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Can infant carrier hip belts of 2-inch, 4-inch, and 6-inch dimensions influence trunk muscle activities during front infant carrying tasks?

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Abstract

Background Utilization of infant carriers (ICs) for childcare activities is common and involves varieties of hip belts to offer maximum maternal and infant support. There is a need to establish ergonomic-based guidelines for IC components as a means of improving their supportive roles.

Objective This study evaluated the effects of infant carrier (IC) hip-belt dimensions on the erector spinae (ES) and multifidus (MF) muscles of healthy adult women during front infant carrying tasks.

Methods It utilized three hip belts with different width dimensions (2 inch, 4 inch, and 6 inch) attached to the IC during three front infant carrying tasks, respectively. During each 5-min trial, the activities of the right and left components of the ES and MF muscles were simultaneously monitored via surface electromyography (EMG). Asymmetry ratios of the normalized EMG values of the right and left components of each muscle were calculated.

Results Utilization of different hip-belt dimensions did not elicit significant ($p < 0.05$) differences in the electrical activities of the back muscles as well as in their asymmetry ratios. However, marginal differences in the normalized EMG values showed that the 4-inch belt elicited the highest muscular activities in three of the four studied muscles.

Conclusion During simulated front infant carrying tasks, hip-belt dimensions of the ICs did not influence back muscle activities in healthy adult women. Long-term effects of IC hip-belt dimensions on back muscle activities should be evaluated in future studies.

Keywords Infant carriers, Hip-belt dimensions, Back muscles, Electromyography

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Introduction

Infants carrying tasks are major aspects of childcare and integral parts of the mothering occupation [1] with several maternal and infant benefits [1–4]. However, these tasks can be physically and energetically demanding as they constitute the bearing of infant weight on the caregiver's trunk, shoulder, or arms. Such demands may also result from changes in gait and posture, resulting from the infant's weight which triggers body compensatory mechanisms to adapt to the increased load and altered stability [5–7]. Cross-culturally, different methods of infant carrying are adopted by mothers and caregivers with back, front, side, and in-arms constituting the most common methods [1]. Infant-carrying tasks are usually performed simultaneously with other tasks, including transportation, house chores, and other activities of daily living. For this reason, there is always a need to support the infant with external support to enable the caregiver to perform other simultaneous tasks. The use of external supports also shields the impact of the physical weight constituted by the infant load as compared to solely supporting the infant on the caregiver's body. Williams et al. [8] reported that the in-arms infant carrying method increases the loading knee abduction moment by 8.7% and the loading knee extension moment by 16.7%, as compared to when using an infant carrier (IC). These external supports thus serve as ergonomic aids and are being used worldwide, [3] predominantly in developed countries [9]. Campaigns promoting the utilization of ICs for infant support have been ongoing [10, 11].

External supports used for infant carrying include slings, flexible pouches, pieces of clothes or wraps, and infant/baby carriers. Choices of external support vary across cultures, countries, and other population categories. For instance, Nigerians traditionally utilized cloth wraps (Oja) as means of supporting their infants on the caregiver's back, while Asian countries traditionally utilized slings for the back and front infant carrying methods. Despite these cultural variations, ICs which were predominantly utilized for front infant-carrying methods in Western countries are becoming more prevalent globally [3, 9]. These carriers are similar to standard backpacks and are utilized for back and front infant carrying tasks with availability in various structures or designs.

Structurally, a typical IC consists of a shoulder harness assembly, which includes two shoulder straps with front and back portions each. These front and back portions of the shoulder straps are attached to a circumferential binder, a seat assembly that has a baby-bottom-receiving portion and a baby-back-receiving portion, a weight-support strap assembly, and a restraint strap (US Pat. No. 5,522,528 by Petricola) [12]. Other models of ICs with minor to major variations are available commercially. For instance, US Pat. No. 5361952 by Gold discloses a soft type baby carrier, which consists of an adjustable pouch, a shaped baby seat for supporting the baby in an upright, sitting position, an adjustable waist belt, and an adjustable yoke system for comfortably supporting the baby carrier about the neck of a wearer [13].

Hip belts are requirements of ICs and backpacks, constituting their major and most important components [14–16]. They offer security, comfort, improved posture, and decreased energy cost and are meant to transfer the vertical force of the carrying device from the shoulders to the pelvis and hips [14, 17]. This weight transfer is speculated to reduce activity in the shoulders and trunk muscles, [14, 17, 18] reduce shoulder-backpack interface pressure [19], and increase the stability of the pelvis-thorax coordination pattern [20]. Thus, the weight of the load is distributed among the hips, chest, and shoulders with hip belts carrying 30–80% of the weight [14, 17]. Load bearing by the pelvis rather than the shoulders has been demonstrated to be more comfortable as the pelvis is less sensitive to contact pressure than the shoulders [21]. The stronger leg muscles also have to perform heavy lifting as compared to the weaker shoulder muscles [17]. The resultant benefits of hip-belt roles during trunk loading tasks are the provision of more comfort and improved performance [18].

Criteria for ergonomically suitable hip-belt designs include being padded with soft foam for comfort as well as having a width of or above 2 inch [17]. Most commercial IC and backpack manufacturers promote their products with an emphasis on hip-belt structures. In their campaigns, they present different widths of hip belts as ergonomic advantages to users of their products. Part of their sales promotion strategies is based on the width of their carrier hip belts. Considering that hip-belt widths are included in the criteria for defining ergonomically suitable trunk-supporting devices, [14, 17] there should be empirical evidence to support their claimed benefits. However, such evidence is lacking relative to IC designs. Golriz et al. [14] studied the effects of hip-belt use in a backpack on perceived exertion and postural stability. Their findings showed that hip-belt use only improved subjective measures of postural stability. More evidence of the effects of hip-belt designs on other biomechanical parameters is required to serve as guidelines for IC designs and choices of use. This study was therefore designed to evaluate the effects of infant carrier hip-belt dimensions on the electrical activities of the erector spinae (ES) and multifidus (MF) muscles of healthy adult women during front infant carrying tasks.

Materials and methods

A repeated measures observational study of 23 apparently healthy nonpregnant nulliparous adult females (18–35 years) was conducted to achieve the aims of this study. Participants were conveniently selected from the undergraduate hostels of a University in Nigeria. A total of 20 participants were estimated for the analysis of variance at the degree of freedom (df_b) = 1, to achieve 96% (0.96) power with a moderate to a large effect size of 0.60 at an alpha level of 0.05 in a preliminary power analysis [22]. Females who have been actively involved in infant carrying or other trunk-loading tasks, for at least 6 months, were excluded from the study to rule out survivor effects. Those with abdominal and spinal surgeries and with neurological or musculoskeletal disorders affecting the trunk

[23] managed in the last 6 months to the study date were also excluded.

The University's Health Research Ethics Committee approved this study with the approval number NHREC/05/01/2008B-FWA00002458-1RB00002323. All participants provided written informed consent, and the study was conducted according to the Declaration of Helsinki.

Following the participants' recruitment, they were assessed for eligibility to undergo physical tasks using the Physical Activity Readiness Questionnaire (PARQ). Relevant biodata information and anthropometric characteristics (weight in kilograms, height in meters, waist and hip ratios) were obtained before they were passed through the testing procedures.

Testing procedures

Each participant underwent three testing conditions and carried a 6-kg weighing infant dummy in a popular market brand carrier (name withheld) with detachable hip belts of different dimensions (2, 4, and 6 inch, respectively). For each condition, the dummy was placed and secured in the carrier, which was strapped across the participant's waist via the hip belt. The hip belt was strapped at the level of the pubic symphysis as the landmark for each participant. The carrier was anteriorly positioned on the participant (front infant carrying position) with the dummy's center of mass located at a corresponding level of 5–6 inch above the participants' umbilicus based on the estimated anterior and posterior shifts of the center of gravity during front loading (Ojukwu et al., 2023). During each testing condition, the participant walked at a self-selected speed on a flat surface with the dummy and carrier in place for 5 min. While in motion, the activities of the right and left components of the erector spinae (ES) and multifidus (MF) muscles were simultaneously monitored via surface electromyography (EMG) during each trial using a MyoPlus2 device (NeuroTrac system, Verity Medicals, Hampshire, UK), which amplified and sampled the EMG inputs at 1000 Hz. Following standard specifications, [24] pairs of electrodes with an inter-electrode distance of 2.5 cm were placed on the midportions of the ES and MF muscles at the levels of L1 and L4 vertebrae, respectively. EMG readings (mv) were normalized to the peak amplitude during each activity [25]. A NeuroTrac software (version 5.0.117) was used to express average EMG values as percentages of the maximum voluntary contractions (MVC) values before statistical analyses.

For the avoidance of fatigue and carry-over effects, participants underwent the three testing conditions in a random sequence generated on a Latin square. For uniformity purposes, all trials were performed between 9:00 am to 12:00 noon daily with a testing interval of 30 min between trials.

Table 1 Physical characteristics of the participants (n = 23)

Variables	Mean ± std	Minimum	Maximum
Age (years)	20.85 ± 1.58	19.00	25.06
Height (m)	1.68 ± 0.05	1.57	1.76
Weight (kg)	62.77 ± 11.63	50.00	91.60
BMI (kg/m^2)	22.12 ± 3.98	17.30	30.97
WHR	0.78 ± 0.06	0.79	0.98

BMI body mass index, *WHR* waist-hip ratio, *Std* standard deviation

Table 2 Comparisons of participants' normalized EMG activities of the back muscles across trials of front infant carrying tasks with three hip-belt dimensions

Muscles	2-inch belt	4-inch belt	6-inch belt	*f*-value	*p*-value
Right ES (%)	53.7 ± 186.66	57.02 ± 143.81	14.65 ± 7.87	1.343	0.283
Left ES (%)	9.40 ± 7.33	11.33 ± 8.59	10.15 ± 6.94	0.698	0.509
Right MF(%)	19.94 ± 21.29	14.48 ± 8.64	16.80 ± 7.52	1.612	0.223
Left MF (%)	17.69 ± 8.71	19.64 ± 8.06	15.04 ± 6.93	2.931	0.075

ES erector spinae, *MF* multifidus

Data analysis

The asymmetry ratios (right: left) of the normalized EMG values of the right and left components of each muscle were calculated for making inferences about postural symmetry/asymmetry. A ratio of > 1 indicates that there was more muscle activity in the right muscular component, < 1 indicates more muscle activity in the left component, while a ratio of 1 shows symmetry/equal muscle activity on both sides of the body.

Descriptive statistics of frequency, mean, standard deviation, and percentages were used to summarize data. Inferential statistics of repeated measures analysis of variance (ANOVA) was used to compare outcomes. Data were analyzed using the Statistical Package for Social Sciences (SPSS, Version 20.0, Chicago, USA) at the significant level of $p < 0.05$.

Results

Participants mean age, body mass index (BMI), and waist-hip ratio (WHR) are 20.85 ± 1.58 years, 22.12 ± 3.98, and 0.78 ± 0.06, respectively (Table 1).

Table 2 shows comparisons of the back muscle activities across the three testing conditions with different hip belts. None of the four muscles (right and left ES; right and left MF) showed significant differences ($p < 0.05$)

in their EMG values across the three trials. Three of the muscles (right ES, left ES, and left MF) recorded their highest activities (57.02 ± 143.81%, 11.33 ± 8.59%, and 19.64 ± 8.06%, respectively) during the 4-inch hip-belt trial, whereas the right MF showed its highest activity (19.94 ± 21.29%) during the 2-inch trial.

Comparisons of the asymmetry ratios of both components of each muscle across the testing conditions are presented in Table 3. The results revealed no significant differences ($p < 0.05$) in the asymmetry ratios across the three trials, although the right muscle components showed higher activities, as compared to the left in all trials.

Discussion

In an attempt to establish guidelines for appropriate choices of ICs to serve as a guide to nursing mothers during infant carrying tasks and for improved health outcomes of infant carrying, this study evaluated the electromyographic activities of the trunk muscles in response to various hip-belt dimensions of ICs. The result showed that hip-belt dimensions had no significant effects on the activities of the back muscles during front infant carrying tasks. This finding did not support the common biomechanical assumption that the wider hip belts will offer more weight distribution characteristics, thereby reducing the activities of the back muscles during infant carrying [26]. For instance, one of the few studies in literature describing force implications for infant carriage systems showed that the structure of a carrier influences the magnitude of force changes when a participant's loading is increased with the wider carrier, producing a more diminished force response [7]. McKinney [27] also long recommended that for hip belts to be adequately protected in function and aid in force dissipation from a load, they should be of substantial width. As well, common commercial hip belts come with hip-belt width dimensions, ranging from 2 to 6 inch. The discrepancy in this study's finding could be linked to the difference in study participants, trials, and measures assessed as this study examined the effects of hip-belt dimensions on healthy adult women, whereas the most closely related study examined the impact of carrier structure on loaded overground walking among mixed gender participants [7].

Table 3 Comparisons of back muscle asymmetry ratios across trials of front infant carrying tasks with three hip-belt dimensions

Muscles	2-inch belt	4-inch belt	6-inch belt	*f*-value	*p*-value
ES	58.76 ± 24.96	56.90 ± 188.1	3.33 ± 6.03	0.992	0.388
MF	1.45 ± 1.39	1.03 ± 1.04	2.08 ± 2.84	1.678	0.211

ES Erector spinae, *MF* Multifidus

However, the finding of this study showed some marginal differences, which showed that the 6-inch belt elicited the least muscular activities in most of the participants. This is supportive of the common biomechanical assumption that the greater the dimensions (width) of the hip belt, the greater the surface area for weight transfer from the back muscles to the lower limbs with a resultant decrease in the muscular activity as much of the load is carried by the stronger lower limb [28]. This particular finding of marginal differences in this present study also agrees with the work of Oberhofer et al. [29] which stated that the increased width of the hip belt maximized the area over which the backpack is coupled, and this not only increased the effective weight transfer but also increased the wearer's comfort. This was also supported by McKinney's [27] study on components of the load-supporting articulated waist belt, which stated that the hip belt must be of substantial width for effective weight transfer, thus reducing the loading task of the low back muscles.

Furthermore, it is worth noting that the use of each belt size allowed for co-contraction between contralateral muscle groups, resulting in postural symmetry. Co-contraction of muscles is a prerequisite for muscular and postural balance, biomechanical stability, and prevention of abnormal postural compensations during a task [30]. Failure of muscles to co-contract results in abnormal muscle lengths while performing a task which can lead to muscle fatigue, decreased range of motion, and biomechanical alterations with resultant back pain.

To verify the impact of the width of baby carriers' hip belt on muscle co-contraction, this study further compared the asymmetry ratios of the right and left components of each of the erector spinae (ES) and multifidus (M) muscles across the three trials. The result showed that the asymmetry ratios were not significantly different across the utilization of the three different hip-belt dimensions. The insignificant asymmetry ratio could be explained by the fact that the bilateral muscles were equally co-contracting [30]. This agrees with the findings above about wider hip-belt dimension and agrees with the works of Oberhofer et al. [29] and McKinney [26] about preference for wider hip-belt dimensions.

However, it was also observed that the 2-inch belt elicited the highest level of activity, while the 6-inch belt recorded the least level of activity in most trial conditions. This is understandable given the limited width of the 2-inch dimension hip belt. It is agreeable that hip belts enable load-weight dissipation across the spine as well as offer back support during trunk loading. Logically reasoned, wider hip belts should offer more of these advantages, as compared to narrower belts. However, this study revealed no significant differences in back muscle activities during the use of various hip-belt dimensions. The findings of this study should be considered given its limitations of small sample size, paucity of related data for the discussion of the study findings, and shorter time of trial compared to real-life scenarios. These suggest further research, which should incorporate more holistic approaches into the biomechanical responses to various hip-belt dimensions. Assessment of more biomechanical parameters in a longitudinal study with more variations of hip-belt dimension options may further elucidate the ergonomic benefits of various hip-belt designs.

Conclusion

During simulated front infant carrying tasks, hip-belt dimensions of the ICs did not influence back muscle activities in healthy adult women. Long-term effects of IC hip-belt dimensions on back muscle activities should be evaluated in future studies.

Abbreviations

ANOVA	Analysis of variance
BMI	Body mass index
EMG	Electromyography
ES	Erector spinae
ICs	Infant carriers
MF	Multifidus
PARQ	Physical Activity Readiness Questionnaire
WHR	Waist-hip ratio

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Authors' contributions
OCP, OCI, and NIB drew the design and concept of the study, including the data collection and data analysis; OCI, ACC, and OCP did the data analysis and statistical analysis; and ESS, IIT, and AIA did the literature search, manuscript preparation, and editing. All authors reviewed and approved the manuscript. Ojukwu CP is the "guarantor" for this study.

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Declarations

Ethics approval and consent to participate
Ethical approval for this study was first obtained from the University of Nigeria Research Ethics Committee, Enugu State of Nigeria, before the commencement of the study.

Competing interests
The authors declare that they have no competing interests.

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