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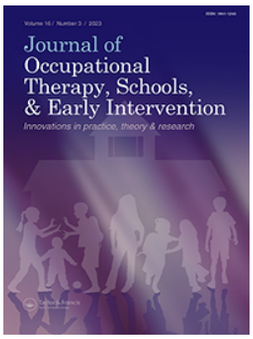

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Theoretical Context for a Wakeful Prone and Vestibular Infant Movement Program to Support Early Infancy Motor Development

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ABSTRACT

A growing awareness and encouragement of the need for infants to spend more awake time in the prone position suggests that the provision of information about infant movement activities that encourage and reassure parents and carers in undertaking daily tummy time incorporating vestibular actions with young infants, is important and timely. There are indications that lack of daily infant tummy play time may be associated with low infant rudimentary skills and with the potential of positional plagiocephaly. This paper presents information on infant motor development in relation to the factors that may be shaping infants' movement maturity and outlines the relationship of the infant's developing sensory system (vestibular, tactile, proprioceptive) to attaining typical motor development. This acts as a detailed theoretical basis for a neurological designed infant movement program to contribute to overall infant motor development. The paper provides background information for the creation, format, and design of an infant development movement program (the 'Back to Sleep, Tummy to Play program) that may be suitable and appropriate for families and early years therapists such as maternal and early childhood nurses, occupational therapists, and physical therapists, to interact with in supporting and developing both infant tummy and vestibular time.

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Infants; rudimentary motor milestones; motor development; prone time; tummy time; vestibular sensory systems; infant motor movements

Introduction

Existing studies have presented findings that reinforce the importance of daily prone (tummy) time for infants younger than six months to promote the development of normal infant milestones and motor functioning (Dudek-Shriber & Zelazny, 2007; Kuo, Liao, Chen, Hsieh, & Hwang, 2008; Lee & Galloway, 2012). Since identification of the term "sudden infant death syndrome" (SIDS) and the "Back to Sleep" awareness campaign of the 1990s (American Academy of Pediatrics Task Force on Infant Positioning and SIDS, 1996) and more recently, the 2016 "Safe Infant Sleep" environment review (Moon, Darnall, Feldman-Winter, Goodstein, & Hauck, 2016), strong recommendations have been made proposing that sleeping infants in supine positions reduce the risk of SIDS. Conversely, researchers continue to present evidence that a lack of awake prone positioning for young infants

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correlates with delays and/or non-achievement of major motor milestones (Guidetti, Wells, Worsdall, & Metz, 2017; Kuo, Liao, Chen, Hsieh, & Hwang, 2008).

Growing awareness and encouragement of the need for infants to spend more awake time in the prone position by early years clinicians including maternal and early childhood nurses, occupational therapists, and physical therapists has led to documents, such as the 24-Hour Movement Guidelines for the Early Years – Birth to 5 years in Australia (Australian Government, 2017). This document recommended a minimum of 30 min or more daily for infants to spend in tummy time or prone positions. Despite this encouragement, there has been a reticence by parents and carers to undertake the desired awake supervised tummy time (Cross, Eastman, Brovender, & Ward, 2017; Felzer-Kim, Erickson, Adkins, & Hauck, 2020). Parents were reported as being uncomfortable when placing their infants in tummy time positions, particularly when infants exhibited frustration and crying behaviors (Vladescu, Schnell, & Day-Watkins, 2020). Additionally, programs were not readily available to provide the necessary confidence, knowledge and skills for parents and carers to support suitable and enjoyable prone activities (Hewitt, Stanley, & Okely, 2017; Koren, Reece, Kahn-D'angelo, & Medeiros, 2010; Zachry & Kitzmann, 2011).

In addition to a proposal of accessible tummy time activity programs, there appears a requisite to research the relevant factors underpinning the achievement of infant motor milestones, particularly in relation to the infant's sensorimotor systems (Cascio, 2010; Lane et al., 2019). There is a disparity from the perspective of parents and carers on understanding of the sensory integration approach to attaining motor skills (Cohn, 2001), particularly regarding the impact adults can have on infants when engaging in daily sensory/vestibular activities to explore motor movements (Dirks, Blauw-Hospers, Hulshof, & Hadders-Algra, 2011; Smith-Roley, Singer, & Roley, 2016). Establishing a functioning vestibular system is critical to an infant's motor development as equilibrium dysfunction may result in delayed infant head control and a lag in achieving the crawling milestones (Gans, 2015). Interestingly, research studies have primarily centered on specific infant prone positioning intervention programs, which encouragingly have resulted in improved infant motor development outcomes (Hewson, 2011; Jennings, Sarbaugh, & Payne, 2005; Lobo & Galloway, 2012). Fewer infant motor development research projects have been undertaken to focus on specific postural control actions (Lee & Galloway, 2012), or in relation to the effect of the vestibular sensory system on "response to gravity" focused activities (Van Hecke et al., 2019).

Key Components to Support Infants Acquiring Early Motor Development Skills

It is relevant to highlight two key components to support an infant's journey to experience the early motor development skills within the rudimentary movement phases including prone control, rolling over, commando, and hands and knees crawling. The first important component incorporates the importance of introducing infants to enjoyable, wakeful prone (tummy time) activities to promote early core strength, head, and upper body control (Dudek-Shriber & Zelazny, 2007; Russell, Kriel, Joubert, & Goosen, 2009). Prone actions also provide opportunities for infants to use the extensor muscles of the back and neck and can contribute to diminishing physiological flexion associated with birth posture (Bales & Godfrey, 2013) and limiting the possibility of positional plagiocephaly (Nitsos, Estrada, & Messias, 2017).

The second key component involves sharing with parents the fun and significance of undertaking safe vestibular (rocking, gentle tipping, and swaying) actions that enhance stability reactions, encourage balance skills and postural control, and foster motor milestone development (Gans, 2015; Nandi & Luxon, 2008; Van Hecke et al., 2019; Verrecchia et al., 2019). The vestibular motions also encourage neurological responses to the pull of gravity that assist with the inhibition of infant primitive reflexes (Gieysztor, Pecuch, Kowal, Borowicz, & Paprocka-Borowicz, 2020; Zafeiriou, 2004). These two key components are fundamental to supporting the young infant's progression through the rudimentary locomotor stages.

An investigation of prone focused programs that included varied amounts of vestibular actions revealed the positive impact that these movement activities can have on early infant motor development (Lee & Galloway, 2012; Lobo & Galloway, 2012). There is a necessity to upskill parents to provide suitable and compatible tummy time activities such as lack of confidence, infant intolerance, knowledge, and available activities may be influencing the reports of low percentages of overall daily tummy time overall percentages (Hesketh et al., 2017; Koren, Reece, Kahn-D'angelo, & Medeiros, 2010; Ricard & Metz, 2014).

Infant skill education practices associated with upskilling parents on the vestibular perspective may also be necessary for early childhood health professionals (including maternal and early childhood nurses, occupational and physical therapists, early years movement educators, osteopaths, and chiropractors) as this cohort may also be less familiar with the benefits of daily infant vestibular participation and its connection to the development of infant responses to gravity (Christy, 2019; Gans, 2015; Van Hecke et al., 2019). The progression of knowledge and awareness within this professional cohort could be important in supporting parents and carers in encouraging vestibular activities. Consequently, research evidence provides general support to develop an infant movement ideas program that is focused on safe and appropriate infant tummy time and vestibular time actions. This type of program could progress the knowledge acquisition and confidence of parents and carers to undertake daily activities with their infants and facilitate the normal achievement of motor milestone development.

Theoretical Structure for a Wakeful Prone and Vestibular Action Program

Evaluation of relevant and applicable theory may serve to frame content and structure for the creation of an infant movement program. Such a theoretical review approach should encompass the consequences of sensory input and motor output experiences, the mirroring of vital early infant reflex sequences, and the integrating of brainstem activity through to cortex growth, within the young infant's environment (Adolph & Franchak, 2017; Gieysztor, Choińska, & Paprocka-Borowicz, 2018; Thomason et al., 2018). In support of this overall theoretical approach, the Pyramid of Learning model (Taylor & Trott, 1996) provides a comprehensive visual interpretation of early learning development across five tiers of development, with learning supported by and reliant on the previous development of essential sensorimotor skills (Williams & Shellenberger, 1996). An adaption of the Pyramid of Learning model (figure 1)

was developed to particularly address infant learning and developmental components with a connection to early rudimentary movement. In the adapted model, tier one focuses on the infant's central nervous system (CNS). The vestibular system is specifically

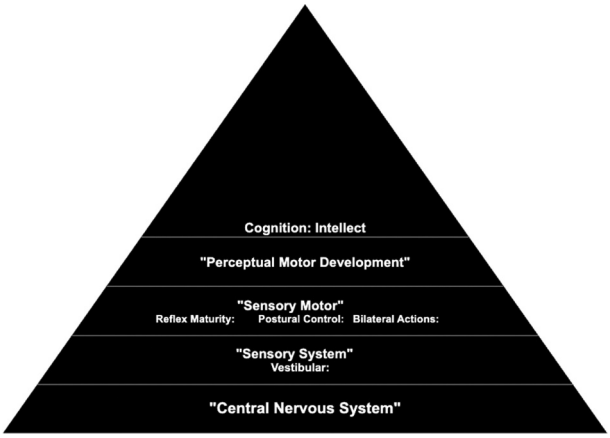

Figure 1. Adaption of the 5 tiers of the Pyramid of learning based on Taylor and Trott, (1996).

represented within sensory systems, Tier Two. The reflex maturity component together with a focus on postural security (control) and bilateral body awareness is presented in the sensory motor level at Tier Three. Tier Four outlines the perceptual motor development concept evolving and progressing into childhood and culminates in cognition and intellect at Tier Five. These final two tiers are not represented in the adapted model as they interrelate more closely to post infancy and fundamental motor skills.

Cascio (2010) outlines that the original Pyramid of Learning (Taylor & Trott, 1991) presents a theoretically based developmental hierarchy for sensory structures, providing a schema to integrate sensory, cognitive, and behavioral systems that are appropriate for sensory integration programs. Kurniawati, Mustaji, and Setyowati (2018) commented on the importance of the specific connection required within each tier of the pyramid model, emphasizing the sensory, motor, and perceptual motor phases (Tiers Two-Five) that link to support the infants' central nervous system journey toward cognitive development.

Consequently, the structure of a wakeful prone and vestibular program can be shaped by the components within the "Pyramid of Learning," with the infant movement program adopting overall objectives that focus on infant CNS response categories that are essential to rudimentary milestone acquisition. The following central core and neurological response categories (a–d) are crucial components to be explored with the intention to analyze within the context of infant rudimentary movement stages. The central categories from within Tier Two and Tier Three of the pyramid include:

a: Postural control (postural security) featuring prone actions for head control, muscle tone/core strength, and muscle flexion; supine muscle stretch positions-

b: Sensory systems: vestibular, tactile, proprioceptive, visual systems.

c: Reflex maturity and inhibition (Crawling, Moro, ATNR, TLR)

d: Bilateral actions (awareness of two sides of the body): limb coordination and body midline crossing.

Malina (2004) presents a comparable viewpoint, discussing that the infant's central nervous system evolves in an interconnected development between the brain, the spinal cord, reflex responsiveness, and the sensory systems all underpinning infant motor development. Further analysis of Malina's perspective supports an infant pre-rudimentary and rudimentary milestone stages progression, enabling a format to shape a wakeful prone and vestibular program structure. These developmental stages include prone body position and head control, roll over (prone to supine/supine to prone), commando tummy crawl, and crawling on hands and knees. In addition, development of the theoretical structure of an infant program is also supported through studies providing perspectives reflecting this specific order of rudimentary milestone development progressions (Gerber, Wilks, & Erdie-Lalena, 2010; Hadders-Algra, 2018; Touwen, 1975).

Theoretical Basis for the Designated Neurological Central Categories of Infant Rudimentary Milestone Stages

In providing a theoretical foundation for the development of an infant development program, it is important to analyze the central core and neurological "response categories" (a–d) within the context of the infant's pre-rudimentary and rudimentary milestone stages (prone body position and head control, roll over, commando tummy crawl, and crawling on hands and knees).

A: Postural Control

The "postural control, prone/tummy time and head control" (category a) should feature as a major concentration within the first pre-rudimentary milestone stage. This infant category from Tier Two of the Pyramid of Learning model (Taylor & Trott, 1991), becomes a specific focus within this stage to promote tummy/prone time for very young infants perhaps 6 weeks to 4 months: post birth. Development of head control is significant during the infant's first months of postnatal life, being instrumental in contributing to the stability of the trunk, arms, body control, and visual focusing, impacting on the learning of more complex movements and behaviors (Lee & Galloway, 2012). Additionally, spending time in the prone position ensures that specific areas at the back of the infant's head receive fewer constant pressures, helping to offset the possibility of head molding leading to plagiocephaly (Kordestani, Patel, Bard, Gurwitch, & Panchal, 2006; van Vlimmeren et al., 2007). Postural control is developing while in the prone position, allowing young infants to acquire and utilize neck-righting responses to contend with antigravity movements and to generate stabilizing postural connections (Lopes, de Lima, & Tudella, 2009; Senju et al., 2018).

Several prone and postural research programs have focused on infant participants aged from 4 to 8 weeks post term, reinforcing support for introducing infants to prone positions at very young ages (Hewson, 2011; Lee & Galloway, 2012; Lobo & Galloway, 2012). Nitsos,

Estrada, and Messias (2017) suggest that tummy time actions also prepare the infant for future movements including head and upper body lift, sliding on the abdomen and crawling. Limitations of play in the prone position have been linked to lags in movement skills requiring antigravity extension (Bales & Godfrey, 2013), together with young infants struggling to maintain the prone position with extended arms that may indicate subsequent motor development difficulties (Senju et al., 2018). In addition, supine muscle flexion and stretch positions can also support the infant's core development with the neck, gluteus, abdominal, hamstring, quadriceps, and lumbar muscle movements all impacting on early postural control. Hadders-algra (2013) outlines that muscle activation and appropriate contraction strength in supine position can support the semi-reclined sitting posture, assisting the infant in developing reaching and postural control.

B: Sensory Systems

The next neurological central category, namely the sensory systems (category b), would allow a wider focus for developing infants exploring both the pre and rudimentary milestones. The vestibular sense would be a major emphasis together with the proprioceptive, tactile, and visual sensory systems as presented in Tier Two of the learning model. Additional sensory systems presented in the Pyramid of Learning model (Williams & Shellenberger, 1996), namely auditory, gustatory (taste), and olfactory (smell) are less interlinked to infant motor learning in comparison to the vestibular, proprioceptive, tactile, and visual sensory systems (Wiener-Vacher, Hamilton, & Wiener, 2013).

The vestibular actions are central to support development of each of the rudimentary milestones (i.e., rolling over, commando tummy crawl, hands, and knees crawl). Le Gall et al. (2019) specifically outlined that vestibular sensory perception contributes crucially to sensorimotor function, particularly in the early stages of the infant's motor development, with this sensory system being a critical but not highly understood purveyor to an infant's overall motor maturity (Schreiber-Nordblum, 1995). The peripheral vestibular organ, located within each ear, consists of three-dimensional semi-circular canals, namely, lateral (horizontal), anteria, and posteria which respond to *angular* acceleration, thus detecting rotational movement in their specific plane located within each ear (Khan & Chang, 2013; Wiener-Vacher, Hamilton, & Wiener, 2013). Accordingly, the otolith organs (saccule and utricle) are also located within the ear and react to *linear* acceleration.

The vestibular organ is mature at 4 months post conception, functional at birth (Cronin, Arshad, & Seemungal, 2017; Le Gall et al., 2019), and integral in the process of birthing through assisting the infant to positioning head-first in the birth canal, thus preparing for the delivery process (Roizen, 2009). Consequently, the newborn who was previously cushioned within the intrauterine fluid medium now relies on the responses of the vestibular sensory receptors to adapt to the effect of gravity (Nandi & Luxon, 2008). (

As the vestibular organ has five functioning structures with each detecting different movements whether rotational, lateral/anteria/posteria accelerations, or linear vertical/horizontal responses to gravity, there is an emphasis on selecting vestibular motions to cover all divergent actions safely and carefully within the infant's first 12 months post birth. Van Hecke et al. (2019) outlines that poor vestibular function in young children may influence development on various levels, including poor postural stability, balance problems, and difficulties with fine motor skills, because the

vestibulo-ocular reflex (VOR) within the brain stem is linked to gaze stabilization and eye-hand coordination.

C: Early Reflex Maturity and Inhibition

The third neurological central category to be analyzed is the primitive reflex segment (category c). This Tier Three category from the Pyramid of Learning (Figure 1), is influential across all the rudimentary milestone sections and relates to the differing emerging and inhibiting factors affecting each of several primitive reflexes. There are four specific primitive reflexes, namely, Crawling, Moro, Asymmetrical Tonic Neck Reflex (ATNR), and Tonic Labyrinth Reflex (TLR) that feature in infant motor development. These primary reflexes are all active in utero and are functioning at birth (Capute et al., 1984; Malina, 2004; Sekulić et al., 2009). Several of these reflexes also assist in the birth process and are activated by the birth process (Berne, 2006; Pecuch et al., 2020). It is beneficial to continue to activate these reflexes post-birth with selected actions that mirror the reflex response (Grigg, Fox-Turnbull, & Culpan, 2018). These targeted responses post birth can provide prompts for the reflex to inhibit, prepare, and allow the infant to develop higher level postural actions to respond to and move against gravity (Bilbilaj, Aranit, & Fatlinda, 2017; Goddard Blythe, 2002).

Additionally, recent research has contributed important findings supporting that an infant's progression from reflexive to voluntary motor movements is also dependent on experiencing awake time in the prone position (Bilbilaj, Aranit, & Fatlinda, 2017; Case-Smith, 2014). This prone positioning may further support the progression toward segmented rolling (head and body as one) and fostering exploration of the rolling over milestone (Capute et al., 1984). In addition, Gerber, Wilks, and Erdie-Lalena (2010) summarize that although infants progress from involuntary primitive reflexive responses to more goal orientated and voluntary actions, this progression can vary due to genetic, cultural, and importantly, environmental influences.

D: Bilateral Actions

The final neurological central category, Tier Three of the learning model (Pyramid of Learning, Figure 1), is the contra (opposing) or bilateral actions (category d). This category focuses more on the later emerging commando tummy crawl and crawl on hands and knees milestones actions. These two later milestones are progressing toward cross-lateral or opposite arm/leg limb actions (Forma et al., 2019; Freedland & Bertenthal, 1994). The bilateral movement actions support the nervous system's sensory and motor fibers when crossing the midline within the body's cortex, brainstem, and spinal cord, affecting a variety of motor and coordination skills (Ocklenburg, Korte, Peterburs, Wolf, & Güntürküna, 2016; Whitehead & Banihani, 2014). Each of the brain's hemispheres are connected predominantly through the corpus callosum. Bilateral movement actions (coordinated use of two sides of the body) can assist infant's arms and legs to flex and extend as they cooperate to meet both at and across the infant's body midline. This contralateral or opposite action can impact on the neural connections during important infant growth phases (Liddle & Yorke, 2004).

Central Categories of the Infant Core and Neurological Responses in Relation to Infant Movement

An overview of the four central categories of the infant core and neurological responses (postural control, sensory systems, primitive reflexes, and bilateral actions) is outlined in Table 1. The analysis frames and guides the activity selection of an infant program, linking the relevant and requisite infant movements within each of the progressive pre- and rudimentary milestone sections. This overview supports and connects the developmental and neurological theory behind the central categories in relation to the proposed four motor milestone sections (Section 1: prone body position and head control, Section 2: rolling over, Section 3: commando tummy crawl, and Section 4: hands and knees crawl).

Table 1 presents each of the four "infant core muscle and neurological responses" central elements that are cross checked against the pre and rudimentary milestone sections. Selected activities are planned from the central element categories that cover the postural and sensory vestibular sections together with primitive reflex inhibition actions, and became the focus in the proposed milestone prone and head control stage, and the roll over stage (milestone sections one and two). Additional planned actions that focus on the later commando tummy crawl and hands and knees crawl milestone stages (milestone sections three and four) link to body and limbs muscle strengthening activities, and bilateral and body awareness movements (Adolph, Vereijken, & Denny, 1998; Hadders-Algra, 2018). The overall sensory systems category features activities strongly located within all four milestone sections, particularly with the interrelating vestibular, proprioceptive, tactile, and visual activities prominent throughout (Cascio, 2010; Fong, Tsang, & Ng, 2012). Interestingly, the visual system activities are more clearly featured in the later milestone stages two, three, and four due to the developing infants' visual ability to track, focus, and to grasp toys during these locomotive movement stages (Adolph & Franchak, 2017).

The Creation, Design, and Format of the Program

Based on the theoretical and research evaluation, a wakeful, prone, and vestibular infant motor program, was simplistically designed for families and carers, and early years clinicians including maternal and early childhood nurses, occupational therapists, and physical therapists, to allow both developing and under developing infants from age 10 weeks to explore progression through the rudimentary motor milestone stages. Table 1 provides an overview of the set of activities that aligned with the four selected milestone's framework together with the infant core and neurological response categories that have theoretical context and support. The developed program is titled the Baby Activity Chart-Program (BAC-Program). The BAC-Program is presented in a booklet format that includes an introduction/information page followed by specifically drawn infant action diagrams divided into four milestone sections (as viewed in Table 1). The infant movement program booklet is designed to provide parents with information and sketches with text on prone and vestibular actions to encourage involvement with their infants in researched movement actions.

The BAC-Program includes an initial introduction section to inform parents and carers of the overall intentions of the program and the principles behind the natural progression of an infant's motor milestone journey. The introduction is followed by four specific

Table 1. Central neurological categories and rudimentary milestones of infant activities including milestone examples.

Central categories: "Infant core and neurological response categories"	Milestone section one 6 weeks – 4 months (post birth) " Prone body position and head contro"'	Milestone section two 4–7 months " Roll over"	Milestone section three " Commando tummy crawl"	Milestone section four " Crawl on hands and knees"
a": Postural control				
Prone/tummy time Head control	Prone rock forwards on large ball. Prone supported head lift	Prone rock forwards on medium ball as infant reaches forward to touch/ pick up an appropriate toy. Prone lying on parent's lower leg, hands held as parent slowly lifts legs	Prone rock forwards on medium ball as infant reaches forward and hands touch the floor- 'Roly-poly hands and feet push' Infant in prone position, with hands on the surface, has lower body lifted and supported by parent's hands under chest and thighs- 'wheelbarrow lift'	Lying over a small roll with a gently tip forward Infant placed onto hands and knees with a toy placed ahead
Muscle tone and core strength,	Bend leg at knee	Gentle infant pull up from supine to sitting position	Less support to enable infant to pull up from supine to sitting position	Roly-poly hands and feet push'
Supine muscle flexion/ stretch	Hug and tip gently back	Supine rock backwards on medium ball to touch a toy.	Infant in suoine position as parent alternately cycles infant's legs	Supine lift/hang from floor with parents holding from hips/ ankles
b: Sensory systems				
Vestibular	Supine rock backwards on large ball	Gently lift each leg over twice then flip to infant from back to land on parent's lower legs- landing on infant on the stomach	Roly-poly backward rock in supine position on a medium ball	Infant held upright, under the arms at the chest, and then legs swung forward and back
Proprioceptive	Prone supported head lift	Infant pulled up from supine to sitting position	Wheelbarrow lift	Infant held upright and then bounced up and down on feet
Tactile	Body awareness massage	Body awareness massage in prone position	Cross over tap- left hand to right foot in supine position	Cross over tap- left hand to right foot in supine position
Visual	Side to side rug sway	Medium ball rock prone/ supine towards a toy- far/ near	Tummy turn in prone position, watching and then reaching for a colourful toy- just out of reach	Infant sits supported between adult's legs as large ball is rolled towards infant
c: Early reflexes				
Crawling motion	Prone foot push away	———————–	Roly-poly hands and feet push'	0-reflex usually weakened
Moro	Hug and tip gently back	Backward lying and toy pick up when lying on a medium ball	Roly-poly backward rock whilst in prone on a medium ball	0-reflex usually weakened
Asymmetrical Tonic Neck (ATNR)	Meet in the middle - opposite hand to knee touch	Back to tummy assisted roll with head turn	Cross over tap	0-reflex usually weakened

(*Continued*)

Table 1. (Continued).

Central categories: "Infant core and neurological response categories"	Milestone section one 6 weeks – 4 months (post birth) " Prone body position and head contro"'	Milestone section two 4–7 months " Roll over"	Milestone section three " Commando tummy crawl"	Milestone section four " Crawl on hands and knees"
Tonic Labyrinth (TLR)	Hug and tip gently back	Medium ball rock prone/ supine	Roly-poly backward rock whilst in prone on a medium ball	TLR- forwards usually weakened TLR - backwards still responding-Roly-poly backwards
d: Bilateral actions Crossing across the midline of the body	Meet in the middle - opposite hand to knee touch	Crossing over right hand to touch opposite foot	Bilateral ball tap of right hand/ left foot whilst prone on a medium ball	Infant placed onto hands and knees with a toy placed ahead

movement sections that were designed according to the developmental milestone progressions commonly occurring during the infant's first 12 months (Malina, 2004). The following four sequential progression sections (Figure 2) define the segments of the BAC-Program: 1: Body awareness, head control, and tummy time (blue) with 12 chosen and created activities, 2: Rolling over (tummy/back or back/tummy) (green) comprising 9 activities, 3: Commando (tummy) crawling (purple) consisting of 10 activities, and 4: Hands and knees crawling (creeping) (red) involving 8 activities.

Consequently, 39 designed activities are theoretically selected, consisting of visual and professionally (artist) drawn sketches or diagrams of infants displaying the particular/appropriate actions. Each diagram is accompanied by step-by-step written instructions of how to prompt or initiate the action with an infant. There is also a detailed explanation section under the additional heading "Why," outlining in simple wording the reasons and explanations behind each individual action. This layout is chosen to meet the objectives of this BAC-Program where parents are first introduced through diagrams or sketches to various interactive tummy and vestibular activities to encourage their infant to explore each motor milestone progression. Secondly, the information and "Why" text snippets are included to provide parents with simplified knowledge regarding the infant's nervous system responses within each of the 39 actions. Studies have shown that parents of infants in the first 12 months are often sleep deprived, anxious to parent correctly, adapting to new life routines, and managing differing infant dispositions (Feldman, Greenbaum, Mayes, & Erlich, 1997; Kennedy, Gardiner, Gay, & Lee, 2007). Therefore, the BAC-Program format presents clear sketches, with well-defined action descriptions together with short neurological explanations (Why) to cater specifically for the parents of young infants.

Importantly, the vestibular actions (whether circular or linear) are visually depicted in this sketch-type format, specifically illustrated to demonstrate parents or carers carefully supporting and holding the infant. A central requirement was to include action sketches of infants being gently tipped and incorporating parents' hand positions clearly and

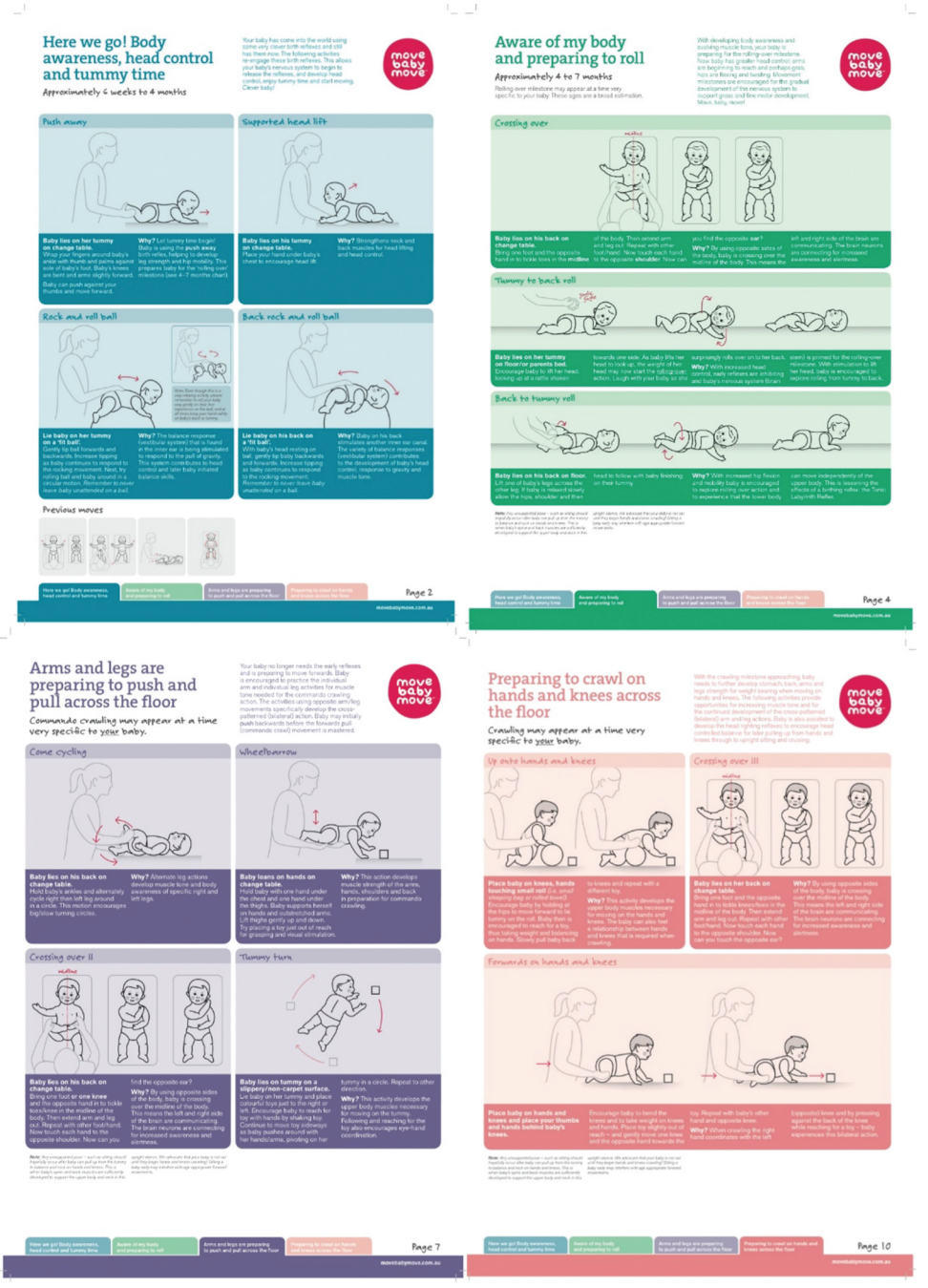

Figure 2. Examples of sketches of specific activities from each of the four coloured sections within the BAC-Program.

purposefully drawn against the infant's body. Additionally, sketches show that the infant's head is always supported, and pillows strategically placed to always ensure safety. Each action includes additional text to help familiarize parents with the vestibular term, with wording such as gently sway, rock, or jiggle and gently tip with safety comments also included. Within and between each of a program's milestone sections, a variety of vestibular actions are sequentially introduced to provide parents with confidence and knowledge to encourage the exploring and undertaking of these important vestibular organ stimulating actions.

The Four Motor Development Milestone Sections of the BAC-Program

Section one of the BAC-Program (blue) with 12 activities, comprises the heading: 'postural control-prone/tummy time and head control, focusing on the younger infant from 6 weeks to 4 months post-term birth. Prone positioning is commonly referred to as tummy time, which has been described as a practice whereby an infant is placed on their stomach during awake play times (Hewitt, Stanley, & Okely, 2017). Several of the activities include laying the supported infant in the prone position while across an adult's knees; swaying baby in the held "rugby" (tummy) position within the adult's arms; gently rocking the infant in the prone position whilst lying on an inflated "fit ball." Head and neck strengthening becomes critical for a range of early motor skills requiring trunk and arm muscles, with visual behaviors also dependent on a stable head to support vision function (Lee & Galloway, 2012). Section one has additional text placed next to the section's headings, outlining how the program's activities in this first section can support the engaging and releasing (inhibition) of early birth reflexes together with fun tummy time actions to encourage infant head control and body extension. The section offers a variety of gentle tummy time positioning, mild vestibular actions, muscle strengthening, flexing, and stretching, together with reflex maturation and bilateral movements. This postural control section provides parents with an opportunity to explore the 12 theoretically selected movements, encouraging progression toward the rolling over milestone, and offsets the risk of plagiocephaly (van Vlimmeren et al., 2007; Zachry, Nolan, Hand, & Klemm, 2017).

It is important to note that the emerging voluntary and more intentional locomotive motor movements (BAC-Program's milestone sections 2, 3, and 4) have a large variation of appearance within the first 18 months post birth (WHO Multicentre Growth Reference Study Group & de Onis & WHO Multicentre Growth Reference Study Group, 2006) with attainment being specific to each infant. The actual acquisition of each motor milestone consists of a course of movement sequences with these sequences generally uniform in appearance (Adolph, Bertenthal, Boker, Goldfield, & Gibson, 1997; Malina, 2004). These sequences begin initially as a "first change" as the infant experiments with the new milestone action. Over time, the action becomes more practiced, and the skill reaches a "final change of a milestone's response" (Touwen, 1975). The implication is that a previous milestone lays down the foundations for subsequent motor skills (Hadders-Algra, 2018; Touwen, 1975). Movement time on the floor or time in selected prone positions whilst interacting with parents is also encouraged to allow opportunities for the infant to explore and experiment with new movement phases.

Section two of the BAC-Program (green) consists of nine activities and is targeted at infants from approximately 4 to 7 months of age, focusing on the first voluntary

milestone-rolling over. This section centers on nine core strength, gentle vestibular, side lying, reflex inhibition, and bilateral actions. Activities within this section include entice the infant with a sound-producing toy to encourage a look up-head lift whilst prone lying (to perhaps enable a roll over motion); lift one leg across baby's other leg when lying in supine position to encourage rotational actions; and gentle support supine lying infant whilst enfolding wrists to assist infant's core muscles to engage in a pull up to sit from the supine position. The rolling over action requires a level of control over head, neck, and trunk muscles with a strong core necessary to enable the body rotations (Gabbard, 2012).

The emergence of the rolling over locomotive milestone initially occurs with the infant rolling from the prone to supine pose, then progressing to rolling from supine to prone position (Robertson, 2011; Shumway-Cook & Woollacott, 2007). This initial propulsion sequence is regularly reversed (Jantz, Blosser, & Fruechting, 1997; Salls, Silverman, & Gatty, 2002). The suggestion of the prone to supine sequence is based on the infant experiencing daily prone-tummy time combined with emerging head and neck control to enable the locomotive roll from front to back (Lenke, 2003; Majnemer & Barr, 2006). (additional sentences were removed here). Thus, the infant's larger proportionally sized head, when raised with adequate head and neck control, can instigate this prone to supine action, propelling the infant into this rolling motion. Lenke (2003) additionally outlines that active head righting in both anterior/posterior and lateral positions should be developing, together with head and neck extension in prone with emerging weight shifts for the prone-to-supine rolling action to occur. The supine-to-prone rolling sequence is also inter-dependent on the development of core strength and rotational body control and awareness, together with the inhibition of the (lateral) asymmetrical tonic neck reflex leading to the segmented (whole body) roll response (Capute et al., 1984). If the infant spends awake time predominately in the supine position, growth in the flexor muscles exceeds growth in the extensor muscles, and when coupled with lack of head control, there may be a delay in the overall rolling over milestone (Salls, Silverman, & Gatty, 2002).

The BAC-Program section three (purple) has 10 activities and presents a focus on the commando crawling (tummy prolusion) milestone with relevant movement activities. There is no actual age range suggested for this purple section, as the wording beneath the main heading states: "commando crawling may appear at a time very specific to your baby." This wording aims to reassure parents and carers that experiencing this movement milestone is more important than the age of occurrence (Hadders-Algra, 2018). There is usually a predictable sequence of infant milestone attainment, although the time of occurrence and progression between infants is quite variable (Flensborg-Madsen & Mortensen, 2017; Sauve & Bartlett, 2010). Movement activities in the program to support commando crawling include individual leg cycling; supported weight on hands in the wheelbarrow position for arm strength; and bilateral hand/foot tap actions.

The rudimentary locomotion stages of motor development potentially progress from the rolling over milestone to the action of prone circular pivoting then emerging to the commando (belly) crawling action (Piper & Darrah, 1994; Shumway-Cook & Woollacott, 2007). The action often begins by infant pushing backwards as the upper body does not initially coordinate with the lower body. Subsequently, when propelling forwards, the right limbs also do not combine with left limbs showing a more ipsilateral (same arm/leg) pattern, with the action generally maturing into a contralateral (opposite arm/leg)

commando crawling motion (Goodway, Ozmun, & Gallahue, 2019; Liddle & Yorke, 2004). A developed commando crawl action evolves, depicting the infant in prone pose, the arms pulling, the toes curled against the ground with the feet and legs propelling the infant forward in a contralateral (bilateral) pattern as the stomach remains in contact with the ground (Goddard Bythe, 2005; Lenke, 2003). Bartlett and Fanning (2003) and Piper and Darrah (1994) propose an alternative commando crawl term as "reciprocal crawling," similarly describing the action as a coordinated right hand/forearm, with opposite left leg/knee/toes exhibiting a bilateral pattern.

Section four (red) of the BAC-Program outlines the commonly acknowledged rudimentary milestone of crawling (creeping) on hands and knees and includes eight selected activities. The BAC-Program text heading in section four would again outline that the crawling action may develop at a time particular to each infant. Hadders-Algra (2018) summarizes that typically developing infants may switch forward and back between commando and hands and knees crawling, indicating that this progression is an expression of regular individual infant milestone variation. Several of the activities to encourage exploration of hands and knees crawling in the BAC-Program include bilateral hand/foot midline cross over; hands and knees rock over small bolster to experience the hand/knee relationship; roly-poly hand/foot push for limb strengthening. Research reveals that the natural progression from commando crawling to the bilateral hands and knees crawling may greatly increase the proficiency regarding the action and speed of the quadrupedal crawling movement (Adolph & Robinson, 2013; Malina, 2004). The mature hands and knees crawling action graduates from the stationary hands and knees four-point pose with the infant often rocking forward and back but not progressing forward (Howard, 2007; Piper & Darrah, 1994). The infant's first attempts at traveling forward on hands and knees are observed with the infant moving one limb at a time and consequently with practice the action becomes a more coordinated, contralateral right hand/arm and left knee/leg synchronized motion (Gabbard, 2012; Gallahue, Ozmun, & Goodway, 2012). (Sentences of this paragraph was removed here). Visser and Franzsen (2010) outline the coordinated bilateral crawling action can become a preparation for walking as well as assisting in the development of motor planning, visual perception, and eye-hand coordination. Furthermore, McEwan, Dihoff, and Brosvic (1991) highlight that the practice of crawling supports vestibular processing improves balance, tactile input, and spatial awareness and facilitates social maturation. Information is provided to parents regarding the body strength required for the specific weight-bearing component of this action, as the infant explores the hands and knees crawling milestone. The BAC-program's text outlines that the activities in Section 4 (red) will assist in the development of muscle tone. In Section 4, it is indicated that the selected activities can also support maturity of the cross-patterned (bilateral) arm and leg action, with the enhanced head control and balance attributes of this rudimentary milestone contributing to the subsequent motor skills of upright sitting and cruising (Alghwiri et al., 2012; Bell & Fox, 1996).

Summary

In this article, we have provided an overview and evaluation of theory and research in support of the selection of the infant movement activities to form the Baby Activity Chart-Program (BAC-Program). The theoretical structure aimed to frame the preferred activities

outlined within the four central categories of postural control, sensory systems, early reflex maturity, and bilateral actions. These categories are aligned with the foundation of the Pyramid of Learning (Taylor & Trott) that the infant's central nervous system is closely linked to their sensory and motor systems. The BAC-Program aims to offer ideas and guidance regarding appropriate prone and vestibular motor actions to parents and carers of young infants. This information can support parents and carers in utilizing these activities during typical parent–child interactions, such as nappy (diaper) changing times, and at awake play times throughout each day.

The selected activities are primarily designed to support the maturation of neural pathways together with infant locomotor behavior and overall motor development (Dewolf, Sylos-Labini, Ivanenko, & Lacquaniti, 2021). The BAC-Program is subsequently created to provide interactive activities to both families and the wider infant allied professions, including maternal and early childhood nurses, occupational and physical therapists, early years movement educators, osteopaths, and chiropractors, to support infants to reach their movement milestones.

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References

Adolph, K., Bertenthal, B., Boker, S., Goldfield, E., & Gibson, E. (1997). Learning in the development of infant locomotion. *Monographs of the Society for Research in Child Development*, *62*(3), 1–158. Serial No. 251. doi:10.2307/1166199

Adolph, K., & Franchak, J. (2017). The development of motor behavior. *Wiley Interdisciplinary Reviews Cognitive Science*, *8*(1–2), 8. doi:10.1002/wcs.1430

Adolph, K., & Robinson, S. (2013). The road to walking: What learning to walk tells us about development. In P. Zelazo (Ed.), *Oxford handbook of developmental psychology* (pp. 403–443). New York: Oxford University Press.

Adolph, K., Vereijken, B., & Denny, M. (1998). Learning to crawl. *Child Development*, *69*(5), 1299–1312. doi:10.2307/1132267

Alghwiri, A., Whitney, S., Baker, C., Sparto, P., Marchetti, G., Rogers, J., & Furman, J. (2012). The development and validation of the vestibular activities and participation measure. *Arch Phys Med Rehabil*, *93*(10), 1822–1831. doi:10.1016/j.apmr.2012.03.017

American Academy of Pediatrics Task Force on Infant Positioning and SIDS. (1996). Positioning and Sudden Infant Death syndrome (SIDS): Update. *Pediatrics*, *98*(6), 1216–1218. doi:10.1542/peds.98.6.1216

Australian Government. (2017). 24-hour movement guidelines for the early years (Birth to 5 years)-An integration of physical activity, sedentary behaviour, and sleep. www.health.gov.au.

Bales, J., & Godfrey, K. (2013). *Effects of infant sleep positioning on motor development. A systematic literature review*. (Degree of Master of Science in Occupational Therapy). The College of St. Scholastica, Duluth, MN. (A Graduate Research Project Submitted In Partial Fulfillment of the Requirements)

Bartlett, D., & Fanning, J. (2003). Use of the Alberta infant motor scale to characterize the motor development of infants born preterm at eight months corrected age. *Physical & Occupational Therapy in Pediatrics*, *23*(4), 31–45. doi:10.1080/J006v23n04_03

Bell, M., & Fox, N. (1996). Crawling experience is related to changes in cortical organization during infancy: Evidence from EEG coherence. *Developmental Psychobiology*, *29*(7), 551–561. doi:10.1002/(SICI)1098-2302(199611)29:7<551:AID-DEV1>3.0.CO;2-T

Berne, S. (2006). The primitive reflexes: Considerations in the infant. *Optometry & Vision Development*, *37*(3), 139–145.

Bilbilaj, S., Aranit, G., & Fatlinda, S. (2017). Measuring primitive reflexes in children with learning disorders. *European Journal of Multidisciplinary Studies*, *2*(5), 285–298. doi:10.26417/ejms.v5i1.p285-298

Capute, A., Palmer, F., Shupiro, B., Wuchtel, R., Ross, A., & Accurdo, P. (1984). Primitive reflex profile: A quantitation of primitive reflexes in infancy. *Developmental Medicine & Child Neurology*, *26*(3), 375–383. doi:10.1111/j.1469-8749.1984.tb04456.x

Cascio, C. (2010). Somatosensory processing in neurodevelopmental disorders. *Journal of Neurodevelopmental Disorders*, *2*(2), 62–69. doi:10.1007/s11689-010-9046-3

Case-Smith, J. (2014). Development of childhood occupations. In J. Case-Smith & O. B. J (Eds.), *Occupational therapy for children* (7 ed., pp. 65–94). St Louis, MO: Mosby-Elsevier.

Christy, J. (2019). Use of vestibular rehabilitation in the pediatric population. *Perspectives of the ASHA Special Interest Groups*, *4*(6), 1399–1405. doi:10.1044/2019_PERS-SIG7-2019-0002

Cohn, E. S. (2001). Parent perspectives of occupational therapy using a sensory integration approach. *The American Journal of Occupational Therapy*, *55*(3), 285–294. doi:10.5014/ajot.55.3.285

Cronin, T., Arshad, Q., & Seemungal, B. (2017). Vestibular deficits in neurodegenerative disorders: Balance, dizziness, and spatial disorientation. *Frontiers in Neurology*, *8*, 538. doi:10.3389/fneur.2017.00538

Cross, J., Eastman, D., Brovender, S., & Ward, M. (2017). Intolerance to prone positioning as a clinical marker of motor delay in infants. *Journal of PediatricsChild Care*, *3*(1), 1–6.

de Onis, M., & WHO Multicentre Growth Reference Study Group. (2006). WHO motor development study: Windows of achievement for six gross motor development milestones. *Acta paediatrica*, *95*, 86–95. doi:10.1111/j.1651-2227.2006.tb02379.x

Dewolf, A., Sylos-Labini, F., Ivanenko, Y., & Lacquaniti, F. (2021). Development of locomotor-related movements in early infancy. *Frontiers in Cellular Neuroscience*, *21*, 1–9. doi:10.3389/fncel.2020.623759

Dirks, T., Blauw-Hospers, C., Hulshof, L., & Hadders-Algra, M. (2011). Differences between the family-centered "COPCA" program and traditional infant physical therapy based on neurodevelopmental treatment principles. *Physical Therapy*, *91*(9), 1303–1322. doi:10.2522/ptj.20100207

Dudek-Shriber, L., & Zelazny, S. (2007). The effects of prone positioning on the quality and acquisition of developmental milestones in four-month-old infants. *Pediatric Physical Therapy*, *19*(1), 48–55. doi:10.1097/01.pep.0000234963.72945.b1

Feldman, R., Greenbaum, C., Mayes, L., & Erlich, S. (1997). Change in mother-infant interactive behavior: Relations to change in the mother, the infant, and the social context. *Infant Behavior & Development*, *20*(2), 151–163. doi:10.1016/S0163-6383(97)90018-7

Felzer-Kim, I., Erickson, K., Adkins, C., & Hauck, J. (2020). Wakeful prone "Tummy time" during infancy: How can we help parents? *Physical & Occupational Therapy in Pediatrics*, *40*(6), 651–668. doi:10.1080/01942638.2020.1742847

Flensborg-Madsen, T., & Mortensen, E. (2017). Predictors of motor developmental milestones during the first year of life. *European Journal of Pediatrics*, *176*(1), 109–119. doi:10.1007/s00431-016-2817-4

Fong, S., Tsang, W., & Ng, G. (2012). Altered postural control strategies and sensory organization in children with developmental coordination disorder. *Human Movement Sciences*, *31*(5), 1317–1327. doi:10.1016/j.humov.2011.11.003

Forma, V., Anderson, D., Provasi, J., Soyez, E., Martial, M., Huet, V., Barbu-roth, M. … Barbu-roth, M. (2019). What does prone skateboarding in the newborn tell us about the ontogeny of human locomotion? *Child Development*, *90*(4), 1286–1302. doi:10.1111/cdev.13251

Freedland, R., & Bertenthal, B. (1994). Developmental changes in interlimb coordination: Transition to hands-and-knees crawling. *Psychological Science*, *5*(1), 26–32. Retrieved from. https://www.jstor.org/stable/40062337

Gabbard, C. (2012). *Lifelong motor development* (Vol. 6). California, US: Pearson.

Gallahue, D., Ozmun, J., & Goodway, J. (2012). *Understanding motor development: Infants, children, adolescents, adults*. New York: McGraw-Hill.

Gans, R. (2015). Paediatric vestibular evaluation. *ENT and Audiology News*, *24*(5), 77–79.

Gerber, J., Wilks, T., & Erdie-Lalena, C. (2010). Developmental milestones: Motor development. *Pediatric Review*, *31*(7), 267–277. doi:10.1542/pir.31-7-267

Gieysztor, E., Choińska, A., & Paprocka-Borowicz, M. (2018). Persistence of primitive reflexes and associated motor problems in healthy preschool children. *Archives of Medical Science: AMS*, *14*(1), 167. doi:10.5114/aoms.2016.60503

Gieysztor, E., Pecuch, A., Kowal, M., Borowicz, W., & Paprocka-Borowicz, M. (2020). Pelvic symmetry is influenced by asymmetrical tonic neck reflex during young children's gait. *International Journal of Environmental Research and Public Health*, *17*(13), 4759. doi:10.3390/ijerph17134759

Goddard Blythe, S. (2002). *Reflexes, learning and behavior: A window into the child's mind*. Eugene, Oregon: Fern Ridge.

Goddard Bythe, S. (2005). *The well balanced child: Movement and early learning*. Gloucestershire: Hawthorn.

Goodway, J., Ozmun, J., & Gallahue, D. (2019). *Understanding motor development: Infants, children, adolescents, adults*. Burlington: Jones & Bartlett Learning.

Grigg, T., Fox-Turnbull, W., & Culpan, I. (2018). Retained primitive reflexes: Perceptions of parents who have used rhythmic movement training with their children. *Journal of Child Health Care*, *22*(3), 406–418. doi:10.1177/1367493518760736

Guidetti, J., Wells, J., Worsdall, A., & Metz, A. (2017). The effect of positional support on tolerance of wakeful prone in infants. *Physical Occupational Therapy Pediatric*, *37*(3), 308–321. doi:10.1080/01942638.2016.1185506

Hadders-algra, M. (2013). Typical and atypical development of reaching and postural control in infancy. *Developmental Medicine & Child Neurology*, *55*, 5–8. doi:10.1111/dmcn.12298

Hadders-Algra, M. (2018). Early human motor development: From variation to the ability to vary and adapt. *Neuroscience & Biobehavioral Reviews*, *90*, 411–427. doi:10.1016/j.neubiorev.2018.05.009

Hesketh, K., Downing, K., Campbell, K., Crawford, D., Salmon, J., & Hnatiuk, J. (2017). Proportion of infants meeting the Australian 24-hour movement guidelines for the early years: Data from the Melbourne InFANT program. *BMC Public Health*, *17*(5), 192–215. doi:10.1186/s12889-017-4856-9

Hewitt, L., Stanley, R., & Okely, A. (2017). Correlates of tummy time in infants aged 0–12 months old: A systematic review. *Infant Behavior & Development*, *49*, 310–321. doi:10.1016/j.infbeh.2017.10.001

Hewson, B. (2011). *The effects of developmental activities, embedded into parent's activities of daily living, on supine sleeping infant milestone development*. Johannesburg: Master of Science Degree in Occupational Therapy). University of Witwatersrand.

Howard, D. (2007). Child development and developmental problems. *MRCPCH MasterCourse*, 8–17.

Jantz, J., Blosser, C., & Fruechting, L. (1997). A motor milestone change noted with a change in sleep position. *Archives of Pediatrics & Adolescent Medicine*, *151*(6), 565–568. doi:10.1001/archpedi.1997.02170430031006

Jennings, J., Sarbaugh, B., & Payne, N. (2005). Conveying the message about optimal infant positions. *Physical & Occupational Therapy in Pediatrics*, *25*(3), 3–18. doi:10.1080/J006v25n03_02

Kennedy, H., Gardiner, A., Gay, C., & Lee, K. (2007). Negotiating sleep: A qualitative study of new mothers. *The Journal of Perinatal & Neonatal Nursing*, *21*(2), 114–122. doi:10.1097/01.JPN.0000270628.51122.1d

Khan, S., & Chang, R. (2013). Anatomy of the vestibular system: A review. *NeuroRehabilitation*, *32*(3), 437–443. doi:10.3233/NRE-130866

Kordestani, R., Patel, S., Bard, D., Gurwitch, R., & Panchal, J. (2006). Neurodevelopmental delays in children with deformational plagiocephaly. *Plastic and Reconstructive Surgery*, *117*(1), 207–218. doi:10.1097/01.prs.0000185604.15606.e5

Koren, A., Reece, S. M., Kahn-D'angelo, L., & Medeiros, D. (2010). Parental information and behaviors and provider practices related to tummy time and back to sleep. *Journal of Pediatric Health Care*, *24*(4), 222–230. doi:10.1016/j.pedhc.2009.05.002

Kuo, Y., Liao, H., Chen, P., Hsieh, W., & Hwang, A. (2008). The Influence of wakeful prone positioning on motor development during the early life. *Journal of Developmental & Behavioral Pediatrics*, *29*(5), 367–376. doi:10.1097/DBP.0b013e3181856d54

Kurniawati, N., Mustaji, M., & Setyowati, S. (2018). Implementation of neuroscience learning to develop early childhood's cognitive. *2nd International Conference on Education Innovation, Advances in Social Science, Education and Humanities Research-212* (pp. 89–93). Atlantis Press

Lane, S., Mailloux, Z., Schoen, S., Bundy, A., May-Benson, T. . . . Schaaf, R. (2019). Neural foundations of Ayres Sensory integration®. *Brain Sciences*, *9*(7), 153–167. doi:10.3390/brainsci9070153

Lee, H., & Galloway, J. C. (2012). Early intensive postural and movement training advances head control in very young infants. *Physical Therapy*, *92*(7), 935–947. doi:10.2522/ptj.20110196

Le Gall, A., Hilber, P., Chesneau, C., Bulla, J., Toulouse, J., Machado, M., Besnard, S. . . . Besnard, S. (2019). The critical role of vestibular graviception during cognitive-motor development. *Behavioural Brain Research*, *372*, 1–9. doi:10.1016/j.bbr.2019.112040

Lenke, M. (2003). Motor outcomes in premature infants. *Newborn & Infant Nursing Reviews*, *3*(3), 104–109. doi:10.1016/S1527-3369(03)00032-1

Liddle, T., & Yorke, L. (2004). *Why motor skills matter: Improve your child's physical development to enhance learning and self-esteem*. Ney York, US: McGraw Hill Professional.

Lobo, M. A., & Galloway, J. C. (2012). Enhanced handling and positioning in early infancy advances development throughout the first year. *Child Development*, *83*(4), 1290–1302. doi:10.1111/j.1467-8624.2012.01772.x

Lopes, V., de Lima, C., & Tudella, E. (2009). Motor acquisition rate in Brazilian infants. *Infant and Child Development: An International Journal of Research and Practice*, *18*(2), 122–132. doi:10.1002/icd.595

Majnemer, A., & Barr, R. G. (2006). Influence of supine sleep positioning on the early motor milestone acquisition. *Developmental Medicine of Child Neurology*, *47*(6), 370–376. doi:10.1016/j.jpeds.2006.05.009

Malina, R. (2004). Motor development during infancy and early childhood: Overview and suggested directions for research. *International Journal of Sport and Health Science*, *2*, 50–66. doi:10.5432/ijshs.2.50

McEwan, M., Dihoff, R., & Brosvic, G. (1991). Early infant crawling experience is reflected in later motor skill development. *Perceptual and Motor Skills*, *72*(1), 75–79. doi:10.2466/pms.1991.72.1.75

Moon, R., Darnall, R. A., Feldman-Winter, L., Goodstein, M. H., & Hauck, F. R. (2016). SIDS and other sleep-related infant deaths: Evidence base for 2016 updated recommendations for a safe infant sleeping environment. *Pediatrics*, *138*(5), e1–34. doi:10.1542/peds.2016-2940

Nandi, R., & Luxon, L. (2008). Development and assessment of the vestibular system. *International Journal of Audiology*, *47*(9), 566–577. doi:10.1080/14992020802324540

Nitsos, A., Estrada, R., & Messias, D. (2017). Tummy time for Latinos with limited English proficiency: Evaluating the feasibility of a cultural and linguistically adapted parent education intervention. *Journal of Pediatric Nursing*, *36*, 31–36. doi:10.1016/j.pedn.2017.04.004

Ocklenburg, S., Korte, M., Peterburs, J., Wolf, O., & Güntürküna, O. (2016). Stress and laterality – the comparative perspective. *Physiology & Behavior*, *164*(Part A), 321–329. doi:10.1016/j.physbeh.2016.06.020

Pecuch, A., Gieysztor, E., Telenga, M., Wolańska, E., Kowal, M., & Paprocka-Borowicz, M. (2020). Primitive reflex activity in relation to the sensory profile in healthy preschool children. *International Journal of Environmental Research and Public Health*, *17*(21), 81. doi:10.3390/ijerph17218210

Piper, M., & Darrah, J. (1994). *Motor assessment of the developing infant*. Philadelphia: WB Saunders;.

Ricard, A., & Metz, A. (2014). Caregivers' knowledge, attitudes, and implementation of awake infant prone positioning. *Journal of Occupational Therapy, Schools, & Early Intervention*, *7*(1), 16–28. doi:10.1080/19411243.2014.898464

Robertson, R. (2011). Supine infant positioning— Yes, but there's more to it. *The Journal of Family Practice*, *60*(10), 605–608.

Roizen, M. (2009). When does the fetus develop the sense of balance? In *YOU: Having a baby: The owner's manual to a happy and healthy pregnancy*. Free Press.

Russell, D., Kriel, H., Joubert, G., & Goosen, Y. (2009). Prone positioning and motor development in the first 6 weeks of life. *South African Journal of Occupational Therapy*, *39*(1), 11–14.

Salls, J., Silverman, L., & Gatty, C. (2002). The relationship of infant sleep and play positioning to motor milestone achievement. *American Journal of Occupational Therapy, Schools, & Early Intervention*, *56*(5), 577–580. doi:10.5014/ajot.56.5.577

Sauve, K., & Bartlett, D. (2010). *Dynamic Systems Theory: A Framework for Exploring Readiness to Change in Children with Cerebral Palsy*. Retrieved from CanChild Centre: School of Rehabilitation Science at McMaster University: Ontario. 14:

Schreiber-Nordblum, C. (1995). *Preschool special education teachers' knowledge regarding the use of sensory integration: Implications for staff development and teacher preparation programs*. D'Youville College, Doctoral dissertation

Sekulić, S., Žarkov, M., Slankamenac, P., Božić, K., Vejnović, T., & Novakov-Mikić, A. (2009). Decreased expression of the righting reflex and locomotor movements in breech-presenting newborns in the first days of life. *Early Human Development*, *85*(4), 263–266. doi:10.1016/j.earlhumdev.2008.11.001

Senju, A., Shimono, M., Tsuji, M., Suga, R., Shibata, E., Fujino, Y., Kusuhara, K., Kusuhara, K. (2018). Inability of infants to push up in the prone position and subsequent development. *Pediatrics International*, *60*(9), 811–819. doi:10.1111/ped.13632

Shumway-Cook, A., & Woollacott, M. (2007). *Motor control: Translating research into clinical practice*. Pennsylvania, USA: Lippincott Williams & Wilkins.

Smith-Roley, S., Singer, M., & Roley, A. (2016). Ayres sensory integration® for infant and toddlers. *The South African Institute for Sensory Integration*.

Taylor, K, & Trott, M. (1996). 'Pyramid of learning'. In M. W. S. Shellenberger (Ed.), in How Does Your Engine Run? A leader's guide to the Alert Program for self-regulation. TherapyWorks, Inc.

Thomason, M., Hect, J., Waller, R., Manning, J., Stacks, A., Beeghly, M., Romero, R., Romero, R. (2018). Prenatal neural origins of infant motor development: Associations between fetal brain and infant motor development. *Developmental Psychopathological*, *30*(3), 763–772. doi:10.1017/S095457941800072X

Touwen, B. (1975). Neurological development in infancy *Doctor of Philosophy*. Groningen: University of Groningen Netherlands.

Van Hecke, R., Danneels, M., Dhooge, I., Van Waelvelde, H., Wiersema, J., Deconinck, F., & Maes, L. (2019). Vestibular function in children with neurodevelopmental disorders: A systematic review. *Journal of Autism Developmental Disorders*, *49*(8), 3328–3350. doi:10.1007/s10803-019-04059-0

van Vlimmeren, L., van der Graaf, Y., Boere-Boonekamp, M., L'Hoir, M., Helders, P., & Engelbert, R. (2007). Risk factors for deformational plagiocephaly at birth and at 7 weeks of age: A prospective cohort study. *Pediatrics*, *119*(2), e408–418. doi:10.1542/peds.2006-2012

Verrecchia, L., Karpeta, N., Westin, M., Johansson, A., Aldenklint, S., Brantberg, K., & Duan, D. (2019). Methodological aspects of testing vestibular evoked myogenic potentials in infants at universal hearing screening program. *Scientific Reports*, *9*(17225). doi:10.1038/s41598-019-53143-z

Visser, M., & Franzsen, D. (2010). The association of an omitted crawling milestone with pencil grasp and control in five-and six-year-old children. *South African Journal of Occupational Therapy*, *40*(2), 19–23.

Vladescu, J., Schnell, L., & Day-Watkins, J. (2020). Infant positioning: A brief review. *Journal of Applied Behavior Analysis*, *53*(3), 1237–1241. doi:10.1002/jaba.746

Whitehead, L., & Banihani, S. (2014). The evolution of contralateral control of the body by the brain: Is it a protective mechanism? *Laterality*, *19*(3), 325–339. doi:10.1080/1357650X.2013.824461

Wiener-Vacher, S., Hamilton, D., & Wiener, S. (2013). Vestibular activity and cognitive development in children: Perspectives. *Frontiers in Integrative Neuroscience*, *7*. doi:10.3389/fnint.2013.00092

Williams, M., & Shellenberger, S. (1996). *How does your engine run?: A leader's guide to the alert program for self-regulation*. Albuquerque, NM: TherapyWorks, Inc.

Zachry, A. H., & Kitzmann, K. M. (2011). Caregiver awareness of prone play recommendations. *Am J Occup Ther*, *65*(1), 101–105. doi:10.5014/ajot.2011.09100

Zachry, A., Nolan, V., Hand, S., & Klemm, S. (2017). Infant positioning, baby gear use, and cranial asymmetry. *Maternal and Child Health Journal*, *21*(12), 2229–2236. doi:10.1007/s10995-017-2344-6

Zafeiriou, D. (2004). Primitive reflexes and postural reactions in the neurodevelopmental examination. *Pediatric Neurology*, *31*(1), 1–8. doi:10.1016/j.pediatrneurol.2004.01.012