

# Effect of slipper wearing and carrying positions of infant on dynamic stability and kinetic variable during level walking

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Recently though various hip seats for carrying infant of women was designed and developed, then, wearing slipper may restrain the movement of bare foot. The study was undertaken to investigate the dynamic stability and kinetic variables according to between position of carrying infant and wearing slipper. Adult female ( $n=10$ ) and under one year age of infant ( $n=10$ ) participated in the study. Extrapolated center of mass, center of pressure, ground reaction force (GRF), and leg stiffness of gait characteristics using 3-dimensional cinematography and GRF were analyzed. Dynamic stability according to position of carrying infant and wearing slipper was not significant. While when carried an infant against normal gait showed significant difference in breaking force, leg

stiffness and loading rate ( $P<0.001$ ). Of which breaking force and vertical impulse were more increased when the back-carried against fore-carried of trunk. Thus it resulted in transformation on types of impulse transfer to leg and COG of women's carrying infant, which may be strategy for securing a dynamic stability. Therefore experts related with exercise rehabilitation should understand sufficiently on gait characteristics of women with diseases on muscular-skeletal system and perform effective rehabilitation and treatment.

**Keywords:** Dynamic stability, Exercise rehabilitation, Carrying position, Slipper, Walking, Leg stiffness

## INTRODUCTION

Skinship between women and infant commonly occurs during standing, sitting and gait, and then, cause of falling injury composes of the two-thirds in a situation of slipping floor and a motion carrying a parcel hastily (Dunning et al., 2003). In spite of complicated nerve-control system during gait, human manages to continue the rhythmic, regular and repetitive movement of gait (Vaughan, 2003). But movement bracing and backing of infant means overloaded body weight as that of infant, and thus elevate whole body weight and height of center of gravity (COG) by added mass.

When these problems interacts during gait, pelvic movement and gait posture with a reciprocity action against gravity may be altered, and also torque and linear force on body structure due to excessive movement of vertebrae increased (Cook and Neumann,

1987; Filaire et al., 2001; Pascoe et al., 1997).

Particularly the added load on trunk causes to alter a position of center of intervertebrae (Bloom and Woodhull-McNeal, 1987; Filaire et al., 2001; Martin and Nelson, 1986), pain and fatigue on shoulder and lower leg (Hong et al., 2008), and increase an occurring possibility of abnormality on muscular-skeletal and cartilage tissue system (Smith et al., 2006).

Inadequate wearing shoe during gait may deteriorate of muscular function contributing to static and dynamic stability (Jackman and Kandarian, 2004), thus which may cause pain and abnormality of foot (Yick et al., 2016). Women usually wears slipper for noise prevention of interfloor and comfort of foot in a condition of backing infant (Zhang et al., 2013), but may injure foot-health and alter the gait movement potentially (Price et al., 2014). Doctors in charge of women of predelivering of baby accentuates exercise and posture control for early prevention on problems of mus-

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cular-skeletal system and rehabilitation management (Foti et al., 2000). Particularly even postdelivering, women undergo swell of ankle and leg, incomplete gait, increase of gait width and pain of hip (Ponnapula and Boberg, 2010). In the course, women usually may undergo abnormality of body shape and deficit of body function by interaction in due to shoe's type and positions of carrying infant.

Therefore the purpose of the study was to investigate the change of dynamic and kinetic variables according to between position of carrying infant and wearing slipper.

## MATERIALS AND METHODS

### Subject

The adult female ( $n=10$ ; mean age,  $28.00 \pm 6.73$  years; mean height,  $163.25 \pm 4.90$  cm; mean weight,  $54.81 \pm 5.54$  kg) and infant ( $n=10$ ; mean weight,  $11.27 \pm 1.51$  kg) were selected as subjects. The experimental approval for safety, prevention and ethics of all was obtained from Institutional Review Board of Jeju National University (JJNU-IRB-2017-020-001).

### Experimental procedure

GRF (AMTI-OR9-7, AMTI, Watertown, MA, USA) in line with the center of gait path and camera (4 ea.) (HDR/HDV 1980i, Sony Corp., Tokyo, Japan) were set up at 60 frame/sec of speed and 1/500 sec of exposure time. All participants performed each 3 times of gait trial in order of fore-carrying and back-carrying of infant in a condition of bare and slipper gait after rehearsing of enough gait exercise on condition of touch of right foot on the ground reaction force (GRF) with carrying infant. The order of experiment was performed randomly, and only 1 trial selected verified from Kwon 3D XP ver4.0 (Visol, Gwangmyeong, Korea) sampled at 600 Hz was analyzed for the study.

### Definition of analysis phase

Gait characteristics were evaluated with trunk declined angle of medial-lateral, COP variables (medial-lateral COP, anterior-posterior COP excursions), GRF variables (peak vertical force, loading rate, decay rate) and leg stiffness.

Appropriate stable area was evaluates with position of medial-lateral COM projected in dynamic situation and COM position and velocity ( $dx/dt$ ) supporting phase using XCOM (extrapolated center of mass position) (Hof et al., 2007).

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

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

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

Nomenclature for XCOM

$\omega_0$  = pendulum eigen frequency

$g$  = acceleration of gravity 9.81 m/sec<sup>2</sup>

$h$  = effective height of the body COM above the floor = 1.34 $l$

$x(i)$  = lateral position of COM

$X(i), Z(i)$  = vertical and lateral position of COM

$x(i), z(i)$  = vertical and lateral position of COP

Index in medial-lateral and anterior-posterior direction, which mean index of stability resulted from value of COP (Michell et al., 2006). The formulae means the increase of COP, the less of stability.

$$M - L \text{ COPE} = \frac{\sum_{t=0}^T |\text{COP}_{x,t} - \text{COP}_{x,\text{mean}}|}{T}$$

$$A - P \text{ COPE} = \frac{\sum_{t=0}^T |\text{COP}_{y,t} - \text{COP}_{y,\text{mean}}|}{T}$$

Leg stiffness was normalized 100% ( $l_0$ ) to the initial touch-down of right foot in 3 dimensional spatial coordinates, and quantified dimensionally by division peak vertical force (N/BW) with change rate ( $(l_0 - l_{\min})/l_0$ ) of leg length ( $l_{\min}$ ) (Silder et al., 2015).

### Analysis and process of data

Primary variables calculated using IBM SPSS Statistics ver. 21.0 (IBM Co., Armonk, NY, USA) was mean  $\pm$  standard deviation and performed repeated two-way analysis of variance according to conditions of position (fore and rear of truck) and gait condition (barefoot and slipper) at  $P < 0.05$  level.

## RESULTS

Velocity and dynamic stability according to position of carrying infant and wearing slipper was as (Table 1). Difference among gait velocity, XCOM, M-LCOPE, and A-PCOPE according to position of carrying infant and wearing slipper was not significant ( $P > 0.05$ ).

Kinetic variables during gait was as (Table 2). Difference between position of carrying infant and wearing slipper in GRF in medial-lateral direction and loading rate was not significant ( $P > 0.05$ ).

Difference between position of carrying infant and wearing slipper in GRF in anterior-posterior direction, loading rate and leg stiffness was significant ( $P > 0.01$ ), while the variables in case of wearing slipper did not show significant difference and interaction effect.

**Table 1.** Change of mean velocity, extrapolated centre of mass position, and center of pressure variables during level walking

Section	Walking conditions (W)	Carrying positions (C)			Total average	Source	F	P-value	Post hoc
		Normal walking	Front of trunk	Rear of trunk					
Mean velocity (m/sec)	Barefoot	1.25±0.15	1.20±0.13	1.24±0.17	1.23±0.15	W	0.432	0.519	NS
	Slipper	1.18±0.06	1.18±0.08	1.24±0.18	1.20±0.12	C	1.004	0.359	NS
	Total average	1.22±0.12	1.19±0.11	1.24±0.17	1.22±0.14	W×C	0.466	0.578	NS
XCOMθ (°)	Barefoot	4.84±4.85	6.38±3.37	6.42±4.48	5.88±1.19	W	0.186	0.671	NS
	Slipper	4.97±2.19	6.91±4.59	7.56±4.42	6.47±3.91	C	2.310	0.114	NS
	Total average	4.90±3.66	6.65±3.93	6.99±4.37	6.18±1.03	W×C	0.119	0.888	NS
M-LCOPE	Barefoot	2.97±1.35	2.92±1.44	2.80±1.11	2.89±1.26	W	0.102	0.754	NS
	Slipper	3.27±1.13	2.48±0.91	2.52±1.11	2.75±1.07	C	2.168	0.128	NS
	Total average	3.12±1.22	2.7±1.19	2.66±1.09	2.82±1.16	W×C	1.244	0.300	NS
A-PCOPE	Barefoot	19.92±1.19	21.15±4.54	21.46±3.04	20.84±3.18	W	0.019	0.891	NS
	Slipper	19.27±3.35	20.58±1.51	23.00±4.44	20.95±3.57	C	2.998	0.062	NS
	Total average	19.59±2.47	20.87±3.30	22.23±3.78	20.89±3.35	W×C	0.669	0.519	NS

Values are presented as mean ± standard deviation.

NS, not significant; M-LCOPE, medial-lateral center of mass excursions; A-PCOPE, anterior-posterior center of mass excursions; W, main effect of the walking conditions; C, main effect of the carrying positions; W×C, interaction.

**Table 2.** Change of ground reaction force variables and leg stiffness during level walking

Section	Walking conditions (W)	Carrying positions (C)			Total average	Source	F	P-value	Post hoc
		Normal walking	Front of trunk	Rear of trunk					
Medial-lateral GRF (N/BW)	Barefoot	-0.05±0.01	-0.06±0.03	-0.06±0.02	-0.06±0.02	W	0.344	0.565	NS
	Slipper	-0.06±0.01	-0.07±0.03	-0.07±0.01	-0.06±0.02	C	1.754	0.188	NS
	Total average	-0.05±0.01	-0.07±0.03	-0.06±0.02	-0.06±0.02	W×C	0.222	0.802	NS
Anterior-posterior GRF (N/BW)	Barefoot	-0.14±0.05	-0.22±0.05	-0.20±0.05	-0.18±0.06	W	4.173	0.056	NS
	Slipper	-0.12±0.06	-0.18±0.07	-0.17±0.03	-0.16±0.06	C	8.284	0.001***	F>R>N
	Total average	-0.13±0.05	-0.20±0.06	-0.18±0.05	-0.17±0.06	W×C	0.074	0.928	NS
Vertical GRF (N/BW)	Barefoot	1.17±0.07	1.34±0.14	1.31±0.14	1.27±0.14	W	0.202	0.659	NS
	Slipper	1.14±0.12	1.38±0.14	1.36±0.13	1.29±0.17	C	24.572	0.001***	F>R>N
	Total average	1.15±0.10	1.36±0.14	1.34±0.13	1.28±0.15	W×C	0.936	0.402	NS
Dimensionless leg stiffness	Barefoot	12.20±3.44	28.28±13.83	29.16±8.37	23.22±12.17	W	0.429	0.521	NS
	Slipper	14.95±6.42	30.24±07.38	29.43±8.04	24.87±10.04	C	26.972	0.001***	F, R>N
	Total average	13.57±5.21	29.26±10.87	29.30±7.99	24.04±11.09	W×C	0.131	0.878	NS
Loading rate (N/BW/sec)	Barefoot	8.19±0.89	10.95±2.69	10.04±1.83	9.72±2.21	W	2.457	0.134	NS
	Slipper	8.89±1.51	11.24±2.50	12.05±1.93	10.72±2.38	C	14.793	0.001***	F, R>N
	Total average	8.54±1.26	11.09±2.53	11.04±2.10	10.22±2.33	W×C	1.386	0.254	NS
Decay rate (N/BW/sec)	Barefoot	-8.08±1.13	-7.21±7.24	-8.46±0.85	-7.92±4.14	W	0.061	0.808	NS
	Slipper	-7.52±1.19	-7.77±1.20	-9.13±0.78	-8.14±1.26	C	1.110	0.340	NS
	Total average	-7.80±1.17	-7.49±5.06	-8.80±0.86	-8.03±3.04	W×C	0.273	0.763	NS

Values are presented as mean ± standard deviation.

GRF, ground reaction force; NS, not significant; W, main effect of the walking conditions; C, main effect of the carrying positions; W×C, interaction.

\*\*\*P<0.001.

## DISCUSSION

Usually female go through abnormal muscular-skeletal during women's delivery, which is a cause of factors of functional deterioration and occurrence of body handicap (Segal et al., 2013). The

high rate of new handicap occurrence of muscular-skeletal system on lower limbs during pregnancy (Foley et al., 2007) and furthermore abnormal exercise of joint due to frequent skinship with infant after delivering may result in acute or chronic deficit of body (Segal et al., 2013). Women delivered an infant generally partici-

pate in various treatment and exercise rehabilitation to resolve physical deficient occurring functionally, but profitable information helpful for prevention and improvement of motor ability is deficient.

In the analysis, difference between wearing slipper and bare gait in variables of dynamic stability and impulse type is not significant. unwell and inconvenience shoe for individual during gait induces insole pressure of foot, which result in pain of foot, injuries of tissue and ulcer, and finally handicap of balancing ability (Burns et al., 2005; Hodge et al., 1999; Jannink et al., 2006). But this study did not give an influence to dynamic stability by wearing slipper.

This result was not certain whether influence of shape, material or size of slipper, or wearing of loosen fixing slipper for long time had relation with pain of heel and excessive injury around of foot finger (Chard et al., 2013; Zhang et al., 2013). In further study, a study of dynamic stability during carrying infant and wearing time is necessary.

Carrying infant showed more increased in variables of anterior-posterior GRF, Max. vertical GRF, leg stiffness, and loading rate, which was inferred to proportionally increasing relation of impulse type due to infant weight, and particularly showed more increased breaking force and impulse force when positioned fore than post of trunk during carrying infant.

Generally when infant was positioned fore of trunk, visual information to move the other foot forward proper position may be interfered, but sensual strategy to secure the dynamic stability may be selected when given a condition at easy (Reynard and Terrier, 2015). But Stable gait based on reverse pendulum model should place COG of whole body to a position on new supporting ground (Hsiang and Chang, 2002), and then added infant weight in the course be due to momentum of forward movement of COG of whole body after touch-down of heel.

As these, regardless of fore or post carrying infant, women can secure a dynamic stability by altering mechanical function (impulse type) during women gait. That is, it suggests that carrying infant during gait has more close relation with increase of impulse type of muscular-skeletal system than decrease of stability. This result may be expected for expert of clinics or exercise rehabilitation to treat an exercise prescription through understanding of gait characteristics in various aspects in women of post delivering. In addition it is necessary to investigate gait stability considering effect slipping friction coefficient and others.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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