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Evaluation of Trunk Muscle Activities in Response to Four Common Infant Carrying Methods Utilized by African Women

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ABSTRACT

Infant carrying has been reported to be physically demanding with risks of physical challenges to mothers/caregivers. This makes it important to evaluate different Infant Carrying Methods (ICMs) to guide choices for the promotion of maternal health. This study evaluated the effects of four ICMs (A–back, B–front, C–side, and D-in-arms) on trunk muscular activities. Thirty women simulated four ICMs while the electrical activities of the right (Rt) and left (Lt) components of the erector spinae (ES), rectus abdominis (RA), and external oblique (EO) muscles were recorded simultaneously during the tasks. Within-subject comparisons of the muscle activities showed that only the front ($p = 0.011$) and side ($p = 0.033$) ICMs elicited significant differences with their highest activities recorded in the left and right EO muscles, respectively. Between-subject comparisons of the muscle activities showed a significant difference ($p = 0.022$) only in the right EO muscle, being most active during the side ICM. The side ICM was observed to elicit the highest activities in three of the four studied muscles. Side ICM has more potential for over-exerting the trunk muscles, which could be a possible factor for muscular fatigue and resultant musculoskeletal impairments.

1. Introduction

Infant Carrying (IC) is the act of carrying an infant close to the caregiver's body with special devices, that aid attachment parenting [1]. It involves carrying or holding an infant or child in close physical contact with their mother and caregiver's body with or without supporting devices, for attachment and accomplishment of requisite activities of daily living by the caregiver or infant. The obvious significance of IC in the natural childcare processes has been described by evolutionary and archeological theories to be an essential adaptation for bipedalism in the hominids [2]. This has evolved to this present dispensation were added to home care tasks, women are increasingly getting involved in the workforce of many countries, creating more needs for carrying and nurturing their infants with a simultaneous performance of other activities of daily living [3], [4]. Besides, several benefits have been associated with IC, including maintaining and regulating the infant's body temperature and breathing, reducing stress hormone levels, and enabling the infant to tune into their natural reflexes and initiate breastfeeding [5], [6]. Others include improved infant physical development, thermal regulation, improved immune system and general health, [7] infant sleep pattern promotion, [8] improved learning strategies, [9] reduced infant crying, [10], [11] promotion of maternal-infant bonding [12] and improved breast milk production and breastfeeding [13]. Additionally, IC helps in baby-mother-communicating and as an intermediate womb (exterogestation) for infants to receive maternal warmth [7], [14], [15].

Despite these known benefits of IC, it constitutes an arduous task, posing physical challenges for the mother and/or caregiver, [3] especially when simultaneously combined with other activities of daily living. Carrying an infant constitutes external and additional load during locomotion. Load carriage is a restricting and sometimes unnatural situation with consequences on an individual's musculoskeletal system and metabolic activities [16]. Several studies have been conducted to evaluate the biomechanical and physiological effects of load carriage in various populations and as such, trunk loading has been associated with significant postural alterations [3], [4], [16- 20]. Increased energetic costs of locomotion have also been associated with IC [2], [21- 25].

Trunk muscle activities may vary among the different ICMs utilized by African women. The commonly utilized Infant Carrying Methods (ICMs) include the back, front, side, and in-arms ICMs that require positioning the infant on the posterior, anterior, lateral aspects of the trunk and anteroinferior to the shoulder, respectively [4]. These methods do not just differ by the infant load positions on the trunk but also in their use of supporting devices. For instance, the front and back ICMs usually require the use of external supporting devices while side and in-arms methods do not require such support in most cases. For the side and in-arms methods, the mother's upper limb stabilizes and supports the infant [26] in place of an external supporting device. Considering these differences in the infant load position and mechanisms of utilizing each of these ICMs, we are proposing intra- and inter-individual muscular activity variations across these methods. It is possible that for a particular individual, those ICMs that involve anteroposterior loading (front and back) may trigger more activities and fatigue in the anteroposterior trunk muscle while those that involve lateral trunk loading (side and in-arms) with possible side flexion may trigger more activities and fatigue in the lateral trunk muscles, respectively. Additionally, such variations in the activities of specific muscles may also be amenable when compared between individuals across different ICMs. According to some previous studies, [3], [27] the side ICM characterized by asymmetric trunk loading has been associated with increased lateral and trunk flexion, as well as a contralateral hip abduction torque with a decrease in ipsilateral hip torque. The front ICM has also been shown to alter the maternal center of mass, gait parameters, and joint angles during standing [3], [28] as well as increase lumbar lordosis and trunk muscle activities [26]. Variations in the musculoskeletal implications of these ICMs may be useful pointers to the nature of musculoskeletal disorders that may be associated with each infant carrying method.

Considering that infant-carrying-related musculoskeletal disorders are quite prevalent among nursing mothers, [20], [29], [30] there is a need for ergonomic considerations when choosing ICMs. To the best of our knowledge, maternal choices of ICMs have not been based on scientific evidence of their biomechanical implications. Previous studies showed that differences in lifestyle, economic conditions, climatic factors, and technological developments played central roles in determining how an infant is carried out [3], [7]. However, most recently, we observed that subjective perceptions of maternal and infant comfort are the main reasons for the selection of ICMs among African women [4], [20]. For support of clinical practices and maternal education programs aimed at reducing the prevalence of childcare-related musculoskeletal disorders and improving maternal quality of life empirical evidence is needed to showcase the differences in the outcomes of different ICMs. For this purpose, this study evaluated trunk muscle activities during the four popular ICMs (back, front, side, and in-arms) utilized by African women.

2. Materials and Methods

2.1 Participants

This study was approved by the College of Medicine Research Ethics Committee (COMREC), University of Nigeria, Enugu Campus, Nigeria. Thirty nulliparous females (18 -35 years) conveniently participated in this study based on the following criteria: the ability to walk independently and non-engagement in physical exercises before recruitment for this study to eliminate possible previous conditioning of musculoskeletal and physiological responses. Exclusion criteria included pregnancy, history of spinal pathologies or traumatic back injuries within the past year, and known history of constant trunk loading tasks to eliminate the confounding influence of the survivor effect [31], [32]. All participants signed informed consent forms before participating in the study.

2.2 Test conditions

Each participant underwent four infant carrying tasks as explained below:

A. The back ICM trial involved supporting the infant in the midline of the mother's mid back (T8 – T9 spinal level) with an infant wrap, both infant's lower limbs clutched unto the sides of the trunk. The wrap supported the infant's entire thighs, back, and cervical region to ensure full support of the body and close contact with the mother.

B. The front ICM trial involved supporting the infant in an infant carrier with crossed straps and positioned in the midline of the mother's anterior trunk (anterior T8, T9 spinal level).

C. The side ICM trial involved positioning the infant on the mother's left pelvic region at the level of the anterior superior iliac spine with the infant's legs astride the mother's anterior and posterior trunk.

D. The in-arms carrying, the infant was placed over the mother's left shoulder, with his chest directly over the mother's left shoulder. The side and in-arms methods required that the mother supported the infant unto her trunk with her left upper limb. Meanwhile, infants were positioned on the mothers' left sides in the side and in-arms method because several studies [33- 36] have shown a very strong bias to left side cradling.

2.3 Procedure

Before the examination, each subject was assessed for eligibility to participate in the study and was randomly assigned to one of the four experimental groups of ICMs (A – back infant carrying, B – front infant carrying, C – side infant carrying, and D - in-arms infant carrying) as they came using the balloting methods. Consequent to this arrangement, each participant served under her control. For the randomization, a Latin square by Leslie and Mary was used to derive four sequences of the experimental protocols - ADCB, BADC, CBAD, and DCBA. Each sequence was written on a paper of equal size and folded such that each participant picks one paper, which determines how she will enter and leave the three experimental conditions without replacement.

Subsequently, participants' biodata and anthropometric data were obtained. For habituation purposes, they were taught the procedures for each task which they practiced thoroughly.

The testing conditions were undertaken in the kinesiology laboratory on four separate days between 9:00

am to 12:00 noon daily. On each of the test days, the participants carried out one of the four test conditions, following the sequence of the Latin square. The right thoracic erector spinae (ES), right lower rectus abdomens (RA), right external oblique (RtEO), and left external oblique (Lt EO) muscles were located. Excessive hair was removed from these sites and a brisk wipe using an alcohol swab was used to remove surface oils and other containments from the skin surface. Pairs of silver-silver chloride surface electrodes were positioned parallel to the direction of the muscle fibers with an inter-electrode distance of 3 cm on the RA, 3 cm lateral to the umbilicus; EO, approximately 15 cm lateral to the umbilicus; and ES at 5cm lateral to the T9 spinous process. These surface electrode sites have previously been shown to be representative of the underlying muscle activity to within 15% root mean square of maximum voluntary contraction [37].

To ensure uniformity during each trial, participants performed a metronome-controlled walking at the rate of 98 bpm for 10 minutes, back and forth on a level-surfaced walkway while carrying a 6kg weighing infant dummy. Electrical activities of the selected trunk muscles were measured simultaneously during each trial via surface electromyography (EMG) (Neurotrac Myoplus 2, Verity Medicals). EMG signals were narrowly filtered and normalized to the peak amplitude across trials. Subsequently, the asymmetry ratios (ES:RA and Rt EO:Lt EO) of the studied muscles were calculated. For the ES: RA ratio, values >1 indicated more muscle activity in the ES, a ratio <1 indicated more muscle activity in the RA, while a ratio of =1 indicated symmetry/equal muscle activity in both the ES and RA. Following the same trend, a RtEO: Lt EO ratio of >1 is indicative of more muscle activity in the RtEO muscle; <1 indicates more muscle activity in the Lt EO muscle while a ratio of =1 indicated equal muscle activity in both muscles.

2.4 Data Analysis

Data were summarized with descriptive statistics of frequency, percentages, mean and standard deviation. One way between-subjects analysis of variance (ANOVA) with Tukey HSD test was used to test for differences across the trunk muscles during each ICM while one way repeated measures ANOVA with Bonferroni Post Hoc analysis was used to compare the muscular activities of the abdominal muscles across the four trials. The significance level was set at $p< 0.05$. Data were analyzed using the Statistical Package for Social Sciences software (SPSS, version 23.0, SPSS Inc., Chicago, IL, USA).

3. Results

Table 1 summarizes the participants' general characteristics with their mean age and BMI.21.27 ± 2.12 years and 25.00 ± 5.63 kg/m2 respectively.

Comparisons of the simultaneous EMG activities of the trunk muscles (ES, RA, Rt EO, and Lt EO) during each of the back, front, side, and in-arms infant carrying methods (ICMs) are presented in table 2. Only the front ($p = 0.011$) and side ($p = 0.033$) ICMs elicited significant differences in the trunk muscle activities with their highest activities recorded in the left and right EO muscles, respectively. Table 3 presented the Post-Hoc analysis results with specific comparisons of muscle activities in the front and side ICM. When the EMG values of each muscle were compared across the four trials (table 4), only the Rt EO muscle showed a significant difference ($p = 0.022$) with the side ICM triggering its highest activity. Similarly, the side ICM elicited the highest EMG values in other muscles (ES and RA) except Lt EO.

Comparisons of ES:RA and RTEO:LTEO asymmetry ratios across the four ICMs (table 5) showed that there were no significant differences ($p>0.05$) recorded. However, the side ICM elicited greater asymmetry values, as compared to the other ICMs.

Table 1: General characteristics of the participants for the laboratory phase

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Variables	Experiment 1	Experiment 2	Experiment 3
Age	21.27 ± 2.12	21.00 ± 2.50	23.95 ± 3.63
Height	1.70 ± 0.06	1.70 ± 0.06	1.70 ± 0.06
Weight	72.50 ± 17.06	60.18 ± 11.71	65.05 ± 12.11
Body mass index	25.00 ± 5.63	21.08 ± 3.76	22.61 ± 4.91
Waist circumference	82.83 ± 11.73	75.52 ± 9.14	77.06 ± 11.20
Hip circumference	103.70 ± 12.33	96.51 ± 8.44	98.56 ± 9.58
Waist-hip ratio	0.79 ± 0.05	0.78 ± 0.05	0.78 ± 0.70

Table 2: Comparisons of the simultaneous normalized EMG activities of the trunk muscles during each of the four infant carrying methods

Muscles	Back	Front	Side	In-arms
ES (%)	11.84 ± 5.07	13.12 ± 8.13	12.74 ± 3.96	12.56 ± 6.36
RA (%)	12.99 ± 8.53	14.06 ± 7.11	10.57 ± 6.12	15.81 ± 5.96
RtEO (%)	16.24 ± 6.74	17.35 ± 6.63	15.75 ± 6.19	17.76 ± 7.32
Lt EO (%)	15.83 ± 6.65	20.15 ± 7.88	13.65 ± 5.67	14.44 ± 7.17
F – value	2.012	3.925	3.053	2.306
P – value	0.119	0.011*	0.033*	0.083

* indicates significance at $p < 0.05$; ES = erector spinae; RA = rectus abdominis; RtEO = right external oblique; Lt EO = left external oblique

Table 2: Post Hoc analysis comparing muscle activities for the front and side ICMs

	ES	RA	RtEO	Lt EO
Front				
ES	1	-0.930 (0.972)	-4.217 (0.245)	-7.030 (0.014*)
RA		1	-3.287 (0.472)	-6.100 (0.046*)
RtEO			1	-2.813 (0.645)

Lt EO				1
Side				
ES	1	2.174 (0.605)	-3.003 (0.294)	-0.902 (0.954)
RA		1	-5.177 (0.020*)	-3.077 (0.315)
RtEO			1	2.100 (0.613)
Lt EO				1

Values are presented as mean difference (p-value); *indicates significance at $p < 0.05$; ES – erector spinae; RA – rectus abdominis; RtEO – right external oblique; Lt EO – left external oblique

Table 4: Comparison of the average rectified EMG values of the trunk muscles across the four infant carrying methods

Muscles	Back	Front	Side	In-arms	F – value	P - value
ES	4.86 ± 1.90	3.99 ± 1.39	7.65 ± 13.10	5.71 ± 1.91	2.532	0.099
RA	4.49 ± 1.79	4.87 ± 3.35	6.06 ± 4.78	5.04 ± 2.74	0.895	0.683
RtEO	5.28 ± 3.47	6.36 ± 3.29	7.14 ± 3.14	5.73 ± 2.43	0.489	0.022*
Lt EO	11.56 ± 17.41	7.64 ± 3.81	6.22 ± 2.46	7.05 ± 3.89	0.792	0.444

*indicates significance at $p < 0.05$; ES = erector spinae; RA = rectus abdominis; RtEO = right external oblique; Lt EO = left external oblique

Table 5: Comparison of ES:RA and RtEO:LtEO asymmetry ratios during the back, front, side and in-arms ICMs.

Muscles	Back	Front	Side	In-arms	F-value	P-value
ES:RA	1.05 ± 0.82	1.16 ± 1.08	1.61 ± 1.03	1.51 ± 2.56	0.978	0.436
RtEO:LtEO	1.43 ± 1.00	0.92 ± 0.44	1.71 ± 1.64	1.67 ± 1.41	1.912	0.186

ES:RA = ratio of erector spinae and rectus abdominis muscle; RtEO:LtEO: ratio of right and left external oblique muscles.

4. Discussion

The EMG activities of the erector spinae (ES), rectus abdominis (RA), right external oblique (RtEO), and left external oblique (Lt EO) muscles were comparatively evaluated during each of the four ICMs. The study showed a statistical difference in the normalized EMG (%MVC) values of the four trunk muscles during the front ICM, with the Lt EO muscle showing the highest muscular activity followed by the RtEO

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muscle. This finding indicates that the lateral trunk muscles are more active than the anteroposterior muscles during the front ICM. Studies are scarce on the effects of anterior trunk loading on the lateral trunk musculature. Typically, related studies [38], [39] only evaluated the activities and associated motions of the anteroposterior trunk muscles in response to trunk loading. Contrary to our expectations, the lateral trunk muscles were more involved in the front infant carrying task as opposed to their anteroposterior counterparts. Kinesiological and biomechanical explanations have it that placement of trunk load anteriorly will elicit an anterior shift in the body's center of gravity which in compensation will result in posterior trunk lean for improved stability. For instance, previous studies have shown increased activities in the ES muscle, as compared to other trunk muscles during front load carriage, [38] confirming the tendencies of posterior trunk lean during front load carriage. Equating anterior load carriage with pregnancy (which is associated with an increase in body mass anteriorly), Whitcome [40] also reported an increase in the posterior trunk lean and curve of the lower back during pregnancy.

The increased activities of the abdominal obliques during the front ICM in the present study suggest a new area of interest in trunk muscular activities that need to be further evaluated during anterior load carriage. The abdominal obliques have been identified as primary factors in the maintenance of torsional stability of the spine [41], [42]. Although empirical evidence [43- 45] has shown that the oblique abdominals as lateral abdominal synergists may not always be optimally recruited even in some asymptomatic individuals, the findings of the present study, on the contrary, shows the increased activity of these muscles during the front ICMs. The increased activities of the abdominal obliques in the present study also suggest the possibilities of changes in lateral trunk angles or increased lateral tilt of the pelvis during the front ICM. The lateral tilt of the spine is usually associated with a secondary movement of the ipsilateral lateral tilt of the pelvis, resulting in postural imbalances and instability of the trunk. Increased muscular activities of the external obliques may also predict rapid fatigability and compromised functions of these muscles as the trunk rotational stabilizers during the front ICM.

Secondly, the side ICM also showed significant differences in the activities of the ES, RA, RtEO, and Lt EO muscles, with the RtEO and Lt EO showing the highest muscular activities. In our study, the infant dummy was carried on the left side of the bearer's trunk during the side ICM. Thus, from the results, the contralateral trunk muscles (RtEO) showed the highest muscular activity, indicating tendencies for lateral trunk lean. This finding supports previous studies [27], [46], [47] that reported that asymmetrical load carrying was associated with increased trunk flexion towards the contralateral side. Conversely, our study findings disagree with the results of [3] who reported no significant difference in the lateral trunk angle during the side sling infant carrying, although there were marginal tendencies of their subjects to lean to the side as the weights of the infant's dummies increased. Contradictions in the findings of these studies may be attributed to the differential load weights used in these studies. Also, the differences in the study designs are possible factors of discrepancy in findings. As earlier mentioned, the present study employed the exact mechanisms adopted by Nigerian women while utilizing these traditional ICMs. As a result, the dummy was carried without external support during the side ICM contrary to the study design by [3] which involved the use of an infant sling to support the infant dummies on the bearer's side during the side ICM.

Similar to the front ICM, the increased activities of the abdominal obliques during the side ICM in the present study further suggests that the postural responses to the side ICM may be similar to the responses associated with the front ICM.

On the other hand, the back and in-arms ICMs showed no significant differences in the EMG activities of the trunk muscles. Interestingly, the RtEO and Lt EO muscles showed the highest activities during the back

ICM. This finding was as surprising as the results of the front ICM which also elicited increased muscular activities in the lateral trunk muscles. Contrary to our findings, [38] reported increased activity in the RA muscle in response to backpack carriage, explaining the tendencies of a forward trunk lean to balance the posterior trunk load. Other studies [3], [18], [39] have also reported forward inclination of the trunk in response to posterior load carriage, as contradicted by our findings. For the in-arms ICM, the RtEO muscle also showed the highest activity. As utilized by African mothers and adopted in this study, the in-arms ICM constitutes an asymmetrical method of load carriage as the load is placed on one side of the chest. Since the load was positioned on the left side of the chest during the laboratory procedures, it was anticipated that the contralateral lateral trunk muscles would show the highest activity as revealed by the study findings. The dominant muscular activity of the RtEO muscle during this task may be attributed to the compensatory postural adaptation in response to the additional load placed on the left side of the trunk.

Comparisons of each trunk muscle's activity across the four ICMs showed that a significant difference only existed in the activities of the RtEO muscle across the four ICMs, with the highest activity recorded during the side ICM. The infant dummy was positioned on the participants' left side, possibly resulting in a gravitational shift towards the loaded side (left). In compensation, there should be an increase in the activities of the contralateral muscles (the right obliques) to enable a right lateral trunk lean to counterbalance the shift in the center of mass, as was seen in this study. This finding further corroborates the results of a previous study [46], which reported contralateral curvature of the spine away from the weight on the trunk during asymmetrical load carriage.

Conversely, there were no significant differences in the average EMG activities of the ES, RA, and Lt EO across the four ICMs. However, marginal differences implicated that the side ICM elicited the highest muscular activities in all the studied muscles except Lt EO. This may suggest some biomechanical implications of this ICM. The lack of external support and asymmetric position of the dummy on the left side may have contributed to these findings.

For a better understanding of the trunk muscle activities and their roles in trunk stability during infant carrying, the ratio of agonist to antagonist muscle activation was used to make inferences about postural symmetry/asymmetry. Our findings showed that there were no significant differences in each of the calculated ratios across the four ICMs. However, some marginal differences were of interest to us. From the ratio values, the ES muscle was more active than the RA in all the infant-carrying tasks while the RtEO was more active than the Lt EO in back, side, and in-arms ICMs. These variations indicate trunk muscle asymmetry from altered co-contractions of these antagonist-agonist muscle groups. Spinal stability can be increased through co-contraction of the agonist and antagonist trunk muscles [48- 50]. It was further observed that the side, followed by the in-arms ICMs resulted in the greatest asymmetries in the anteroposterior and lateral muscle groups. This implies that both ICMs will result in more spinal instability, as compared to the back and front ICMs. The side and in-arms tasks were performed without any external support for the infant. This may explain their tendencies for greater asymmetries. However, it may not be most appropriate to conclude spinal instability from the few muscles that were evaluated in this study. A wider and deeper look into the activities of the entire trunk ICMs will give a more encompassing outlook of the co-contraction mechanisms during infant-carrying tasks. Hence, our study is limited in its inclusion of only a fraction of the trunk muscles.

The strength of our study lies in its novelty in comprehensively evaluating the muscular responses to common ICMs utilized by African women. However, we will further suggest that future studies should focus on upgrading the deficient aspects of our study, which may have influenced our findings. This study was limited by the use of a simulated infant in a laboratory setting. Pragmatic or cohort study designs among mothers and their infants may be most suitable to elucidate the roles of different muscle groups during infant-carrying tasks.

5. Conclusion

Simultaneous muscular activations of the four studied muscles varied significantly during the front and side ICMs with more activities in the lateral trunk muscles. Only the Rt Eo muscle varied in its activation across the four ICMs. Most importantly, this study revealed that the side ICM elicited the highest muscle activities in all the studied muscles, as compared to the back front, and in-arms ICMs. Together with the in-arms ICM, they also elicited greater asymmetry in the anteroposterior and lateral trunk muscle groups. Infant carrying with external support (as seen in the back and front ICMs) as well as intentional postural corrections should be encouraged among mothers and caregivers to reduce possible muscle fatigue, postural asymmetry, and possible musculoskeletal disorders.

6. Reference

[1] Szeverényi C, Varga M. Orthopaedic relevance of baby carrying. Orv hetil. 2013;154(30):1172-9. doi: 10.1556/OH.2013.29673.

[2] Wall-Scheffler CM, Geiger K, Steudel-Numbers KL. Infant carrying: the role of increased locomotory costs in early tool development. Am J Phys Anthropol. 2007;133(2):841-6. doi: 10.1002/ajpa.20603.

[3] Singh T, Koh M. Effects of backpack load position on spatiotemporal parameters and trunk forward lean. Gait Posture. 2009;29(1):49-53. doi: 10.1016/j.gaitpost.2008.06.006.

[4] Ojukwu CP, Fab-Agbo CC, Onuchukwu CL, Anekwu EM. Relationship between Baby Carrying Methods and Low Back Pain in postpartum mothers. Int J Med Biomed Res. 2017a;6(3):125-35.

[5] Berchelmann K, Lee K, Ross K, Bhaskar S, Lenhardt S. Should You Wear a Baby Sling?; 2015 [cited Jul 18, 2016]. Available from: http://www.childrensmd.org.

[6] Wagg A. Prescribing skin-to-skin contact and baby-wearing: interventions in Norfolk. J Health Visiting. 2013;1(4):218-20. doi: 10.12968/johv.2013.1.4.218.

[7] Schön RA, Silvén M. Natural parenting—back to basics in infant care. Evol Psychol. 2007;5(1). doi: 10.1177/147470490700500110.

[8] Ayres B. Effects of infant carrying practices on rhythm in music. Ethos. 1973;1(4):387-404. doi: 10.1525/eth.1973.1.4.02a00020.

[9] Ferber SG, Makhoul IR. The effect of skin-to-skin contact (kangaroo care) shortly after birth on the neurobehavioral responses of the term newborn: A randomized, controlled trial. Pediatrics. 2004;113(4):858-65. doi: 10.1542/peds.113.4.858.

[10] Hunziker UA, Barr RG. Increased carrying reduces infant crying: A randomized controlled trial. Pediatrics. 1986;77(5):641-8. doi: 10.1542/peds.77.5.641.

[11] Williams L, Standifird T, Madsen M. Effects of infant transportation on lower extremity joint

moments: baby carrier versus carrying in-arms. Gait Posture. 2019;70:168-74. doi: 10.1016/j.gaitpost.2019.02.004.

[12] Anisfeld E, Casper V, Nozyce M, Cunningham N. Does infant carrying promote attachment? An experimental study of the effects of increased physical contact on the development of attachment. Child Dev. 1990;61(5):1617-27. doi: 10.1111/j.1467-8624.1990.tb02888.x.

[13] Lonstein JS. Regulation of anxiety during the postpartum period. Front Neuroendocrinol. 2007;28(2-3):115-41. doi: 10.1016/j.yfrne.2007.05.002.

[14] Laura S. Ten Reasons to Wear Your Baby; 2016 [cited Sep 13, 2016]. Available from: http://www.naturalchild.org.

[15] Mbada CE, Adebayo OS, Olaogun MO, Johnson OE, Ogundele AO, Ojukwu CP et al. Infant-carrying techniques: which is a preferred mother-friendly method? Health Care Women Int. 2022;43(6):535-48. doi: 10.1080/07399332.2019.1615915.

[16] Knapik J, Harman E, Reynolds K. Load carriage using packs: a review of physiological, biomechanical and medical aspects. Appl Ergon. 1996;27(3):207-16. doi: 10.1016/0003-6870(96)00013-0.

[17] Bobet J, Norman RW. Effects of load placement on back muscle activity in load carriage. Eur J Appl Physiol Occup Physiol. 1984;53(1):71-5. doi: 10.1007/BF00964693.

[18] Hong Y, Cheung CK. Gait and posture responses to backpack load during level walking in children. Gait Posture. 2003;17(1):28-33. doi: 10.1016/s0966-6362(02)00050-4.

[19] Al-Khabbaz YS, Shimada T, Hasegawa M. The effect of backpack heaviness on trunk-lower extremity muscle activities and trunk posture. Gait Posture. 2008;28(2):297-302. doi: 10.1016/j.gaitpost.2008.01.002.

[20] Ojukwu CP, Anyanwu GE, Anekwu EM, Chukwu SC, Fab-Agbo C. Infant carrying methods: correlates and associated musculoskeletal disorders among nursing mothers in Nigeria. J Obstet Gynaecol. 2017b;37(7):855-60. doi: 10.1080/01443615.2017.1306840.

[21] Falola JM, Delpech N, Brisswalter J. Optimization characteristics of walking with and without a load on the trunk of the body. Percept Mot Skills. 2000;91(1):261-72. doi: 10.2466/pms.2000.91.1.261.

[22] Bastien GJ, Willems PA, Schepens B, Heglund NC. Effect of load and speed on the energetic cost of human walking. Eur J Appl Physiol. 2005;94(1-2):76-83. doi: 10.1007/s00421-004-1286-z.

[23] Grenier JG, Peyrot N, Castells J, Oullion R, Messonnier L, Morin JB. Energy cost and mechanical work of walking during load carriage in soldiers. Med Sci Sports Exerc. 2012;44(6):1131-40. doi: 10.1249/MSS.0b013e3182456057.

[24] Borg-Stein J, Dugan SA. Musculoskeletal disorders of pregnancy, delivery and postpartum. Phys Med Rehabil Clin N Am. 2007;18(3):459-76. doi: 10.1016/j.pmr.2007.05.005.

[25] McKay RD. Observing mothers lifting their children in their own home to identify factors which might

ISSN: 0005-2523
Volume 63, Issue 02, February, 2023

give rise to musculoskeletal disorders [Master's thesis]. Auckland University of Technology; 2008.

[26] Schmid S, Stauffer M, Jäger J, List R, Lorenzetti S. Sling-based infant carrying affects lumbar and thoracic spine neuromechanics during standing and walking. Gait Posture. 2019;67:172-80. doi: 10.1016/j.gaitpost.2018.10.013.

[27] Matsuo T, Hashimoto M, Koyanagi M, Hashizume K. Asymmetric load-carrying in young and elderly women: relationship with lower limb coordination. Gait Posture. 2008;28(3):517-20. doi: 10.1016/j.gaitpost.2008.02.001.

[28] Lymbery JK, Gilleard W. The stance phase of walking during late pregnancy: temporospatial and ground reaction force variables. J Am Podiatr Med Assoc. 2005;95(3):247-53. doi: 10.7547/0950247.

[29] Petronilla OC, Moris AE, Emmanuel MC, Ozioma TN, Justina OA, Kenneth AD. Are infants at risk of breast feeding-and infant carrying-related musculoskeletal disorders? Arch Physiother Glob Res. 2018;22(1).

[30] Park HK, Shin HK, Nam KS. Investigation of wearing methods of a baby carrier on muscle activation during trunk flexion-extension in healthy women. Phys Ther Rehabil Sci. 2020;9(1):36-42. doi: 10.14474/ptrs.2020.9.1.36.

[31] Evanoff B. Work-related musculoskeletal disorders: examining the Research Base epidemiology: physical factors: an assessment of the NIOSH review. Work-related musculoskeletal disorders [report], workshop summary and workshop papers. Washington, (DC)- National Academy Press; 1999. p. 152-4.

[32] Tinubu BM, Mbada CE, Oyeyemi AL, Fabunmi AA. Work-related musculoskeletal disorders among nurses in Ibadan, South-West Nigeria: A cross-sectional survey. BMC Musculoskelet Disord. 2010;11(1):12. doi: 10.1186/1471-2474-11-12.

[33] Suter SE, Huggenberger HJ, Richter S, Blumenthal TD, Schachinger H. Left side cradling of an appetitive doll is associated higher heart rate variability and attenuated startle in nulliparous. Int J Psychophysiol. 2009;74(1):53-7. doi: 10.1016/j.ijpsycho.2009.07.002.

[34] Huggenberger HJ, Suter SE, Reijnen E, Schachinger H. cralding side preference is associated with lateralized processing of baby facial expressions in females. Brain Cogn. 2009;70(1):67-72. doi: 10.1016/j.bandc.2008.12.010.

[35] Reissland N, Hopkins B, Helms P, Williams B. Maternal stress and depression and the lateralisation of infant cradling. J Child Psychol Psychiatry. 2009;50(3):263-9. doi: 10.1111/j.1469-7610.2007.01791.x.

[36] Abdulrahman Derbash M, Alzahrani. Effects of depression, stress and Other factors on cr xadling bias in Saudi males and females [University of Edinburgh PhD thesis]; 2012.

[37] McGill SM, Juker D, Kropf P. Appropriately placed EMG electrodes reflect deep muscle activity (psoas, quadratus lumborum, abdominal wall) in the lumbar spine. J Biomech. 1996;29(11):1503-7. doi: 10.1016/0021-9290(96)84547-7.

[38] Motmans RR, Tomlow S, Vissers D. Trunk muscle activity in different modes of carrying schoolbags. Ergonomics. 2006;49(2):127-38. doi: 10.1080/00140130500435066.

[39] Devroey C, Jonkers I, De Becker A, Lenaerts G, Spaepen A. Evaluation of the effect of backpack load and position during standing and walking using biomechanical, physiological and subjective measures. Ergonomics. 2007;50(5):728-42. doi: 10.1080/00140130701194850.

[40] Whitcome KK. Obstetric load and the evolution of human lumbopelvic sexual dimorphism [PhD dissertation]; 2006, University of Texas at Austin: August.

[41] Bogduk N, Macintosh JE, Pearcy MJ. A universal model of the lumbar back muscles in the upright position. Spine. 1992;17(8):897-913. doi: 10.1097/00007632-199208000-00007.

[42] Gracovetsky S, Farfan H, Helleur C. The abdominal mechanism. Spine. 1985;10(4):317-24. doi: 10.1097/00007632-198505000-00005.

[43] Caix M, Outrequin G, Descottes B, Kalfon M, Pouget X. The muscles of the abdominal wall: A new functional approach with anatomical deductions. Anat Clin. 1984;6(2):101-8. doi: 10.1007/BF01773161.

[44] Parnianpour M, Nordin M, Kahanovitz N, Frankel V. 1988 Volvo award in biomechanics. The triaxial coupling of torque generation of trunk muscles during isometric exertions and the effect of fatiguing isoinertial movements on the motor output and movement patterns. Spine. 1988;13(9):982-92. doi: 10.1097/00007632-198809000-00004.

[45] Jull G, Richardson C, Toppenberg R, Comerford M, Bui B. Towards a measurement of active muscle control for lumbar stabilisation. Aust J Physiother. 1993;39(3):187-93. doi: 10.1016/S0004-9514(14)60481-5.

[46] Pascoe DD, Pascoe DE, Wang YT, Shim DM, Kim CK. Influence of carrying book bags on gait cycle and posture of youths. Ergonomics. 1997;40(6):631-41. doi: 10.1080/001401397187928.

[47] Fowler NE, Rodacki AL, Rodacki CD. Changes in stature and spine kinematics during a loaded walking task. Gait Posture. 2006;23(2):133-41. doi: 10.1016/j.gaitpost.2004.12.006.

[48] Gardner-Morse M, Stokes IAF, Laible JP. Role of muscles in lumbar spine stability in maximal extension efforts. J Orthop Res. 1995;13(5):802-8. doi: 10.1002/jor.1100130521.

[49] Cholewicki J, McGill SM. Mechanical stability of the in vivo lumbar spine: implications for injury and chronic low back pain. Clin Biomech (Bristol Avon). 1996;11(1):1-15. doi: 10.1016/0268-0033(95)00035-6.

[50] Cholewicki J, Panjabi MM, Khachatryan A. A stabilising function of trunk flexor-extensor muscles around a neutral spine posture. Spine. 1997;22(19):2207-12. doi: 10.1097/00007632-199710010-00003.