Post-Natal Positioning through Babywearing: What the Orthopaedic Surgeon Needs to Know

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Abstract: Babywearing is the practice of using a swathe of fabric or purpose-built carrier to hold an infant or toddler close to the caregiver’s torso for multiple hours of the day. The child’s legs are often positioned in an “M” shape, with hips and knees flexed and the hips abducted. There is increasing interest in the potential for babywearing to assist in hip development, as the “M” position assumed in most carriers is similar to the position achieved in harnesses/braces used in the treatment of developmental dysplasia of the hip (DDH). The association between low incidence of DDH in babywearing populations suggests this may play a role in optimal hip development. The purpose of this review is to present epidemiological, comparative, biomechanical, and imaging studies that investigate the potential impact of babywearing on hip development while outlining other benefits such as caretaker-infant responsiveness, attachment and bonding, and potential parental benefits such as decreased crying, improved breastfeeding, caregiver multi-tasking, as well as potential complications and impact on gait and posture for those supporting an infant.

Key Concepts:
- Babywearing involves using a swathe of fabric or purpose-built carrier to hold an infant or toddler close to the caregiver’s torso for multiple hours of the day.
- Observational population studies demonstrate an association between babywearing and low incidence of DDH, although genetic factors may also play a role.
- Babywearing in an “M” position with hips flexed and abducted mimics the position obtained in a Pavlik harness and is theorized to promote hip development.
- Non-orthopaedic benefits of babywearing include stimulating caretaker-infant responsiveness, improving attachment and bonding, promoting language development, decreasing infant crying, supporting breastfeeding.

Introduction
Babywearing is the practice of using a swathe of fabric or purpose-built carrier to hold an infant or toddler close to the caregiver’s torso, be it the front, back or side (Figure 1). The child is close enough to feel the parent’s warmth, and hear their heartbeat, voice, and breathing. Often, the infant’s legs are positioned in an “M” shape, with hips and knees flexed and the hips abducted. Babywearing has been used for thousands of years in
some cultures, keeping the child close, warm, calm, and allowing the caregiver’s arms to be free for other work. Babywearing involves carrying the baby for multiple hours in the day by a parent or caregiver. It has also been trending in recent years, concurrent with parental interests in attachment parenting (promoting the attachment of parent and infant not only by maximal parental empathy and responsiveness but also by continuous bodily closeness and touch). Multiple carriers exist, ranging from a simple piece of fabric that is tied about the body to custom made carriers with extensive fastening clips, cushions, and pockets. Families are using baby carriers, and orthopaedic surgeons need to know the orthopaedic and non-orthopaedic benefits and potential complications of this form of post-natal positioning.

The etiology of DDH has not been fully elucidated but a combination of genetic, hormonal, and mechanical factors may play a role in its development. While associations with positive family history\(^1\) and female sex\(^2\) may be due to genetic and hormonal factors, the risks associated with firstborns,\(^3\) post-maturity birth,\(^2\) birth weight >4 kg,\(^2,4\) oligohydramnios,\(^5\) breech position\(^4\) in utero, and vaginal birth of breech babies all seem consistent with abnormal peri-natal mechanics. Postnatal positioning has also been implicated. In particular, swaddling and carrying practices that restrict hip and knee flexion are believed to increase the risk for DDH,\(^6\) while the “M” position is hypothesized to be protective.\(^7\)

The primary objective of this review is to provide comprehensive and up-to-date information on babywearing and its impact on hip position and development, focusing on reports of DDH incidence in cultures that practice babywearing as well as studies that utilize imaging and biomechanical models to investigate hip position and anatomy during babywearing. The secondary objective is to contrast these findings with other forms of post-natal hip positioning and their associations with hip development. Practical information on non-orthopaedic benefits and potential complications are also provided.

**Association Between Babywearing and DDH**

A systematic review of 422 articles focusing on the epidemiology and demographics of DDH reported an incidence ranging from 0.06/1000 in Africa to 76.1/1000 in Native Americans.\(^8\) The significant variability in incidence within these racial and geographic groups could be genetic but may also be influenced by cultural/ethnic post-natal positioning practices.

A retrospective review of medical records between 1960 and 1975 reported an incidence of 0.005-0.009% of DDH in Southern China, approximately 10 times less than that found in Caucasians.\(^10\) In Southern China,
infants are traditionally held in the “Hong Kong” position, on their mothers’ backs with hips flexed and abducted. Of those with hip dislocations, 41% were carried in the “Hong Kong” position during the first 6 months of life compared to 49% in a control group without DDH. During the first 2 years of life, 67% with DDH were held in the “Hong Kong” position compared to 54% in the control group. There was no difference in the number of hours of carrying between the DDH and control groups. The authors concluded that while the Hong Kong position could be beneficial, other factors such as genetics likely account for the rarity of DDH in Southern China.

A population-based study of children born in Western Australia in 1981 to 1983 showed low rates of DDH among infants born to Aboriginal mothers, with a rate of 3.7/1000 births in Aboriginal women compared to 6.6/1000 births in non-Aboriginal women. The authors reported that Aboriginal infants spend a large proportion of their early lives being carried with their hips abducted, either by their mother or members of the extended family. This cultural practice was hypothesized to be the primary explanation for the differences in DDH incidence. However, this relationship with babywearing was observational and speculative; there was no direct measurement of babywearing in either group.

Inuit living around the North Pole commonly carry their infants in a hood (amauti) inside their parkas. This practice abducts the infant’s hips by straddling the mother’s back. Despite a genetic origin believed to be similar to Native Americans who have a high incidence of DDH, Inuit’s practice back-carrying are reported to have a significantly lower incidence of DDH compared to Caucasians. Of note, the original article that was cited documenting the incidence in this population could not be obtained and checked for accuracy.

Several case series have commented on the low rates of DDH among African cultures. Many Central and Southern African populations traditionally back-carry their infants. Roper et al. observed the rarity of DDH in the Bantu population; in an estimated total of 40,000 patients seen over 35 years, there was only one reported case of typical DDH. Due to the concurrent low incidence of osteoarthritis in the Bantu adults, Roper and colleagues believed genetics to be the greatest protective factor in this population. Griffiths and van Meerdervoort also presented cases of infants from

Table 1. Incidence of DDH by Infant Hip Position in Communities that Practice Babywearing

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study Population</th>
<th>Infant Hip Position</th>
<th>Incidence of DDH</th>
</tr>
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<tbody>
<tr>
<td>Graham 2015</td>
<td>Malawi, November 2002-September 2012</td>
<td>Back-carry infants for first 2-24 months in “M” hip position</td>
<td>0% (0/40683)</td>
</tr>
<tr>
<td>Hoaglund 1981</td>
<td>Southern China, 1968-1974</td>
<td>Back-carry infants in “M” hip position (~50% of the population)</td>
<td>0.005-0.009%</td>
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<tr>
<td>Bower 1987</td>
<td>Western Australia, 1981-1983</td>
<td>No direct measurement of baby-carrying; Aboriginal infants are known to spend a large proportion of their lives being carried with their hips abducted by mother or other family member</td>
<td>0.37% (Aboriginal) 0.66% (non-Aboriginal)</td>
</tr>
<tr>
<td>Roper 1976</td>
<td>Bantu people, 35 years</td>
<td>Traditional Bantu infant carrying method, “M” hip position</td>
<td>0.0025% (1/40000)</td>
</tr>
<tr>
<td>Authors</td>
<td>Study Population</td>
<td>Infant Hip Position</td>
<td>Incidence of DDH</td>
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<tr>
<td>Ishida 1977</td>
<td>Kyoto City, Japan, 1971-1976</td>
<td>Tight swaddling was used before a local campaign emphasized the importance of preventing DDH. In 1973, the educational program included recommendations to avoid prolonged extension of the hip and knee during early postnatal life.</td>
<td>5.3% in 1971–1973 versus 0.6% in 1974–1976</td>
</tr>
<tr>
<td>Yamamuro 1984</td>
<td>Japan, 1975</td>
<td>Tight swaddling was used before a 1975 national Japanese campaign with recommendations to avoid prolonged extension of the hips and knees of infants during the early postnatal period</td>
<td>3.5% before 1975 campaign versus less than 0.2% after 1975 campaign</td>
</tr>
<tr>
<td>Mellbin 1962 and Getz 1955</td>
<td>Sámi, indigenous people of Sápmi, the circumpolar areas Europe (Sweden, Norway, Finland, Kola Peninsula of Russia)</td>
<td>Cradleboard (gietka or komse) hollowed from a log tightly swaddling the lower extremities and allowed for minimal movement</td>
<td>2.5% (Mellbin) 4.0% (Getz)</td>
</tr>
<tr>
<td>Salter 1968</td>
<td>Canadian Indian Tribes, 1963</td>
<td>Cradleboard (Tikonagan) with hips in extension and adduction</td>
<td>12.3% (250/2032 live births with cradleboard use) vs. 1.2% (17/1347 live births without cradleboard use)</td>
</tr>
<tr>
<td>Rabin 1965</td>
<td>Navajos born 1910-1930 and 1955-1961</td>
<td>Cradleboards were traditionally used, with hips in extension and adduction. Diapers were introduced before 1955 leading to a decreased use of cradleboards</td>
<td>2.6% (1910-1930) versus 0.7% (1955-1961)</td>
</tr>
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Central and Southern Africa with DDH; however, they suggested that back-carrying is an important preventative measure in addition to genetic factors.

To further investigate this hypothesis, a recent review and retrospective cohort examined the diagnosis and management of all infants seen at the Beit CURE International Hospital in Malawi and its mobile clinics, from November 2002 to September 2012. In a population of 40,683 children, Graham et al. found no patients with a diagnosis of DDH. The majority of mothers in Malawi back-carry their infants for the first 2 to 24 months in the “M” position; the authors believed this was primarily responsible for the low incidence of DDH in Malawi.

The low incidence of DDH in Africa (weighted average 0.06/1000) and the higher incidence of DDH among Blacks in the United States (weighted average 0.40/1000) is of interest. Between 1977 and 1982, the incidence of DDH at a single institution in Louisiana was reported to be 1.5/1000 among White children and 0.46/1000 among Black children. A retrospective review at a single institution in Indiana assessed the race distribution of patients with DDH to the race distribution of live births. They found that 4.0% of infants with DDH were Black, while Black babies made up 11.7% of the live births. In comparison, 80.8% of infants with DDH were White, while White babies made up 77.0% of live births. Overall, the incidence of DDH among Blacks in the United States is higher than in Africa but lower than for Whites in the United States. The authors believed the etiology of these differences to be multifactorial and related to both genetic heterogeneity (intermarriage of Blacks and Whites in the United States) and to cultural baby transporting practices. It was hypothesized that Black infants in North America are more likely to be transported in baby strollers and car seats, rather than carried with the hips in an abducted position.

### Hip Biomechanics in Babywearing

Recent studies on hip biomechanics suggest that babywearing is beneficial to hip development. A computational model of a 1-year-old infant’s lower extremities was constructed with modeling software to investigate the relationship between babywearing positions and hip joint reaction forces. The model was subjected to a range of hip flexions and abductions, while keeping external rotation fixed at 10 degrees. At 60 degrees of abduction and 120 degrees of flexion, the infant right hip model produced a joint reaction force of 244 N, closest to the value reported to be beneficial for healthy hip development and to the in vivo joint reaction forces known to be present with a standing leg raise. The authors concluded that babywearing in the “M” position with hips abducted and flexed is conducive to healthy hip development.

In another study, lower-extremity muscle activity and hip position was measured in 20 healthy full-term infants positioned in a Pavlik harness, a rigid hip abduction brace, an inward-facing soft-structured baby carrier, a standard car seat, and held in arms. Surface EMG was used to record muscle activity and marker-based motion capture was used to track lower extremity motion. The authors found no difference in hip flexion, abduction, external rotation, and lower limb muscle activity between the Pavlik harness and the baby carrier. In contrast, having the infant in a car seat resulted in approximately half of mean adductor and quadriceps muscle activity compared to the Pavlik harness. The authors suggested that baby carriers could play a crucial role in preventing DDH and/or supplementing the treatment of DDH.

### Hip Ultrasound While Babywearing

Imaging has also been utilized to characterize hip position while babywearing. Fontecha et al. used ultrasound to assess whether three different baby-carriers ranging from a loose semi-flexed “M” position (original Baby Bjorn, BabyBjörn, Lanna, Sweden) to a moderate...
“M” position (Baby Bjorn One, BabyBjörn, Lanna, Sweden) to a more extreme hyper-flexed “M” position (Manduca, Wickelkinder GmbH, Marburg, Germany) could influence the femoral head position (alpha angle and % acetabular coverage) while in the carriers.20 Fifteen healthy infants aged 1.5 to 3.5 months underwent bilateral on-table static diagnostic ultrasounds, and were confirmed to have Graf 1 (normal) hips. Right hip static ultrasounds in the three baby-carriers were then obtained and no difference in alpha angle, acetabular coverage, or distance to the pubis was identified. The authors concluded the infants’ hip maintains normal ultrasound parameters when placed in the tested baby-carriers, with the caveat that dysplastic hips may react differently. It should be noted that this was immediate testing, and the authors did not investigate the effects of long-term positioning in these carriers.

Other Post-Natal Positioning and Effects on Hip Development

In contrast to the “M” hip position, swaddling the legs in an extended and adducted position is a risk factor for DDH (Table 2). DDH is rare in cultures where swaddling is not used (Southern Chinese,10 African Bantu,14 Thailand,21,22 North Korea,23 Sri Lanka24). In contrast, communities with prevalent swaddling practices have higher incidences of DDH. In Saudi Arabia, studies have demonstrated that swaddling is an important factor in the etiology of DDH.25,26 The high incidence of DDH in Arabic peoples in Western Galilee27 and Iraqi immigrants in Israel28 has been attributed to this practice. In Hungary,29 swaddling was believed to account for the high incidence (28.7/1000) of DDH which is much greater than incidences in countries of Western Europe and North America. A retrospective cohort of 392 patients from a multicenter database in the United States reported that babies with a history of swaddling have a 2x greater odds of developing late-presenting DDH compared to babies who were not swaddled.30 A systematic review cited 11 additional epidemiologic studies that have shown a strong correlation between incidence of DDH and the traditional use of swaddling for newborn infants.31

Public health campaigns educating patients on the problems associated with swaddling in extension have been utilized to reduce the incidence of DDH. In Kyoto, Japan, the incidence of DDH dropped from 52.9/1000 in 1971–1973 to 5.6/1000 in 1974–1976 after an educational campaign against tight lower extremity swaddling.32 The results from Kyoto led to a national Japanese education and prevention program with similarly striking reductions in incidence of DDH: from 3.5% before 1975 to less than 0.2% following the national program.33 In Turkey, the odds ratio of DDH in swaddled children compared to non-swaddled children has been reported to range from 2.9 to 6.134,35 and one study found that 98% of DDH patients were swaddled compared to 87.1% of non-DDH patients (p<0.05).36 Despite efforts in Turkey to educate parents about the risks of tight swaddling of lower extremities, one institution reported that approximately 75% continued to swaddle their babies with legs extended.37 In Qatar, the implementation of a community awareness program demonstrating the harmful effects of swaddling reduced the incidence of ultrasonographic dysplasia in children at high risk for DDH from 20% to 6%.38

Ultrasound has also been used to evaluate hip joint stability in infants who were swaddled by the traditional tight method, safe blanket techniques, and commercial devices.39 Harcke et al. compared 16 infants in a Pavlik harness “treatment group” and 14 infants in a “non-treatment” group. They reported that tight swaddling restricts range of motion in comparison with range of motion allowed by safe (allowing hip flexion and abduction) swaddling methods.39 Safe swaddling does not affect hip position; no stable or unstable hip exhibited an immediate position change in comparison with the initial sonogram. Lastly, they concluded that safe swaddling does not affect stable hips in a Pavlik harness but can affect unstable hips.39
Cradleboards have been used in some cultures for keeping children warm, still, away from hazards such as open fires, and for transportation. Similar to traditional swaddling, cradleboards typically restrict the legs in a static extended position. In Canada, the Cree of northern Quebec used cradleboards until 1.5 years of age.\textsuperscript{40} This population was noted to have a high burden of DDH. In addition to the use of cradleboards, they were noted to have significant multidirectional ligamentous laxity of the hips, and femoral anteversion, with preferred W sitting.\textsuperscript{40} Due to spontaneous normalization of some hips, the author hypothesized that much of the hip dysplasia was due to hip adduction forces caused by the cradleboards, and the hips normalized once these forces were discontinued. Similarly, a 10-fold increase in DDH (12.3\% versus 1.2\%) was reported in Canadian First Nations people from Ontario who used the cradleboard compared to those who did not.\textsuperscript{41} In the United States, a study of approximately 2,300 Navajos\textsuperscript{42} found hip dislocation to be more prevalent in adults than children (2.6\% versus 0.7\%, p<0.01). The authors postulated that the decreased dislocation in children was due to the transition from exclusive use of the Navajo cradleboard to the more frequent use of diapers, which had not traditionally been used, and may have resulted in comparatively greater hip abduction.

In Sámi, indigenous people of Sápmi, the circumpolar areas of Europe (Sweden, Norway, Finland, Kola Peninsula of Russia), the cradleboard (gietka or komse) was believed to account for the high incidence (24.6 to 40/1000) of DDH.\textsuperscript{43,44} The gietka is a cradle hollowed from a log and where the child is placed with tight swaddling of the lower extremities and allowing only for minimal movement. This cradle was practical in the Sámi nomadic culture and lifestyle, allowing mothers to carry the cradle across their shoulders, or onto a reindeer’s pack saddle.\textsuperscript{43} As nomadic reindeer herding culture and lifestyles have changed, the prevalence of DDH in the Sámi has fallen.\textsuperscript{45,46}

### Non-Orthopaedic Benefits of Babywearing

In addition to the potential positive effects on hip development, babywearing has been shown to have several other benefits (Table 3). Babywearing allows frequent close physical contact between the caregiver and infant, thereby promoting caregiver responsiveness, secure attachment, and bonding.\textsuperscript{47,48} Hours spent babywearing has also been positively correlated with secure attachment and negatively correlated with disorganized attachment in a cohort of infants born to adolescent mothers, a population that is at particularly high risk of developing insecure attachments and attachment disorders into adulthood.\textsuperscript{49,50} Babywearing may also stimulate infant language development\textsuperscript{51} while decreasing infant crying. In a randomized control trial, infants exposed to increased carrying throughout the day

<table>
<thead>
<tr>
<th>Benefits of Babywearing</th>
<th>Risks and Complications Associated with Babywearing</th>
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<tr>
<td>Hip development (does not harm and may improve)</td>
<td>Sudden infant death/asphyxia</td>
</tr>
<tr>
<td>Promotes caretaker-infant responsiveness, attachment, and bonding</td>
<td>Falls/trauma</td>
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<tr>
<td>Language development</td>
<td>Baby-carrier purpura</td>
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<tr>
<td>Decreases infant crying</td>
<td>Impact on caregiver energy expenditure and fatigue</td>
</tr>
<tr>
<td>Improves breastfeeding</td>
<td>Impact on caregiver gait and posture, low back pain</td>
</tr>
<tr>
<td>Convenient (allows for multi-tasking)</td>
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cried 43% less than infants in the control group at 6 weeks. Whilst babywearing, it is possible to position the infant to facilitate breastfeeding. Babywearing increases the likelihood of responsive breastfeeding, feeding that is initiated in response to an infant’s early hunger cues. Mothers who self-reported responsive feeding were more likely to exclusively breastfeed for the first 6 months and breastfeed more frequently throughout the day. Practically speaking, babywearing also allows caregivers to engage in day-to-day activities while staying in close proximity to their infants. Caregivers can walk and multi-task, all while the infant remains close-by. Additionally, babywearing is thought to have a positive impact on maternal emotional well-being.

Risks and Complications of Babywearing

Suffocation has been reported while babies have been positioned in carriers. Poor positioning in a sling or carrier, such that the infant’s face is covered by fabric and the nose and mouth are pressed against the adult’s body can increase the risk of asphyxiation. Parents should be educated on proper babywearing, with infant’s face and head visible at all times, nose and mouth free, and avoidance of the flexed chin-on-chest position. Falls and trauma to infants in carriers have also been reported. Modes of injury included: cloth tearing, zippers coming undone or separating, hooks or fastening rings breaking, infants falling through leg openings, straps breaking, stitching unraveling, clasps or brackets breaking, and parents falling while carrying their child.

Rumpel-Leede phenomenon associated with baby carriers has also been described in the literature. This phenomenon is characterized by petechiae and purpura localized to the lower extremities due to tourniquet-like forces from the cinching of the baby carrier tightly around the extremities. “Baby carrier purpura” is benign and lesions spontaneously resolve in a few weeks.

Babywearing increases caloric output and can also alter gait and walking speed. Carrying an infant in arms without the use of a sling has been shown to increase the mechanical load placed on the knee and hip joints in the frontal plane; however, babywearing with an anteriorly-worn carrier (with the infant facing the caregiver) was shown to more closely resemble unloaded walking. Finally, infant carrying can also alter posture and the biomechanical alignment of the mother’s trunk, which may constitute a potential risk factor for development of musculoskeletal pain. In caregivers with lumbar pain, the authors recommended lowering the wearing height of the baby carrier to pelvic level so that the external load could be transferred to the lower extremities (Table 3).

Conclusion

This review presents comprehensive evidence on the association between babywearing and improved hip development, as well evidence demonstrating diminished hip development (dysplasia) with alternate post-natal positioning (swaddling and cradleboards). Incidence of DDH is low amongst people who practice babywearing, including Southern China, Aboriginal people of Western Australia, Central and Southern Africa, Malawi, and the Inuit of the circumpolar north. Incidence of hip dysplasia is higher in American Indians and Sámi populations where cradleboards have traditionally been used. Granted, it is difficult to parse out the genetic versus environmental contributory factors. Biomechanical studies demonstrate that babywearing in the “M” position provides a healthy hip position, with similar positioning and muscle activation as achieved in a Pavlik harness. In addition to potentially promoting healthy hip development, babywearing stimulates caretaker-infant responsiveness, improves attachment and bonding, promotes language development, decreases infant crying, supports breastfeeding, and allows for caregiver multi-tasking. Caregivers must be aware of the rare but important risks of babywearing including asphyxia, falls/trauma, and baby-carrier purpura, all of which most commonly occur due to improper use or positioning.
Acknowledgements
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