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Original Article

Influence of Load Carriage on the Gait Characteristics of the Obese

Checheong RYEW, *Seunghyun HYUN

Department of Kinesiology, College of Natural Science, Jeju National University, Jeju, Republic of Korea

***Corresponding Author:** Email: hshyun0306@jejunu.ac.kr

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Abstract

Background: Gait mechanism due to overloaded weight of the obese may be altered, but yet uncertain whether an added loaded weight on body weight can alter or not gait characteristics.

Methods: We applied with 0 kg (no load), 5 kg, 10 kg, and 15 kg of the load carriage respectively on the obese (n=11) to grasp a mechanism on the control of impact types and dynamic stability during gait. Gait characteristics was analyzed with three-dimensional cinematography and ground reaction force system consisted of a length of 1 stride, mean velocity of center of gravity during supporting phase, breaking force, propulsive force, dynamic posture stability index (DPSI), and extrapolated centre of mass (XCoM) respectively. We performed repeated measures one-way analysis of variance (0 kg, 5 kg, 10 kg, and 15 kg) and performed the post hoc test (Duncan) at (P<0.05) in case of significant level respectively.

Results: Onestride length and mean velocity were decreased according to gradual increase of a load carriage, but breaking and propulsive force were somewhat increased. Particularly a decrease of gait velocity and stride length kept the range for DPSI and XCoM theta of a level of no-load carriage.

Conclusion: Usually load carriage during prolonged time of the obese is few case, but rather a load carriage of 5 kg may alter a gait posture potentially with prolonged time of load carriage.

Keywords: Obese; Gait; Load; Dynamic stability; Extrapolated center of mass

Introduction

The obesity comes from mainly improper physical activity (1). The serious problems due to increase of disease rate has almost linear relation between overweight of body and instability of body posture (2), thus which increases a falling injuries including alteration of gait posture together (3, 4). Nevertheless, the obese performed hard locomotion with various load carriage in daily life and working environment frequently. It is unclear that how interaction relation by change of body weight and obesity alter the gait characteristics.

High rate of falling injuries observed on the obese is due to partially not only deficiency of instantaneous balancing ability but also mechanism of biomechanics and physiology when sliding was occurred between foot and ground surface (5). Also decrease of instability of the obese may be resulted from a delayed perception on the sliding by deficient sensitivity of the sole of a foot (4). While the obese showed higher vertical ground reaction force (GRF) than the normal when normalized (100%) by body weight (3). These characteristics of gait was due to mechanism to minimize or to re-control an ability on neuromuscular function adaptable on an overweight load and loading on lower leg (6).

Like the above, while previous mentioned studies reported a mechanism to decrease a gait stability of the obese, on the other hand, suggested possibility controllable an impact type properly. However, added weight to body weight alters center of gravity (COG) to forward position in direction of load carriage (7). That is, added weight to body weight is,

which may alter gait posture potentially, necessary to test over the various weight to overcome the limitation. Also the obese who is opened to high possibility of falling injuries, is required a specific treatment (8). Therefore clinical and therapist of exercise rehabilitation who do enough comprehension on the mechanism may be recommended a proper exercise program on the rehabilitation treatment and prevention of falling injury.
Therefore the aim of the study was to quantify the mechanism on gait and adaptation relative to various modification of weight applied to the obese.

Materials and Methods

Subjects

The obese male adult (n=11, mean age: 32.90±1.85 yr, mean height: 1.77±0.03 m, mean weights: 99.26±10.12 kg, mean body mass index: 31.50±3.15 kg/m^2) participated in the experiment. The participants informed to the researcher whether condition on one's abnormality on walking, neuro-muscular-skeletal system, and handicap of balancing etc. by individual judgment was or not. First of all, experiment was proceeded on experimental schedule after being explained and consented about the details on the range of the study.
The study consented detail was obtained and was conducted in accordance with the Declaration of Helsinki. The study protocol was approved by the Jeju National University Institutional Review Board, S. Korea.

Experimental procedure

Gait was progressed to pass through on GRF (AMTI-OR-7, Advanced Mechanical Technology Inc., Watertown, MA, USA) set up at mid-point of straight path of 10 m along with one's preferred velocity on condition of bare foot. Sampling rate was collected at 60 Hz. Then 4 camera (HDR/HDV 1980i, Sony Corp, Tokyo, Japan) set up in line with a diagonal direction of both GRF and subject and filmed 60 frame/sec. Body segment parameter for COG of whole body (9) were composed of 21 points was as follows; right/left toe, right/left heel, right/left lateral-medial malleolus, right/left shank, right/left lateral/medial epicondyle, right/left thigh, right/left anterior superior iliac spine, sacrum, right/left lateral-medial wrist, right/left lateral-medial elbow, right/left shoulder, chin, nose respectively. Experiment on load carriage positioned on front position of trunk was performed in order of 5 kg, 10 kg, 15 kg on each 3 times randomly, of which only successful 1 trial was selected for analysis. Total experiment time was elapsed about 13 and performed in a condition of 22-25 °C and 50-55% of humidity.

Experimental procedure

GRF variables for supporting phase were consisted of breaking and propulsive force, which the former meant 1st peak vertical force at initial touch-down, the latter meant 2nd peak vertical force after 1st PVF and normalize by body weight.

$MLSI = \sqrt{[\sum(0-x)^2}$/Number of data points]

$APSI = \sqrt{[\sum(0-y)^2}$/Number of data points]

$VSI = \sqrt{[\sum(body\ weight - z)^2}$ /Number of data points]

$DPSI = \sqrt{[\sum(0-x)^2 + \sum(0-y)^2 + \sum(body\ weight - z)^2}$/Number of data points]

DPSI (10) meant the higher an index value, the lower the stability and on the other hand, the lower an index value, the higher the stability. These indices mean square deviations assessing fluctuations around a 0 point, rather than SDs assessing fluctuations around a group mean. This is done to normalize the vertical scores among individuals with different body weights (mass). The DPSI is a composite of the MLSI, APSI, and VSI and is sensitive to changes in all 3 directions (10).
Appropriate stable area was evaluated with position of medial-lateral COM projected in dynamic situation and COM position and velocity (*dx*/*dt*) supporting phase using XCOM (11).

$$\omega_0 = \sqrt{g/h}$$

$$XCOM = x\ (i) + (1/\omega_0) \cdot (dx\ /dt)$$

$$XCOM\theta\ (i) = \tan^{-1}(X\ (i) - x1\ (i), Z\ (i) - z1\ (i))$$

Nomenclature for XCOM
ω_0 = pendulum eigen frequency

g = acceleration of gravity 9.81 m/s^2
h = effective height of the body COM above the floor=1.34l
$x\ (i)$ = lateral position of COM
$X\ (i), Z\ (i)$ = vertical and lateral position of COM
$x\ (i), z\ (i)$ = vertical and lateral position of COP
The average and the standard deviation on the calculated variables were obtained using PASW 21.0 program SPSS Inc., (Chicago, IL, USA), and was performed repeated measures one-way analysis of variance and performed the post hoc test (Duncan) at (*P*<0.05) in case of significant level respectively.

Results

Kinematic and kinetic variables on preferred gait velocity relative to change of load carriage was as Table 1. One stride length and walking velocity gradually were decreased relative to increase of load carriage, and was significant (*P*<0.05). Difference between breaking and propulsive force relative to increase of load carriage existed and was significant (*P* <0.01) (Fig. 1). DPSI and XCoM theta relative to increase of load carriage did not show difference, and was not significant (Fig. 2).

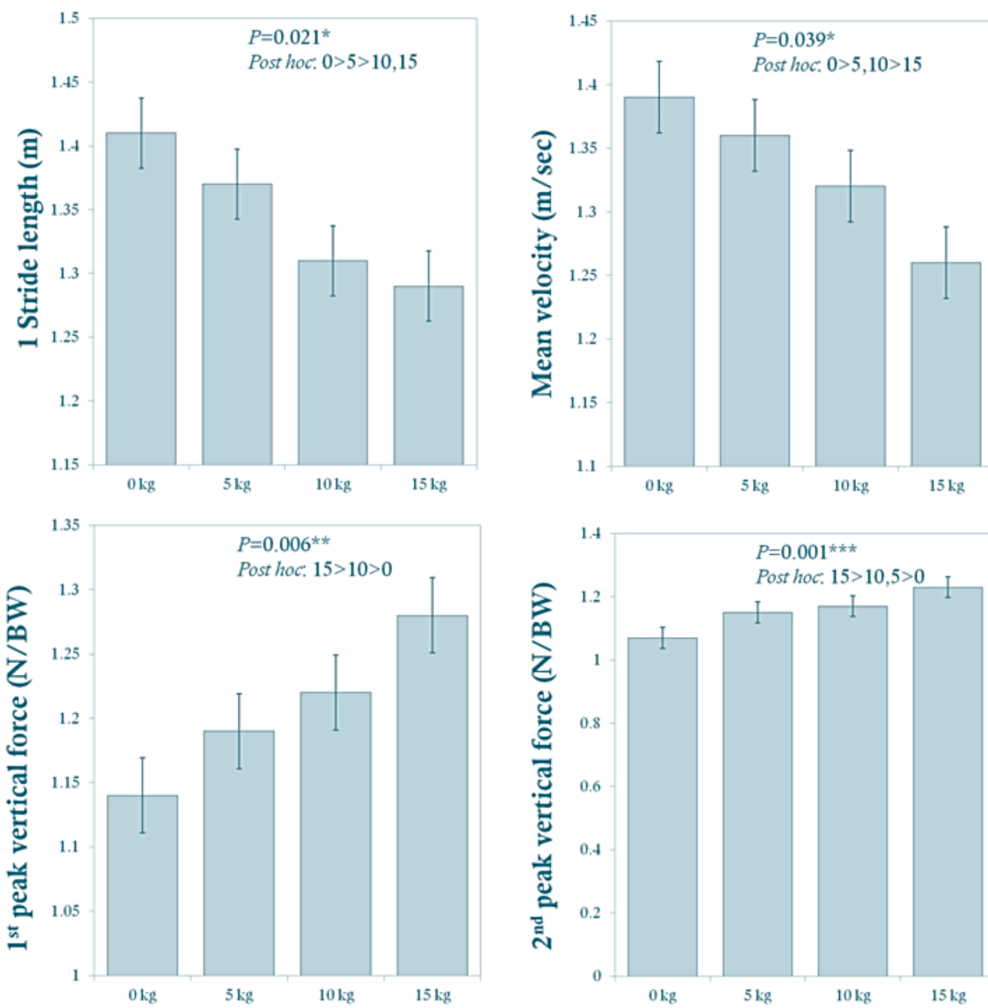

Fig. 1: Results of kinematic and GRF variables

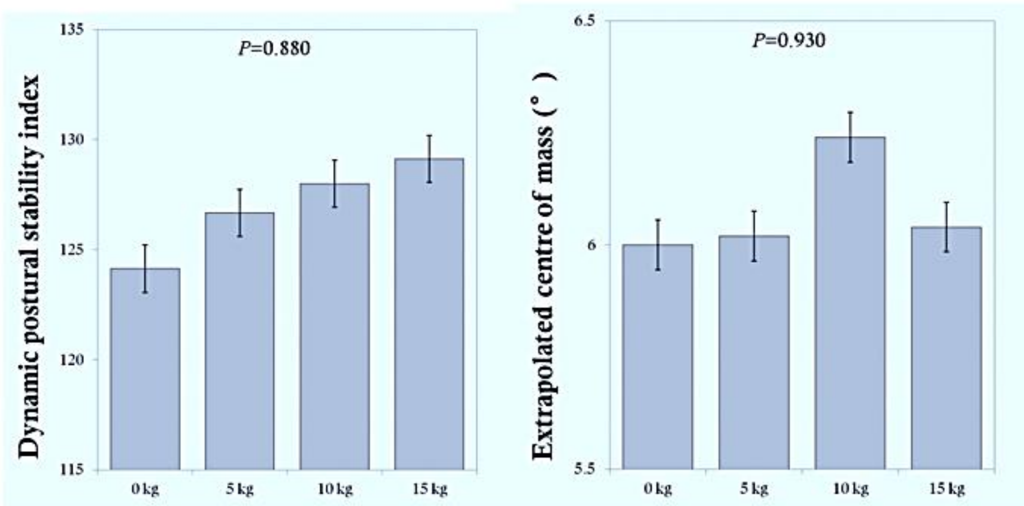

Fig. 2: Results of DPSI and XCoM

Table 1: Results of kinematic and kinetic variables according to the change of load during walking

Section	*Load carriage (kg)*				*F*	*P*	*Post-hoc*
	No load	*5 kg*	*10 kg*	*15 kg*			
1 Stride length (m)	1.41±0.14	1.37±0.07	1.31±0.06	1.29±0.07	3.807	0.021*	0>5>10, 15
Mean velocity (m/sec)	1.39±0.10	1.36±0.08	1.32±0.10	1.26±0.11	3.214	0.039*	0>5, 10> 15
1 st peak vertical force (N/BW)	1.14±0.07	1.19±0.13	1.22±0.13	1.28±0.21	5.243	0.006**	15, 10>0
2 nd peak vertical force (N/BW)	1.07±0.02	1.15±0.06	1.17±0.04	1.23±0.05	32.161	0.001***	15>10, 5>0
Dynamic postural stability index	124.14± 16.55	126.68± 9.05	128.00± 19.22	129.13± 8.15	0.220	0.880	NS
Extrapolated centre of mass (degree)	6.00±1.76	6.02±1.06	6.24±2.04	6.04±1.51	0.053	0.983	NS

Values are presented as mean±standard deviation
***P<0.001, ** P <0.01, * P <0.05, NS: no significant difference

Discussion

The hypothesis #1 that locomotion velocity and 1 stride length relative to increase of a load carriage of the obese will decrease was accepted. That is, when led at one's preferred velocity, elapsed time during supporting phase of both foot to minimize an alteration total gait system was increased. The hypothesis #2 that medial-lateral incline angle of XCoM gradually will increase relative to increase of a load carriage of the obese was rejected in a view of no difference.

As this, this study showed similar result with the previous studies that stride length and gait velocity of the obese was shorten and decreased and thus biped-supporting time was more delayed rather than that was not (6, 12). Particularly, biped-supporting time suspended during gait due to lowered vertical position of COG relatively rather contributed to mechanism of stable gait (7). That is, decrease of gait velocity by additional weight was occurred commonly in both child and adult untrained (7) and also in the obese.

Also the obese showed an increased wavering area of COM with decrease of dynamic stability due to excessively cumulated fat of inward thigh rather than the normal (12). As these, relative vertical position of COG was lowered relative to increase of elapsed time during supporting phase of both foot (7). That is, while trunk during walking was supported by one leg and was not positioned on the one supporting leg (11), It was judged that range of M-L incline angle could decrease through mechanism of an active control which might decrease the 1 stride length and locomotion velocity relative to load carriage of the obese.

The hypothesis #3 that impact type and DPSI will increase and decrease locomotion velocity respectively may influence on number of sample and impact type. The case related to increase of a load carriage of the obese was accepted only in case of breaking and propulsive force. Foot segments supporting the body weight was detected frequently in ground reaction force occurring during exercise and thus excessive overweight of body by obese may be detrimental to health of foot and lower limb (13). In kinematic view, while the obese usually has rather high torque, and usually has lower knee joint torque than that of the normal to decrease the load on knee through restructuring the neuromuscular function (14). Though the mechanism is for prevention of knee joint (15, 16), additional load on body weight during gait in the obese may be resulted in injuries of exercise function and potential strain of body posture by appropriate use of muscle strength and GRF (13).

On the other hand, the decrease of locomotion velocity according to increase of weight of this study may assumes that supporting time (sample number of GRF) by one leg may be increased. Thus preferred gait velocity of the obese had negative (-) correlation with BMI, and preferred a slower gait velocity in case of the knee pain syndrome (14). Consequently the obese during short time in proportional to additional weight generate, but the decrease of gait velocity may be important factor to improve DPSI during supporting phase.

This study applied various weights on the obese. The fact that did not accompany with falling, slipping and pain during the experiment might prove the proper acceptance and modification of position, velocity of COM and inertia characteristics to maintain the stability in the course of forward locomotion (17-19). But in condition of 5 kg wore weight to be rather light weight, prolonged gait may contribute to decrease of dynamic stability and accumulation continuously of injurious impulsive force on body. The obese might have high possibility of falling injuries and thus require specific treatment (8).

This study can be supported within 2 kinds of limit. The 1st: the study was limited to the obese who performs normal gait under condition of flat surface. The 2nd: When considering a sensitivity of the sole of a foot of the obese, shoe's material excepted for bare foot may influence gait characteristics.

Conclusion

The manual for more safe gait-habits for overweight body carrying heavy load in industrial field. Also, the result of the study will beneficial for development of exercise program and understanding of gait mechanism under the load carriage of the obese who is under knee pain or potentiality of falling injury.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that there is no conflict of interest.

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