34 ± 575.17	1128.73 ± 1202.77	1308.46 ± 1111.47	12.336(0.000)	B,C>A
GSwS	1.91 ± 2.56	2.02 ± 1.80	2.73 ± 2.83	2.244(0.117)	

Values are Mean ± standard deviation, GStR: Gastrocnemius stance phase RVC, GStS: Gastrocnemius stance phase symmetry index, GSwR: Gastrocnemius swing phase RVC, GSwS: Gastrocnemius swing phase symmetry index.

3.3 Change in Tibialis anterior

Comparison of RVC and symmetric index of tiblialis anterior muscle depending on the three types of wearing backpacks while walking is shown in Table 4. There showed a no significant difference among the three states.

3.4 Change in gastrocnemius

Comparison of RVC and symmetric index of gastrocnemius muscle depending on the three types of wearing backpacks while walking is shown in Table 5. DMBs and GBs showed a significance level more than NBs in gastrocnemius muscle RVC change in a stance phase and DMBs and GBs also showed a significance level more than NBs in gastrocnemius muscle RVC change in a swing phase.

4. Discussion

Many studies on balancing ability, walking ability and erector muscles of neck and spine according to backpack's weights, forms and location have been conducted. These studies stated that backpack's weight is properly distributed to sustain normal posture when the weight is under 10% of body weight[23].

This study conducted an analysis to examine muscle activities of trunk and lower extremities according to wearing and forms of backpack. The results of this study are following. First, DMBs and showed a significance level more than GBs and NBs in oblique muscle RVC change in a stance phase and quadriceps muscle RVC change in a swing phase. Secondly, DMBs and GBs showed a significance level more than NBs in oblique muscle RVC change in a swing phase, quadriceps muscle RVC change in a stance phase, gastrocnemius muscle RVC change in both a stance phase and a swing phase.

Front trunk muscles and spine erector muscle provide a stability of spine through reaction force when an outer pressure like backpacks is applied[24]. However, if methods of carrying bags are not proper, it can cause damage to muscle and bones due to disarrayed body condition, resulting in muscular imbalance. Thus, this study conducted an experiment to solve musculoskeletal system problems in back and legs and to suggest a proper backpack wearing forms[18,25,26]. While previous studies were centered to forms and weights of backpack due to changes in a way of life, this study additionally adjusted lengths of shoulder straps to change a center of gravity in body, making curves in waist to check electromyograms of trunk and legs.

Hong et al (2008) conducted an experiment with a hypothesis that muscle activities of abdominal and lower extremities will increase in order to sustain a backpack's weight exerted on the back when one wears a backpack. A center of gravity of backpack changes in accordance to locations of wearing backpack[27], and when one carries it with one shoulder or with one hand, a center of gravity is leaned toward one side, incurring imbalance in muscle activities of both rectus abdominis muscle and spine erector muscle[28,29].

In this study, DMBs showed a statistical significance level more than NBs and GBs in oblique muscle RVC change in a stance phase and in quadriceps muscle electromyogram RVC change in a swing phase. This result is same as the study of Al-Khabbaz et al (2008) on 19 male university students which showed an incremental activities of muscle rectus abdominis according to increasing backpack's weight by analyzing muscle activities when they wore backpacks of 0%, 10%, 15%, 20% weight of their body weight. As backpack is located behind of body, the body becomes leaned toward front as a reaction to the weight during walking and standing[11,16,30].

Through this forward leaning, it thinks that front muscles are being activated. Trunk curve increases shearing forces in spine and changes muscle tensions[31,32]. This increases pressure and shearing forces even more in spines, and adhering backpacks close to the lumbar by using shoulder straps distributes pressures on spine, ultimately reducing stress applied to muscles and soft tissues of backside of waist.

DMBs and GBs showed a statistical significance level more than and NBs in oblique, quadriceps, gastrocnemius muscle RVC change when walking. However, bilateral symmetry index of walking body showed no significant different in all three states. This corresponds to the study of Cho (2014) that showed an increase in muscle activities of muscle vastus lateralis and vastus medialis of quadriceps according to weights and locations of backpacks while climbing stairs[33]. In the study of Chow et al (2005) on 22 adolescent girls wearing backpacks of 0%, 7.5%, 10%, 12.5%, 15% weight of their body weight, increasing backpack's weight remarkably reduced walking speed and cadence and showed a noticeable change in proximal part, supporting this study[23]. It is thought that as two forms of wearing backpack both carries the backpack with shoulders, there showed no significant changes in both sides of muscular symmetry due to a difference in arm lengths. It was also because the study did not set a condition for not carrying backpack and measured the weight under level that can be effectively distributed.

The merit of the backpack used in this study is that its straps on the upper, sides, and bottom minimized a distance between backpack and torso, using it more effectively.

This study has some limitations. Firstly, the number of participants are small, and it could not check the longevity of the effects since it did not conduct a tracer study. Secondly, it is necessary to see changes in dynamic conditions according to weights and types of backpack. Third, the study could not know posture changes or pains according to the time of wearing backpack. Lastly, although it measured muscle activities of trunk and lower extremities, there should be an assessment on upper limb and neck areas. In the near future, it is need to study effects of epidemiological variables according to wearing and forms of backpack.

5. Conclusion

In order to examine an increase in healthy person's muscle activity of trunk and lower extremities, this study applied wearing and not wearing of backpack, and different forms of backpacks. As a result, it found out that there was a positive impact on the DMBs. Moreover, the state that can adjust shoulder straps of loaded backpack weighing 10% of their body weight showed a significant increase in muscle activity of trunk and lower extremities.

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