The Ergonomic Evaluations of Three Front Baby Carriers: Mother's Perspective

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Abstract. This paper evaluates the physiological and psychophysical response of mothers carrying their own baby using three different front baby carriers. Eleven mothers (aged 28–37 years) with their own baby (weight: 9.18 ± 2.1 kg) participated in this study. Maximum right shoulder pressure was measured before walking. The electromyography (EMG) and skin temperature of the shoulder and abdomen area were measured during walking. Immediately after walking, the Borg's rating scale of perceived exertion was used to collect discomfort ratings at various body parts. The results were similar in all response factors to our previous study, which used a convenient sample of women and dummy doll. However, with further comparison, mothers showed significantly lower EMG activities and all Borg's scales, but higher temperatures apply in both shoulder and abdomen areas. In conclusion, Type A, B and C carrier performed similar in either mother or women, but in mothers the effect was smaller in most responses.

Keywords: Baby carrier · Electromyography (EMG) · Skin temperature · Borg's scale

1 Introduction

Baby carrier or baby sling for carrying infant or toddler is often more practical and convenient than pushing a stroller—especially during hiking, traveling, or running errands. Carrying baby in the front has been promoted by World Health Organization [1]. Rey and Martinez first introduced Kangaroo mother care (KMC) and was initially designed to care low birth weight (LBW) infants. It is skin-to-skin contact between the baby and the holding person and is similar to marsupial caregiving, [2] and would enhance the mother-baby attachment [3]. While caregiver's responses to carrying a baby in the front had been evaluated, mother's responses of carrying their own baby are still undiscovered. Using the front carrier compared to the traditional baby sling has found to have higher muscle activities of paraspinal muscles [4]. Wu et al. [5] evaluated both men and women using three different front worn baby carriers including a baby

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sling while walking with a dummy doll. They found that the baby sling had similar responses in EMG activities to the two front worn baby carriers. In shoulder pressure measures, the baby sling also performed similarly to the padded shoulder straps. The skin temperature results showed that padded shoulder straps did increase skin temperature and females had higher skin temperature than males in abdomen area. The EMG results showed males used more upper back muscles whereas females used more belly muscles when carrying a baby in the front. Although, these results have given the reader a great deal of information in terms of choosing a baby sling or front worn harnessed baby carrier. It would be interesting to see what would the physiological and psychophysical responses for mothers while carrying their own child using these three different baby carriers. Thus, the purpose of current study was to evaluate mother's responses in terms of EMG, skin temperature, heart rate and perceived exertion while using different front baby carriers.

2 Methods

2.1 Subjects

Eleven mothers (age 31.3 ± 2.8 years old, height 160.8 ± 6.5 cm, weight 60.5 ± 11.2 kg) with their own baby (weight 9.18 ± 2.09 kg) were recruited. The inclusion criteria were: 1. no current musculoskeletal pain or pathology; 2. no any systemic disease. Each subject was asked to sign an informed consent form approved by the Institutional Review Board of the MacKay Memorial Hospital after informed about the purpose and procedure of the study.

2.2 Study Design

This study was a single factor design. The independent variable was the three baby carriers. The dependent variables included peak shoulder pressure, surface electromyography, skin temperature, heart rate, and the perceived exertion using Borg CR10 scales.

2.3 Instrumentation

Surface Electromyography (SEMG) and Skin Temperature. NeXus 10 (Mind Media Inc., Netherlands) is an 8-channel wireless device and used to measure SEMG and skin temperature. The SEMG of upper trapezius, rectus abdominis, and erector spinae were recorded using Ag/AgCl adhesive disposable surface electrodes. The BIOMED II recommendations of the European Union was used for electrode placement for each muscle group and the maximum voluntary contraction (MVC) testing procedure. The EMG activities (sampling rate of 2048 Hz with low-pass filtering at 500 Hz and high-pass filtering at 20 Hz) during carrying were calculated by using the formula [6] and were expressed in % standardized EA (sEA).

Skin temperature of the upper back and abdomen were collected using two thermistors which were attached 1. between mid-point between C7 and the acromion for

the upper back probe and 2. 3 cm above the belly button for the abdomen probe. The sensor was reported to measure the change within 1/1000 of a degree.

Body Pressure Distribution. A flexible pressure sensor sheet (CONFORMat®, Tekscan, Inc., USA) was used for shoulder peak pressure. The CONFORMat® was a 53.92 × 61.84 cm^2 sheet (sensor matrix: 471.4 × 471.4 cm^2) with 1024 pressure sensors embedded between the soft fabrics.

Heart Rate. Heart rate was recorded using a heart rate monitor (RS800CX, Polar Electro, Finland). The heart rate monitor (H3 heart rate sensor, Polar, USA) was attached to a strap tied onto the subject's chest, transmitting data to a watch on the subject's wrist. During carrying activities, the heart rate monitor was used to record the subject's heart rate and ensure the subject's heart rate did not exceed 75% of their maximum heart rate (220-age). The exercise intensity was also calculated using the Karvonen equation [7].

Perceived Exertion. The Borg rating of perceived exertion scale (Borg CR10) [8] was used to collect the subjective discomfort feeling in 7 different body regions, including: neck, right shoulder, left shoulder, upper back, mid-back, low back, and abdomen.

Baby Carriers. Three commercially popular front baby carriers were selected for evaluation. Each baby carrier claimed to be comfortable to wear and had its unique design described as fallow: baby carrier A is a carrier using mesh fabric with 2-part designed; baby carrier B uses padded shoulder straps and waist-belt; baby carrier C is a cotton ring sling.

2.4 Study Protocol

Two researchers conducted the experiment and each had different jobs during the protocol. The two investigators standardized the wearing methods for the three baby carriers prior to the experiment. After each subject's body height and weight were recorded, the EMG electrodes, skin temperature probes and the heart rate sensor were then attached. Resting EMG and heart rate were collected for three minutes followed by measuring the maximum voluntary contraction for the three muscle groups. The order of using the three baby carriers was randomized. The baby carrying mothers carried their baby and walked at a comfortable speed for 20 min. A 10-min rest was given between each experiment combination.

2.5 Data Analysis

Analysis of variance was performed to evaluate the effect of baby carriers on the response measures. Duncan's multiple range tests were conducted as a post-hoc testing. Statistical analyses were performed using the statistical analysis software SPSS v.20.

3 Results

SEMG and Skin Temperature. The effects of baby carriers on EMG of the three muscles and skin temperatures in upper back and abdomen are summarized in Table 1. The EMGs in all three muscles were found to have no significant differences while using the three baby carriers. For skin temperature, significantly higher upper back temperature was found in baby carrier B.

Table 1. The mean and standard deviation of SEMG and skin temperature.

Muscles	Baby carriers			Sig.
	A	B	C	
Upper trapezius	2.28 ± 1.04	3.70 ± 1.97	4.78 ± 3.23	
Erector spinae	10.06 ± 4.59	9.47 ± 5.69	11.52 ± 3.67	
Rectus abdominis	1.78 ± 1.52	1.44 ± 1.29	1.63 ± 1.49	
Skin temperature				
Upper back	34.24 ± 0.58[b]	35.2 ± 0.62[a]	33.99 ± 0.52[b]	***
Abdomen	35.46 ± 1.09	36.29 ± 0.98	35.97 ± 1.09	

Note: Data are given as mean ± SD %MVC for EMG and mean ± SD °C for skin temperature.
a, b: Duncan grouping code
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Body Pressure Distribution. The baby carrier B revealed significantly smaller in peak shoulder pressure (Table 2).

Heart Rate and Exercise Intensity. The average heart rate and exercise intensity during walking showed in Table 2. There were no significant influences on heart rate and exercise intensity.

Table 2. The mean and standard deviation of peak shoulder pressure, heart rate, and exercise intensity.

Items	Baby carriers			Sig.
	A	B	C	
Peak shoulder pressure	2.97 ± 1.05[b]	1.68 ± 0.67[a]	2.87 ± 0.71[b]	***
Heart rate	86.21 ± 8.27	85.61 ± 7.78	85.86 ± 6.31	
Exercise intensity	14.91 ± 4.40	14.3 ± 4.80	14.51 ± 4.62	

Note: Data are given as mean ± SD kPa for pressure, mean ± SD bpm for heart rate; mean ± SD % for exercise intensity
a, b: Duncan grouping code
*** $P < 0.001$

Perceived Exertion. The results of subjective rating using Borg CR10 are listed in Table 3. Baby carrier B showed significantly lower perceived exertion in both shoulders and upper back areas.

Table 3. The means and Duncan groupings of Borg CR10 scale

Areas	Baby carriers			Sig.
	A	B	C	
Neck	1.41 ± 1.59	0.36 ± 0.64	1.36 ± 1.29	
Left shoulder	2.14 ± 0.75[b]	0.86 ± 0.92[a]	0.91 ± 0.83[a]	*
Right shoulder	2.82 ± 2.16[b]	0.64 ± 0.64[a]	3.55 ± 2.46[b]	**
Upper back	1.27 ± 2.04[a]	0.45 ± 0.42[a]	3.32 ± 3.08[b]	*
Mid-back	0.77 ± 0.85	0.86 ± 1.45	2.18 ± 2.40	
Low back	1.82 ± 2.31	2.14 ± 1.70	1.73 ± 1.89	
Abdomen	0.59 ± 0.77	0.86 ± 1.21	0.95 ± 1.19	

* $P < 0.05$, ** $P < 0.01$

a, b: Duncan grouping code

4 Discussion and Conclusion

In current data, three baby carriers showed significant differences in both objective and subjective data in shoulder-upper back areas. EMG data did not show significant differences among the three baby carriers. It is different from the report of Wu et al. [5], that higher upper trapezius activities in baby carrier B, and the sling carrier (baby carrier C) did perform similar to either front-worn harnessed carrier. When we compared previous data of female subjects who were not mother, it is interesting to find the inexperienced subject's EMG activities were significantly higher in both erector spinae and rectus abdominis. This same trend could be found in exercise intensity. In our survey, among the 11 mothers, four of them used baby carriers similar to baby carrier B and four of them used baby carriers similar to baby carrier C, others did not use any baby carrier. Further, mothers may carry their baby for longer than 20 min, which may explain why perceived exertions (Borg's scale) were smaller than the previous study [9]. Skin temperature in shoulder area showed higher in type B carrier. This result was similar to previous study [5], however, in current study, mothers had higher skin temperature in both shoulder and abdomen areas. The fact that carrying real baby could potentially increase skin temperature was observed. In conclusion, Type A, B and C carrier performed similar in either mother or woman, but for mothers the effects were smaller in most responses.

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