School of Physiotherapy and Exercise Science
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The relationships between motor practice, temperament and motor skills in term and preterm infants

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This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University

December 2015

DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number HR148/2010.

Lynn Jensen

Signature:_______________________________________

Date:____

ABSTRACT

Motor development in infancy may be influenced by infant gestational age and birth weight. Infants born earlier than 37 weeks gestational age are preterm and are at risk of motor delay. Not all preterm infants are at equal risk. Earlier gestations, low birth weight and conditions affecting the neurological and musculoskeletal systems confer higher risks. Some preterm infants do not have neurological or musculoskeletal sequelae as a consequence of their early gestation and are considered to be low risk. One other risk factor that may increase the risk of motor delay in term and preterm infants is birth weight that is less than the 10^{th} percentile for gestational age.

Infants learn motor skills through practice with some infants practicing with greater frequency and intensity. The differences in practice may be related to factors such as premature birth or infant temperament. The aim of this thesis was to investigate the role of motor practice in the acquisition of motor skills in term and preterm infants and to determine whether infant temperament influenced the relationship between practice and motor skills. A cross sectional study was conducted which allowed four major analyses.

The first study examined gross and fine motor skills of term (n = 93) and low-risk, healthy preterm (n = 87) infants between three and 12 months corrected age. The preterm infants had similar gross and fine motor skills compared with the term infants, but male infants ($p < .001$) and infants born small for gestational age ($p < .05$) had lower fine motor scores.

The second study examined infant temperament in the term and preterm infants. Gestational age did not affect temperament characteristics with both groups being described similarly by their mothers.

Study three measured infant motor practice over 24 hours using a daily routines diary and accelerometer. This study generated a number of novel findings. Duration of care over 24 hours decreased with age ($p < .001$), play duration increased with age ($p < .001$) and sleep duration decreased with age ($p < .05$). The amount of assistance required for care and play activities decreased with age ($p < .001$ for both activities). Infants who were small for gestational age had lower awake activity counts compared with infants who were appropriate for gestational age ($p < .01$).

The final study combined data from the term and preterm infants and proposed a mediational model to test the presence of a direct effect between temperament and an indirect effect through practice on motor skills. Two novel outcomes were that

infants with high surgency/extraversion practiced more intensely ($p < .001$), and infants who practiced more intensely had better gross motor skills ($p < .01$). However, there was no correlation between infant temperament and gross motor skills.

Cumulatively, the evidence from these four studies showed that early gestation alone in healthy low-risk preterm infants was not a risk factor for motor delay, but being small for gestational age increased the risk of fine motor delay and was associated with less intensity of practice. The thesis confirms that intensity of motor practice impacts infant gross motor skill acquisition and that infant temperament may impact this relationship.

Acknowledgements

"Magic is believing in yourself, if you can do that, you can make anything happen." Johann Wolfgang von Goethe

This thesis would not have been possible without the support from a number of people.

Firstly, I would like to thank my two supervisors: Emeritus Professor Jan Piek for sharing her research experience and knowledge of infant development. Your guidance has been invaluable. Thank you for allowing me to explore this rich field of knowledge. Dr Jenny Downs, thank you for your enthusiasm, your collegial support and attention to detail. You have taught me to not settle for second best.

Dr Robert Kane, a master statistician, who didn't make me feel ignorant when I had no idea what you were talking about.

My paediatric physiotherapy colleagues: Helen, Rose, Bev, Kim and Jenni. Thanks for keeping me on track and in touch when I needed you.

To the mothers and children who participated – thank you for giving up your time and for being enthusiastic about the study. I look forward to watching your children grow.

Heather, David and Gail – thanks for your advice and feedback and for listening.

And lastly, my boys. I am blessed to have three lovely men in my life. Michael, I am so grateful that I have you around. Your tolerance and patience are my bedrock. Thank you for letting me follow my dream – I promise this is the last big one. Matthew, you've grown up with a researcher mother and I hope it will spark your intellectual curiosity. Tristan, my research assistant – I hope this encourages you to enjoy research one day.

List of Conference Presentations

Poster presentations

Jensen L.M., Piek J.P. and Downs J. (2011). Measuring infant daily activity using accelerometry and parent report diary – a preliminary report. 10th Motor Control and Human Skill Conference, Mandurah, Western Australia.

Jensen L.M., Piek J.P. and Downs J. (2013). Temperament and activity levels in term and preterm infants. International Conference on Infant Studies, Berlin, Germany.
and at
Mark Liveris Seminar, Faculty of Health Science Research Seminar, Curtin University, Perth, Australia. Awarded best poster 2014.

Oral presentations

Jensen L.M., Piek J.P. and Downs J. (2013). Measurement of term and preterm infant activity using accelerometry. Australian Physiotherapy Association Congress, Brisbane, Australia.

Jensen L.M., Piek J.P. and Downs J. (2013). Quantifying daily activities of term infants. Australian Physiotherapy Association Congress, Brisbane, Australia.

Jensen L.M., Piek J.P. and Downs J. (2015). Male infants and infants born small for gestational age are at risk of fine motor delay in infancy. World Confederation of Physical Therapy Conference, Singapore.

Jensen L.M., Piek J.P. and Downs J. (2015). Infants who are more active when awake have better gross motor development. World Confederation of Physical Therapy Conference, Singapore.

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List of abbreviations

AIMS	Alberta Infant Motor Scale
AGA	Appropriate for gestational age
BW	Birth weight
BWGA	Birth weight for gestational age
CA	Corrected age
DAIS	Daily Activities of Infants Scale
ELBW	Extremely low birth weight
EPT	Extremely preterm
FM	Fine motor
FMQ	Fine motor quotient
GA	Gestational age
GM	Gross motor
GMQ	Gross motor quotient
IBQR	Infant Behaviour Questionnaire – Revised
LBW	Low birth weight
M	Mean
NA	Negative affectivity
OR	Orienting / regulation
PDMS2	Peabody Developmental Motor Scales, Version 2
SD	Standard deviation
SE	Surgency / extraversion
SGA	Small for gestational age
VLBW	Very low birth weight
VPT	Very preterm

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Chapter 1 – Introduction

Esther Thelen (2000) defined the term "embodied mind" as an individual's motoric interactions with the world to explain how cognition and motor functions are inextricably linked. From a developmental perspective, body and mind create a framework within which an infant's memory, reasoning and doing result in functional outcomes that respond to and effect changes in the environment (Smith, 2010; Thelen, 2000a). Iverson (2010) and Adolph et al. (2010) argue for the inclusion of language development and social referencing, respectively, within the framework. However, Adolph and Robinson (2015) propose that motor development alone is the frame off which all other aspects of development hang and that to understand behavioural development one need only understand motor development. They refer to the changes in perception, cognition, language and social development as being a "developmental cascade" that follows changes in motor skills (Adolph & Robinson, 2015, p 115). Other researchers would disagree explaining that children are not developing in one domain at a time but in multiple domains at any one time, most of which are interlaced (Smith, 2010). For example, an infant who is crawling is learning to organize their own body to negotiate the floor surface while carrying a toy and using vision to scan the environment for people to engage in social interactions and objects to explore.

Infant motor development involves change that is influenced by environment and experience (Masten, 2006) and is responsive to culture-specific contexts (Kolling et al., 2014). Every infant is characterized by his or her own body structures, cognition and temperament and his or her interactions with family and community, therefore the process of motor development is individualized but is also universal (Kolling et al., 2014; Thelen & Smith, 1994).

Some infants appear to be inherently motivated to move and to be active participants in their exploration of the world, while others appear to be more passive or apprehensive. These inherent behavioural and emotional traits describe an infant's temperament (Gartstein & Rothbart, 2003). The amount of spontaneous activity in which an infant engages may be supported by their parents and possibly extended.

This bi-directional interaction between infant and parent could be interpreted as a form of motor practice (Bartlett, Fanning, Miller, Conti-Becker, & Doralp, 2008). How infants and their families negotiate the development of motor skills can be influenced by infant birth history. Infants born preterm are at a higher risk of motor delay (de Kieviet, Piek, Aarnoudse-Moens, & Oosterlaan, 2009) primarily due to the vulnerability of their body systems (Committee on Understanding Premature Birth and Assuring Healthy Outcomes, 2007). Delays in motor development in preterm infants may result in delays in cognition (Hutchinson, De Luca, Doyle, Roberts, & Anderson, 2013), language and social skills (Potijk, Kerstjens, Bos, Reijneveld, & de Winter, 2013). However, term infants may also be delayed in motor skills with subsequent delays in other domains of development (Piek, Barrett, Smith, Rigoli, & Gasson, 2010; Piek, Dawson, Smith, & Gasson, 2008).

To prevent the possible adverse effects of motor delay a better understanding of the effects of infant temperament and motor practice on motor development of full term and low risk healthy preterm infants is warranted. In Western Australia, the management of preterm infants, particularly those considered to be at risk of adverse outcomes, is concentrated at one tertiary hospital. There is an opportunity to assess the motor outcomes of this group of infants.

Thesis structure

There are nine chapters in this thesis, including this introduction chapter. Chapter two presents a review of the literature on the factors that impact typically developing infant gross and fine motor development and the effects of preterm birth on motor development. Term and preterm infant temperament and motor practice are also reviewed.

Chapter three summarises the gaps in our understanding of the effects of infant motor practice and temperament on motor development, states the rationale and justifies the main study aim.

Chapter four describes the methods, the cross-sectional sample and procedures. From this one methodology, four studies were conducted to evaluate separate research questions, with the final study addressing the main study aim. The four studies are reported in chapters five to eight. Chapter nine is a final discussion drawing together the main findings of the thesis.

Chapter 2 – Literature review

2.0 Introduction

Infant motor development is flexible, adaptive and responsive to changes in the infant's physical and social environments. For typical infants motor development occurs within a body that is growing and moving in changing environments and enables the infant to take control of his or her world (Adolph & Robinson, 2015). This contemporary view of motor development is far removed from the prescriptive definition that described motor development as a sequential, irreversible process that resulted in new and specific motor skills that were qualitatively different to earlier skills (Baltes, Reese & Lipsitt, 1980). The traditional view of milestone acquisition is modified to reflect more current opinions shifting from body structure to function (Heriza, 1991), an increase in knowledge about childrearing practices in a range of cultures (Kolling et al., 2014) and a broader understanding of the role of the environment (Adolph & Robinson, 2015).

Development of motor skills occurs concomitantly with development in other domains, such as language (Conti-Ramsden & Durkin, 2012), social interactions, executive functions (Center on the Developing Child at Harvard University, 2011) and exploratory play (Pelligrini & Smith, 1998). Change in motor skills may also be the impetus for change in other domains of development (Soska, Robinson, & Adolph, 2015). For example, some of the benefits for infants when transitioning from crawling to walking are that the infant covers more distance walking than when crawling and an expanded visual field stimulates exploratory play. Infants who are walking share toys and elicit richer language exchanges with parents that does not occur when they are crawling (Adolph & Tamis-LeMonda, 2014). Development across all domains is interactive either between the infant and its parents or the surroundings or both.

The risks to the infant with delayed motor development therefore are not restricted to the motor domain but can impact on mental and physical health (Piek et al., 2010), language (Conti-Ramsden & Durkin, 2012), and cognition during infancy and potentially into childhood and beyond (Piek et al., 2008).

Irrespective of the infant's sex, ethnicity or environment, the universality of motor development results in the gaining of key motor skills that are relatively consistent in typical infants but the age range when skills appear varies widely (WHO Multicentre Growth Reference Study Group, 2006b). Some authors have asserted that the sequence of motor development is attributed to infant genetics (Gilbert, 2006) and biological factors (Baltes, Reese & Lipsitt, 1980). However, more recent studies have shown that there is variability in motor skills at both an intra- and inter-individual level due to the impact of culture, differences in opportunities for practice, and the influences of a post-natal gravitational environment on the infant's biomechanical system (Adolph, Cole, & Vereijken, 2015; Karasik, Tamis-LeMonda, Adolph, & Bornstein, 2015).

2.1 Theories of motor development

There are many theories that describe motor development in infancy from different perspectives, but two influential theories are now discussed with a focus on understanding motor development in term and preterm infants.

2.1.1 Neuromaturational model

The neuromaturational model of motor development proposes that the maturation of the central nervous system (CNS) is the driving force that results in changes in motor skills over time (Heriza, 1991). The main proponents of this model were Gesell and Amatruda (Gesell & Amatruda, 1974) and McGraw (Bergenn, Dalton, & Lipsitt, 1992) in the 1940's and 1950's based on their observations of infants and an emerging understanding of neural structures in human and animal embryos. Guiding principles of this model propose that changes to brain structures drove function (Hadders-Algra, 2000). Gesell's views on the observable ordered development of behaviours of infants was influenced by the order of development of the nervous system, in the absence of practice or environmental influences (Thelen & Adolph, 1992). Coghill (1930) showed that motor neurons grew in cephalocaudal and proximal to distal directions (Coghill, 1930). The neuromaturational model is also referred to as a reflex-hierarchical model as movement was thought to occur when the infant was presented with a sensory stimulus. As the brain matured the reflexes disappeared to be replaced by movements that were controlled by higher centres in the brain (Heriza, 1991).

Gesell and Amatruda (1945) proposed seven principles in their neuromaturational model, critiqued by Thelen and Adolph (Thelen & Adolph, 1992) and summarized by Piper and Darrah (1994) into four concepts. The first concept states that movement progresses from primitive, reflexive movements in response to sensory stimuli to voluntary controlled movement which develops with growth and maturation of the brain. Examples of this principle were the asymmetrical tonic neck reflex in response to rotation of the neck (face arm extends, skull arm flexes – "fencer" pose), alternate stepping movements when the ball of the foot is placed on a firm surface, and the abduction/extension movement of the shoulders on rapid extension of the neck (Moro reflex).

The second concept was based on the notion that motor development proceeds in cephalocaudal and proximal to distal directions. Infants show an orderly pattern of development of head control before shoulder girdle, trunk, pelvis and lower limbs. On observation, the infant learns to extend the neck in prone, before sitting, then crawling and standing. It was considered that control is sequential from proximal to distal in the upper and lower limbs. That is, the infant learns to control the shoulder and hip before learning to control the elbow and knee and then hand and foot, respectively. This principle is demonstrated in the upper limb as the infant progresses from large swiping movements before being able to grasp a toy and then uses individual finger movements to point, poke and flick. In the lower limb by random kicking in supine is followed by taking weight in standing.

The third concept was that the sequence of motor development was consistent between infants but the rate was consistent for each infant. Therefore, motor development was described as being non-linear. Infants were considered to be self-regulatory as a stable pattern of movement might co-exist with an unstable pattern allowing learning of new movement skills.

The last concept is related to the previous as the consistency between infants was considered to be ontogenetic and a function of brain maturation. The differences between infants were due to environmental factors that affected the expression of the genetic code (Gesell & Amatruda, 1947). Bergenn, Dalton and Lipsitt (1992) state that McGraw was a strong proponent of the balance between nature and nurture in infant motor development.

Some of the limitations of the neuromaturational model are that it does not explain the process of change in the development of motor skills, neither does it explain the adaptability of infant movement in reaction to varying environmental conditions, nor how movements are refined and become efficient (Thelen, Kelso, & Fogel, 1987). In response to the limitations of the neuromaturational model, the dynamic systems theory was proposed.

2.1.2 Dynamic Systems theory

The dynamic systems theory (DST) of motor development is based on the work of Nikolai Bernstein, a Russian neurophysiologist who conceived the term "motor control" in 1947. He argued that human movement was more than reflexive movement organized by the brain in response to stimuli, as the stimuli in the environment varied enormously and unpredictably. The brain would not have the capacity to organize multiple joints and muscles, in changing environmental conditions and store solutions for the range and volume of movement options. This conundrum he termed the "degrees of freedom" problem.

His work was further developed by Kelso and others in the 1980's who began to interpret human movement as being a dynamic system that was self-organising and resulted in non-linear changes due to the varying timeframes of the multiple contributing body systems embedded in a changing environment (Kugler, Kelso, & Turvey, 1982). The principles of the DST that they proposed were explored further by Thelen, Kelso and Fogel (1987) and Thelen and Smith (1994) to provide a better understanding of infant motor development. Their research challenged the principles of the neuromaturational model by shifting the emphasis from solely nervous system control to an appreciation that the brain was only one of many body structures that contributed to infant movement. Complex interactions between the characteristics of the infant, parent and environment either promote or delay motor development during the first year of the infant's life.

The first principle of the neuromaturational theory stating that early movements such as early infant kicking are reflexive and not organized has been contradicted by studying the movement of the lower limbs in term and healthy low-risk preterm infants. During spontaneous reciprocal kicking, term and preterm infants show that the joints in the lower limbs work in an organized pattern, limiting the degrees of freedom in a complex bilateral task (Heriza, 1988a; Piek & Carmen, 1994). Less time was spent in kicking with increasing age and changes in posture and as infants increased their gross motor repertoire (Piek & Carmen, 1994). Large joint amplitudes were seen when infants were more aroused, but when their limbs were heavier there were reduced amplitudes at the hip and knee and fewer kicks (Heriza, 1988b). Besides demonstrating that infant kicking is an organized movement, other infant characteristics such as their alertness, limb weight, muscle strength and passive elastic properties of the lower limb were implicated in the development of lower limb skills (Thelen, Fisher, Ridley-Johnson, & Griffin, 1982).

The principle that development is cephalocaudal was refuted when early stepping was examined by Thelen, Fisher & Ridley-Johnson (1984). Early stepping seen in infants when held in standing, at approximately two weeks of age, was thought to be a reflexive movement in response to tactile input to the ball of the infant's foot which disappeared at about four weeks of age due to the maturation of the brain. This motor behaviour was tested by manipulating the infant's weight. Firstly, infants who were no longer stepping were held in water to reduce their lower limb weight and were able to step in the water. Weight of the infants' lower limbs was then increased by using ankle weights and infants who were stepping on land were unable to step when their legs became artificially heavier. These two experiments demonstrated that changing weight of the infant's lower limbs was the controlling factor in whether infant's stepped or not, not the maturation of the brain. The mis-match between infant weight and strength determined whether infants were able to step (Thelen, Fisher, & Ridley-Johnson, 1984). Further, the experiment demonstrated that infant stepping was not reflexive and development was not cephalocaudal as the infant had head control and lower limb movements but no trunk or pelvic control.

One of the earliest studies to challenge the assumption of the proximal to distal concept investigated reaching in typical infants between five and nine months of age (Fetters & Todd, 1987). Fetters & Todd demonstrated that arm joints worked as a movement unit for purposeful reaching in infants at five months and only the reaching path changed with age at nine months. Control of arm joints was not from shoulder to elbow, wrist and hand but all joints worked cooperatively from the first and earliest attempts at five months. This study showed that development of control of upper limb joints happened concurrently, not from proximal to distal control (Fetters & Todd, 1987).

Further evidence that development is not restricted to proximal to distal control are the rhythmical movements of hands and feet that occur concurrently with spontaneous kicking (Piek & Carmen, 1994). Coordinated movements in distal body segments appear to be as well organized as reciprocal kicking. These repetitive movements might be the infant's attempt at independent practice as some repetitive movements decreased once a new motor skill emerged (Thelen, 1981).

Muscle activity is organized from distal to proximal in standing postural control even before infants have independent stance. What changes across the lifespan is the timing of the muscle activity not the sequence which starts from the base of support, that is, the feet and then moves from distal to proximal in the lower limbs and from pelvis to shoulders and head, from caudal to cephalad (Woollacott & Shumway-Cook, 1990).

Infant anthropometry also plays a role in organizing motor behaviour. Heavier infants achieve crawling (Adolph, Vereijken, & Denny, 1998) and walking (Adolph, Bertenthal, Boker, Goldfield, & Gibson, 1997) later than slimmer infants. The rate of lower limb growth proceeds at a faster rate than that of trunk length and head circumference (Lampl, Veldhuis, & Johnson, 1992) altering the biomechanics and impacting on the development of crawling and walking. A longitudinal prospective study of term infants (n = 217) aged three to 18 months found that infants who were overweight had delayed motor skills. Infants >90th percentile *z*-score on weight-for-length were nearly twice as likely to have delayed motor development, scored with the Bayley Scales of Infant Development – II, psychomotor index, and infants with subcutaneous fat >90th percentile were more than twice as likely to be delayed (Slining, Adair, Goldman, Borja, & Bentley, 2010). As this was a correlational study, causality cannot be inferred, but suggests that infant anthropometry could have an impact on motor development.

Brain growth and volume in infancy is rapid (Toft et al., 1995) with an increase in myelination that occurs in a well organized manner in different parts of the brain (Deoni et al., 2011; Stiles & Jernigan, 2010). These brain changes occur concomitantly with growth in other body systems.

Spatial and temporal characteristics of muscle activity contributing to balance are well organized in infancy to support the development of walking and reaching (Rocha & Tudella, 2008; van der Fits & Hadders-Algra, 1998). Disorganisation of this muscle activity for balance in sitting is a limiting factor in the development of reaching in term, low-risk preterm and high-risk preterm infants (Hadders-Algra, 2013). Reaching also requires visuomotor processes which are present from birth and refined during the first six months of life to enable the infant to reach and grasp (Barrett, Traupman, & Needham, 2008; Fagard, Spelke, & von Hofsten, 2009).

Coordination of body systems in real time, measured in seconds and minutes, enables the infant to organize a movement pattern to suit the immediate task objective and the environmental features to achieve the movement outcome (Heriza, 1991). Thelen et al. (1984) demonstrated this concept in the infant stepping experiment where the infants adjusted their stepping pattern within minutes of having their lower limb weight altered. Over the course of infancy change in motor skills is measured in developmental time. As body systems develop asynchronously, change in motor skills is dependent on the slowest changing system or the rate limiting system and is therefore non-linear (Thelen, 2000a).

The importance of an intact CNS in the acquisition of motor skills is evident when an infant has a brain injury, such as intracranial hemorrhage, motor skills are delayed or abnormal (Perlman, 2004; Takenouchi, Kasdorf, Engel, Grunebaum, & Perlman, 2012). Infants born preterm are also vulnerable to adverse consequences to their body systems and potentially delayed motor development.

2.2 Preterm birth

More than 25,000 (8.3% of all live births) infants were born preterm in Australia in 2011 (the most recent year with complete data), with 2,757 (8.6%) of those being born in Western Australia (Z. Li, Zeki, Hilder, & Sullivan, 2013). Preterm birth is defined as infants born before 37 weeks gestation and is more common in males (Blencowe et al., 2012). Gestational age (GA) is currently the most frequently used method of determining infant biological maturity with preterm further classified as extremely (<28 weeks GA), very (28 weeks to <32 weeks GA), and moderate to late (32 weeks to <37 weeks) (Blencowe et al., 2012; World Health Organisation, 2013). These categories are important as morbidity and mortality associated with preterm birth increase at earlier gestations (Z. Li et al., 2013).

In Western Australia, for the years 2004 to 2007, the survival of infants born at 25 weeks gestation was 78% rising to greater than 90% for infants with gestations later than 27 weeks (French & McMichael, 2010). There was a decrease in the proportion of preterm infants with any level of disability from 21% to 10% for infants born at 27 to 36 weeks. However, for infants born earlier than 26 weeks gestation the proportion rises from 29% to 62% (French & McMichael, 2010).

Birth weight (BW) may also confer risks on an infant's development with birth term and preterm infants being affected. Low birth weight (LBW) is <2500g and can be further divided into very LBW (VLBW) <1500g and extremely LBW (ELBW) <1000g but these categories are not mutually exclusive, so consequences of LBW encompass those of ELBW (United Nations Children's Fund and World Health Organisation, 2004). LBW is associated with high risks of mortality with epidemiological studies indicating that infants born <2500g are approximately 20 times more likely to die in infancy than infants born at heavier weights (United Nations Children's Fund and World Health Organisation, 2004).

BW may also be interpreted with reference to GA. Three categories are defined: small for gestational age, (SGA) (BW <10th percentile for the week of gestation), appropriate for gestational age (AGA) (≥10th and <90th percentile) and large for gestational age (LGA) (BW ≥90th percentile) (WHO, 2011). When BW is viewed using this classification, infants with BW <2500g may in fact be appropriate weight for gestation. Across all gestations, infants SGA are at an increased risk of morbidity and mortality (Vashevnik, Walker, & Permezel, 2007).

2.2.1 Effects of preterm birth on infant body structures

Infants who survive premature birth may present with problems that vary in severity and may affect a number of body structures, including the lungs, muscles, brain, immune system, eyes, ears and gastrointestinal tract.

Respiratory disease is reported to be the single greatest cause of illness and death in preterm infants (Moss, 2005; Stoll et al., 2010). The respiratory system is often unable to cope with the demands of breathing due to immature alveoli, absence of surfactant, a highly flexible rib cage, and floppy airways, all of which are undeveloped at 24 to 28 weeks GA (Dargaville & Tingay, 2012). While medical management aims to achieve optimum gas exchange with minimal disruption to the developing respiratory system, nevertheless the use of assisted ventilation for preterm infants with lung disease is a major cause of lung injury and inflammation and the primary risk factor for bronchopulmonary dysplasia or chronic lung disease (M. K. Brown & DiBlasi, 2011). The consequences of lung disease include a higher prevalence of hospital admissions compared with term infants (Moss, 2005) and poorer neurodevelopmental outcomes such as cerebral palsy and learning impairments (B. Schmidt et al., 2003).

Impaired muscle development can be due to a combination of inadequate protein function, altered nutrition, and the early effects of gravity during the differentiation of muscle fibre types (Yan, Zhu, Dodson, & Du, 2013). A reduction in strength has not been reported for preterm infants although reduced strength has been found in adolescents who were born preterm (Rogers, Fay, Whitfield, Tomlinson, & Grunau, 2005). In turn inadequate use and pull of muscle on bone limits bone growth in length and cross-sectional strength in preterm infants (Rauch & Schoenau, 2002).

Injuries to the preterm brain are common and variable in severity, although their consequences may not be evident during infancy (Kidokoro et al., 2014; Volpe, 2009). The most common brain injuries are intraventricular haemorrhage (IVH), periventricular leukomalacia (PVL) and encephalopathy of prematurity. This latter condition is PVL accompanied by diffuse neuronal/axonal disease in the cerebrum and cerebellum, and is associated with cerebral palsy, seizures, cognitive impairments and motor disability of varying severity (Volpe, 2009). The preterm brain is especially vulnerable to hypoxia and haemorrhage due to trauma to fragile blood vessels which are side-effects of assisted ventilation and fluctuations in blood pressure (M. K. Brown & DiBlasi, 2011; Dargaville & Tingay, 2012). These injuries occur while the brain is undergoing extensive development and proliferation, such that growth interacts with destruction, thereby interfering with the induction that growth in one area of the brain has on another (Raybaud, 2013; Raybaud, Ahmad, Rastegar, Shroff, & Al Nassar, 2013).

There is a much higher risk of somatic conditions such as retinopathy of prematurity (ROP) and necrotizing enterocolitis (NEC) in both SGA infants and earlier gestational ages (Rogvi, Forman, & Greisen, 2015). ROP is the most common cause of visual impairment in preterm infants. The retina of the preterm infant is not completely vascularized at birth and vascularization stops at the time of birth due to the cessation of maternal hormones. In ROP, high dosages of supplemental oxygen may cause primary microvascular degeneration which is then followed by neovascularisation leading to retinal detachment (Rivera et al., 2011).

NEC is the most commonly acquired gastrointestinal disorder due to preterm birth and is associated with a mortality rate of 20 to 40% depending on whether the infant requires surgical intervention. Infants with NEC are more likely to develop chronic lung disease and neurodevelopmental disorders, with an increasing risk of cerebral palsy if the infant also develops a secondary infection. Three main factors are thought to contribute to the development of NEC: early gestation, reduced blood flow to the intestine and infection. But this is a multifactorial condition that may be triggered by enteral formula feeding, as breast milk appears to be a protective factor (Morgan, Young, & McGuire, 2011).

2.2.2 Consequences of preterm birth

The consequences of preterm birth can have significant effects on body system structure as well as on function. GA alone is not considered to be the best predictor of outcome in extremely preterm infants (22 to 25 weeks gestation), but rather a cluster of factors together with GA, including BWGA, sex, plurality and antenatal corticosteroid use are associated with adverse outcomes (Stoll et al., 2010). The effect of these five factors, when combined, on mortality was tested by Boland et al. (2013) in a sample of extremely preterm infants born in Victoria, Australia. The combination of factors predicted 47% mortality at two years of age but was 49% when the factors were not taken into account (Boland, Davis, Dawson, & Doyle, 2013). Male sex alone predicts a higher risk of neonatal mortality and later complications in preterm infants (Blencowe et al., 2012).

While LBW is associated with lower infant survival and increased risk of medical complications in the short and long term (Committee on Understanding Premature Birth and Assuring Healthy Outcomes, 2007; Stoll et al., 2010), infants who are born growth restricted or preterm and growth restricted have higher risks (WHO, 2011). Term infants who are growth restricted are at risk of a range of disorders, while infants who are both premature and growth restricted, have an increased risk of hospitalisations during childhood and early adulthood due to a wide range of diseases in almost all organ systems (Rogvi et al., 2015).

Growth restriction may be symmetrical or asymmetrical. If symmetrically growth restricted as a fetus, the infant at birth has BW <10th percentile for gestational age, that is SGA, as well as shorter length and a smaller head circumference. Symmetrical growth restriction generally occurs throughout the pregnancy and while there is an increased risk of perinatal mortality, infants who survive may present with a range of health and neurodevelopmentally adverse consequences throughout life. It was hypothesised that in utero adaptation affects all body systems, not just the brain (Hay, Catz, Grave, & Yaffe, 1997; Jelliffe-Pawlowski & Hansen, 2004). Symmetrical growth restriction is more likely to be evident in term SGA infants. If the infant is born preterm, then the combination of growth restriction in utero from conception together with the potential for adverse effects due to premature birth may compound developmental outcomes. Furthermore, infants who are at risk of negative environmental influences, such as poor maternal health and low socio-economic status tend to be symmetrically small (Black et al., 2004; Hediger, Overpeck, Ruan, & Troendle, 2002).

Infants who are asymmetrically growth restricted have BW <10th percentile for gestation, but length and head circumference within the expected range. This type of fetal growth pattern tends to occur in the last trimester of pregnancy, often due to placental insufficiency (GRIT Study Group, 2003). This places the fetus at an increased risk of hypoxia-ischaemia with the potential to compromise brain development (GRIT Study Group, 2003; Roelants-van Rijn, Van der Grond, Stigter, De Vries, & Groenendaal, 2004). It has been suggested that the fetus adapts to placental insufficiency by buffering brain growth at the expense of growth and development of other body systems (Hay et al., 1997; Jelliffe-Pawlowski & Hansen, 2004). This finding has been supported by a study that looked at cerebral structure and metabolism and outcomes of SGA compared with AGA preterm infants. There were no differences between the groups on cerebral metabolism, brain growth or developmental outcome at two years of age and no association between the measures (Roelants-van Rijn et al., 2004). In asymmetrical SGA, depending on GA, preterm birth may or may not enable the infant to engage in a brain adaptive process. Extremely and very preterm infants would appear to be most vulnerable to adverse outcomes as they would not have the benefit of time to safeguard brain growth, compared with moderate to late preterm birth. For all weeks of gestation, SGA increases the risks of poorer outcomes for the infant (Battaglia & Lubchenco 1967). The motor development of SGA infants whether term or preterm needs further investigation.

2.2.3 Motor development in preterm infants

In the absence of a diagnosed neurodevelopmental disorder, evidence suggests that preterm infants have an increased risk of motor delay in infancy that may track into childhood, adolescence and early adulthood (L. Brown, Burns, Watter, Gibbons, & Gray, 2015; de Kieviet et al., 2009; Husby, Skranes, Olsen, Brubakk, & Evensen, 2013; Kiechl-Kohlendorfer, Ralser, Pupp Peglow, Reiter, & Trawoger, 2009). However, some preterm infants without motor problems in infancy may present with motor impairments in early childhood (Evensen, Skranes, Brubakk, & Vik, 2009), while others do not show any delays in motor development and develop motor skills consistent with their term peers (Gurka, LoCasale-Crouch, & Blackman, 2010).

When comparing the motor development of preterm infants with term infants, conventional practice recommends that age is adjusted for prematurity, using corrected age (CA) until the preterm infant is at least three years of chronological age (American Academy of Pediatrics, 2004). Using CA as the criterion for comparison between preterm and term infants' motor development acknowledges that preterm infants are less mature and that more time is needed for age appropriate functioning. If CA is not used there is a risk that high proportions of preterm infants might be delayed resulting in interventions to improve motor function that may not be warranted.

However, there are some arguments that CA should not be used in comparison of motor skills (Wilson & Cradock, 2004). Firstly, using CA strongly favours those infants who are born at very early GA, as the differential is greater for lower gestations than higher gestations (DiPietro & Allen, 1991). For example, for an infant born at 24 weeks gestation (16 weeks early = ~ four months), at eight months of age their CA is four months; but an infant born at 34 weeks gestation (six weeks early = ~1.5 months), at eight months of age their CA is 6.5 months. While age increases linearly motor development does not, and the younger gestation infant may be advantaged during assessment. Secondly, term birth is defined as 37 to 40 weeks completed weeks of gestation, yet CA is calculated as 40 weeks minus number of weeks of gestation (DiPietro & Allen, 1991). So the infant born at 35 weeks GA is five weeks preterm, not two weeks preterm. Thirdly, from a dynamic systems perspective, the infant despite its GA, maximises its opportunities for movement through the inherent coordination of infant body systems, family function and environmental affordances, in the same way that term infants develop motor skills. There is a risk that by using CA as the criterion for comparison between preterm and term infants' motor development, actual delays may be masked.

The identification of potential motor problems in preterm infants may be achieved through the use of cranial ultrasound (US) and magnetic resonance imaging (MRI). The use of US prior to term age, may not detect subtle defects, while MRI can assist with more precise information but is most useful at term age when it can assess both brain injury and brain growth (Kidokoro et al., 2014; Whyte & Blaser, 2013). However, diagnostic tools are unlikely to be predictive of outcomes as infants are active participants in their development. Brain injury associated with poorer motor and cognitive outcomes have been identified at term equivalent age (Kidokoro et al., 2014), although the effects of a protective family and environment may lessen the impact of the brain injury.

Gross motor (GM) development of preterm infants has been extensively researched during infancy, but there are fewer studies on fine motor (FM) development possibly because there are a limited number of assessment tools appropriate for infants (Krumlinde-Sundholm, Ek, & Eliasson, 2015). A summary of studies describing GM and FM skills in infancy is presented in Table 2.1. Only studies with low risk preterm infants less than 18 months of age were included as this was the age group of interest in this thesis. Low risk was defined as infants without a brain injury diagnosed by head US or clinical examination, absence of congenital and chromosomal abnormalities and musculoskeletal conditions.

2.2.3.1 Gross motor development in preterm infants

GM outcomes differed among the 17 studies that were published between 1986 and 2015. All the studies (n = 5) published prior to 1991 reported that the infants at CA were not delayed, but were delayed at chronological age. This could be related to the health status of the infants who participated. Medical management of the infants in the neonatal unit has changed considerably since the 1990's, especially regarding assisted ventilation and nutrition, and monitoring of procedures. Speculatively, it is possible that preterm infants who survived their early birth and medical care were inherently more robust and had better motor outcomes as a result. The converse is also a possibility. Infants born prior to 1991 who did not survive, may have been more vulnerable to negative consequences in all domains if they had survived. An alternative explanation as to why the infants were not delayed at CA might relate to the assessment tools used. In one study, the parent was asked to recall when their infant achieved particular milestones without the use of a real-time diary (Case-Smith, 1993) which is potentially open to recall error. One other study used an assessment without justifying its suitability as a discriminative tool (Den Ouden, Rijken, Brand, Verloove-Vanhorick, & Ruys, 1991). Two studies used the original Peabody Developmental Motor Scale (PDMS) and longitudinal study designs (Palisano, 1986; Piper, Byrne, Darrah, & Watt, 1989) which may have accounted for GM performance during the second year of life observed to be closer to the norm. The final study used the original Bayley scales and found no delay at 12 months CA (Ross, 1985) but this might be due to only including one age group with the possibility that the infants may have been delayed at earlier ages but made developmental gains by 12 months of age.

Eleven studies published in the past 13 years report that preterm infants have delayed GM skills at CA when compared with term infants. These studies vary in their inclusion criteria of the infants reflecting differences in relative risks of the infants, the type of assessments used, and their study designs.

Two Brazilian studies, one cross-sectional (Formiga & Linhares, 2011) and the other longitudinal (Saccani & Valentini, 2012) and one Dutch cross-sectional study (van Haastert, De Vries, Helders, & Jongmans, 2006) compared their sample of preterm infants to the published Canadian norms for the Alberta Infant Motor Scale (AIMS) and found that the preterm infants had lower scores. It has been suggested that countries should construct their own culture specific term norms to enable accurate assessment of infants with motor delay (De Kegel et al., 2013; Fleuren, Smit, Stijnen, & Hartman, 2007; van Haastert, Eijsermans, & de Vries, 2007) instead of comparison with AIMS Canadian norms. This was accomplished in a large Brazilian cohort with the preterm infants showing delay at CA (Saccani & Valentini, 2012).

Whilst there are no Australian norms for the AIMS, two studies used a term born sample for comparison and found that the preterm infants were relatively delayed at CA (Pin, Darrer, Eldridge, & Galea, 2009; Pin, Eldridge, & Galea, 2010). These findings were similar to another Australian study which did not have a term born comparison, but reported very high proportions of preterm infants who were delayed at CA (Spittle, Spencer-Smith, Lorefice, Anderson, & Doyle, 2015), even though the preterm group mean score was within the normal range. The latter Australian study tested the same infants with an Australian assessment, the Neurosensory and Motor Development Assessment (NSMDA) as well as the AIMS and found similar high proportions with both assessments (Spittle et al., 2015).

Studies using measures other than the AIMS have found similar results. Three longitudinal studies with term comparisons and using the Griffiths (Sansavini et al., 2010), Bayley Scales of Infant Development, version 2 (Wolf et al., 2002) and Ages and Stages Questionnaire (Gasson & Piek, 2003) reported delays in GM skills at CA. Sansavini et al. (2010) and Gasson & Piek (2003) reported different trajectories for the preterm infants compared with the term infants.

GM skills were tested at only 12 months CA using the AIMS and NSMDA (Spittle, Boyd, Inder, & Doyle, 2009) with high proportions of infants being classified as delayed. One other study assessed preterm infants at 12 months CA with the AIMS, PDMS2 and Battelle Developmental Inventory (BDI) (Snider, Majnemer, Mazer, Campbell, & Bos, 2009). These authors found high proportions of infants who were delayed with the AIMS and BDI but only one infant delayed on the GM component of the PDMS2.

On the other hand only one recent study has shown that preterm infants at CA are not delayed for GM skills. This was a longitudinal study of Brazilian infants from one to 12 months CA who were assessed at monthly intervals with the AIMS and mean scores were plotted for chronological and CA. The infants were delayed at chronological age but not CA and the CA scores followed the same trajectory as the Canadian norms (Restiff & Gherpelli, 2006).

None of the studies reported differences in GM skills attributed to BWGA or sex.

2.2.3.2 Fine motor development in preterm infants

Table 2.1 summarises FM outcomes of nine studies of preterm infants. Two studies report preterm infants were delayed at chronological age but not at CA compared with term infants (Gasson & Piek, 2003; Palisano, 1986). Of the remaining seven studies, four report delay in FM skills at CA compared with term infants (Case-Smith, 1993; Churcher et al., 1993; Piper et al., 1989; Snider et al., 2009) and the other three found that the preterm infants scored within the normal range but their scores were lower than term infant scores (Ross, 1985; Thun-Hohenstein, Largo, Molinari, Kundu, & Duc, 1991; Wolf et al., 2002).

For both GM and FM skills, preterm infants were either very or extremely preterm, with a few studies including moderate to late preterm. None of the studies reported on whether the infants were SGA. Preterm girls had better FM skills compared with boys in one study (Palisano, 1986) but there were no sex differences in any other study.

Further assessment of GM and FM outcomes for preterm infants to determine whether they were delayed compared with term infants would complement available literature. The role of SGA irrespective of GA and the effects of sex are not clear in the literature to date.

Table 2.1 A summary of the studies of motor outcomes in preterm infants.

Author, year	Inclusion criteria	Exclusion criteria	Sample	Country	Measure	GM Outcomes	FM Outcomes
Allen & Alexander, 1990	<32 weeks GA, biological and environmental risk factors	Nil	n = 100 M = F = 50	USA	Parent recall of GM skills every 3 – 4 months until 12months CA	Delayed at chronological age. Not delayed at CA. Milestones followed term pattern	
Case-Smith, 1993	<37 weeks GA, < 2000g, Term	CP	n = 23 PT, M = 14, F = 9 n = 65 T, M = 30, F = 35	USA	PFMAI, 2 – 6months		Delayed at CA compared with T
Churcher et al. 1993	<1000g, <1500g	Congenital, neurological or sensory abnormalities	n = 13 (<1000g) n = 34 (<1500g) Sex not reported	Canada	PDMS, 3, 6, 12 and 24 months CA		Delayed at CA compared with T, <1000g had lowest scores compared with <1500g
Den Ouden, et al. 1991	<32 weeks GA	Congenital, neurological or sensory abnormalities	PT n = 555 T n = 550 Sex not reported	Holland	Van Wiechen neurodevelopmental assessment (based on Gesell and Amatruda)	Delayed at chronological age. Not delayed at CA.	
Formiga & Linhares, 2011	<32 weeks GA <2500g	Congenital, neurological or sensory abnormalities	n = 308 M = 164 F = 144	Brazil	AIMS, from 1 – 12 months CA	Outcome at chronological age not reported. Delayed at CA compared with	

						Canadian norms	
Gasson & Piek, 2003	High risk PT <33 weeks GA <1500g SGA, Low risk PT 33 – 37 weeks GA AGA, Term >37 weeks GA	Not reported	High risk PT n = 17, M = 11, F = 6 Low risk PT n = 17, M = 10, F = 7 Term n = 43, M = 22, F = 21	Australia	ASQ, 6, 12, 24 months	At 6 months chronological age delayed GM skills between groups, No difference at 12 or 24 months No sex differences	At 6 months chronological age delayed FM skills between groups, No difference at 12 or 24 months No sex differences
Palisano 1986	29 - <32 weeks GA, Term	Congenital, neurological or sensory abnormalities	n = 23, T = PT M = 13, F = 10	USA	PDMS, 12, 15 and 18 months chronological age	Delayed at chronological age. Not delayed at CA No sex differences	Delayed at chronological age. Not delayed at CA Females better than males
Pin et al. 2009	<29 weeks GA, Term	Congenital, neurological or sensory abnormalities	n = 58 PT n = 51 T sex not reported	Australia	AIMS, 4 and 8 months CA	Delayed at 4 and 8 months CA compared with term	
Pin et al. 2010	< 29 weeks GA, Term	Congenital, neurological or sensory abnormalities	n = 58 PT n = 52 T sex not reported	Australia	AIMS 4, 8, 12 and 18 months CA	Delayed at all CA compared with term	
Piper et al. 1989	VPT <32 weeks GA, M-LPT 32 - <37 weeks GA	Congenital, neurological or sensory abnormalities	n = 45 M = 25, F= 20, total group n = 17 VPT	USA	PDMS at 8 months chronological and CA, Griffiths at 12 months chronological and CA	Delayed at chronological age. Not delayed at CA	Delayed at chronological age and CA

			n = 28 M-L PT				
Restiff & Gherpelli 2006	26 – 37 weeks GA	Congenital, neurological or sensory abnormalities	n = 43, M = 26, F = 17	Brazil	AIMS, from 1 – 12 months CA	Delayed at chronological age. Not delayed at CA	
Ross 1985	<35 weeks GA, <1500g Caucasian, middle-class, Term	Chromosomal abnormality	n = 46 PT n = 46 T	USA	BSID, 12 months CA	PT mean within normal range for motor score, but lower than T	PT mean within normal range for motor score, but lower than T
Saccani & Valentini 2012	<37 weeks GA PT Term	Congenital, neurological or sensory abnormalities	n = 137 PT n = 658 T M = 388 F = 407	Brazil	AIMS, monthly from birth to 18 months	Combined group lower at all ages, except at 18 months compared with Canadian norms	
Sansavini et al. 2010	EPT <28 weeks GA VPT 28 – 32 weeks GA Term	Congenital, neurological or sensory abnormalities	n = 29 EPT n = 49 VPT n = 10 T	Italy	Revised Griffiths Mental Development Scales 0 – 2 at 6, 12, 18, 24 months CA	EPT, VPT and T mean within normal range at each time frame EPT mean decreased over time, VPT decreased but not significantly, T stayed stable	

Snider et al. 2009	<32 weeks GA	Nil reported	n = 95, M = 55, F = 40	Canada	AIMS, PDMS2, BDI at 12 months CA	AIMS 26% below normal (<5th percentile) PDMS2, GM 1 infant delayed, BDI 85% below normal	PDMS2, FM 11 infants delayed
Spittle et al. 2009	<30 weeks GA	Congenital, neurological or sensory abnormalities	n = 86, M = 42, F = 44	Australia	AIMS, NSMDA at 12 months CA	AIMS n = 30 (35%) <5th percentile NSMDA n = 16 (18%) mild – severe dysfunction	
Spittle et al. 2015	<30 weeks GA	Congenital, neurological or sensory abnormalities	N = 97	Australia	AIMS, NSMDA, 4, 8, 12 months CA	AIMS 4 months CA n = 22 <10th percentile, 8 months CA n = 26 <5th percentile, 12 months CA n = 35 <5th percentile NSMDA 4 months CA n = 20 delayed, 8 months CA n = 26 delayed, 12	

						months CA n = 18 delayed	
Thun-Hohenstein et al. 1991	<36 weeks GA	Nil reported	n = 97 PT M = 54, F = 43 n = 94 T M = 47, F = 47	Switzerland	Griffiths, 1, 3, 6, 9, 12, 18, 24 months CA		No delay at CA, although delayed compared with term No sex differences
van Haastert et al. 2006	<32 weeks GA	Congenital, neurological or sensory abnormalities	n = 800, M = 364 F = 444	Holland	AIMS, 1 – 18 months CA	Delayed at all ages compared with AIMS Canadian norms	
Wolf et al. 2002	<32 weeks GA, <1500g Term	Congenital, neurological or sensory abnormalities	n = 20 VLBW M = 11, F = 9 n = 10 T M = 3, F = 7	Holland	BSID-II, 3, 6 months CA	PDI at 3 months CA – mean significantly lower than T PDI at 6 months CA – mean significantly lower than T	MDI at 3 months CA – mean significantly lower than T MDI at 6 months CA – mean significantly lower than T

T = term, PT = preterm, EPT = extremely preterm, VPT = very preterm, M-LPT = moderate-late preterm, AIMS = Alberta Infant Motor Scale, ASQ = Ages and Stages Questionnaire, BDI = Battelle Developmental Inventory, BSID = Bayley Scales of Infant Development, BSID-II = Bayley Scales of Infant Development, version 2, MDI = Mental Developmental Index, NSMDA = Neurosensory and Motor Developmental Assessment, PDI = Psychomotor Developmental Index, PDMS = Peabody Developmental Motor Scales, PFMAI = Posture and Fine Motor Assessment of Infants

Motor delays in infancy appear to persist into childhood and adolescence, with varying degrees of severity (de Kieviet et al., 2009; Saigal & Doyle, 2008). Furthermore, if there are delays in motor skills there is an increased risk of delay in cognition and mental health in childhood (Piek et al., 2010; Piek et al., 2008).

Multiple factors predict mortality and morbidity of preterm infants and account for some of the variation in preterm outcomes. Infants in all preterm GA categories can have problems at school age in the form of literacy and numeracy difficulties and behavioural problems in the classroom (Hutchinson et al., 2013; Saigal & Doyle, 2008). Some moderate to late preterm infants who were considered to be low risk, appear to have "hidden" problems that do not manifest until school age and may present with global developmental delay (Potijk et al., 2013) but the effect appears to be multiplicative if the infant lives in a family with low socioeconomic status (Potijk et al., 2013). Academic underachievement, difficulties with executive function and mental health problems can exist separately to motor function in childhood and adolescence (O'Shea, Downey, & Kuban, 2013; Saigal & Doyle, 2008).

Consistent with the dynamic systems theory (Monterosso, Kristjanson, Cole, & Evans, 2003; Piek & Gasson, 1999), apart from infant body systems, family factors such as the early social environment, in particular maternal stress and depression and the lack of social supports, have greater impacts on preterm development in the early years (Miceli et al., 2000). The child's problems in the short and long term impact maternal and paternal stress (Howe, Sheu, Wang, & Hsu, 2014; Schappin, Wijnroks, Uniken Venema, & Jongmans, 2013) and family social functioning (Saigal & Doyle, 2008).

2.2.4 Intervention for motor delay in preterm infants

Given the increased risk of developmental delay for the preterm infant and the effects on the infant's family, early intervention programs are recommended to facilitate both infant development and parental well-being. Various interventions have been offered but not all are effective in the short term and few have had longitudinal follow-up.

Interventions have been offered while preterm infants were still in the neonatal unit and/or on discharge. Kangaroo care, that is, skin-to-skin contact between mother/father and infant provided while the infant was in the neonatal unit found better maternal affect and infant regulation when the infants reached term GA. Follow-up at three months CA showed that both mothers and fathers were more responsive to their infant and at six months CA mother's remained highly sensitive to the infant and infants had higher mental and motor function (Feldman, Eidelman, Sirota, & Weller, 2002).

A specific program designed for preterm infants that is delivered in the neonatal unit, the Newborn Individualized Developmental Care and Assessment Program (NIDCAP), had immediate benefits to the infants in respiratory status and nutrition resulting in a shorter hospital stay and better weight gain (Als et al., 1994). The long term effects with the NIDCAP have not been demonstrated.

Another semi-structured program, the Mother-Infant Transaction Program (MITP) was designed to be implemented pre- and post-discharge (Kyno et al., 2012). Seven sessions were conducted during the last week of hospital stay and one-off sessions at three, 14, 30 and 90 days after discharge. Moderate to late preterm infants and their mothers were randomized to the MITP or no intervention groups and were assessed at 36 months of age. There were no differences between groups on cognitive, motor or behavioural development. The authors suggested that the MITP might be more beneficial for infants who were of earlier gestations and that the program could be modified to address specific needs of the infant and mother (Kyno et al., 2012).

Kaaresen et al. (2006) also implemented the MITP with preterm infants <2000g and their parents, but in this cohort, parent stress was measured in mothers when infants were six and 12 months CA and at 12 months CA in fathers. Parenting stress was reduced for both parents compared with a non-intervention group at infant 12 months CA and was comparable to stress levels of parents of term infants (Kaaresen, Ronning, Ulvund, & Dahl, 2006).

A home-based program was investigated by Spittle et al. (2010) targeting language, cognitive and motor development of infants born <30 weeks GA and care giver well being. This program was implemented once a month for nine months and compared the intervention group with a randomized control group who received standard care. There were no differences in infant clinical outcomes at two years of age between the intervention and control groups. However, parents in the intervention group reported that their infants had less externalizing and dysregulation behaviours and had higher competence and that they themselves had less anxiety and depression (Spittle et al., 2010). It is possible that the improvements on the parents' responses might be due to the parents not being blinded to group and biased positively to intervention. Even if the result was based on a placebo effect, the importance of the outcome of better interaction between parent and infant would be beneficial.

In another study, Lekskulchai & Cole (2001), provided a three month physiotherapy sensori-motor program including gross and fine motor skills, tailored to the needs of the infant and taught to parents. At 40 weeks post-conceptual age, the preterm infants in the intervention group, the preterm infants in the control group and the term infants who were the comparative group had similar motor scores. At follow up at four months CA, the preterm intervention infants had better motor performance than the preterm control infants ($p < .001$) and did not differ from the term comparative infants (Lekskulchai & Cole, 2001).

A systematic review by Fernandez, Gomez and Perez (2012) of 16 studies of the intervention effects of physiotherapy follow-up intervention with 1075 participants precluded meta-analysis as the research designs were heterogenous. The authors reported that not all studies had adequate detail on the content of the intervention, the outcome measures used to determine efficacy, the duration of the programs and how intervention effects were analysed. However, they noted that physiotherapy interventions should be individualized to the needs of the infant (Fernandez, Gomez, & Perez, 2012).

A more recent systematic review in 2015 by Spittle et al. of early developmental intervention programmes in preterm infants found positive effects on motor and cognitive outcomes in infancy. This review had 3615 participants and included interventions of heterogeneous designs and preterm infants of varying GA. Longitudinal follow-up showed that cognitive benefits persisted to preschool age.

A meta-analysis of programs offered for mothers of preterm infants found that there were positive and clinically meaningful effects for the mothers for anxiety, depression and self-efficacy (Benzies, Magill-Evans, Hayden, & Ballantyne, 2013). Benzies et al. (2013) suggest that if interventions that target maternal mental health and competence are beneficial then infant outcomes should also be measured as maternal depression can have negative consequences on infant development (Benzies, Magill-Evans, Hayden, & Ballantyne, 2013).

Interventions that target both infant and parents appear to have the best short and long term outcomes (Bonnier, 2008), possibly because they empower parents in their parenting role and specifically in parenting preterm infants. The more positive view by mothers of their preterm infants may be due to successful intervention programs that aim to enhance the mother-infant relationship by reducing maternal stress and enhancing infant outcomes (Evans, Whittingham, Sanders, Colditz, & Boyd, 2014).

The underlying aim of intervention is therefore to provide the preterm infant with opportunities to practice motor skills and in some instances to also affect other domains of development.

2.3 Motor practice in infancy

Practice is repetitive activity to acquire or maintain proficiency in a motor skill (Teulier, Lee, & Ulrich, 2015). It is a dominant factor in the development of motor skills for typical infants (Adolph & Tamis-LeMonda, 2014) and infants with motor delay (Novak et al., 2013; Ulrich, Ulrich, Angulo-Kinzler, & Yun, 2001). Practice may be controlled independently by the infant during play or through interactions between the infant and its parents. It may also be structured, for example infant swimming lessons or baby-gym classes or unstructured, such as independent play in the family home or local park or interactions with a parent that occur during everyday tasks. The relationship between infant practice and motor development has been studied by measuring structured and unstructured practice.

2.3.1 Structured motor practice

A number of studies have investigated practice parameters under experimental conditions. Rovee-Collier (1995, 1997), in a series of seminal studies, demonstrated the role of memory in learning motor skills. Infants at two months of age practiced during a 15 minute session to activate a mobile that was attached to their ankle by a ribbon. Infants increased the vigor and rate of their kicking when their kicks increased the movement of the mobile. In an alternate test condition, infants decreased the vigor and rate of kicking when the ribbon was not attached to their ankle but they could still see the mobile. They demonstrated understanding of cause and effect and appeared to remember the movement patterns between consecutive days (Rovee-Collier, 1995, 1997). These studies support the use of feedback and memory as components of practice that are present in very young infants.

A more recent study by Sargent et al. (2014) extended this practice and learning by examining how three month old infants learn to move their legs without external assistance to achieve the task of activating a mobile. The task set-up more closely resembled the naturalistic learning that occurs in an infant's home environment. The learning demonstrated by the infants was of self-discovery which the authors assert may be providing infants with an opportunity to learn a process (how to), rather than an outcome (mobile moves), and therefore may be more beneficial for generalizing to other tasks (Sargent et al. 2014).

Lobo and Galloway (2012) implemented a targeted motor skills program (intervention group) for typical infants at two months of age compared with a socialization intervention (control group). The motor skills program was appropriate to the age group and included education for the parents regarding indoor and outdoor play activities, appropriate toys and socialization. Parents were provided with a written illustrated manual and were asked to keep a record of their infant's daily practice. Parents were asked to practice the motor skills daily for 15 minutes per day for three weeks only. The socialization interaction was not prescribed but parents were asked to place their infant in supine and engage in any form of socialization daily for 15 minutes per day for three weeks only. Infants who participated in this short intervention had significantly better fine and gross motor skills immediately at the cessation of the program measured with the AIMS and maintained the effects at 12 months of age. The infants in the socialization interaction group also improved their motor skills but this was consistent with developmental change whereas the rate of change of the infants in the intervention group was more rapid (Lobo & Galloway, 2012).

The effect of walking practice using a treadmill on acquisition of independent walking has been demonstrated with infants with Down syndrome (Ulrich et al., 2001). Thirty infants with Down syndrome entered the study at a mean age of 10 months and half were randomized to an intervention group who practiced for eight minutes per day for five days per week on a treadmill running at .2 metres per second until they were able to take three independent steps. The infants in the control group continued with usual care. The infants who received the walking practice, walked on average three months earlier than the control group ($p < .05$) with an effect size of .83. Earlier walking was attributed to an increase in strength of the lower limbs as well as the development of coordinated muscle patterns that support reciprocal gait (Ulrich et al., 2001).

Learning to reach has been examined by manipulating practice schedules in low-risk late preterm infants ($n = 36$) at 2.5 to three months chronological age (de Almeida Soares, van der Kamp, Savelsbergh, & Tudella, 2013). Infants were randomized to groups to receive blocked, serial or no practice with each practice session facilitated by a physiotherapist, consisting of three different reaching tasks and lasting four minutes. Infants in the serial schedule group increased unilateral and bilateral reach immediately after the practice session compared with baseline. Infants in the block and no practice schedules did not change compared with baseline. There was no retention one day later for any of the groups (de Almeida Soares et al., 2013). A similar study was conducted by Cunha et al. (2013) with term infants at three to four months of age, who practiced reaching for four minutes in supine or reclined or in supine but with no intervention. In both of the training groups, the frequencies of reaches, hand position and bi- and uni-manual reaches increased, but there was no change in the no intervention group (Cunha, Soares, Ferro, & Tudella, 2013). The findings from these two studies suggest that a low dose of practice may be effective in changing reaching performance immediately, but not of sufficient duration to effect a change in behaviour through learning. What is not reported in either of these studies is whether there were social incentives or feedback provided by the physiotherapist, whether some infants were keen to persevere with the tasks for longer than four minutes or whether some infants became disinterested in the tasks. Infant traits such as motivation may have an effect on motor development (Doralp & Bartlett, 2014).

Heathcock, Lobo and Galloway (2008) also investigated the effectiveness of a reaching intervention but used a different study design and compared low-risk very preterm infants with term infants. Preterm infants were randomized to motor practice or socialization groups and matched with term infants in a socialization group. All infants practiced for 15 to 20 minutes per day for five days per week for eight weeks. The results showed that both preterm groups had fewer hand-toy contacts, less duration of hand-toy contact and used different hand positions compared with the term infants. However, the preterm infants who practiced reaching performed better than the preterm infants who did not practice. While there were improvements in hand-toy play for the preterm infants who practiced for eight weeks, the authors acknowledge that modifying the intensity, duration, type and content of practice may show greater improvements in reaching performance (Heathcock, Lobo, & Galloway, 2008).

These few studies demonstrate that targeted practice for short periods of time can result in improvements in specific GM and FM skills. Unstructured practice has also been studied.

2.3.2 Unstructured motor practice

Infant initiated and independent practice is spontaneous (Adolph, Vereijken, & Shrout, 2003), self driven (von Hofsten, 2009a) and context specific (Adolph, Bertenthal, Boker, Goldfield, & Gibson, 1997). Typical infants are motivated to practice movements that are described as goal-directed and guided by environmental information so that much practice is controlled by the infant and performed independently (von Hofsten, 2004). Spontaneous rhythmical movements, such as kicking, arm waving and rotation of the ankles, do not appear to be goal directed but occur frequently, especially in infants younger than 24 weeks of age (Piek & Carmen, 1994). Kicking practice in term and preterm infants between four and 24 weeks found improvements in intralimb control of the hip, knee and ankle and then interlimb control (Piek & Gasson, 1999). Similarly, intralimb and interlimb coupling was found in the upper limbs. The findings from these studies suggest that spontaneous practice results in changes to muscle patterns and joint coordination (Piek, Gasson, Barrett, & Case, 2002). The developmental course of these rhythmical movements suggests that they are purposeful and may be precursors for functional motor skills as they reduce in frequency as motor skills emerge (Thelen, 1981).

As infants are highly dependent for their physical and emotional care, parents may assist infants in motor practice as part of the infant's daily routine which provides opportunities for the infant to play (Sawyer & Campbell, 2009). Routines provide the infant with opportunities to develop motor skills that are flexible and adaptable to the task and the environment (Adolph et al., 2015). Daily activities and routines occur in the infant's natural environment (Cripe & Venn, 1997) and are predictable, repetitive and functional (Woods, Kashinath, & Goldstein, 2004). The establishment of routines is a transactional process between child and parent (Spagnola & Fiese, 2007). For example, infants practice sitting on the floor to play, in a high chair for feeding, in a bath, in a pram and in a car seat. As each task has its own cognitive demands and constraints on postural control, the infant needs opportunities to practice the task of sitting in multiple ways. Practice may be well served through everyday routines as the parent may provide physical assistance and the infant participates in the task at their motor developmental level (Bartlett, Fanning, Miller, Conti-Becker, & Doralp, 2008). Another benefit of infant-parent dyadic practice is that it may have positive benefits for the infant's cognitive and socio-emotional skills (Adolph & Robinson, 2015; Campos et al., 2000). Enhanced parental responsiveness and attachment behaviours between infant and parent have also been noted (Masur & Flynn, 2008).

The development of essential skills such as sitting, crawling and walking appear to develop as part of a daily routine, without reference to specific practice parameters. Karasik et al. (2015) assert that sitting practice may be shaped by cultural and maternal expectations, with mothers deciding where infants would sit and for how long and their access to infant equipment. Infants were placed in sitting on a variety of surfaces, such as a firm dirt floor, infant seats, adult furniture and being carried in a sitting position. Their bouts of sitting varied depending on what their mothers were doing and whether the infants needed supervision. Sitting bouts ceased because the mother moved the infant to another position or picked them up to carry or the infant fell or the infant moved to prone independently (Karasik et al., 2015). The richness of the practice environment provided by the mother is evident from this cross-sectional study. However, more importantly duration and frequency of sitting practice was not prescribed and likely varied from day to day, yet infants acquired the skill.

Similarly, Adolph, Vereijken and Denny (1998) studied the development of floor mobility by tracking infants longitudinally until they were standing and walking independently. Infants demonstrated a range of crawling postures including commando crawling, hands-and-knees, and "bear walk", and different patterns from contralateral arms and legs, symmetrical pull with arms and push with legs *à la* "caterpillar" and asymmetrical arm-leg couple on both right and left sides of the body. There was no strict progression from what might be construed as an immature to more mature pattern. Duration of practice was related to gradual, continuous improvements in crawling proficiency with commando crawling benefitting hands-and-knees crawling. There were also abrupt changes from commando crawling, which was fast and stable, to hands-and-knees which was unstable and slow, but improved in speed and control. Importantly, the infants practiced with different forms of crawling which may have resulted in improvements to postural control, muscular and skeletal demands to transition from one form of crawling to another (Adolph et al., 1998).

A more recent examination of crawling behaviour by Soska, Robinson and Adolph (2015) showed that crawling practice bouts last for only one to three seconds with infants spending about 12 minutes per hour crawling. They transition to sitting by orientating themselves 90° away from the original direction in which they were moving. With approximately seven transitions per minute of crawling, transitions between crawling and sitting occurred about 80 times per hour (Soska et al., 2015).

The variety in crawling patterns provides evidence that through practice infants maximise their physical attributes to achieve the task of floor mobility. By adding in the transition between sitting and crawling, other practice parameters become evident. Firstly, the very short bursts of practice possibly place high energy demands on the infant. This might limit the duration of each repetition, but the number of repetitions is high. Secondly, the movement patterns described are possibly challenging biomechanically and are potentially a way of building muscle strength and endurance. Furthermore, as infants are practicing two discrete tasks – crawling and sitting – there is no interference between tasks, which is recommended for motor learning. Therefore, crawling practice appears to be distributed and frequent. And thirdly, task specific practice is required for the infant to learn a motor pattern (R. A. Schmidt & Lee, 2011).

Task-specific practice is also evident in the development of walking, from the first hesitant steps to independent gait (Adolph et al., 2012). Infants' walking practice was characterized as being repetitive, distributed within and between days, random and variable. Mistakes in the form of falls, which occurred approximately 30 times per hour, did not deter infants from making more attempts, even if the fall resulted in minor bruises as reported by their parents using an unstructured diary and interview (Adolph et al., 2012). Infants practiced gait in different rooms and floor surfaces in their homes and outdoor play areas, up to six hours per day, taking on average 1400 steps per hour and travelling approximately 300 metres per hour (Adolph et al., 2012; Adolph et al., 2003). This spontaneous walking practice differs from the treadmill training protocol discussed earlier, as it occurs during infant wake time where walking may be part of play and care activities (Tulve, Jones, McCurdy, & Croghan, 2007). Walking practice, similarly to crawling practice meets the principles of motor learning (Adolph et al., 2003).

The key factors identified in these papers on unstructured practice of kicking, sitting, crawling and walking are the variability of contexts and the adaptable movement patterns infants use to accommodate their bodies' biomechanical constraints and physical environments. It would appear that infants take advantage of as much of their wake time as possible to practice, although the frequency, duration and vigour of practice that occurs during a daily routine is not reported. Not only do routines provide predictable structures that may guide infant behaviour they also offer an emotional climate that supports an infant's efforts (Spagnola & Fiese, 2007).

These studies highlight the link between infant practice that occurs in naturalistic settings and the development of specific motor skills. Interventions for infants with motor delay are based on the principle that motor skills can be learnt during everyday tasks (Bernheimer & Keogh, 1995; Cripe & Venn, 1997).

2.3.3 Benefits of motor practice

Practice of motor activity results in changes to the infant's body and brain. The evidence from treadmill training of typical infants shows changes to underlying neuromuscular activation in the lower limbs that is nonlinear and therefore, non-linear changes occur in step length, cadence and speed of gait (Teulier et al., 2015). Similar findings are evident for infants with Down syndrome and myelomeningocele who participated in treadmill training and walked earlier than their peers who did not receive the training. Structured treadmill practice appears to not only facilitate the earlier appearance of independent walking in infants with some developmental disabilities it also appears to increase muscle strength, bone mineral density and neural control of peripheral structures (Teulier et al., 2015).

The effect of practice on the process of change of neural circuits both structurally and functionally is neural plasticity. Connections between neurons and organization of pathways are strengthened through use and by the demands of motor tasks (Berardi, Sale, & Maffei, 2015). Functional magnetic resonance imaging (fMRI) has provided insight on how the developing brain copes with injury and responds to intervention. Neural plasticity works in both negative and positive ways. Following injury the immature brain may construct abnormal connections in an attempt to recover. With positive experiences, such as practice, the brain appears to adapt by setting up alternate pathways to improve structure and function (Fiori & Guzzetta, 2015). Importantly, some of these changes can only happen during critical periods of brain development, with different functions, such as sensorimotor and visual development have different critical periods (Berardi et al., 2015).

Decreased levels of activity appear to be associated with increased adiposity in infancy (R. Li, O'Connor, Buckley, & Specker, 1995; Street, Wells, & Hills, 2015; Worobey, 2014) and increased adiposity with delayed infant GM skills (Neelon, Oken, Taveras, Rifas-Shiman, & Gillman, 2012; Slining et al., 2010).

In summary, both structured and unstructured practice promote changes in infants at three levels: behavioural (changes in movements), body systems (kinematics and muscle activation patterns) (Teulier et al., 2015) and within the CNS (neural plasticity) (Berardi et al., 2015; Fiori & Guzzetta, 2015). More information on practice parameters is required to know how much practice term infants and low risk healthy preterm infants require to learn motor skills. Temperament has been suggested as one reason why infants differ in the amount of practice in which they engage spontaneously as well as with their parents.

2.4 Infant temperament

Temperament as a construct for understanding infant behaviour was first coined by Chess and Thomas in 1956 for the New York Longitudinal Study (NYLS). They were among the first researchers to recognize that children were active participants in their development engaging in bi-directional interactions with their parents (McClowry, Rodriguez, & Koslowitz, 2008). Temperament is defined as inherent behavioural and emotional traits that differentiate individuals and is exhibited in different contexts in response to stimulation (Carey, 1970; Rothbart, 1981). Temperament traits are relatively stable from three to 12 months of age, for male and female infants and for term and preterm infants (Bornstein et al., 2015; Calkins, Fox, & Marshall, 1996; Casalin, Luyten, Vliegen, & Meurs, 2012).

Genetics, biology, maturation and experience may interact at different points in developmental time to shape the expression of temperament traits (Rothbart, Derryberry, & Hershey, 2000). Twin studies of temperament show similarity between monozygotic twins that is not explained by family influences suggesting a strong genetic effect on infant temperament (Saudino & Eaton, 1995). Biological mechanisms include neurohormonal signals, in particular the role of dopamine in regulating behaviour as brain structures mature. Dopamine pathways are not established at birth but during brain development and through experience and interaction with the environment they influence the infant's behavioural responses (Posner, Rothbart, Sheese, & Voelker, 2012). Infant experiences with their parents also influence temperament traits and associations have been shown between parenting styles and the expression of infant fear, negative affectivity and positive affectivity (Bornstein et al., 2015; Combs-Orme, Wilson, Cain, Page, & Kirby, 2003).

Infant temperament has been described in a variety of ways depending on the measure used. From the NYLS, an infant's main behavioural response was described in one of four ways, as either "difficult", "easy going", "slow to warm up" or "average" (Chess & Thomas, 1977). Carey (1983) cautions that although an infant is described by their mother as "difficult" based on the NYLS parent questionnaire, the mother may not perceive her infant as being difficult (Carey, 1983). This fine distinction is likely to affect the bi-directional interaction between a mother and her infant. When there is congruence between the expectations of the parent and their child's characteristics then it is more likely that the child's development will be optimized. This has been termed "goodness of fit". The converse is also true – children's development may be compromised when there is a mis-match between child and parent temperament and behaviour (Chess & Thomas, 1977).

Infant temperament can be measured by parent questionnaire, independent observer report of infant behaviour in a variety of settings or interviews with parents (Kagan, Snidman, McManis, Woodward, & Hardway, 2002). The most commonly used are parent questionnaires but there are many limitations depending on the design of the questionnaire. If the questions are open-ended, parents may respond in a way that they hope is socially acceptable and may not want to describe their child negatively, closed-ended questions may not capture the complexity of emotional responses, questions may ask a parent to compare their child to other children but may be difficult if the parent has limited experience of infancy (first time parents) and the literacy of the parent may compromise their understanding of the question (Kagan et al., 2002). Questionnaires that are designed for low-inference of items and that are focused on infant behaviour during a variety of everyday tasks are less likely to result in parent bias and to be more reliable (Eaton, McKeen, & Campbell, 2001).

2.4.1 Temperament and motor development

There are few studies that report on the relationship between temperament and motor development in infancy. Activity level is a temperament trait included in many measures of infant temperament and tends to remain relatively constant across the lifespan and in varying situational contexts (Goldsmith et al., 1987). Eaton et al. (2001) cite a number of infant temperament studies that have measured activity level using parent diaries, direct observation and activity monitors and have concluded that the temperament trait of activity alone is associated with behavioural change in a number of domains of development including motor development. The inference is that infants who exhibit a higher degree of activity have better movement skills. However, this relationship has not been proven.

The association between temperament and motor development has been explored in Bangladeshi mothers and infants (n = 652) followed from the last trimester of pregnancy until the infants were eight months of age (Nasreen, Kabir, Forsell, & Edhborg, 2013). Infant temperament was measured using the Infant Characteristics Questionnaire (ICQ) (Bates, Freeland, & Lounsbury, 1979) which comprises four factors – fussy/difficult, unadaptable, unpredictable and dull and has been validated for Bangladeshi infants. Motor development was based on observation of predetermined gross and fine motor skills. This study found that infants who had fussy and unadaptable temperament characteristics had significantly poorer motor outcomes, but this relationship appeared to be mediated by maternal post-natal depression. The authors suggested that maternal depression might result in reduced attachment which interacts with infant temperament possibly reducing maternal responsiveness and limiting infant exploratory play (Nasreen et al., 2013). The relationship between infant temperament and motor development is complex and multi-factorial and warrants further investigation.

2.4.2 Preterm infant temperament

There are mixed reports on temperament profiles of preterm infants. Langkamp, Kim and Pascoe (1998) measured temperament in preterm infants (n = 36) born earlier than 34 weeks GA when they were four months CA and compared them to term infants (n = 39). Temperament was measured with the Early Infant Temperament Questionnaire (EITQ) designed for the NYLS. Mothers reported that their preterm infants were more irritable, more difficult to settle, less adaptable to changes in their environment, less regular, and had more negative moods compared with term infants (Langkamp, Kim, & Pascoe, 1998).

Using the same questionnaire (EITQ), preterm infants (n = 74) born between 24 and 36 weeks GA were assessed at six weeks, six months and 12 months CA, and compared with term standardised norms. The preterm infants at six weeks CA were less regular, more distractible and more withdrawn compared with term norms. While there were differences at six months, these characteristics approached the term norms by 12 months CA (Hughes, Shults, McGrath, & Medoff-Cooper, 2002).

Gennaro et al. (1990) found that preterm infants (n = 59) at three and six months CA were described by their mothers as being less adaptable, less predictable and more fussy-difficult compared with term infants (n = 38) based on the four factor structure of the ICQ. All infants were reported to be less difficult at six months compared with three months (Gennaro, Tulman, & Fawcett, 1990). This apparent improvement in temperament characteristics might be due to an increase in parenting ability and confidence, thereby shaping the parents' perceptions of their infants' behaviours.

Some of the reasons suggested for the more difficult temperaments of the preterm infants were due to the changes in CNS organisation as a function of preterm birth and the effects of medical care and stressful life course for the infant and parents. Infants born preterm may be at a greater risk of delayed regulation, social behaviour and physiological functioning (Hughes et al., 2002).

Parents of preterm infants who attend follow-up playgroups often perceive their infants as being more vulnerable and requiring more care (Bartlett, Nijhuis-van der Sanden, Fallang, Fanning, & Doralp, 2011). These interpretations of preterm infant behaviour may be due to the increased levels of stress that parents of preterm infants experience. Parents of high risk preterm infants are reported to have the highest levels of stress compared with parents of low risk preterm infants and parents of term infants (Singer et al., 1999). Parental stress and perceptions of their preterm infant might influence their perceptions of their preterm infant's temperament.

In an Australian sample of low risk preterm infants (n = 126), born between 26 and 36 weeks GA and tested at five months CA, Oberklaid et al. (1991) found no differences with term infants (n = 150). They used the Infant Temperament Questionnaire (ITQ) modified for use with Australian infants and reported similar behaviour between the two groups on maternal global rating of temperament, individual dimensions and clinical categories of temperament (Oberklaid, Sewell, Sanson, & Prior, 1991).

Langerock et al. (2013) measured temperament at 12 months CA in term (n = 21) and preterm (n = 16) infants born earlier than 29 weeks GA comparing six traits from the Infant Behavior Questionnaire – Revised (IBQR). There were no differences between groups on any of the six traits (Langerock et al., 2013).

Differences in outcomes from these studies may be due to the choice of parent questionnaire. The ITQ and the ICQ ask parents to compare their preterm infant's behaviour to term infant behaviour. If parents perceive their preterm infant as being vulnerable then they might score them more negatively. However, the IBQR which found no differences between groups, asks the parent to comment on their infant's behaviour during everyday tasks and interactions, without reference to term infants. The other possibility is that the infants and their families in the studies are not similar, so that study outcomes are not comparable. Finally, sample sizes have been small in some of the studies, potentially reducing study power.

2.5 Summary

A plethora of information exists to explain the role of infant body systems on the process of infant motor development. However, there are gaps in knowledge of the effects of infant temperament and motor practice and their relationships with motor development.

Chapter 3 – Rationale and Aims

3.1 Summary of the literature and rationale

The dynamic systems theory of motor development proposed that infant's characteristics interact with their parents' attributes within a variety of physical environments to enable the infant to acquire gross and fine motor skills (Thelen & Smith, 1994). The infant's anthropometric (Thelen et al., 1984), neurological (T. T. Brown & Jernigan, 2012), musculoskeletal (Thelen, 2000b), and biomechanical (Heriza, 1991) functions, in conjunction with cognition (von Hofsten, 2009b) and motivation (Adolph & Tamis-LeMonda, 2014) can support or impede the learning of gross and fine motor skills. Parents may either enhance or retard infant motor learning by providing affordances (Cacola, Gabbard, Santos, & Batistela, 2011; Lobo & Galloway, 2012) and constraints (Council on Communications and Media, 2011; Masur & Flynn, 2008) respectively, that interact with the infant characteristics.

Although there are multiple factors interacting at various levels and over different time frames (Masten, 2006), the sequence of gross motor development is relatively consistent for healthy term born infants in the first year of life (WHO Multicentre Growth Reference Study Group, 2006b) irrespective of the infant's sex and ethnicity (WHO Multicentre Growth Reference Study Group, 2006a). The World Health Organisation's large cross-cultural study on gross motor (GM) skills did not assume a progression or hierarchy in gross motor skills but included six skills that were considered to be universal and fundamental to achieving independent gait (WHO Multicentre Growth Reference Study Group, 2006b). Similar evidence on the sequence of fine motor (FM) development that has an end-point that is universal and applicable to infants across cultures has not been reported. Diverse physical environments and culture specific child rearing practices may result in variations in the rate of gross motor development (WHO Multicentre Growth Reference Study Group, 2006a), whilst culture and maternal education (Kolling et al., 2014), infant health and family socioeconomic status appear to have an impact on the rate of fine motor development (Angulo-Barroso et al., 2011). The term equifinality is used to describe the principle that even though infants might differ markedly in the circumstances of their birth and their trajectories might differ, their GM and FM outcomes in the first year of life tend to be similar, in the absence of significant adverse events (Kolling et al., 2014; Masten, 2006).

Preterm birth, that is, delivery earlier than 37 weeks gestational age (GA), is one such adverse event that might result in delays in motor development. In Australia approximately 8% of all live births are born preterm (Z. Li et al., 2013). The consequences of preterm birth may affect the child's physiological (M. K. Brown & DiBlasi, 2011; Volpe, 2009; Yan et al., 2013), motor (L. Brown et al., 2015; de Kieviet et al., 2009), cognitive (O'Shea et al., 2013), and social (O'Shea et al., 2013) development across the lifespan (Saigal & Doyle, 2008).

Delayed motor development in the preterm infant can negatively impact cognitive (Piek et al., 2008; Wocadlo & Rieger, 2008) and social-emotional (Piek et al., 2010) development in childhood. Furthermore, the child's problems in the short and long term may impact maternal and paternal stress (Howe et al., 2014; Schappin et al., 2013) and family social functioning (Saigal & Doyle, 2008). Therefore, it is important to understand the factors that may be associated with motor delay in preterm infants.

The principles of the dynamic systems theory that explain motor development in term infants have equal applicability to motor development in preterm infants. Infant anthropometric (Bertino et al., 2012), muscular (Yan et al., 2013), neurological (Volpe, 2009), and respiratory (M. K. Brown & DiBlasi, 2011) systems are affected by preterm birth and may negatively impact motor development. The preterm infant faces complications due to the interaction between natural growth and development of immature body systems that must cope with the effects of gravity, assisted ventilation and other medical complications and interventions (Committee on Understanding Premature Birth and Assuring Healthy Outcomes, 2007).

The consequence of altered body systems growth is that preterm infants, particularly those born earlier than 32 weeks GA, are delayed in motor development if assessed at corrected age (Spittle et al., 2015). However, at CA the evidence is conflicting and possibly due to differences between studies in inclusion criteria of infants (Saccani & Valentini, 2012; van Haastert et al., 2006), cross-sectional (Formiga & Linhares, 2011) and longitudinal (Pin, Eldridge, et al., 2010) study designs, age of infants (Spittle et al., 2009), cultural (Sansavini et al., 2010) and child rearing practices (Fleuren et al., 2007), the reliability (Allen & Alexander, 1990) and validity (Den Ouden et al., 1991) of the motor assessments used, and a combination of these factors.

Even when GM assessments with robust psychometric properties are used, there may be variations in motor scores, such that an infant might be classified as delayed in GM skills on one measure and not delayed on another measure. Some of the variability in findings might be due to the items included in the assessments (Snider et al., 2009), the norms and standardization samples (Restiff & Gherpelli, 2006) and interpretation of results (Pin et al., 2009). In the assessment of FM skills, a systematic review concluded that there were no measures that quantify asymmetry and bimanual hand skills in infancy (Krumlinde-Sundholm et al., 2015). More than one measure is recommended to ensure accurate measurement and interpretation of FM development (Connolly et al., 2006; Provost et al., 2004).

Another group of infants who are at risk of motor delay, whether born term or preterm, are those born small for gestational age (SGA). Similar to preterm infants, SGA infants are at risk of medical sequelae due to their compromised neurological (Roelants-van Rijn et al., 2004), respiratory (Hay et al., 1997) and muscular (Hediger et al., 1998) systems. SGA infants who are also preterm may be included in early intervention follow-up programs as the primary criterion for inclusion in these programs is GA less than 37 weeks (Spittle, Orton, Anderson, Boyd, & Doyle, 2012). Follow-up programs may not be available to term born SGA infants as there do not appear to be guidelines similar to that available for preterm, VLBW infants (Wang et al., 2006).

Body systems are well understood in their contribution to motor development in both term and preterm infants, but one factor that requires further investigation is that of infant temperament. Temperament comprises inherent traits that shape variability in infants' levels of active and exploratory play, and in the way they respond behaviourally and emotionally to their parents and environment (Carey, 1970; Rothbart, 1981). The activity trait of term infants has been shown to correspond to objective measures of activity but not with motor development (Eaton et al., 2001). Associations between temperament and motor development of preterm infants are less well understood. Parent reports of preterm infant temperament are that they either have more difficult temperaments compared with term infants (Hughes et al., 2002; Langkamp et al., 1998) or that they are comparable to term infants over the first 12 months of life (Gray, Edwards, O'Callaghan, Cuskelly, & Gibbons, 2013; Larroque et al., 2005). GA alone may not be a risk factor for apparent negative temperament traits.

Parent report questionnaires can be accurate in measuring infant temperament from a parent perspective as long as they are well constructed to limit reporting bias and avoid leading questions (Eaton et al., 2001). The association between temperament profiles and motor development have not been investigated in preterm infants (Gartstein & Rothbart, 2003).

Practice appears to be the most important factor for typically developing infants learning to sit (Karasik et al., 2015), crawl (Adolph et al., 1998) and walk (Adolph et al., 2003). The converse also appears to be true – infants who do not practice skills develop skills at a later age (Davis, Moon, Sachs, & Ottolini, 1998; Majnemer & Barr, 2006). The positive and negative effects of practice are evident in the brain due to neural plasticity (Berardi et al., 2015), in the body with changes to the muscular system (Teulier et al., 2015) and behaviourally with changes in movement skills (Lekskulchai & Cole, 2001).

Practice embedded into everyday routines is advocated to prevent or ameliorate motor delay (Bonnier, 2008; Sawyer & Campbell, 2009). This form of practice is unstructured (Kyno et al., 2012) and appears to promote motor skills in the short term (Benzies et al., 2013; Lekskulchai & Cole, 2001; Spittle et al., 2010). Practice that occurs as part of the infant's daily routine is frequent, distributed within and across days and is context specific (Adolph et al., 1997; Adolph, Robinson, Young, & Gill-Alvarez, 2008; Adolph et al., 1998; Adolph et al., 2003). It is likely to be a combination of infant-independent and infant-parent-dyadic practice (Masur & Flynn, 2008). This unstructured practice possibly contributes to infants' motor development and requires further investigation.

Karasik et al. (2015, p2) comment that: "What is missing in studies of motor development is a description of infants' everyday opportunities to practice specific skills in natural contexts." Parent-report diaries appear to be the most common method of recording what infants do in their day and the duration and frequency of their activities. However, many of these diaries are not standardised or were created to track practice of specific motor skills. Understanding the daily routines of infants and their families could provide information regarding the opportunities for practice as they occur in the infant's natural environment (Cripe & Venn, 1997). Furthermore, daily routines are repetitious and functional (Woods et al., 2004). The structure and rhythmicity of daily routines of term and preterm infants requires further investigation as a better understanding of infants' daily routines may assist parents to maximize the potential for their infants to learn motor skills.

While parent-report diaries provide environmental information about infant activity they are prone to bias and missing information (Hoyt & Kerns, 1999). A more objective measure of infant activity is the use of an accelerometer that complements the diary. Activity monitor measured practice of typical infants found that activity levels increased between three to 14 months of age (Eaton et al., 2001), that term male infants were more active than female infants (Campbell & Eaton, 1999) and slimmer infants were more active than chubbier infants (Eaton & Dureski, 1986). Very high variability between infants has also been reported and might be due to unknown influences on movement during each infant's day, suggesting that activity monitors alone lack situational contexts (Eaton et al., 2001). Activity monitors cannot differentiate infant-independent from infant-parent practice so the recommendation is that activity monitor data are better understood if the situational context of movement was interpreted by the use of a parent-report diary (Worobey, Vetrini, & Rozo, 2009).

The measurement of practice in infancy using accelerometers is gaining momentum with recent studies showing that accelerometers can differentiate the intensity of activity between typically developing infants and infants with Down syndrome (Angulo-Barroso, Burghardt, Lloyd, & Ulrich, 2008) and other forms of motor delay (Angulo-Barroso, Tiernan, Chen, Ulrich, & Neary, 2010). However, unlike with older children there are few guidelines on the best methods for measuring practice in infants (Worobey, 2014).

3.2 Study aim

Our current understanding of complex systems underpins this thesis as it clarifies the role of the infant in his or her interaction with the social and physical environments in the development of motor skills. Temperament is the infant's contribution to this interaction while the parent provides opportunities for practice during everyday care and play.

The aim of this thesis was to examine the effects of infant temperament and motor practice on gross and fine motor development in term and preterm infants and to determine whether the relationships were influenced by infant GA, age, sex and BWGA. This aim was addressed by a series of four studies.

3.3 Study 1 – The effects of chronological and corrected ages, infant sex and birth weight for gestational age on term and preterm infants' motor skills

The main aim of study 1 was to compare the motor skills of term and preterm infants aged three to 12 months at chronological and CA, controlling for sex and BWGA. The literature is inconclusive as to the motor outcomes of preterm infants at CA, therefore the first step to understanding the roles of temperament and motor practice on motor skills was to determine whether this sample of low-risk, healthy preterm infants at CA had motor skills that differed from term infants. A secondary aim of the current study was to compare the GM performance of the infants using two discrete measures of GM skills.

One reason that preterm infants at CA might have poorer motor skills than term infants might be due to the measure used. A number of motor assessments have been used to measure GM skills in term and preterm infants, but there are few that measure FM skills. For the purposes of the current study the assessments needed to: (1) measure gross and fine motor skills, (2) discriminate and detect differences in motor performance between term and preterm infants, (3) be suitable for infants between three and 12 months of age, (4) have established and standardised testing procedures with high intra-rater reliability to reduce examiner error, (5) have high content, construct and concurrent validity, (6) have age standardised scores as the sample was cross-sectional, (7) the examiner would not require training in the use of the instrument and (8) the duration of testing would be kept manageable given the age of the children.

The PDMS2 met all criteria and has been used in other studies of term and preterm infants. The AIMS measures only GM skills but has been used extensively to assess development of preterm infants and therefore would enable the sample of infants in the current study to be compared with published results of other samples of preterm infants. The PDMS2 and the AIMS are appropriate for classifying infants with and without motor delay and are suitable for monitoring change in motor skills.

3.4 Study 2 – Temperament in term and preterm infants

The aim of study 2 was to determine whether there were differences in temperament in this sample of term and preterm infants, accounting for infant age, sex and BWGA and maternal age and education.

There are inconsistent descriptions of temperament of preterm infants compared with term infants, with some studies suggesting that preterm infants have more difficult temperaments (Gennaro et al., 1990; Hughes et al., 2002; Langkamp et al., 1998) and others that there are no differences (Langerock et al., 2013; Oberklaid et al., 1991). This might be due to the degree of early gestation and medical complications of the preterm infants (Hughes et al., 2002) or maternal stress levels (Gray et al., 2013). Prematurity *per se* may not be a risk factor for difficult temperament.

Infant temperament can be measured using a parent report questionnaire, which is reliant on the parent's perception of their infant's behaviour, but potentially to parental bias in interpretation (Kagan et al., 2002). The Infant Behaviour Questionnaire – Revised (IBQR) (Gartstein & Rothbart, 2003) was chosen for the current study as it is reported to have advantages over other questionnaires, thus making it more acceptable. Its structure is based on low-inference focused items (Eaton et al., 2001) and asks parents to report on the frequency of their infant's behaviour during routine daily tasks, such as feeding, bathing, shopping, playing and sleeping. It does not ask parents to compare their child to other children, nor to state their own behavioural or emotional response to their infant's behaviour (Montirosso, Cozzi, Putnam, Gartstein, & Borgatti, 2011).

Parent observations of their infant's temperament is shaped by the parent's own temperament and parenting experience (Kagan et al., 2002). Cross-cultural studies using the IBQR in infants from China, Italy, Japan, Poland, Russia, Spain and the US report differences in some traits that might reflect cultural interpretations of infant behaviour (Gartstein, Gonzalez, et al., 2006; Gartstein, Knyazev, & Slobodskaya, 2005; Gartstein, Slobodskaya, Zylicz, Gosztyla, & Nakagawa, 2010; Montirosso et al., 2011). The IBQR has not been used with Australian infants so prior to comparing the groups, the Infant Behavior Questionnaire – Revised (IBQR) was examined for this sample of Australian infants.

3.5 Study 3 – The Measurement of Motor Practice in Infancy

The aim of study 3 was to investigate the characteristics of infant practice measured with accelerometry and a daily activity diary and to ascertain whether practice parameters were influenced by infant age, GA, sex or BWGA.

Practice was defined for this study as the type, duration, frequency and intensity of activity during day wake time and measured with a diary and an accelerometer. This is similar to the definition of practice applied by Angulo-Barroso et al. (2010) in their study of physical activity for infants with neuromotor delay.

Practice is important in the development of motor skills in infancy therefore accurate measurement is essential. However, measurement is challenging in this age group for a number of reasons (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009).

Motor activity or practice can be measured directly or indirectly. Adamo et al. (2009) conducted a systematic review of measurement of physical activity of children between three and 19 years of age and found that the most commonly used direct measure was accelerometry which was used in 57 of 83 studies. Activity diaries (50 of 83) were the most common indirect measure. For children between three and five years, 17 studies used parent-report as a proxy measure. There were substantial discrepancies and moderate correlations between direct and indirect measures (Adamo et al., 2009).

Accelerometry has been used to measure activity in typical infants and infants with motor disorders (Angulo-Barroso et al., 2008; Angulo-Barroso et al., 2010; Angulo-Kinzler, Peirano, Lin, Garrido, & Lozoff, 2002; Tulve et al., 2007). Due to the limited number of studies measuring activity in infants using accelerometers there are no methodological guidelines for their use. However, there are protocols for accelerometer use in children aged three to five years and these can be applied to children aged less than 12 months and interpreted based on an understanding of infant motor development.

Considerations when deciding on the type of accelerometer include (1) dimensions and weight of the accelerometer, (2) practical issues relating to infant hygiene and (3) planes of movement being measured. Adding a small weight to an infant's legs can alter their stepping pattern (Thelen et al., 1984) so a small, lightweight, water-proof and easy to clean accelerometer that does not interfere with movement should be a priority. Infants demonstrate movements in multiple planes so a tri-axial accelerometer would record a variety of movements, better than a uni-axial or bi-axial accelerometer.

Accelerometers can only measure activity of the body part on which they are placed (Cliff, Reilly, & Okely, 2009), therefore for measuring motor activity, accelerometers worn on the infant's trunk, arm and leg would provide information on GM and FM movements and movements in multiple body planes (Atallah, Lo, King, & Yang, 2011; Cleland et al., 2013). However, this is impractical for infants and parents. Ankle and hip placement have been used in the studies with term infants and infants with Down syndrome and motor delay (Angulo-Barroso et al., 2008; Angulo-Barroso et al., 2010; Angulo-Kinzler et al., 2002). Ankle placement would capture all types of GM movements and may be more practical for the infant to wear than placement on the infant's hip.

Epoch duration should accurately capture infant activity but may be constrained by the options of accelerometers that are available. From the study of infant crawling it was noted that some infants crawled for one to three seconds (Soska et al., 2015). Newer models of accelerometers have epochs of one second duration and would be ideal, although most accelerometers have minimal epochs of 15 seconds. Recommendation for duration of monitoring of toddlers is between three and seven days, although the difference in activity between weekdays and weekends do not tend to differ as much as in school aged children. Monitoring per day should be at least between three and 10 hours (Cliff et al., 2009), although 24 hours is more appropriate.

Interpretation of counts is problematic as counts vary between monitors and deciding on whether counts are biologically plausible can be difficult. Furthermore, as infants are physically dependent for their everyday needs, parent handling of their infant is likely to also generate counts. There are many occasions in the day when infants are assisted with movement (Worobey et al., 2009). Similarly, measurement of sleep-wake cycles of two to10 month old term infants found that external motion of the infants (for example, being carried by a parent) significantly increased the activity counts during sleep and when awake. To help in the interpretation and accuracy of accelerometer counts, infant activity benefits from the use of an activity diary to give context to the counts (Shao-Yu, Burr, & Thomas, 2009; Worobey et al., 2009).

The diaries that are used with accelerometers in infants in other studies have not been described in detail. For example, it is not known what types of activities are recorded or the frequency of recording and they do not appear to be validated. Parent-report diaries may be time-consuming, unreliable and biased but are necessary to give context to accelerometer counts.

The Daily Activities of Infants Scale (DAIS) (Bartlett et al. 2008) is a parent report pictorial diary designed to be "…a quantitative measure of the activities that parents do with their infants throughout their days to support the development of antigravity postural control and movement exploration…" (p 614). This diary may provide context to help in the interpretation of activity counts and was designed for use by parents of preterm infants. Using the DAIS would enable an observer to describe the activities in which an infant engages, the duration of the activities, the relationship between activities and how much assistance the infant required to perform activities. An accelerometer would add information about the vigor with which activities are performed.

3.6 Study 4 – The Effects of Infant Temperament and Practice on Term and Preterm Infants' Motor Skills

This study addressed the main aim of the thesis which was to investigate the relationship between infant temperament, motor practice and motor skills, controlling for infant GA, sex and BWGA. A mediational model was proposed, as shown in figure 3.1. It was hypothesized that infant temperament would have a direct effect on motor skills and an indirect effect through practice.

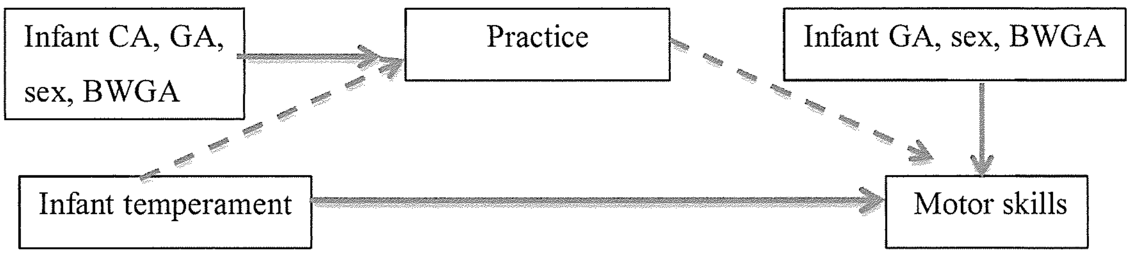


Figure 3.1 Conceptual model and path diagram showing relationships between temperament, practice and motor skills, controlling for infant gestational age, sex and birth weight for gestational age.

Temperament characteristics could be considered important for learning movement skills and may therefore be related to practice and to motor development. Practice of motor skills is likely to differ between infants as infants vary in their levels of active and exploratory play and in the way they respond physically and emotionally to their parents and environment. The relationships between temperament factors, practice and motor skills have not been investigated.

3.7 Significance of the study

The findings from this thesis can inform parents and clinicians of the importance of motor practice in infancy and how they can assist infants to develop motor skills. Measurement of motor practice in infancy is in a nascent phase and the outcomes of this thesis could potentially add to the knowledge on ways to measure, interpret and promote practice.

Individual differences in infant's activity levels are in part attributed to infant temperament, and understanding the relationship between infant temperament and practice may help individualise interventions for infants with motor delay. Preventing or ameliorating motor delay in infancy has potential benefits to development of other domains, such as cognition, language and socialization.

Chapter 4 – Methodology

4.1 Introduction

A cross-sectional sample was used to answer the research questions in the series of studies posed in chapter three. This chapter describes the participants, the materials used for testing, the test procedures and the ethical considerations. Data management for each of the factors being investigated is discussed in the relevant results chapters.

4.2 Recruitment of participants

Term born infants were recruited using multiple sources to ensure a broad representative sample of the Perth metropolitan community. Following approval from the Curtin University Human Research Ethics Commmittee (Appendix 1) and the Child and Adolescent Community Health (CACH) Executive committee (Appendix 2), meetings were arranged for the investigator's attendance at staff meetings with community and child health nurses. The study was explained and permission was sought to display advertisements in the waiting rooms of the metropolitan child health and community centres. Nurses agreed to direct parent attention to the advertisements. The nurses advised that recruitment would be more expedient if the investigator attended the drop-in clinics at the child health centres so that parents could be approached in person. Network sampling was also used to recruit term born infants based on the investigator's contacts. The final source of term born infants occurred when the investigator contacted the coordinators of local playgroups and was given permission to attend playgroups and speak to parents. Mothers were provided with an information sheet (Appendix 3) explaining the study and a verbal explanation. Mothers of 95 term infants consented to participate in this study.

Preterm infants were recruited from the physiotherapy department of King Edward Memorial Hospital (KEMH), the only tertiary neonatal hospital in Perth, Western Australia. Preterm births and other high risk pregnancies are delivered at KEMH. As part of the follow-up of preterm infants the physiotherapy department conducts a bi-weekly playgroup. Infants and their parents are invited to the playgroup if the infant was born earlier than 32 weeks GA and / or less than 1500 grams. Infants attend at approximately monthly intervals from when they are one month CA until they are 12 months CA. Ethics approval was sought from the Women and Newborn Health Service Ethics Committee (Appendix 4) to recruit preterm infants from the playgroup. Initially, the ethics approval stipulated that the physiotherapists conducting the playgroup were to distribute the parent information sheets. This resulted in very low response from the parents. Subsequently, an amendment was submitted to the ethics committee requesting that the investigator be granted permission to attend the playgroup and speak to the parents face-to-face. This strategy was successful. The mothers were given a parent information sheet (Appendix 3) and verbal explanation regarding the study.

Recruitment for the study occurred between January 2012 and May 2013, during which time approximately 282 infants (162 males, 120 females) were invited to attend the preterm follow-up physiotherapy playgroup (playgroup statistics are not accessible). Anecdotal reports from the physiotherapists conducting the playgroup are that not all infants who are invited attend the playgroup due to a variety of reasons, including but not limited to, geographical location of the playgroup in relation to the family home, parental responsibilities to work or other children, and lack of interest from the parents. The investigator was not granted permission to access demographic or birth information of the infants who did not attend playgroup, therefore comparisons between the infants who did and did not attend was not possible. The investigator is unable to ascertain whether the infants who were recruited to the study were a representative sample.

The other source of preterm infants was the Miracle Babies® playgroups. The coordinators of the playgroups gave permission for the investigator to attend the playgroups and speak directly to the parents. Infants attending this parent-organised playgroup were born less than 37 weeks gestation and of varying BW.

Mothers of 104 (61 male and 43 female) preterm infants consented to participate in this study.

4.2.1 Inclusion criteria

Term born infants were included in the study if they were between three and 12 months of age at the time of testing; were born at or later than 37 weeks GA; and were developmentally normal as per parent report and not receiving medical or therapy intervention for any congenital or acquired conditions affecting any body systems.

Preterm infants were included if they were between three and 12 months CA at the time of testing; were born earlier than 37 weeks GA; and without brain injury, such as IVH, PVL or HIE diagnosed with head US or MRI. The infants did not have musculoskeletal conditions that would affect motor development. If they required supplemental oxygen following discharge from the neonatal unit, the supplemental oxygen had ceased prior to admission to the study.

4.2.2 Exclusion criteria

There were 17 sets of twins: one pair of male term infants, eight pairs of male preterm infants, six pairs of female preterm infants and two pairs of male-female preterm infants. The rate of preterm birth is reportedly higher for twin pregnancies than for singleton pregnancies (Gardner et al., 1995) which was evident in the current study. Comparisons on the achievement of motor milestones in infancy between twins and singletons suggest that there are no differences in their time of reaching milestones (Brouwer, van Beijsterveldt, Bartels, Hudziak, & Boomsma, 2006) and that the common twin environment was the biggest predictor for milestone achievement after correcting for GA (Peter, Vainder, & Livshits, 1999). However, examination of other factors in the current study, for example duration and quantity of activity could potentially be compromised by the genetic and family environment that twins share (W. Johnson, Turkheimer, Gottesman, & Bouchard Jr, 2010). To prevent violation of inter-dependence of twins one twin was excluded from each pair based on the following criteria: (1) the mother did not complete questionnaires for one twin, (2) where information was available for both twins, then one was randomly excluded, and (3) for male-female pairs, the male twin was excluded as there were fewer females in the study. One male term infant, aged eight months was uncooperative during the home visit and was not tested with the motor assessments, despite three home visits to enhance compliance. Although his mother completed all the questionnaires, he was excluded from analyses as the primary outcome measure was not available.

4.2.3 Withdrawal criteria

One preterm female infant aged nine months CA was withdrawn from the study as she showed neurological symptoms that were evident during testing for the study but had not been identified prior to the parent consenting to be part of the study. One mother withdrew her term female infant aged six months for personal reasons.

4.3 Description of the participants

There were 180 infants in the final sample: 93 term and 87 preterm. Table 4.1 shows the distribution of the final sample for infant age and sex.

Table 4.1. Distribution of term, preterm and total infants per month of age (chronological for term and corrected for preterm).

	Term		**Preterm**		**Total for sex**	
Age (mths)	**M**	**F**	**M**	**F**	**M**	**F**
3	5	5	5	5	10	10
4	4	5	5	5	9	10
5	5	5	5	6	10	11
6	6	5	4	5	10	10
7	5	5	5	4	10	9
8	4	3	5	3	9	6
9	5	5	4	5	9	10
10	5	5	5	5	10	10
11	5	4	6	3	11	7
12	3	4	2	0	5	4
Total for sex and group	**47**	**46**	**46**	**41**	**93**	**87**
Total for group	**93**		**87**		**180**	

4.3.1 Comparison between term and preterm infants

Comparison of the mean and standard deviation (SD) of the characteristics of the term and preterm infants at the time of testing are reported in Table 4.2. Infant and family demographic data were collected using a questionnaire (Appendix 5).

As would be expected the term infants on average had significantly later GA ($p < .001$) and higher BW ($p < .001$). The preterm infants on average weighed less than 1500 grams at birth. Preterm infants at CA were significantly lighter in weight at the time of testing than the term infants ($p < .001$). When examined by group and sex, the preterm female infants on average were shortest ($p < .05$), lightest ($p < .01$) and had the smallest head circumference ($p < .001$) compared with the preterm male infants and the term male and female infants.

Variables describing family structure are shown in Table 4.3. Family structure was similar for both groups: 97% were two-parent families, 1% were single (mother) families and 1% were lesbian couples. Sixty-seven (71%) term infants were singletons, one was a twin and 26 (28%) had one or more siblings. Fifty-one (59%) preterm infants were singletons, 16 (18%) were twins and 23 (26%) had one or more siblings. The majority of mothers and fathers were university educated which is reflected in the distribution of family incomes and indicated that most families in this study were of high socio-economic status.

Family income was categorized consistent with the Australian Bureau of Statistics (ABS, 2013). Fifty percent of the term infants had family income greater than $125,000, 38% had incomes between $60,000 and $124,999, 10% were between $30,000 and $59,999 and only 2% were less than $30,000. In comparison, 36% of preterm infants had family income in the highest category, 40% were in the $60,000 to $124,999, 15% in the $30,000 to $59,999 and 2% in the lowest income bracket.

Parents were asked, using an open-ended question, to describe which ethnic group they identified with. Replies did not conform with Australian Bureau of Statistics descriptors of ethnicity. Categories were created specifically for this study sample and were summarized to describe the parents of the term and preterm infants and to show that there were relatively equal distributions between descriptors as Caucasian, Australian and European with smaller percentages reported for other groups.

Table 4.3 shows that there were no differences between the term and preterm groups on maternal and paternal characteristics or family factors.

Table 4.2 Characteristics of the term and preterm infants, reported as mean and standard deviation.

	Term			Preterm		
	Male (n = 47)	**Female** (n = 46)	**Total** (n = 93)	**Male** (n = 46)	**Female** (n = 41)	**Total** (n = 87)
Age (wk)	33.6 (12.2)	33.5 (12.5)	33.6 (12.3)	43.2 (12.8)	41.8 (12.4)	42.5 (12.6)
CA (wk)	33.1 (12.2)	33.5 (12.5)	33.1 (12.4)	32.9 (12.2)	30.6 (11.8)	31.8 (12.0)
GA (wk)	39.4 (1.0)	39.4 (1.1)	39.4 (1.1)*	30.1 (2.9)	29.3 (3.0)	29.8 (3.0)*
BW (g)	3473.3 (432.2)	3356.6 (457.2)	3414.9 (446.3)*	1389.9 (549.5)	1286.7 (462.4)	1343.2 (511.6)*
Lt (cm)	69.6 (5.3)	68.1 (4.8)	68.8 (5.1)	68.6 (5.2)	65.6 (6.3)**	67.2 (5.9)
Wt (kg)	8.7 (1.4)	7.9 (1.3)	8.3 (1.4)	7.9 (1.5)	7.2 (1.2)**	7.6 (1.4)
HC (cm)	44.8 (2.4)	43.1 (2.0)	43.9 (2.4)	44.7 (2.4)	42.9 (2.1)**	43.9 (2.4)

Age = chronological age, CA = corrected age for prematurity, GA = gestational age, BW = birth weight, Lt = length, Wt = weight, HC = head circumference, *differences between groups $p < 0.001$; **differences between sex and group $p < 0.05$

4.3 Maternal and paternal characteristics for the term and preterm infants.

	Maternal factors		**Paternal factors**	
	Term	**Preterm**	**Term**	**Preterm**
Age (yr)	(n = 92)	(n = 85)	(n = 92)	(n = 83)
<20	0	1 (1.1%)	0	0
21 – 30	27 (29%)	31 (35.6%)	16 (17.2%)	15 (17.2%)
31 – 40	61 (65.6%)	49 (56.3%)	66 (71.0%)	48 (55.2%)
41+	4 (4.3%)	4 (4.6%)	10 (10.8%)	20 (24.1%)
Education	(n = 91)	(n = 85)	(n = 91)	(n = 82)
< High school	3 (4.3%)	8 (9.2%)	7 (7.6%)	13 (14.9%)
High school	4 (4.3%)	3 (3.4%)	3 (3.2%)	6 (6.9%)
Technical training	18 (19.6%)	25 (28.7%)	23 (24.7%)	26 (29.9%)
University	66 (71.8%)	49 (56.0%)	58 (63.1%)	37 (45.1%)
Ethnicity (%)	(n = 86)	(n = 85)	(n = 86)	(n = 82)
Caucasian	26 (29.9%)	25 (29.4%)	26 (29.9%)	25 (30.5%)
Australian	26 (29.9%)	19 (22.4%)	21 (24.1%)	22 (26.8%)

Mixed Australian	6 (6.9%)	5 (5.9%)	5 (5.7%)	1 (1.2%)
European	17 (19.5%)	14 (16.5%)	25 (28.7%)	19 (23.1%)
Asian	9 (10.3%)	15 (17.6%)	5 (5.7%)	7 (8.5%)
African	1 (1.1%)	2 (2.3%)	2 (2.2%)	2 (2.4%)
Middle Eastern	1 (1.1%)	3 (3.5%)	1 (1.1%)	2 (2.4%)
Indigenous	0	0	1 (1.1%)	2 (2.4%)

4.3.2 Description of preterm infants

Table 4.4 describes the preterm infants. Preterm infants are generally described based on weeks of completed gestation, however BW and birth weight for gestation can also be used to categorise infants born prematurely. GA categories are based on the WHO definitions: extremely preterm is < 28 weeks GA, very preterm is ≥28 weeks to < 32 weeks GA, and moderate to late preterm is ≥32 weeks to < 37 weeks GA (March of Dimes, PMNCH, Save the Children, & WHO, 2012). Where parents have reported GA as weeks plus days, eg. 30 weeks + 4 days, the accepted convention is to report GA as the number of completed weeks. More than 50% of the preterm infants were in the very preterm group.

Birth weight categories are also based on the WHO definitions: extremely low birth weight (ELBW) is <1000 grams, very LBW (VLBW) is ≥1000 grams to <1500 grams, low birth weight (LBW) is ≥1500 grams to <2500 grams, and healthy weight is ≥2500 grams (United Nations Children's Fund and World Health Organisation, 2004). Approximately one-third of the male and female preterm infants were in each of the birth weight categories, with three male infants in the healthy birth weight category.

4.3.3 Description based on birth weight for gestational age

Infants who are small for gestation are at the highest risk of adverse outcomes, irrespective of GA (Briana & Malamitsi-Puchner, 2013). Birth weight for GA (BWGA) categories were defined as small for GA (SGA) as <10th percentile for gestation, ≥10th but ≤90th as appropriate for GA (AGA) and >90th percentile as large of GA (LGA) based on the WHO definitions (United Nations Children's Fund and World Health Organisation, 2004). Participants in this study were categorised using the Australian BWGA reference values (Dobbins, Sullivan, Roberts, & Simpson, 2012). Only one parent of a male term infant did not report their infant's BW.

Table 4.5 reports the percentage of term and preterm infants in each BWGA category and description of BW for each category. More than 50% of the preterm infants were in the AGA category. The minimum values of BW within each category for the preterm infants were in the ELBW range. It is possible for preterm infants to be both

AGA or LGA and to also be LBW of any severity. Approximately 80% of the term infants were in the AGA category. As with preterm infants, some male term infants were both SGA and LBW.

Table 4.4 Distribution of gestational age and birth weight categories for the preterm infants.

	Male (n = 46)			Female (n = 41)			Total (n = 87)		
	N (%)	**Mean (SD)**	**Range**	**N (%)**	**Mean (SD)**	**Range**	**N (%)**	**Mean (SD)**	**Range**
GA (weeks)									
<28	9 (19.6%)	25.9 (1.6)	23.4 – 27.9	12 (29.3%)	25.5 (0.9)	23.6 – 26.7	21 (24.1%)	25.7 (1.2)	23.4 – 27.9
≥28 to <32	25 (54.3%)	29.9 (1.2)	28.0 – 31.9	23 (56.1%)	30.3 (1.6)	25.4 – 31. 7	48 (55.1%)	30.1 (1.4)	25.4 – 31.9
≥32 to <37	12 (26.1%)	33.8 (1.5)	32.0 – 36.0	6 (14.6%)	33.4 (1.3)	32.0 – 35.9	18 (20.6%)	33.7 (1.4)	32.0 – 36.0
BW (grams)									
<1000	13 (28.3%)	816.9 (120.6)	650 - 970	14 (34.1%)	752.2 (122.8)	586 - 965	27 (31.0%)	783.7 (123.8)	586 - 970
≥1000 to <1500	17 (36.9%)	1288.2 (138.3)	1070 - 1485	13 (31.7%)	1250.3 (143.1)	1054 - 1460	30 (34.4%)	1271.8 (139.5)	1054 – 1485
≥1500 to <2500	13 (28.3%)	1759.6 (137.3)	1500 - 2000	14 (34.1%)	1761.1 (269.5)	1500 - 2300	27 (31.0%)	1760.4 (212.2)	1500 – 2300
≥2500	3 (6.5%)	2846.7 (384.2)	2520 - 3270	0	0	0	3 (3.4%)	2846.7 (384.2)	2520 – 3270

Table 4.5 Distribution of birth weight by birth weight for gestational age categories for the term and preterm infants.

	Preterm (n = 87)								
	Male (n = 46)			Female (n = 41)			Total		
	N (%)	Mean (SD)	Range	N (%)	Mean (SD)	Range	N (%)	Mean (SD)	Range
SGA (g)	15	1140.7	685 - 2000	5	838.2	586 – 1410	20	1065.0	586 – 2000
	(32.6%)	(398.2)		(12.2%)	(333.0)		(22.9%)	(397.8)	
AGA (g)	26	1428.3	650 - 2520	32	1311.6	590 – 2300	58	1363.9	590 – 2520
	(56.5%)	(439.5)		(78.0%)	(445.8)		(66.7%)	(442.9)	
LGA (g)	5	1938.0	1085 - 3270	4	1320.0	720 – 2000	9	1663.3	720 – 3270
	(10.9%)	(1008.5)		(4.6%)	(554.5)		(10.3%)	(854.4)	
	Term (n = 93)								
	Male (n = 47)			**Female (n = 46)**			**Total**		
	N (%)	**Mean (SD)**	**Range**	**N (%)**	**Mean (SD)**	**Range**	**N (%)**	**Mean (SD)**	**Range**
SGA (g)	4	2722.5	2000 - 3000	6	2768.3	2540 – 2950	10	2750.0	2000 – 3000
	(8.5%)	(482.5)		(13.0%)	(1645.7)		(10.7%)	(305.4)	
AGA (g)	39	3485.1	2890 - 4400	34	3344.5	2700 – 4042	73	3419.6	2700 - 4400
	(82.9%)	(318.5)		(73.9%)	(346.6)		(78.5%)	(337.1)	
LGA (g)	4	4152.8	4098 - 4200	6	4101.5	3790 – 4340	10	4122.0	3790 - 4340
	(8.5%)	(43.9)		(13.0%)	(220.8)		(10.7%)	(168.6)	

AGA = appropriate for gestational age, LGA = large for gestational age, SGA = small for gestational age

4.3.4 Assisted ventilation requirements

Table 4.6 summarises the assisted ventilation requirements for the preterm infants. Parents were asked to report on their infant's ventilatory and supplemental oxygen requirements as the investigator was not granted permission to access the medical records of the infants. One male term infant required continuous positive airway pressure (CPAP) for two days and supplemental oxygen for four days and one male term infant required supplemental oxygen for seven days. No female term infant required assisted ventilation or supplemental oxygen.

Just over half of the preterm infants required CPAP and the majority were in the very preterm GA category. The earliest gestation infants required ventilation for the longest period of time compared with the later gestations. Duration of ventilation was spread relatively evenly for the infants in the very preterm GA category. Information was not provided regarding use of ventilation for one male and two female preterm infants.

Seven (26.9%) male extremely preterm infants required supplemental oxygen for on average 113 days, ranging from 42 to 210 days. Fifteen (57.7%) male very preterm infants required oxygen for on average 44 days, ranging from one to 280 days. Four (15.4%) male moderate-late preterm infants required oxygen for on average five days, ranging from one hour to 14 days. Information was not provided for 20 male preterm infants regarding supplemental oxygen requirements.

Nine (36.0%) female extremely preterm infants required supplemental oxygen for on average 112 days, ranging from seven to 266 days. Twelve (48.0%) female very preterm infants required supplemental oxygen for on average 15 days, ranging from one to 105 days. Four (16.0%) female moderate-late preterm infants required supplemental oxygen for on average 2.5 days, ranging from three hours to seven days. Information was not provided for 16 female preterm infants.

Table 4.6. Ventilation requirements of preterm infants stratified by gestational age and sex.

	Males (n = 45)			Females (n = 39)			Total group (n = 85)		
	N (%)	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
GA (wk)	**EPT**	**VPT**	**M-LPT**	**EPT**	**VPT**	**M-LPT**	**EPT**	**VPT**	**M-LPT**
Type									
Full		1 (2.2%)		2 (4.9%)			2 (2.3%)	1 (1.1%)	
CPAP	5 (10.9%)	14 (30.4%)	6 (13.0%)	3 (7.3%)	14 (34.1%)	4 (9.8%)	8 (9.2%)	28 (32.2%)	10 (11.5%)
Combined	4 (8.7%)	6 (13.0%)		6 (14.6%)	4 (9.8%)		10 (11.5%)	10 (11.5%)	
Not specified				1 (2.4%)			1 (1.1%)		
Nil		3 (6.5%)	6 (13.0%)		3 (7.3%)	2 (4.9%)		6 (6.9%)	8 (9.2%)
Duration (wk)									
<0.5		6 (18.2%)	5 (15.2%)	1 (3.3%)	4 (13.3%)	3 (10.0%)	1 (1.6%)	10 (15.9%)	8 (12.7%)
≥0.5 to <1		3 (9.1%)			4 (13.3%)			7 (11.1%)	
≥1 to <2		2 (6.1%)	1 (3.0%)		4 (13.3%)	1 (3.3%)		6 (9.5%)	2 (3.2%)
≥2 to <4		1 (3.0%)		1 (3.3%)	1 (3.3%)		1 (1.6%)	2 (3.2%)	
≥4 to <8	2 (6.1%)	3 (9.1%)		1 (3.3%)	2 (6.7%)		3 (4.%)	5 (7.9%)	
≥8	7 (21.2%)	3 (9.1%)		8 (26.7%)			15 (23.8%)	3 (4.8%)	

CPAP = Continuous Positive Airway Pressure, EPT = extremely preterm, M-LPT = moderate-late preterm, VPT = very preterm

4.4 Materials

4.4.1 Peabody Developmental Motor Scales, Version 2 (Folio & Fewell, 2000)

The primary outcome measure was the Peabody Developmental Motor Scales, Version 2 (PDMS2) (Folio & Fewell, 2000) which is a standardized measure of gross and fine motor skills of children from birth to 72 months of age intended to determine whether children have delayed motor development.

4.4.1.1 Structure and scores

The PDMS2 consists of six subtests that measure aspects of gross and fine motor skills. Three subtests comprise the gross motor composite: reflexes (n = 8), stationary (n = 30) and locomotion (n = 89) for infants less than 12 months of age, with object manipulation (n = 24) replacing the reflexes items for infants older than 12 months. Two subtests comprise the fine motor composite: grasping (n = 26) and visual-motor integration (n = 72). Scoring for all items is on a three-point ordinal scale, zero, one or two based on the criteria for the item. Higher scores indicate better performance. Test administration was consistent with the instructions in the examiner's manual.

Scoring the PDMS2 is a multi-step process. Firstly, the raw score for each subtest is determined by summing the scores for the items for the subtest. The raw scores for each subtest are converted to a subtest standard score and a subtest percentile using the tables provided in the test manual. These were calculated based on the infant's chronological and CA. The gross motor (GM) standard score is derived by summing the standard scores for the three subtests (reflexes/object manipulation, stationary and locomotion). Then using the age appropriate table, the GM standard score (GMSS) is converted to the GM quotient (GMQ) and GM percentile. Similarly, the fine motor (FM) standard score (FMSS) is derived from the summation of the standard scores for the two subtests (grasping and visual-motor integration) and the FM quotient (FMQ) and FM percentile are calculated using the age appropriate tables. A total motor (TM) standard score (TMSS) is calculated by summing the GMSS and FMSS and then converted to a TM quotient (TMQ) and TM percentile.

There are a number of ways in which the PDMS2 scores may be analysed and interpreted. Each subtest standard score has a mean of 10 and a standard deviation of 1.5. For each subtest an infant's standard score of seven or less is categorized as being below average performance. The authors do not provide means and standard deviations for GMSS or FMSS. The GMQ, FMQ and TMQ each have a mean of 100 and a standard deviation of 15. An infant is considered to have GM, FM or TM delay if the quotient is ≤ 85. The normative sample used to calculate standard scores, quotients and percentiles consisted of 2003 children from the USA and Canada, representing various geographical regions, urban and rural areas, sex, family socioeconomic status and ethnicities (Folio & Fewell, 2000).

4.4.1.2 Psychometric properties

Folio & Fewell (2000) report that the test items were generated based on a literature review for construct validity, and that a factor analysis showed that the GM and FM raw scores increased with age for infants. Inter-rater reliability for infants for the GMQ was $r = .97$ and FMQ $r = .98$ and internal consistency Cronbach's alpha for GMQ = .97 and FMQ = .96 (Folio & Fewell, 2000).

Provost et al. (2004) conducted independent analyses comparing the PDMS2 with the Bayley scales of infant development II (BSID-II) motor scales in children with developmental delay ranging in age from three to 41months. They found significant ($p < 0.001$) high correlations between the five subscales of the PDMS2 and the age equivalent motor scores of BSID-II, ranging from $r = .85$ to .97. However, when the standard scores of the PDMS2 were compared with the BSID-II motor standard score the correlations reduced to $r = .67$ for the FMQ and .76 for the GMQ but were still significant at $p < .001$. Importantly, the percentage agreement computed with the kappa coefficient between the PDMS2 GMQ, FMQ and total TMQ and the BSID-II motor scale were .13, .02 and .09 respectively, indicating slight agreement. McNemar's test of symmetry showed significant differences on classification of delay between the GMQ ($\chi^2(1) = 54.01, p < .001$) , FMQ ($\chi^2(1) = 61.02, p < .001$) and TMQ ($\chi^2(1) = 52.01, p < .001$) and the BSID-II motor score such that fewer infants were identified with motor delay with the PDMS2 than the BSID-II (Provost et al.,

2004). There is a possibility that the PDMS2 may not be sensitive enough to detect the severity of GM and FM delay in infants with motor delay.
Concurrent validity comparing the PDMS2 with the BSID-II in a sample of typical infants at 12 months of age found very low correlations for age equivalent scores ranging from r = -.41 to .71 (highest for locomotor subtest). Significant ($p < 0.05$) but low correlations r = .22 to .32 were found for standard scores between the two measures (Connolly et al., 2006).

Test-retest reliability of the GMQ, FMQ and TMQ for preterm Iranian infants at a mean age of 18 months and BW <1900 grams was ICC = .97 to .99. Concurrent validity between PDMS2 and BSID-II for the GMQ was r = .93 and the FMQ was r = .91 (Tavasoli, Azimi, & Montazari, 2014). The authors do not report which scores for the BSID-II were used for comparison.

A Rasch analysis of the FM items with Taiwanese children from birth to 72 months found that the three scoring criteria for 19/26 items in the grasping subset and 52/72 items in the visuo-motor subset could be collapsed to a dichotomous scale and that principle component analysis suggested that the two subtests (grasping and visuo-motor) could be a uni-dimensional fine motor composite. There were also ceiling effects for some items. The authors recommended that the PDMS2 FM composite should undergo significant revision in subsequent iterations (Chien & Bond, 2009). Statistical tests were for children from birth to 72 months, therefore conclusions as to whether dichotomous scoring for each item would be sensitive enough to detect delays in children aged three to 12 months cannot be determined.

The author is not aware of any other independent analyses that have tested the psychometric properties of the FM scale of the PMDS2, likely because there are few standardised measures of FM skills.

A systematic review of the clinimetric properties of nine motor assessments for preterm infants by Spittle et al. (2008) found that the PDMS2 was a suitable measure (Spittle, Doyle, & Boyd, 2008). There are two disadvantages to using the PDMS2. One is that it has not been used in Australian infants, although it has been used with

Australian children and secondly, it is based on the neuromaturational model of development and includes a "reflexes" section for children under 12 months. Overall, the PDMS2 meets all eight criteria required for the current study and its advantages outweigh the possibility that it might lack discriminative rigor.

Connolly et al. (2006) state that motor development is multifaceted and different assessment tools measure different aspects, therefore more than one assessment should be used to determine motor ability in a child (Connolly et al., 2006).

In summary, the PDMS2 has robust properties for GM and FM subscales as reported by the authors (Folio & Fewell, 2000) and confirmed in a number of independent evaluations (Provost et al., 2004; Tavasoli et al., 2014).

4.4.2 Alberta Infant Motor Scale (Piper & Darrah, 1994)

The Alberta Infant Motor Scale (AIMS) is an observational assessment of GM performance for infants from birth to 18 months of age and is able to discriminate between typical and atypical GM development (Pin, de Valle, Eldridge, & Galea, 2010). It is used extensively in the assessment of GM skills in children born preterm. Norm referencing was conducted on 2202 term Canadian infants and there were no sex differences.

4.4.2.1 Structure and scores

The AIMS comprises 58 items divided into four subscales based on body positions: prone (21 items), supine (9), sitting (12) and standing (16). Using the guidelines in the examiner's manual and the score sheet, the infant is credited with an item if they fulfill all the key descriptors. A total raw score is calculated by summing all achieved items in each subscale. Using the table provided in the examiner's manual, the percentile rank-by-age of the infant can be determined. An infant's performance can only be interpreted in comparison with infants of the same age using the percentile values (Piper & Darrah, 1994). The authors advise that for infants at four months of age scores $<10^{th}$ percentile would be considered to have GM delay and at eight months and 12 months scores $<5^{th}$ would have GM delay (Darrah, Piper, & Watt, 1998). However, as this is a cross-sectional study and infants ranged in age from three to 12 months, then a consistent cut-point $<5^{th}$ percentile was chosen to indicate delay, which was recommended by the authors to maintain high specificity (Darrah et al., 1998).

4.4.2.2 Psychometric properties

The authors report on inter-rater and test-retest reliabilities and concurrent validity. Two hundred and fifty-three (n = 253) term infants were stratified into four age bands for the reliability testing: birth to three months, four to seven months, eight to 11 months and 12 to 17 months. ICC's ranged from .96 to .99 for inter-rater reliability between two assessors on one occasion and six assessors on two occasions. ICC's for test-retest reliability ranged from .82 to .99. One hundred and three term infants from birth to 13 months were tested with the AIMS and the motor scale of the BSID-II and the gross motor scale of the PDMS for concurrent validity. Correlations with the BSID-II ranged from $r = .84$ to .93 and with the PDMS from $r = .90$ to .98. Concurrent validity was also evaluated with infants who were at risk of delay with $r = .93$ with the BSID-II and $r = .95$ with the PDMS (Piper & Darrah, 1994).

Concurrent validity has been examined in Taiwanese and Brazilian preterm infants comparing the AIMS with the BSID-II at six and 12 months CA with r ranging from .74 to .95 (Almeida, Dutra, de Mello, Reis, & Martins, 2008; Jeng, Yau, Chen, & Hsiao, 2000). Similar results were found with Japanese term infants, 22 days to 16 months, comparing the AIMS with the Kyoto Scale of Psychological Development, $r = 0.97$ (Uesugi, Tokuhisa, & Shimada, 2008).

A Rasch analysis by Liao and Campbell (2004) with infants with varying degrees of risk for motor delay (n = 95) confirmed that the items in each posture were arranged in increasing levels of difficulty, but that ceiling effects were evident after the infant could lower from standing with control (approximately nine months) (Liao & Campbell, 2004).

Bartlett and Fanning (2003) examined whether the AIMS was able to differentiate between preterm infants at eight months CA with different levels of motor ability. Preterm infants were assessed with the AIMS by a physiotherapist and independently classified by a medical specialist as being neurologically abnormal (n = 5), suspect (n

= 30) or normal (n = 25). Mean (SD) AIMS total scores were 22.0 (9.4), 29.7 (7.7) and 38.0 (8.9) respectively. There were significant differences in total scores between groups (F = 11.03, df = 59, $p < .001$) (Bartlett & Fanning, 2003). What the authors do not report is the percentile-by-age ranks for each group. On inspection of the total scores the most delayed infants had a mean percentile of three, the suspect group had a percentile of 13 and the normal group percentile was 42. What this study demonstrates is that the AIMS total score alone is not adequate for clinical decision making. According to the recommendations by Piper and Darrah (1994) scores less than the 5^{th} percentile would be classified as delayed. In the Bartlett and Fanning (2003) study only the infants in the neurologically abnormal group would be delayed.

Inter-rater reliability has been examined in Greek (Syrengelas et al., 2010) and Japanese (Uesugi et al., 2008) term infants and Australian (Pin, de Valle, et al., 2010), Brazilian (Almeida et al., 2008) and Taiwanese (Jeng et al., 2000) preterm infants with ICC's ranging from .73 to .99.

The sensitivity of the AIMS to detect infants with gross motor delay varies between cultural groups. A study with Dutch term infants (n = 100) from birth to 12 months (Fleuren et al., 2007) and Flemish term infants (n = 270) from birth to 18 months (De Kegel et al., 2013) found that both cohorts scored lower at all ages compared with the Canadian norms. The authors suggest new norms were needed for Dutch and Flemish infants due to cultural differences. van Haastert, Eijsermans and de Vries (2007) commented that the Fleuren et al. (2007) study may have been underpowered and was unlikely to be representative of the Dutch population. They added that further studies should be conducted before deciding that Dutch norms are needed (van Haastert et al., 2007).

A comparison between term and preterm Brazilian infants (n = 561), birth to 18 months, found that the term infants scored higher than preterm for total score and percentile-by-age ranks (Valentini & Saccani, 2011).

Unlike these studies, Greek term infants (n = 424), seven days to 18 months, had mean AIMS scores that were not different to the Canadian norms, and the percentile-by-age ranks were similar at all age groups and all percentiles (Syrengelas et al., 2010).

The "Back to sleep" campaign to prevent SIDS has raised some speculation that the AIMS may not be relevant to infants born after the start of the campaign, and that the AIMS normative data has not been updated since 1992, before the campaign. Darrah et al. (2014) compared the original normative data with a contemporary sample of 650 Canadian term infants and found no difference in the age of appearance of the skills between the original sample, measured in 1992 and the current sample of infants. It would appear that the AIMS remains relevant for assessing gross motor skills in infants raised after the "Back to sleep" campaign (Darrah, Bartlett, Maguire, Avison, & Lacaze-Masmonteil, 2014).

One negative feature of the AIMS is that of the 21 items in the prone section two are creeping and five are crawling. Not all infants crawl (Adolph et al., 1998), so an infant might score low overall if they do not use some form of prone mobility. Liao and Campbell (2004) found that the AIMS measured ability best between three and nine months of age, with the older age group not necessarily achieving all prone items and having large gaps in the standing items. There are no sitting mobility items (as in bottom shuffling) to compensate. The assumption being that bottom shuffling is not a normal GM skill.

The AIMS was found to have the best psychometric properties and clinimetric usefulness compared with nine other measures for preterm infants (Pin, de Valle, et al., 2010; Spittle et al., 2008). It complements the PDMS2 as both measures are discriminative and predictive (Spittle et al., 2015). It is a suitable measure of GM skills and has been used with Australian term and preterm infants and meets the criteria for the current study.

4.4.3 Daily Activities of Infants Scale (Bartlett & Fanning, 2004)

The Daily Activities of Infants Scale (DAIS) is a parent-report diary consisting of daily routine activities for infants between four and 12 months of age.

4.4.3.1 Structure and scoring

The DAIS is structured around the daily activities in which infants and their parents engage and is divided into eight activities: feeding, bathing, dressing, carrying, quiet play, active play, outings and sleep. Each activity (except sleep) is divided into three levels indicative of the amount of support the infant requires: level A being maximum support, level B moderate and level C minimal or no support. Written instructions provided in the diary ask parents to complete the diary every 15 minutes by choosing the dominant activity in the previous 15 minutes and then the level of support required during that activity. They are then asked to mark a box corresponding to the appropriate activity and support required. For example, if a four month old infant was being breastfed from 7.30am to 8.00am, the activity would be feeding and level A, maximum support, with the parent recording two marks for that time.

Scores are determined for each activity per 15 minutes by allocating one point for each mark in level A, two points for each mark in level B and three points for each mark in level C. These values are summed for each activity (except sleeping) and a total score. Higher scores indicate less support required for an activity.
In this study the DAIS was used to complement and interpret the data from the activity monitor, so the instructions to parents were modified slightly. Parents were asked to complete the DAIS every 15 minutes by identifying the main activity and level of support required by the infant but rather than marking a box, they were asked to record the start and finish time for the dominant activity. Using the example cited earlier, the parent would write 7.30am to 8am in the feeding domain, level A. The diary is then interpreted as feeding requiring maximum support occurred for 30 minutes and scored as two points, one point for each 15 minute epoch. Parents were not required to complete the diary during the night but to record the infant's sleep time after waking the next day. The diary was completed for the 24 hour period

when the accelerometer was worn. The DAIS can be downloaded from the website http://www.canchild.ca/en/measures/dais.asp.

4.4.3.2 Psychometric properties

Psychometric evaluation of the DAIS on a sample (n = 50) of very preterm infants is reported by Bartlett et al. (2008). There were no differences in total DAIS scores between one day and three consecutive days and significantly ($p < .001$) higher total scores for older infants compared with younger infants suggesting discriminative validity. Convergent validity of DAIS scores had a part correlation of .20 ($p < .01$) with the AIMS. ICC's for inter-rater and test-retest reliabilities on total scores were .76 and .77 respectively (Bartlett et al., 2008). No independent evaluations have been reported on the DAIS for either term or preterm infants.

4.4.4 Activity monitor

To provide independent objective data on infant activity the infant was required to wear an accelerometer. Evidence based practice protocols in the use of accelerometers have not been published for children birth to two years of age but are provided for children aged three to five years (Cliff et al., 2009). This protocol was followed and modified for the current study and was consistent with the methodologies described in studies using accelerometers to measure activity in typical infants and infants with Down syndrome (Angulo-Barroso et al., 2008; Angulo-Kinzler et al., 2002; McKay & Angulo-Barroso, 2006) and in sleep/wake studies of typical infants (Shao-Yu, Burr, & Thomas, 2009; So, Adamson, & Horne, 2007).

The Actical® accelerometer was chosen for the current study as it was the most frequently used commercial product by infants (Rowlands & Eston, 2007). It is an omni-directional accelerometer (Respironics, Pennsylvania, 2011) purported to capture movement in any direction and was deemed appropriate as infant movement occurs in multiple planes (Cliff et al., 2009). Furthermore, this accelerometer was light-weight weighing 16gms, small with dimensions of 29mm x 37mm x 11mm in size and waterproof (Actical® instruction manual, Respironics, 2011) and therefore suitable for infants (Appendix 6). According to the manufacturer's specifications the

Actical® is designed to detect low frequency (0.5 – 3.2Hz) movement forces within the normal movement range.

The monitor was placed on the infant's right ankle, just proximal to the lateral malleolus, using a Velcro strap and over a piece of sock to protect the infant's skin and orientated consistent with the instructions in the Actical® manual (Appendix 6). Ankle placement has been used in other studies of infant movement (Angulo-Barroso et al., 2008; Angulo-Kinzler et al., 2002) and in studies of accelerometer placement for adults, counts have not differed significantly between body part sites. More importantly the site should reflect the type of activities that are being monitored (Atallah et al., 2011; Cleland et al., 2013). Infants wore the monitor for a continuous 24 hours to correspond to the same 24 hour period that the parent completed the DAIS, but was removed for water-based activities, such as bathing or swimming.

A meta-analysis of infant activity using parent report diaries, direct observation in the infant's home and activity monitors of varying degrees of sophistication, found that up to two days of monitoring was ideal, but that a shorter duration was a reliable timeframe for infants (Campbell & Eaton, 1999). The requirement for the parent in the current study to complete a 24 hour diary increased the burden of participation for the mother; so while not ideal, 24 hours was deemed appropriate for infants in the current study. Twenty-four hour monitoring has also used previously when measuring activity in infants with Down syndrome (Angulo-Barroso et al., 2008).

Activity was recorded in 15 second epochs. Studies of school aged children show that their activity can be in bursts of as little as two to five seconds (Rowlands & Eston, 2007), at the time of data collection the Actical® had a minimum epoch duration of 15 seconds. The accelerometer recorded infant movement at a sampling rate of 32Hz and expressed it as activity counts every 15 seconds.

The monitor was calibrated prior to use with the start date and time and commenced recording immediately after calibration every 15 seconds continuously for seven days. Date and time (hours, minutes, seconds) and activity counts were downloaded to an Excel spreadsheet.

4.4.5 Infant Behavior Questionnaire – Revised (Gartstein & Rothbart, 2003)

The Infant Behavior Questionnaire – Revised (IBQR) measures temperament of infants aged three to 12 months from the parent's perspective.

4.4.5.1. Structure and scores

The IBQR was normed on 360 US term infants, with equal numbers of male and female infants (Gartstein & Rothbart, 2003). It consists of 191 statements that reflect daily activities for infants. Infant's temperament is described as 14 traits: Activity level, Distress to limitations, Fear, Duration of orienting, Smiling & laughter, High pleasure, Low pleasure, Soothability, Rate of recovery from distress, Cuddliness, Perceptual sensitivity, Sadness, Approach and Vocal reactivity. The score for each trait is calculated by averaging the responses of the questions ascribed to the subscale. The resulting score is interpreted as a temperament trait that is rarely evident (low scores) or highly likely (high scores) in the child.

These 14 traits contribute to three factors derived by factor analysis. The first factor is termed Surgency/Extraversion (SE) and is calculated by summing the scores for Activity level, Smiling and laughter, High pleasure, Perceptual sensitivity, Approach and Vocal reactivity. The second factor is Negative Affectivity (NA) and is calculated by summing the scores for Sadness, Distress to limitations, and Fear and subtracting the score for Falling reactivity. The third factor is Orienting/Regulation (OR) and is calculated by summing the scores for Low pleasure, Cuddliness, Duration of orienting and Soothability.

Mothers were asked to complete the questionnaire by reading each statement and then choosing one response from seven options that ranged from "never" to "always" that best described her child during their daily interactions. Each response is attributed a score on a seven point Likert scale, ranging from one = never to seven = always. There is also an option of "does not apply" for each statement that mothers could choose if they believed that the statement did not apply to her child. For example, question four asked: "During feeding, how often did the baby notice lumpy texture in food (e.g. oatmeal)?" This question may elicit a "does not apply" if the child had not yet been introduced to solid foods.

4.4.5.2 Psychometric properties

Gartstein and Rothbart (2003) investigated the reliability of each trait and factor for three age groups. For infants aged three to six months, the Cronbach's alpha for the 14 traits ranged from .77 to .90, infants aged six to nine months had alphas from .70 to .89 and for infants aged nine to 12 months the reliability ranged from .71 to .87. Reliability of the factors scores were reported for the whole group. SE was .92 and for the other two factors was .91 each (Gartstein & Rothbart, 2003).

Although the IBQR has not been tested in Australian infants, it has been used in a number of cross-cultural studies, including infants from China, Italy, Japan, Poland, Russia, Spain and the USA. Internal consistency in these samples remained high with Cronbach's alphas ranging from .77 to .96 (Gartstein, Gonzalez, et al., 2006; Gartstein et al., 2005; Gartstein, Slobodskaya, & Kinsht, 2003; Gartstein et al., 2010; Montirosso et al., 2011).

Gartstein and Rothbart (2003) investigated the psychometric properties of the questionnaire with a sample of 360 infants stratified into three age groups: three to six months, six to nine months, and nine to 12 months. Factor analysis using principal axis extraction confirmed three factors: SE, NA and OR. Internal consistency of the 14 traits for the three age groups ranged from $\alpha = .7 - .9$. There were low correlations between the three factors SE – NA $r = .16$, SE – OR $r = .25$ and NA – OR $r = -.30$ suggesting that they identify separate behavioural traits. Internal consistency of the factors were SE $\alpha = .92$, and $\alpha = .91$ for both NA and OR. With a smaller sample of 26, inter-rater reliabilities between the primary and secondary caregivers for the 14 traits were low to moderately correlated $r = .06$ to .75, although not all correlations were significant. Correlations for inter-rater reliability between carers for the factors were higher SE $r = .49$, NA $r = .70$, and OR $r = .31$. There were gender differences for some traits with male infants scoring higher for the activity and high intensity pleasure traits and female infants scoring higher for fear. There were no gender differences for any of the three factors (Gartstein & Rothbart, 2003).

The IBQR has been independently evaluated in a sample of US term infants (n = 115) at six months of age and their mothers and found that internal reliability of traits was $\alpha = .70$ and there were no gender differences. There was low agreement between the IBQR traits of approach, fear and distress to limitations and observations of fear and anger during a laboratory task (Parade & Leerkes, 2008).

A number of cross-cultural studies have been conducted requiring back-translations for Chinese, Italian, Japanese, Polish, Russian and Spanish infants and parents. Structure of the IBQR has been tested in two separate Russian studies, and Polish and Italian studies. One Russian study (n = 90) found that a two factor structure was a better fit (Gartstein et al., 2003), while a larger sample (n = 202) found general agreement with the IBQR three factor structure (Gartstein et al., 2005). The Polish study also found a three factor structure but with different traits to both the original IBQR (Gartstein & Rothbart, 2003) and the larger Russian study (Gartstein et al., 2005), while the three factor structure of the original IBQR was satisfactory for the Italian study (Montirosso et al., 2011).

Internal consistency of the 14 traits Cronbach's alpha ranged from .60 to .92 for Russian (Gartstein et al., 2003), Spanish, Chinese (Gartstein, Gonzalez, et al., 2006), US (Parade & Leerkes, 2008), Polish (Dragan, Kmita, & Fronczyk, 2011) and Italian (Montirosso et al., 2011) samples. This is the same range as reported by the Gartstein and Rothbart (2003). Inter-rater reliability was significant $r = .61$ to .8 in a Polish sample (Dragan et al., 2011).

Cross-cultural administration of the IBQR has identified differences in infant traits and factors that appear to be culture specific, gender specific and an interaction between culture and gender. The differences do not follow any pattern, although there has been some speculation that Eastern-Western/Individualistic-Collectivistic comparisons are potential (Dragan et al., 2011; Gartstein, Gonzalez, et al., 2006; Gartstein et al., 2005; Gartstein et al., 2003; Gartstein et al., 2010; Montirosso et al., 2011).

The IBQR has not been used to interpret the temperament of preterm infants but has been used for infants with Down syndrome (Gartstein, Marmion, & Swanson, 2006). Permission to download the questionnaire and score sheet was granted on application to the authors via their website. The questionnaire was administered and scores calculated as per the authors' instructions.

4.5 Procedure

Following contact with families, a verbal explanation and the parent information sheet (Appendix 1) explaining the study were provided. A mutually convenient time was arranged for testing the infant in the family home. Prior to testing, the investigator explained what the motor assessment tests would involve, the questionnaires and how to complete the diary. The mother was given time to seek clarification before giving written consent to participate in the study (Appendix 7).

Infants were assessed using the PDMS2 and the AIMS, and their length, weight and head circumference measured. Crown-heel length with the ankles dorsiflexed to 90° was measured using a non-elastic tape measure fixed to a wooden ruler and recorded to the nearest .5 cm. Two measures were taken and a third if the previous two measures varied by more than 1.0 cm. Weight was measured using calibrated electronic infant scales (Charder Electronics, Cupid 2, Taiwan) and recorded in grams. Head circumference was measured using an inelastic tape measure positioned above the ears and recorded to the nearest .5cm. These measurements were conducted in a random order depending on the comfort and cooperation of the infant.

At the conclusion of the tests, the activity monitor was placed on the infant's right ankle and the mother shown how to orientate the activity monitor as she would need to remove it for bathing the infant. The monitor was worn continuously for 24 hours and only removed for water based activities.

The parent was asked to place the monitor, questionnaires and diary in an envelope (provided) in their letterbox for the investigator to collect. At the time of collection the investigator provided the parent with a written summary of their child's results of the PDMS2 and AIMS assessments.

4.6 Ethical issues

Ethical approval was granted from Curtin University's Human Research Ethics Committee, Women and Newborn Health Service ethics committee and the Child and Adolescent Health Service. The investigator had a current Working with Children Check and Police clearance documents.

Mothers who gave consent for their infants to participate were also included in the study. If English was the mother's second language or if the mother could not read English, then they were advised to seek language support so that they could complete the questionnaires and hence participate in the study.

The initial application to the Women and Newborn Health Service ethics committee stated that the physiotherapists conducting the preterm follow up playgroup would recruit suitable infants to the study and that the investigator would not contact families directly. This process required the physiotherapists to give the information sheet to the parents and the parents would then contact the investigator if they were interested in participating. There was very low uptake through this process. An amended ethics application was submitted and approval was granted for the investigator to approach parents in person during the follow up playgroup.

The parent information sheet stated that the researcher was an experienced paediatric physiotherapist, that parent and child participation in the study was voluntary and that they were free to withdraw from the study at any time without prejudice. Measures of their child's motor skills that were obtained as part of the study would not be released to therapy staff or any other third party by the investigator. Parents were provided with the motor assessment results for their child and were free to use those results with therapists at their discretion.

Consideration was given to the possibility that an infant may have abnormal movement or other developmental concerns that were not identified at the time of recruitment and prior to the parent consenting to participate. In the event that while testing of the infant during the home visit it became evident to the investigator that an infant had a movement disorder, then the outcome from the assessment was communicated to the parents. The mother was advised to seek further assessment by a general practitioner, paediatrician or physiotherapist. Only one preterm infant demonstrated abnormal movement patterns – the parent was advised to discuss the outcome of the assessment with the physiotherapist at the preterm follow-up playgroup.

Mothers who chose to participate were required to provide written consent for themselves and their child. They needed to be present with their infant throughout the testing. Each infant was allocated a study number that was used on all documentation to ensure infant and parent anonymity. Testing was conducted on a day and time that was convenient to the parent and when the infant was awake and ready to play (not tired or hungry).

Parents did not incur any expense while participating in the study, except time. Parents were informed that only group results from the study would be reported in the scientific literature and presented at conferences and no individual participant would be identified. At the conclusion of data collection, parents were sent group results of the outcomes of the motor testing (PDMS2 and AIMS), infant temperament and infant activity.

Chapter 5

Study 1 – The Effects of Chronological and Corrected Ages, Sex and Birth Weight for Gestational Age on Term and Preterm Infants' Motor Skills

5.1 Introduction

Motor development of infants born earlier than 32 weeks GA is delayed in the first year of life when assessed at chronological age (Allen & Alexander, 1990; Den Ouden et al., 1991; Palisano, 1986). The recommendation therefore is that evaluation of preterm infant motor development should be based on CA rather than chronological age. However, when corrected for gestation, the findings have been inconclusive. Some authors report that preterm infants' motor development during the first year of CA is similar to term infants (Restiff & Gherpelli, 2006; Gasson & Piek, 2003; Den Ouden et al., 1991; Allen & Alexander, 1990; Piper et al., 1989; Palisano, 1986), while other studies show a delay (Formiga & Linhares, 2011; Pin, Eldridge, et al., 2010; van Haastert et al., 2006). The discrepancy between motor outcome for chronological and CA differs as studies are not homogenous in terms of infants' GA, BW and body system sequelae and would benefit from further investigation. Cross-sectional studies report differences between term and preterm infants at CA, however some longitudinal studies show no difference and the potential for catch up, while others show delays that persist.

Early gestation is one risk factor for motor delay, but low BWGA has also been investigated. In particular, across all gestations, infants who are small BW for GA (SGA) are at a higher risk of morbidities compared with infants who are appropriate BW for GA (AGA) (Kiechl-Kohlendorfer et al., 2009; Pulver, Guest-Warnick, Stoddard, Byington, & Young, 2009). The association between SGA and motor development is inconsistent (Gagliardo, Goncalves, Lima, Francozo, & Netto, 2004; Roelants-van Rijn et al., 2004). Where motor delay is present this may be due to reduced muscle mass (Hediger et al., 2002) or a reduction in volume of cerebral cortical gray matter volume (Tolsa et al., 2004). SGA together with low family socio-economic status (Jelliffe-Pawlowski & Hansen, 2004), male sex and multiple birth (Lee, Green, Hintz, Tyson, & Parikh, 2010) appear to increase the risks of neurodevelopmental difficulties.

Differences in infant motor development have been found between male and female infants and may be due to the influence of sex hormones in the prenatal and early postnatal periods on brain development (Berenbaum & Beltz, 2011), brain structures (Peterson et al., 2000) and infant physiology (Alexander & Wilcox, 2012; Nagy, Kompagne, Orvos, & Pal, 2007; Piek et al., 2002).

The primary aim of this study was to investigate the contributions of GA, BWGA and infant sex on infant motor performance. The secondary aim was to determine if the term and preterm infants' gross motor performances were similar or different when measured using two different motor assessments, the PDMS2 and the AIMS.

5.2 Hypotheses

- Preterm infants at chronological age will have gross and fine motor delay compared with term infants, independent of sex and BWGA.
- There will be no difference in gross and fine motor performance between term and preterm infants at CA, independent of sex and BWGA.
- The PDMS2 GMQ and the AIMS percentile will not differ for infants at chronological and CA.

5.3 Data analysis

5.3.1 Sample size

An infant with a GMQ or FMQ of less than 85 points or 1SD on the PDMS2 is considered to be delayed. The same cut-point was used in this study as would be applied in a clinical setting.

Based on a mean of 100 and a standard deviation of 15, a minimum sample of 44 infants would be required to detect a difference of 15 points in GMQ or FMQ between two groups based on GA with 80% power and a probability of .05. A further 88 infants would be required to detect the same difference between male and female infants, and between infants SGA and AGA. Therefore, based on 1SD, then 132 infants in total would be required. The final sample of 180 (93 term and 87 preterm) infants is therefore adequate to detect differences in GMQ and FMQ between term and preterm infants, accounting for sex and BWGA.

5.3.2 Measures

Raw scores from the PDMS2 were converted to chronological age standardised gross motor (GMQ) and fine motor (FMQ) quotients for all infants and CA standardised quotients for preterm infants.

The number of successful items in each posture (supine, prone, sit, stand) and the total were ascertained for both groups of infants. Percentile-by-age ranks based on chronological age were ascertained for all infants and CA for preterm infants using the AIMS manual. While the authors advocate different percentile cut-points to determine delay (Darrah et al., 1998), as this is a cross-sectional study, a consistent cut-point $<5^{th}$ percentile was chosen to indicate delay, which was recommended by the authors to maintain high specificity (Darrah et al., 1998).

5.3.3 Assumption testing

The distributions of GMQ, FMQ and AIMS percentile-by-age rank data for chronological age and CA were checked by examining skewness (S) and kurtosis (K) values. Values for S and K were considered to be non-significant if the z-score was < 3.29 (Field, 2009). Homogeneity of variance for the term and preterm groups for GMQ, FMQ and AIMS percentiles for chronological age and CA were examined using Levene's test.

Agreement between the GMQ and the AIMS percentile-by-age rank for chronological age and CA was tested using cross-tabulations to determine positive and negative predictive values and Cohen's Kappa values.

Mean, standard deviation and range values are reported for GMQ, FMQ and AIMS percentiles for chronological age and CA for male and female infants. Percentages of male and female infants who were delayed and the proportions delayed based on BWGA status are also described.

Pearson's correlation coefficients were calculated between GA, sex and BWGA, and between GMQ, FMQ and AIMS percentiles for chronological age and CA with GA, sex and BWGA.

The data were examined to ensure that the regression assumptions were satisfied. Standardised residuals and Cook's distances were checked for outliers, graphs of the standardised Studentised residuals (*SRESID) were plotted against the standardised predicted (*ZPRED) values to examine the data for linearity and homoscedasticity (Field, 2009).

Four multiple hierarchical linear regressions were conducted to determine the main effects of GA, sex and BWGA on the GMQ at chronological age and CA; and FMQ for chronological age and CA. Interactions between GA and sex, and sex and BWGA were also entered into the model.

Data analyses were conducted using SPSS, version 19 (IBM Corporation, 2013).

5.4 Results

5.4.1 Assumption testing

Histograms of the GMQ, FMQ and AIMS percentiles for the term and preterm infants at chronological age and CA were visually inspected and are presented in Appendix 7. For the term infants the GMQ, FMQ and AIMS percentiles were normally distributed with acceptable S and K given the sample size. *Z*-scores were less than 3.29 for S and K for all three measures, except the FMQ had a K = 3.04 with a standard error of .49 and a *z*-score of 6.145 and was significant ($p < .05$).

For the preterm infants the GMQ, FMQ and AIMS percentiles for CA were normally distributed and the GMQ and FMQ for age were also normally distributed. The AIMS percentiles for chronological age were not normally distributed showing that there was a significant ($p < .05$) and very high proportion of infants who scored <5th percentile, S = 1.77 (SE = .26, *z*-score = 6.844) and K = 2.11 (SE = .51, *z*-score = 4.125).

The variances between the term and preterm groups for GMQ for chronological age and CA and the FMQ for CA were equal, but the variance was significantly different for FMQ for chronological age ($F(1, 178) = 11.09, p < .001$).

The assumptions for all four regression analyses were satisfied. Individual plots of *SRESID against *ZPRED were distributed randomly along the horizontal central axis indicating linearity and homoscedasticity for the four analyses. Cook's distances ranged from .000 to .145 (for GMQ chronological A), .000 to .091 (GMQCA), .000 to .083 (FMQ chronological A) and .000 to .091 (FMQCA). Collinearity was not a problem for any of the four models with all predictors having tolerance statistics in the range of .9 and a variance inflation factor (VIF) close to 1. However, when interactions were included in the model the collinearity statistics were problematic, with tolerance statistics decreasing to .1 and the VIF to greater than 10. GA, sex and BWGA were centred to improve the collinearity statistics and interactions again tested in the regression analyses but GA remained outside the limits of acceptability so interactions were excluded from the model.

5.4.2 Agreement between PDMS2 and AIMS

Table 5.1 reports the results of the testing for concordance between measures at chronological age. For all infants at chronological age, the positive predictive value was 87.9% that both measures identified the same infants as having GM delay, and the negative predictive value of 80.9% that both measures identified the same infants as not having GM delay. There was a chance agreement of 82.2% that the two GM measures would correctly identify the same infants as being either delayed or not delayed. Cohen's Kappa was .54 which is a substantial level of agreement (Viera & Garrett, 2005) and was significant at $p < .001$.

Table 5.1 Number of infants who were delayed or not delayed at chronological age based on their gross motor quotient and percentile-by-age rank values.

		AIMS percentile-by-age rank		
		Delayed	**Not delayed**	**Total**
PDMS2 GMQ				
	Delayed	29 (a)	4 (b)	33
	Not delayed	28 (c)	119 (d)	147
	Total	57	123	180

AIMS = Alberta Infant Motor Scale, PDMS2 = Peabody Developmental Motor Scales, version 2, GMQ = gross motor quotient, a = true positive, b = false positive, a/(a+b) = positive predictive value, c = false negative d = true negative, d/(c+d) = negative predictive value

Table 5.2 reports on the agreement between measures at CA. When the association between GM delay was examined for the term infants and the preterm infants at CA, 162 were not delayed on both measures and only one infant was delayed. The positive predictive value was low at 25% while the negative predictive value was high at 92%. Chance agreement that the two measures would identify infants correctly as delayed or not delayed was 90.5%. Cohen's Kappa percentage of agreement was 7.3% which is negligible (Viera & Garrett, 2005) and not significant (p = .22). The low level of statistical agreement is primarily due to the mis-match in number of cases in each cell, specifically the low numbers of infants identified as delayed by both measures.

Table 5.2 Number of term and preterm infants who were delayed or not delayed at corrected age based on their gross motor quotient and percentile-by-age rank values.

		AIMS percentile-by-age rank		
		Delayed	**Not delayed**	**Total**
PDMS2 GMQ				
	Delayed	1 (a)	3 (b)	4
	Not delayed	14 (c)	162 (d)	176
	Total	15	165	180

AIMS = Alberta Infant Motor Scale, PDMS2 = Peabody Developmental Motor Scales, version 2, GMQ = gross motor quotient, a = true positive, b = false positive, a/(a+b) = positive predictive value, c = false negative, d = true negative, d/(c+d) = negative predictive value

5.4.3 Chronological age

Tables 5.3 and 5.4 report the mean (SD) GMQ, FMQ and AIMS percentiles and the percentage of infants who were delayed, respectively. For the term infants, the mean GMQ and FMQ were close to the mean normative quotient of 100 stated in the PDMS2 manual. Three infants (two males and one female) had GM delay (< 85, 1SD < mean) and none had FM delay. Based on the mean AIMS percentile-by-age ranks the majority of the term infants were in the "not delayed" range, seven infants (three males and four females) had GM delay as they were below the 5th percentile (Tables 5.3 and 5.4). One male and one female infant with GM delay on the PDMS2 were also delayed on the AIMS.

The preterm infants for chronological age had mean GMQ and FMQ that were close to the cut-point for delay, that is 85. Of the 30 infants (16 males, 14 females) with GM delay, 11 had quotients that were < 78 (-1.5SD) and 19 had quotients between 78 to 85. Twenty-nine preterm infants (18 males, 11 females) had FM delay, with eight scoring < 78 and 21 scoring between 78 to 85. The mean AIMS percentile-by-age ranks were in the lower range of percentiles, with 50 preterm infants (25 males, 25 females) having GM delay as they were below the 5th percentile for chronological age (Tables 5.3 and 5.4). Twenty-eight infants with GM delay on the PDMS2 were also delayed on the AIMS.

5.4.4 Corrected age

GMQ and FMQ for the preterm infants at CA were similar to the term infants. The preterm infants at CA had mean GMQ and FMQ that were approximately 100; with only one male infant having GM delay with a quotient < 78, and one having FM delay with a quotient < 85. The mean AIMS percentile-by-age rank values were in the "not delayed" range and eight infants (three males, five females) had GM delay (Tables 5.3 and 5.4). The one male infant with GM delay on the PDMS2 was not delayed on the AIMS.

Table 5.3 PDMS2 mean (SD) gross, fine and total motor quotients and mean (SD) AIMS percentiles for term infants and preterm infants at chronological and corrected ages.

	Term			**Preterm**					
	Chronological Age			**Chronological Age**			**Corrected Age**		
	M	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**
	(n = 47)	(n = 46)	(n = 93)	(n = 46)	(n = 41)	(n = 87)	(n = 46)	(n = 41)	(n = 87)
PDMS2									
GMQ	98.2	99.2	98.7	85.3	85.8	85.5	97.0	99.3	98.1
	(6.8)	(6.3)	(6.5)	(7.6)	(6.5)	(7.1)	(6.9)	(5.5)	(6.4)
FMQ	99.0	101.1	100.1	85.5	87.6	86.5	97.6	100.9	99.2
	(4.9)	(6.1)	(5.6)	(7.0)	(5.6)	(6.4)	(6.1)	(3.8)	(5.4)
AIMS									
%-age	32.4	39.4	35.8	10.4	11.2	10.8	35.3	34.5	34.9
	(25.8)	(26.8)	(26.4)	(15.4)	(17.8)	(16.5)	(26.1)	(28.1)	(26.9)

PDMS2 = Peabody Developmental Motor Scales, version 2; AIMS = Alberta Infant Motor Scale; GMQ = gross motor quotient; FMQ = fine motor quotient; %-age = percentile-by-age rank, quotients < 85 = delay, percentiles < 5^{th} = delay

Table 5.4 Number (percentage) of term and preterm infants who were delayed at chronological and corrected ages.

	Term			Preterm					
	Chronological Age			Chronological Age			Corrected Age		
	M	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**
PDMS2									
GMQ	2	1	3	16	14	30	1	-	1
	(4.3)	(2.2)	(3.2)	(34.8)	(34.1)	(34.5)	(2.2)		(1.1)
FMQ	-	-	-	18	11	29	1	-	1
				(39.1)	(26.8)	(33.3)	(2.2)		(1.1)
AIMS									
%-age	3	4	7	25	25	50	3	5	8
	(6.4)	(8.7)	(7.5)	(54.3)	(61.0)	(57.5)	(6.5)	(12.2)	(9.2)

PDMS2 = Peabody Developmental Motor Scales, version 2; AIMS = Alberta Infant Motor Scale; GMQ = gross motor quotient; FMQ = fine motor quotient; %-age = percentile-by-age rank

5.4.5 Birth weight for gestational age

There were 149 (83.2% of total sample) who were AGA and 30 (16.8%) infants who were SGA. There were 82 term and 67 preterm infants in the AGA group, with mean (SD) BW of 2555.4g (1137.2), ranging from 590 to 4400g. In the SGA group, 10 infants were term and 20 were preterm, with mean (SD) BW of 1626.7g (886.1) and ranging from 586 to 3000g.

Table 5.5 reports the mean (SD) GMQ and FMQ for SGA and AGA term and preterm infants. Mean GMQ at chronological age (GMQA) for the term and preterm infants and the total SGA group were lower than for the AGA infants. Mean GMQ for CA (GMQCA) was also lower for the term and preterm and the total SGA group compared with the AGA infants.

Similarly, mean FMQ at chronological age (FMQA) and CA (FMQCA) and AIMS percentiles for the term and preterm and total SGA group was lower than for the AGA group.

Table 5.5 PDMS2 mean (SD) gross and fine motor quotients and mean (SD) AIMS percentiles for infants born small- and appropriate-for-gestational age.

	SGA			AGA		
	Term (n = 10)	**Preterm** (n = 20)	**Total** (n = 30)	**Term** (n = 82)	**Preterm** (n = 67)	**Total** (n = 149)
GMQA	97.3	84.5	88.8	98.9	85.8	93.0
	(3.3)	(8.8)	(9.6)	(6.8)	(6.5)	(9.3)
GMQCA	97.3	95.5	96.1	98.9	98.9	98.9
	(3.3)	(7.8)	(6.7)	(6.8)	(5.7)	(6.3)
FMQA	97.6	85.0	89.2	100.3	86.9	94.3
	(3.9)	(7.2)	(8.7)	(5.8)	(6.2)	(8.9)
FMQCA	97.6	96.7	97.0	100.3	99.9	100.1
	(3.9)	(6.1)	(5.4)	(5.8)	(4.9)	(5.4)
AIMS %-A	22.7	7.8	12.8	37.7	11.6	25.9
	(19.3)	(12.7)	(16.5)	(26.8)	(17.4)	(26.4)
AIMS %-CA	22.7	29.5	27.2	37.7	36.6	37.2
	(19.3)	(23.9)	(22.4)	(26.8)	(27.7)	(27.1)

SGA = small for gestational age; AGA = appropriate for gestational age; GMQA = gross motor quotient chronological age; GMQCA = gross motor quotient corrected age; FMQA = fine motor quotient chronological age; FMQCA = fine motor quotient corrected age; AIMS%-A = percentile-by-chronological age rank; AIMS%-CA = percentile-by-corrected age rank, quotients < 85 = delay, percentiles < 5^{th} = delay

5.4.6 Correlations

Table 5.6 reports the correlations between the main factors. GA, sex and BWGA were not correlated. GA was significantly positively correlated with GMQ and FMQ at chronological and CA and AIMS percentile at chronological age. Female sex was positively correlated with FMQ at CA only. AGA was positively correlated with GMQ and FMQ at chronological and CA and AIMS at chronological age.

Table 5.6 Correlations between gestational age, sex and birth weight for gestational age with gross and fine motor quotients at chronological and corrected ages.

	GA	**Sex**	**BWGA**
GA	___	.00	.10
Sex	.00	___	.11
GMQA	.78***	.06	.17*
GMQCA	.12*	.11	.15*
FMQA	.64***	.09	.17**
FMQCA	.12*	.19**	.17**
AIMSA	.44***	.05	.15*
AIMSCA	.08	.04	.11

GMQA = gross motor quotient chronological age, GMQCA = gross motor quotient corrected age, FMQA = fine motor quotient chronological age, FMQCA = fine motor quotient corrected age, AIMSA = percentiles-by-chronological age, AIMSCA = percentile-by-corrected age, GA = gestational age, *$p < .05$, ** $p < .01$, ***$p < .001$

5.4.7 Main effects

The main effects for the regression analysis for the GMQ for chronological and CA are reported in Table 5.7. For chronological age, the main effect of GA was significant showing that for every one week of age infants' GMQ increased by 1.4 points. The effects of sex and BWGA were not significant. With increasing GA, female sex and AGA together predicted 61% of the change in GMQ. For CA, later GA, female sex and AGA statistically together accounted for only 5% of the change in GMQ but this was significant ($p < .05$).

Table 5.7 shows the regression analyses for the main effects for the FMQ for chronological and CA. For chronological age, each of the three main factors were predictive of the variance in FMQ. For every additional week of GA there was an increase of 1.4 points in the FMQ, female infants contributed to 2.4 points in the

FMQ compared with male infants, and AGA contributed 2.8 points compared with SGA infants. Female infants for chronological age had a mean FMQ of 94.8 compared with males of 92.3; AGA infants had a mean of 94.3 and SGA of 89.2. The three factors together accounted for 70% of the variance.

For CA, GA was no longer significant. Female infants contributed 2.6 points to the FMQ as did AGA infants which were significant. Female infants had a mean FMQ of 101.0 compared with males 98.3. AGA infants had 100.1 and SGA of 97.0. GA, female and AGA infants accounted for 11% of the variance which remained significant.

Table 5.7 Multiple regression analyses predicting gross motor quotients and fine motor quotients for chronological and corrected ages from gestational age, sex and birth weight for gestational age.

GMQA	**Predictors**	**B**	**95% CI**	***B***	***sr²* x 100**	***p*-value**
	GA	1.368	1.202, 1.533	.769	58.369	.000
	Sex	1.075	-.686, 2.836	.057	.324	.230
	BWGA	2.052	-.318, 4.421	.081	.640	.089
	$R^2 = .614, p < .000$					
GMQCA	**Predictors**	**B**	**95% CI**	***B***	***sr²* x 100**	***p*-value**
	GA	.159	-.022, .339	.128	1.638	.084
	Sex	1.579	-.339, 3.497	.120	1.416	.106
	BWGA	2.270	-.310, 4.851	.129	1.638	.084
	$R^2 = .054, p = .021$					
FMQA	**Predictors**	**B**	**95% CI**	***B***	***sr²* x 100**	***p*-value**
	GA	1.372	1.232, 1.513	.805	64.000	.000
	Sex	2.394	.903, 3.885	.132	1.716	.002
	BWGA	2.724	.718, 4.730	.112	1.232	.008
	$R^2 = .699, p < .000$					
FMQCA	**Predictors**	**B**	**95% CI**	***B***	***sr²* x 100**	***p*-value**
	GA	.126	-.020, .272	.122	1.464	.090
	Sex	2.596	1.045, 4.146	.236	5.522	.001
	BWGA	2.561	.475, 4.648	.174	2.958	.016
	$R^2 = .114, p < .000$					

GMQA = gross motor quotient chronological age; GMQCA = gross motor quotient corrected age; FMQA = fine motor quotient chronological age; FMQCA = fine motor quotient corrected age; GA = gestational age; BWGA = birth weight for gestational age

5.5 Discussion

The major finding in this study is that preterm infants at chronological age were delayed in gross and fine motor skills compared with term infants, but at CA preterm infants' gross and fine motor skills were comparable with term infants. The other findings of significance are that male infants and infants SGA are at a higher risk of FM delay. Finally, the PDMS2 GMQ and the AIMS percentiles identified GM ability similarly for both term and preterm infants.

5.5.1 Effects of chronological and corrected ages on motor scores

Delay in GM and FM skills at chronological age are reported in the literature in low-risk preterm infants born less than 32 weeks GA (Allen & Alexander, 1990; Den Ouden et al., 1991; Palisano, 1986; Restiff & Gherpelli, 2006) and are consistent with the findings in this current study despite the differences in methodologies.

Allen and Alexander (1990) used a parent questionnaire when the preterm children (n = 100) were two years of age, to ask about selected gross motor milestones until the infant was walking and running. This method is at risk of recall bias, missing information, and differences in interpretation of skills as criteria for each skill were not specified. Den Ouden et al. (1991) assessed preterm infants at three, six, nine and 12 months of age using a developmental checklist specific to the Netherlands. While the preterm infants (n = 555) were delayed at all ages in their longitudinal study, the contribution of gross and fine motor skills to the overall delay could not be ascertained. The study by Palisano (1986) with a small sample (n = 23) used the original PDMS and assessed the children at 12 months and 18 months of age. While these findings are consistent with the current study, they are not directly comparable as the current study used a wider age group and the newer version of the PDMS. Finally, Restiff and Gherpelli (2006), in a cross-sectional prospective study (n = 43) assessed low-risk preterm infants using the AIMS. They concluded that while the infants were delayed during the first 12 months of life when they were assessed based on their chronological age, by 13 months chronological age, the infants' gross motor performance was similar to the expected norms of the AIMS. They recommended that preterm infants' motor development should be assessed based on CA during the first 12 months.

The risk with using chronological age for diagnostic purposes for preterm infants is that a disproportionate number of children may be classified as delayed because their degree of prematurity is not taken into account. The results from the current study found approximately one-third of the infants had GM and FM scores indicating delay, meaning that these infants would be labelled as delayed and offered services that might not be appropriate. The value of the earlier studies was that they reported outcomes for the preterm infants when they were toddlers and showed that the children's motor development approached term performance at 18 months to two years. Two key conclusions should be noted from these earlier studies: the first, is that CA in infancy may give a truer picture of an infant's motor development; and secondly, that low risk infants appear to catch up to their term peers by two years of age. This may be because body systems mature at different rates (Allen & Alexander, 1990; Den Ouden et al., 1991). Therefore the recommendation is that CA should be used when assessing motor development in preterm infants.

When corrected for prematurity, the preterm infants in the current study had similar GM and FM development compared with the term infants. This finding is supported by some published studies, but disagreed with others. The previously mentioned early studies by Palisano (1986) and Den Ouden et al. (1991) found no differences between the term and low risk preterm infants for both GM and FM skills at CA; and Allen and Alexander (1990) and Restiff and Gherpelli (2006) found no differences between groups in GM skills alone at CA.

The majority of studies have found delays in GM and FM skills at CA, whether GM and FM results are combined for a composite motor score (de Kieviet et al., 2009; Wolf et al., 2002), or separate for GM and FM skills (Sansavini et al., 2010; Snider et al., 2009), or only for GM skills (Bartlett & Fanning, 2003; Formiga & Linhares, 2011; Pin, Eldridge, et al., 2010; Spittle et al., 2009; van Haastert et al., 2006) or FM (Case-Smith, 1993; Churcher et al., 1993; Goyen & Lui, 2002; Thun-Hohenstein et al., 1991). There are a number of possible reasons why the current study findings differ from the literature. Broadly, these reasons can be grouped as 1) the sample of preterm infants, in particular recruitment and inclusion criteria, 2) the study designs and assessments used, and 3) social factors that influence infant motor development.

The years of recruitment for the previously cited studies range from the late 1970's to 2012. Infants for the current study were born between 2012 and 2013. Medical and nursing practices have changed considerably from the late 1970's to the mid-1990's, so it would be reasonable to suggest that infants with extremely early gestations who were born during those decades would be at a higher risk of adverse outcomes (Baron & Rey-Casserly, 2010). There are, however, some studies that have found no differences in motor development for infants born during those decades (Allen & Alexander, 1990; Den Ouden et al., 1991; Palisano, 1986). One possibility with the earlier studies is that some infants born with very early gestations were excluded as they had neurological or other conditions, or that the sample was strengthened because the more robust infants survived and thrived despite their low GA. Survival rates are high and incidence rates for common conditions associated with prematurity are low for the tertiary neonatal unit from where the sample included in the current study were recruited (French & McMichael, 2010). Data for 2012 and 2013 when the sample were recruited are not yet published.

Some studies have recruited infants from therapy follow-up programs (Bartlett & Fanning, 2003; Churcher et al., 1993; Formiga & Linhares, 2011; Goyen & Lui, 2002). Despite attendance at follow-up clinics these authors report that the preterm infants at CA were delayed in GM and FM skills compared with the term infants. In the current study, the majority of preterm infants were recruited from a preterm follow-up playgroup conducted in a tertiary hospital by physiotherapists, which might have assisted with their motor development. Infants were eligible to attend the playgroup if they were born earlier than 32 weeks gestation and/or BW <1500 grams. The rationale for inviting infants to the playgroup who met the eligibility criteria is that correcting for gestation acknowledges that premature delivery might compromise infant body systems and directly or indirectly affect motor development. Via the playgroup, parents are educated to stimulate their infant's development and to provide opportunities for practice and learning. However, not all the preterm infants in the current study received on-going care from allied health practitioners, so their motor development cannot be attributed entirely to the outcomes from therapy. The infants with gestations between 32 weeks to 37 weeks who participated in the current study attended a community based support group and did not have ready access to therapy services. While attending a therapy follow-up playgroup might have facilitated the motor development of the preterm infants, therapy input alone is unlikely to be the sole reason for the similarity between the term and preterm infants' motor skills in the current study.

Apart from GA, the other main inclusion criterion for preterm infants in many studies is whether they are deemed to be low or high medical risk. Studies vary in their definition of risk. Some studies define high risk as infants <32 weeks GA and <1500 grams, and some define low risk as infants with grades I and II intra-ventricular haemorrhage (IVH). For example, the combination of very preterm birth with IVH, chronic lung disease and antenatal steroid use has been associated with lower AIMS scores compared with term infants (Pin, Eldridge, et al., 2010). Other factors that increase the risk of poorer outcomes include type and duration of assisted ventilation, duration of supplemental oxygen, and social factors. In the current study, preterm infants were defined as being low risk if they did not have comorbidities in any body systems that would contribute to motor delay, that is no apparent chronic lung disease, an intact digestive system, no cerebral dysfunction identified by cranial ultrasound, no visual or hearing impairments, and no musculoskeletal disorders. Infants requiring assisted ventilation or supplemental oxygen during the neonatal period were not excluded as some infants were of very early gestations. The combination of medical and social/environmental factors may result in motor delay but the interaction of these factors are not reported in the studies that show a delay in GM and FM skills for preterm infants at CA.

Another inclusion criterion that differs between the published studies that report that preterm infants are delayed in GM and FM skills and the current study is the age group of the preterm sample. Some studies have included preterm infants at only one time point, for example eight months or 12 months (Bartlett & Fanning, 2003; Snider et al., 2009; Spittle et al., 2009) so it is difficult to know whether the delay they report between the term infants and the preterm infants is transient or persistent over developmental time. In contrast the current study included preterm infants from three to 12 months CA, however the cross-sectional study design may mask differences between term and preterm infants in GM and FM skills at specific ages.

More compelling evidence is provided by studies that have used longitudinal study designs and wider age ranges (Case-Smith, 1993; Churcher et al., 1993; de Kieviet et al., 2009; Fallang, Saugstad, & Hadders-Algra, 2003; Formiga & Linhares, 2011; Pin, Eldridge, et al., 2010; Sansavini et al., 2010; Thun-Hohenstein et al., 1991; van Haastert et al., 2006; Wolf et al., 2002). These longitudinal studies show the trajectory of motor development and in particular the peaks and troughs that are consistent with the Dynamic systems theory of motor development. For example, Sansavini et al. (2010) stratified their preterm group to extremely and very preterm based on GA and compared their GM trajectory from six to 24 months CA with term infants using the Griffiths Mental Development Scales birth to two years. Different trajectories and varying severity of outcome were evident in both the preterm groups but at different ages, and more adverse outcomes not being evident until the second year of age.

What also appears evident from the longitudinal studies is that preterm infants acquire GM skills differently to term infants, possibly due to motor strategies that constrain degrees of freedom (Fallang et al., 2003). van Haastert et al. (2006) suggest that one option is to compare motor development of preterm infants against their own normative data rather than using term normative data, at least in the first two years of life.

Additionally, assessment tools vary between studies to include those that measure quality of movement in clinical settings (The AIMS as used in the current study, (Pin, Eldridge, et al., 2010; Snider et al., 2009; van Haastert et al., 2006)), psychomotor assessments (such as the Bayley Scale of Infant Development – II, (Wolf et al., 2002) and the revised Griffiths Mental Development Scales, Birth to Two Years, (Sansavini et al., 2010)), and specific motor development (PDMS2, as used in the current study (Snider et al., 2009)).

The AIMS is one of the most frequently used measures of GM skills in preterm infants, but studies vary in the way in which the score is reported, making comparisons between studies difficult. Studies that have reported a difference in total AIMS score between preterm and term infants (Pin, Eldridge, et al., 2010) and between preterm infants with different levels of GM ability (Bartlett & Fanning, 2003) do not report the percentile-by-age rank as recommended by Piper and Darrah (1994). While both studies were adequately powered to detect differences in the total AIMS score, what is not reported is whether the small number of items that differentiated the groups was clinically significant. Reporting the percentile-by-age ranks and the number of preterm and term infants whose percentile was $<5^{th}$ indicating motor delay would assist readers to interpret scores accurately. The current study used the definition of delay as a total score $<5^{th}$ percentile for age to enable comparisons to be made across ages as this was a cross-sectional study.

Only one published study with preterm infants < 32 weeks GA (n = 100) has used both the PDMS2 and the AIMS and the same cut-points for defining GM delay (Snider et al., 2009) as the current study. The percentage of preterm infants who were delayed based on the GMQ (n = 1) was similar to the current study, but the percentage who were delayed based on the AIMS percentile (n = 26) was higher than the current study. The difference in outcomes between the Snider et al. (2009) study and the current study may be due to differences in age (12 months CA versus three to 12 months CA) and GA (<32 weeks versus <37 weeks). In particular, the current study found that the GMQ and the AIMS percentiles had a very high level of agreement and were able to identify the same infants as being delayed.

Similar findings are reported for preterm infants' FM skills at CA compared with the term infants (Case-Smith, 1993; Churcher et al., 1993; Thun-Hohenstein et al., 1991). These studies have used different assessment tools and both cross-sectional and longitudinal designs. The Case-Smith (1993) study used the Movement Assessment for Infants (Chandler, Andrews, & Swanson, 1980) which had a limited number of FM items and little fine grading within each item to differentiate between age groups (Harris, Haley, Tada, & Swanson, 1984). Churcher et al. (1993) used the original version of the PDMS, a high risk preterm sample and no term group comparison. While the mean FMQ was within the average range, the percentage of infants with FMQ below average varied depending on the age of the infants. Finally, the Thun-Hohenstein et al. (1991) study included a large sample (n = 505) born between 1974 to 1978 and followed preterm infants at one, three, six, nine and 12 months using the Griffiths assessment. They found differences at six and nine months only. The authors believed that environmental influences strongly impacted FM development.

The limited studies on development of FM skills may be due to the difficulty in identifying key FM skills that are applicable for infants from different cultures and environments. A broad universal approach to measuring FM skills similar to the assessment of GM skills conducted by the WHO in healthy term infants (WHO Multicentre Growth Reference Study Group, 2006b) has not been reported. In the current study, FM skills were similar between the preterm group at CA and term infants, although FM skills were delayed for male infants and infants born SGA.

There are a number of social factors that should be considered that might explain the apparent or actual delay in GM and FM skills between preterm and term infants reported in the published studies, and the similarity between preterm and term infants in the current study. The first of these is the influence of culture on parenting practices. Parenting is shaped by the social context in which the parent-child relationship is embedded (Halpern, Brand, & Malone, 2001). Social behaviours are unique in a culture such that parenting practices comprise distinctive patterns that regulate daily life (Bornstein, 2012). For example, mothers who encourage their infants' motor development by providing them with activities with the aim of increasing their development have infants with better motor development (Arnott & Brown, 2013; Bornstein, 2012).

Within cultures the effects of sociodemographic factors, such as maternal education and age (Keller et al., 2009) and socioeconomic status (SES), in particular family income (Fouts, Roopnarine, & Lamb, 2007) have been shown to influence infant outcomes. In some instances these more proximal factors result in infant behaviours that appear to eliminate the effects of culture such that infants are more alike because of SES despite cultural diversity (Keller et al., 2009). This might be an effect in the current study as the majority of mothers were educated and the family income favoured economic advantage.

Some of the differences in motor outcomes reported in the literature may be due to the social milieu in which the study was conducted. van Haastert et al. (2006) found that their Dutch preterm sample followed from one to 18 months CA had lower scores compared with the published Canadian term norms (Piper & Darrah, 1994). This is consistent with the findings of Formiga and Linhares (2011) who sampled Brazilian preterm infants between one and 12 months CA, but differs to that of Jeng et al. (2000) who assessed Taiwanese preterm infants at the same age and found no differences between their sample and the Canadian norms.

In summary, the current study found that low risk, healthy preterm infants between three and 12 months CA had similar GM and FM skills to term infants, measured using two comparable discrete tools. This finding is not supported by the majority of published studies possibly due to a combination of factors including differences in inclusion criteria of preterm infants, study designs, assessment tools used and social factors.

5.5.2 Sex differences

When comparing term and preterm infants' GM and FM skills only two studies have reported sex differences. Snider et al. (2009) found that male preterm infants had better GM skills measured using the AIMS at 12 months CA, while Vohr et al. (2000) found that male extremely preterm infants were at a higher risk of motor delay based on the BSID-II total motor score and for overall neurodevelopmental morbidity.

The current study found that male infants had lower FM skills compared with female infants, independently of GA. Naeye et al. in 1971 described the higher rates of morbidity and mortality of male term infants compared with female term infants as the "male disadvantage" (Naeye, Burt, Wright, Blanc, & Tatter, 1971). Similar findings are reported for male preterm infants (Stevenson et al., 2000). Both of these studies have focused primarily on health status of male and female term and preterm infants. More recent data report that 55% of preterm births are male, and that they have higher risks of fetal and neonatal mortality and long term impairments compared with female infants of the same GA (Blencowe et al., 2012). Therefore, the findings in the current study of male infants having poorer FM skills would appear to support this.

Sex differences in infant motor development have been found on direct observation and kinematics, and an increased understanding of infant physiology and brain development. An observational study of neonates (six to 96 hours of age) showed that term females had more spontaneous and better imitative finger movements than term males (Nagy et al., 2007), while a kinematic study in early infancy (six to 18 weeks of age) found that coordination and coupling of upper limb movements were better in females than males (Piek et al., 2002). The results of the current study would suggest that these early differences continue during the first year of life and are supported by studies based on parent report of infants from two weeks to two years that male term infants had poorer FM skills compared with female term infants (Capute, Shapiro, Palmer, Ross, & Wachtel, 1985; Touwen, 1976).

Similarities between male and female infants in FM skills in term (Angulo-Barroso et al., 2011) and preterm (Thun-Hohenstein et al., 1991) infants are also reported. The study by Angulo-Barroso et al. (2011) included term infants (n = 209) aged nine months but did not use a standardised measure. The strength of their study however, was that it included urban infants from China, Ghana and the US, with cultural and parental factors being stronger predictors of infant performance. Thun-Hohenstein et al. (1991), in a longitudinal study of preterm infants (n = 97) born between 27 to 36 weeks GA and AGA and term infants (n = 93), found no sex differences in FM skills measured using the Griffiths developmental test (earliest version, 1956) at CA of six and nine months.

The inconsistent findings between male and female infants' FM skills is likely due to a combination of factors, including differences in measurement tools, study samples and study designs. Similar to other aspects of human behaviour, multiple factors interact and contribute to development of FM skills. However, the male disadvantage (Naeye et al., 1971) appears to predispose males to more neurodevelopmental disorders, such as developmental coordination disorder, autism spectrum disorder, attention deficit/hyperactivity disorder and specific language impairment (Bao & Swaab, 2010).

The increased risk to male children has been partly attributed to sex differences in the brain due to the presence of two peaks in the levels of testosterone from six to 12 weeks of pregnancy and again in the first three months of life. Testosterone is thought to influence the structure and function on the fetal and infant brain such that the presence of the hormone facilitates male brain growth, and its absence promotes female growth (Bao & Swaab, 2010). Structurally, overall brain weight is higher in male infants but not when corrected for body weight; and various regions of the brain differ in weight between male and female infants and children (Ruigrok et al., 2014; Sacher, Neumann, Okon-Singer, Gotowiec, & Villringer, 2013). The magnitude of the difference in gross architecture of the brain is small, even in the areas that are associated with visuo-spatial ability which has one of the largest sex differences. While gross architecture may be different between the sexes studies of neural circuits do not show sex differences (Eliot, 2011). Studies using functional magnetic resonance imaging (fMRI) show that many areas of the brain are active during motor tasks, so differences in brain volume between male and female infants are not necessarily indicative of FM delay. Furthermore, the relationship between structure and function is not well understood, specifically in children and for motor development (Ruigrok et al., 2014).

With gathering evidence that there are likely physiological reasons for sex differences, there is also evidence that parenting behaviours differ for male and female infants. Mothers are reported to place more emphasis on development of their female infant, such as encouraging motor and cognitive skills and ensuring that their female infant met developmental milestones (Arnott & Brown, 2013). Female infants tend to show more interest in their mother's faces and boys to objects (Alexander & Wilcox, 2012); and there are sex differences in temperament traits (Gartstein & Rothbart, 2003). Infant and parent social behaviours and expectations independently and in combination might contribute to differences in the amount and type of practice in which infants engage when learning motor skills, favouring better outcomes for girls.

5.5.3 Small for gestational age

The third key finding in the current study is that infants born SGA have a greater risk of FM delay. A number of studies have confirmed delay in motor skills in SGA infants compared with AGA infants based on the psychomotor development index (PDI) from the BSID-II, which is a combination of gross and fine motor skills (Black et al., 2004; Hediger et al., 2002; Jelliffe-Pawlowski & Hansen, 2004). Two of these studies were large population based cohorts and included term and preterm infants, while the third study also had a large sample (n = 200) but of term infants only. However, a recent study with a small preterm sample of SGA and AGA infants found no differences between groups at one year of age based on the PDI (Pinello, Manea, Pozza, Mazzarolo, & Facchin, 2013). The effect of SGA on FM skills specifically cannot be ascertained from the results of these studies as the PDI is a composite of GM and FM skills.

Gagliardo et al. (2004) measured FM skills using the items from the BSID-II in term born (n = 42) SGA and AGA infants at one (n = 20 AGA, 11 SGA), two (n = 19 AGA, 14 SGA) and three (n = 21 AGA, 13 SGA) months of age. They found no differences in total FM scores (a computed variable from the test items). This was a cross-sectional study, with a different cohort and varying small sample size of infants in each age group at each age (Gagliardo et al., 2004). The similarity in FM skills between SGA and AGA infants in this study might be due to the scoring procedure and the sample size.

While there are only a few studies reporting an association between SGA and FM skills in infancy, Bos et al. (2013), in a comprehensive review, report that SGA increases the risk of FM delay in school aged children (Bos, Van Braeckel, Hitzert, Tanis, & Roze, 2013).

There are a number of reasons why SGA infants might be delayed in FM skills. Fetal growth patterns and the effect on fetal body systems in utero as well as post-natal growth have been investigated. The fetal growth patterns of SGA infants whether term or preterm can affect outcomes from infancy through adulthood (Hay et al., 1997). Infants with symmetrical growth restriction are often at risk of negative environmental influences, such as poor maternal health and low SES so tend to have compromised growth throughout the pregnancy. These environmental factors are not associated with specific FM delay but are associated with an increased risk to overall development (Black et al., 2004; Hediger et al., 2002). A major contributor to infants with asymmetrical growth restriction is placental insufficiency which tends to place the infant at an increased risk of hypoxaemic-ischaemic encephalopathy with the potential to compromise brain development (GRIT Study Group, 2003; Roelants-van Rijn et al., 2004).

In the current study, infant BW and GA were recorded, but not birth length or head circumference, nor were maternal risk factors such as placental insufficiency or antenatal health factors, so the delay in FM skills of the SGA infants, could not be associated with type of fetal growth pattern. Also, the SGA infants were not delayed for GM skills. However, the finding remains credible and is supported by a large population based study that found motor delay at eight months in SGA infants compared with AGA infants on the PDI but no difference between asymmetric and symmetric SGA infants (Jelliffe-Pawlowski & Hansen, 2004).

5.5.4 Congruency between measures

The final significant finding in the current study was that both the PDMS2 GMQ and the AIMS percentiles-by-age identified similar percentages of infants with and without delay. This consistency strengthens the conclusions regarding the GM skills of the infants appear sound. The authors of the AIMS report concurrent validity with the original PDMS for typically developing and at risk infants from birth to 13 months of age as $r = .99$ and .91, respectively (Piper & Darrah, 1994). Comparisons between the AIMS and the PDMS2 scores for typical and preterm infants are not reported but would likely be similar.

5.5.5 Summary

In summary, the main findings of this study are that healthy, low risk preterm infants at CA are not delayed in their GM and FM performance compared with term infants. These findings are consistent with two discrete comparable measures of GM performance. Male infants and infants SGA are at risk for FM delay. Consistent with the finding in this study, in the remaining studies only CA will be used in analyses.

Chapter 6

Study 2 – Temperament in term and preterm infants

6.1 Introduction

Infant temperament is a broad construct that has been described as an organizer of development, but not motor development *per se* (Eaton et al., 2001; Marshall, Fox, & Henderson, 2000). Temperament is inherent (Goldsmith et al., 1987) and comprises behavioural and emotional responses that infants display towards people and their environment (Rothbart, Chew, & Gartstein, 2001). It is relatively stable over time (Casalin et al., 2012; Pedlow, Sanson, Prior, & Oberklaid, 1993; Riese, 1987; Rothbart et al., 2000) and can be described as a number of traits. These traits appear to be consistent irrespective of the task or the situation in which the infant is engaged (Gartstein et al., 2003), but individual experiences and environmental factors may influence how temperament traits are expressed (Anzman-Frasca, Stifter, & Birch, 2012).

Infant interactions with their parents during routine daily activities, whether during feeding, bathing or playing provide opportunities for measuring infant temperament from the parent's perspective (Gartstein & Rothbart, 2003). A parent's perception of their infant's temperament may differ from those of independent observers as parents interpret their infant's behaviour idiosyncratically (Crockenberg & Acredolo, 1983).

While the temperament traits are considered to be inherent and behaviourally consistent, nevertheless as the infant develops there are developmental changes that occur in the expression of those traits (Pedlow et al., 1993). In a number of temperament studies of typical infants, parents report differences in some temperament traits between male and female infants (Gartstein, Gonzalez, et al., 2006; Gartstein et al., 2010; Montirosso et al., 2011), between younger and older infants (Gartstein et al., 2003; Gartstein et al., 2010; Montirosso et al., 2011), cultural differences (Dragan et al., 2011; Gartstein, Gonzalez, et al., 2006; Montirosso et al., 2011) and cultural differences for some traits that outweigh both sex and age differences (Gartstein, Gonzalez, et al., 2006; Super et al., 2008). Where cultural differences exist these have been explained as the influence of Eastern (eg. China, Japan, Poland) versus Western (USA, Spain, Italy) aspects of culture (Gartstein et al., 2010) or as collectivistic (China, Italy) versus individualistic (US, Australia) aspects of culture (Montirosso et al., 2011). Culture potentially shapes the infant's temperament, but may also influence how parents interpret their infant's temperament.

Studies of temperament in preterm infants have yielded varying results. Comparisons of temperament traits of preterm with term infants as reported by parents show that preterm infants are more irritable, have more negative mood, are less regular, are less adaptable and difficult to settle (Gennaro et al., 1990; Langkamp et al., 1998). There appears to be less stability of temperament traits in preterm infants during the first 12 months of life. Hughes et al. (2002) report that by 12 months CA preterm infants show less persistence and shorter attention to task than term infants. They postulated that the central nervous system of preterm infants may be disorganised due to the combination of the immature premature brain with the early medical care required and other postnatal events thereby influencing the preterm infants' behavioural responses (Hughes et al., 2002). Interaction between parents and their preterm infant could also be influenced by parental anxiety and over-protectiveness due to the vulnerability they perceive of their preterm infant (Gennaro et al., 1990; Hughes et al., 2002).

In contrast, cross-sectional and longitudinal follow-up of Australian children found no differences between preterm and term infants in individual temperament traits or global maternal ratings or sex differences. Further, temperament appeared stable for both groups of infants from six months to six years (Oberklaid, Prior, & Sanson, 1986; Oberklaid et al., 1991). A more recent study comparing a few select temperament traits between preterm and term infants found no difference between groups for any trait (Langerock et al., 2013). Some traits appear to be stable while others have less stability between six and 12 months CA (Bornstein et al., 2015).

Many of the published studies on temperament in preterm infants have been conducted more than two decades ago and primarily used the temperament measures designed by Chess and Thomas (1977). The current study measured temperament using the IBQR that has not been used with term or preterm Australian infants.

The aim of this study was to investigate term and preterm infant temperament by addressing the following research questions:

1. Do Australian term and preterm infants have similar temperament profiles measured using the IBQR?
2. Do mothers of preterm infants interpret their infants' temperaments differently to mothers of term infants and are their views influenced by infant CA, sex and BWGA?

6.2 Hypotheses

The following hypotheses were tested:

- Australian infants will have similar trait scores as the original US sample, independently of infant CA, sex and BWGA.
- Mothers of term and preterm infants will score their infants differently, independently of infant CA, sex and BWGA for the three temperament factors of surgency/extraversion, negative affectivity and orienting/regulation.

6.3 Data analysis

6.3.1 Sample size

Four mothers did not complete the IBQR. Their infants were one term male infant three months of age, two preterm female infants six months CA and one preterm male infant 11 months CA. This reduced the sample from 180 infants to 176 infants, with 92 term (46 males, 46 females) and 84 preterm (45 males, 39 females) infants.

Maternal age was dichotomised from four categories into "younger mothers" (< 30 years) and "older mothers" (≥ 30 years), and mothers' level of education was also dichotomised into "technical education or less" and "university education". Mothering experience was defined as "inexperienced" if the infant was the mother's first child (including twins) and "experienced" if the infant was the second or subsequent child.

6.3.2 Measures

The 14 trait scores of the IBQR were calculated and factor scores were calculated from trait scores as follows:

- Surgency/extraversion (SE) = activity level + vocal reactivity + high pleasure + smiling and laughter + approach + perceptual sensitivity
- Negative affectivity (NA) = sadness + distress to limitations + fear - falling reactivity
- Orienting/regulation (OR) = low pleasure + cuddliness + duration of orienting + soothability

The 14 traits and three factor scores were used in analyses.

6.3.3 Assumption testing

The distribution of trait and factor scores of the IBQR for term and preterm infants was checked by examining skewness (S), kurtosis (K) and homogeneity of variance using Levene's test. Z-scores for S and K are considered to be non-significant if < 3.29 when the sample size is moderate (that is > 50 but < 300) (Field, 2009). However, a more conservative z-score of <1.96 was applied for this sample as the sample sizes for the term and preterm groups were not appreciably higher than 50 (Field, 2009).

Mean (SD) trait and factor scores of the IBQR were calculated and independent samples t-tests were used to compare the scores for the traits and factors between term and preterm and male and female infants. To determine whether the Australian infants in the current study were comparable with US infants a series of single sample t-tests were conducted on the 14 traits using the results published in 2005 (Gartstein et al., 2005). The t-tests were computed by using syntax in SPSS (Field, 2009) with the mean, SD and sample size of the US sample. Correlations between the factors were calculated for the Australian sample and referenced against the published values from the validation of the IBQR with a US cohort (Gartstein & Rothbart, 2003).

Only CA was used in analyses, consistent with the findings in the previous study that found that preterm infant motor development is best interpreted using CA. Chronological age was examined as well and is reported in Appendix 8.
Prior to testing whether infant CA, sex and BWGA predicted any of the three temperament factors, correlations were calculated between infant characteristics and SE, NA, and OR. For all correlations, Pearson's correlations were calculated for continuous data and point-biserial for discrete and dichotomous data.

Linear regressions were used to test the relationship between infant characteristics and temperament factors. Infant characteristics that were significantly correlated with temperament factors were entered into each regression model to increase the power of the analysis.

The models were examined to ensure that the regression assumptions were satisfied. Standardised residuals and Cook's distances were checked for outliers. Graphs of the Studentised residuals (*SRESID) were plotted against the standardised predicted (*ZPRED) values to examine the data for linearity and homoscedasticity (Field, 2009).

Data analyses were conducted using SPSS, version 19 (IBM Corporation, 2013).

6.4 Results

6.4.1 Australian infants' temperament

Tests for normality for the term infants' found that fear (S = 1.309, *z*-score = 5.215, K = 2.332, *z*-score = 4.682), high pleasure (S = -1.295, *z*-score = 5.159, K = 2.244, *z*-score = 4.506), falling reactivity (S = -.580, *z*-score = 2.310), vocal reactivity (S = .520, *z*-score = 2.071) and OR (K = 1.097, *z*-score = 2.202) had *z*-scores that were outside the acceptable limit and indicated non-normal distribution. These scores suggest that either term infants in the study were "easy going" infants or that their behavior was interpreted by their mothers as "easy going". Infants who were easy to parent may have been over-represented in this study. The demands of the study methods may have biased mothers with easier infants to volunteer to participate. The distribution of the remaining traits and factors were satisfactory (Field, 2009).

For the preterm infants, fear (S = .927, z-score = 3.524), high pleasure (S = -1.114, z-score = 4.235, K = 1.122, z-score = 2.157), cuddliness (S = -.607, z-score = 2.307), approach (S = -.965, z-score = 3.669), soothability (K = 1.16, z-score = 2.230) and OR (K = 1.908, z-score = 3.669) had z-scores that exceeded the acceptable limit, indicating non-normal distributions. Similar to term infants, mothers of preterm infants with easier temperaments may have been more likely to participate. Skewness and kurtosis of the remaining traits and factors were satisfactory.

Means (SD) for the traits and factors for the term and preterm and male and female infants are reported in Table 6.1. There was a significant difference between the term and preterm infants for only the smiling and laughter trait (F = 6.050, $p < .05$, df = 174) with the preterm infants reported to demonstrate more smiling and laughter behaviours than term infants. There was a significant difference between male and female infants for only the NA factor (F = 6.642, $p < .05$, df = 174) with female infants having higher NA scores than male infants.

As there were no differences between the term and preterm infants except for the smiling trait, data for both groups were pooled for further analyses. There were low correlations between SE and NA (r = .086, p = .255), SE and OR (r = .29, $p < .01$), and NA and OR (r = -.19, $p < .05$). The magnitude of these correlations are comparable to those reported for the validation study with US infants (n = 360): SE and NA (r = .16), SE and OR (r = .25), NA and OR (r = -.30) (Gartstein & Rothbart, 2003).

The mean (SD) values of the total Australian sample and cross-cultural samples from the literature are provided in Table 6.2. Comparing the Australian infants in the current study with a large US cohort of 379 infants (Gartstein et al., 2005) on traits. The Australian infants scored higher on the activity level trait (t = 2.54, $p < .01$), duration of orienting trait (t = 2.78, $p < .01$), smiling trait (t = 2.14, $p < .05$) and perceptual sensitivity trait (t = 2.54, $p < .01$), and were comparable with the US infants for all other traits.

It would appear that the mothers of the term and preterm infants in the current study score their infants similarly to mothers of US infants and therefore based on these comparisons, the IBQR appears to be an appropriate measure of temperament for Australian infants.

Table 6.1 Mean (SD) temperament trait and factor scores of the term and preterm infants.

Characteristics	**Term**			**Preterm**		
	M (n = 46)	**F (n = 46)**	**Total (n = 92)**	**M (n = 45)**	**F (n = 39)**	**Total (n = 84)**
Factors and Traits						
Surgency/Extraversion	28.3 (4.4)	29.4 (3.7)	29.4 (4.1)	29.9 (4.4)	28.9 (4.8)	29.5 (4.6)
Activity level	4.6 (0.9)	4.4 (0.9)	4.5 (0.9)	4.5 (0.9)	4.3 (0.8)	4.4 (0.9)
Vocal reactivity	4.6 (1.1)	4.9 (0.9)	4.7 (1.0)	4.7 (1.1)	4.8 (1.1)	4.7 (1.1)
High pleasure	5.9 (0.6)	5.7 (0.9)	5.8 (0.8)	5.8 (0.7)	5.8 (0.8)	5.8 (0.8)
Smiling & laughter	4.8 (0.8)	4.9 (0.6)	4.8 (0.7)*	5.1 (1.0)	4.9 (1.1)	4.9 (1.0.)*
Approach	5.1 (0.9)	5.2 (1.0)	5.1 (1.0)	5.3 (1.0)	5.1 (1.3)	5.2 (1.1)
Perceptual sensitivity	4.2 (1.1)	4.3 (0.9)	4.2 (1.0)	4.4 (1.1)	4.2 (1.3)	4.3 (1.2)
Negative affectivity	4.0 (2.7)**	4.8 (2.3)**	4.4. (2.5)	3.9 (2.9)**	5.0 (2.1)**	4.4 (2.6)
Sadness	3.3 (0.9)**	3.4 (0.7)**	3.3(0.8)	3.3(0.9)**	3.7 (0.8)**	3.4 (0.9)
Distress to limitations	3.6 (0.9)	3.7 (0.8)	3.6 (0.9)	3.4 (0.8)	3.7 (0.6)	3.5 (0.7)
Fear	2.4 (1.1)	2.6 (0.7)	2.5 (0.9)	2.3 (0.9)	2.6 (0.9)	2.4 (0.9)
Falling reactivity	5.3 (0.8)	4.9 (1.0)	5.1 (0.9)	4.9 (0.9)	4.9 (0.8)	4.9 (0.9)

	Term			Preterm		
	M	**F**	**Total**	**M**	**F**	**Total**
Orienting/regulation	19.4 (1.9)	19.1 (2.2)	19.3 (2.0)	19.4 (2.4)	19.6 (1.8)	19.5 (2.2)
Low pleasure	4.9 (0.9)	4.9 (0.7)	4.9 (0.8)	5.1 (0.8)	5.1 (0.8)	5.1 (0.8)
Cuddliness	5.7 (0.6)	5.3 (0.7)	5.4 (0.7)	5.3 (0.7)	5.5 (0.6)	5.4 (0.7)
Duration of orienting	3.9 (1.0)	3.9 (0.9)	3.9 (0.9)	4.1 (1.1)	4.2 (0.9)	4.1 (1.0)
Soothability	4.9 (0.7)	4.9 (0.7)	4.9 (0.7)	4.9 (0.7)	4.9 (0.8)	4.9 (0.7)

* significant difference between term and preterm infants, ** significant difference between male and female infants

Table 6.2 Comparisons of the mean (SD) traits scores of the Australian infants with US, Russian and Polish infants.

	Australia (n = 176)	**USA'03 (n = 90)**	**Rus'03 (n = 90)**	**USA'05 (n = 379)**	**Rus'05 (n = 202)**	**USA'08 (n = 115)**	**Poland'11 (n = 383)**
Activity level	4.5 (0.9)*	4.2 (0.9)	4.0 (1.1)	4.3 (0.8)*	4.1 (1.1)	4.5 (0.8)	4.1 (0.8)
Vocal reactivity	4.7 (1.1)	4.7 (0.9)	4.0 (1.1)	4.7 (0.9)	4.2 (1.1)	5.0 (0.9)	4.5 (0.9)
High pleasure	5.8 (0.8)	5.8 (0.7)	5.2 (1.5)	5.9 (0.7)	5.5 (1.3)	5.6 (0.6)	5.1 (1.1)
Smiling & laughter	4.9 (0.9)*	4.8 (0.9)	4.1 (1.3)	4.7 (0.9)*	4.3 (1.1)	5.2 (0.9)	4.5 (0.9)
Approach	5.2 (1.1)	4.8 (1.2)	4.4 (1.5)	4.9 (1.1)	4.8 (1.4)	5.4 (0.9)	4.8 (1.0)
Perceptual sensitivity	4.3 (1.1)*	4.1 (1.1)	3.2 (1.4)	4.0 (1.1)*	3.5 (1.5)	4.1 (1.0)	3.7 (1.1)
Sadness	3.8 (0.8)	3.5 (0.9)	3.7 (1.1)	3.5 (0.9)	3.7 (1.2)	3.1 (0.9)	3.8 (0.8)
Distress to limitations	3.6 (0.8)	3.6 (0.8)	3.9 (0.9)	3.6 (0.9)	3.8 (0.9)	3.2 (0.7)	3.9 (0.7)
Fear	2.5 (0.9)	2.5 (0.9)	2.9 (1.4)	2.6 (1.0)	2.9 (1.3)	2.2 (0.8)	3.4 (1.1)
Falling reactivity	5.0 (0.9)	4.9 (1.1)	4.5 (1.2)	5.0 (1.0)	4.8 (1.2)	5.3 (0.8)	4.5 (0.8)
Low pleasure	5.0 (0.8)	5.2 (0.8)	4.7 (1.2)	5.1 (0.9)	4.6 (1.2)	5.6 (0.8)	4.6 (0.9)
Cuddliness	5.4 (0.7)	5.5 (1.0)	5.4 (0.9)	5.4 (1.0)	5.5 (0.9)	5.8 (0.7)	5.4 (0.9)
Duration of orienting	4.0 (1.0)*	3.8 (1.2)	4.1 (1.3)	3.8 (1.0)*	4.2 (1.2)	4.3 (1.0)	3.8 (1.0)
Soothability	4.9 (0.7)	4.7 (1.2)	4.3 (1.4)	4.8 (1.0)	4.7 (1.2)	5.1 (0.6)	4.6 (0.9)

*Difference between Australian sample and US 2005 sample $p < .05$

6.4.2 Relationship between infant characteristics and infant temperament

Table 6.3 reports the correlations between the infant characteristics and temperament factors. There was a positive correlation between infant CA and SE and a negative correlation between CA and OR. Female sex was positively correlated with NA. GA and BWGA were not correlated with any of the three temperament factors.

Table 6.3 Correlations between infant characteristics with infant temperament.

	CA	**GA**	**Sex**	**BWGA**
Surgency/extraversion	.548***	.028	-.042	.038
Negative affectivity	.018	-.017	.177*	.005
Orienting/regulation	-.214**	-.062	-.002	-.109

*$p < .05$, **$p < .01$, ***$p < .001$

The first regression model tested whether CA predicted SE, the second model tested whether CA predicted OR and the last model whether sex predicted NA. Regression assumptions were met for all three models, including the tolerance and VIF statistics that were both 1.0, the graph showing that the data were randomly and evenly dispersed indicating that linearity and homoscedasticity were met, and Cook's values less than 1.

CA predicted 30% ($p < .001$) of the variation in the SE score. The unstandardized B = .195 (95% CI .151 to .240) indicating that for an increase of one week of CA there was an increase of .2 points in the SE score, with CA accounting for a substantial 30% of the change. The relationship between CA and SE are shown in Figure 6.1.

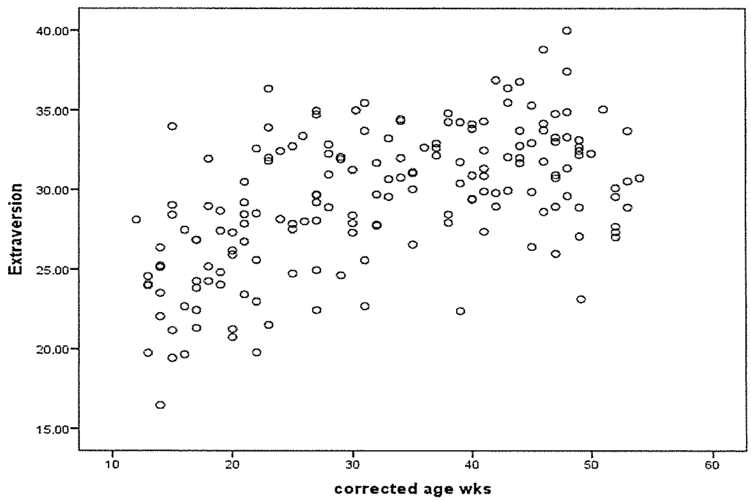


Figure 6.1 Relationship between corrected age and the Surgency/extraversion factor.

CA predicted 5% ($p < .01$) of the variation in the OR score. The unstandardized B = -.037 (95% CI -.062 to -.012) indicating that an increase of one week of CA decreased the OR score by .04 points. While there is a statistical relationship between CA and OR score, the practical implications are likely to be minimal as CA accounts for only 3% of the very small variation in OR score. Figure 6.2 depicts the relationship.

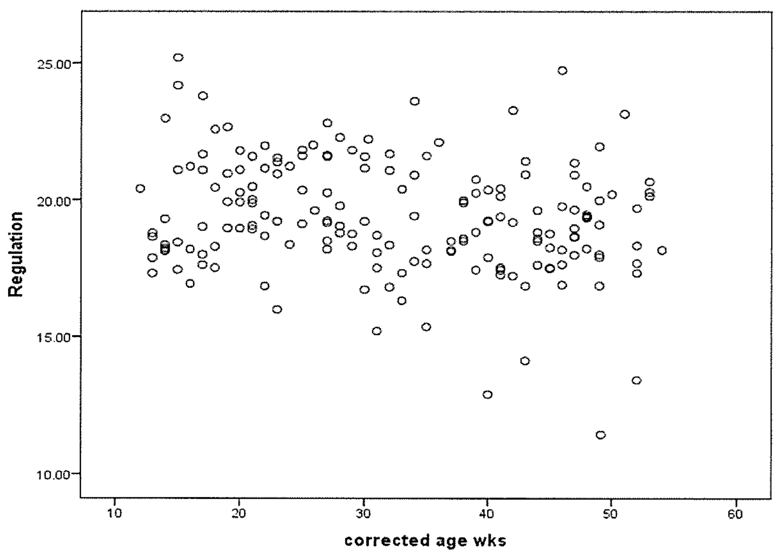


Figure 6.2 Relationship between corrected age and the Orienting/regulation factor.

Female sex predicted 3% ($p < .019$) of the variation in NA score. The unstandardized B = .892 (95%CI .149 to 1.636), showing that female infants scored .9 points more than male infants but only accounted for 3% of the change in NA score. Female infants mean (SD) NA score was 4.9 (2.2) compared with male infants 3.9 (2.7). Female infants were described by their mothers as having higher NA compared with male infants. While the mean difference in NA between female and male infants is small, it is the distribution of scores that have contributed to the significant but small difference between groups. A larger and more varied sample may yield a different result. This relationship is shown in Figure 6.3.

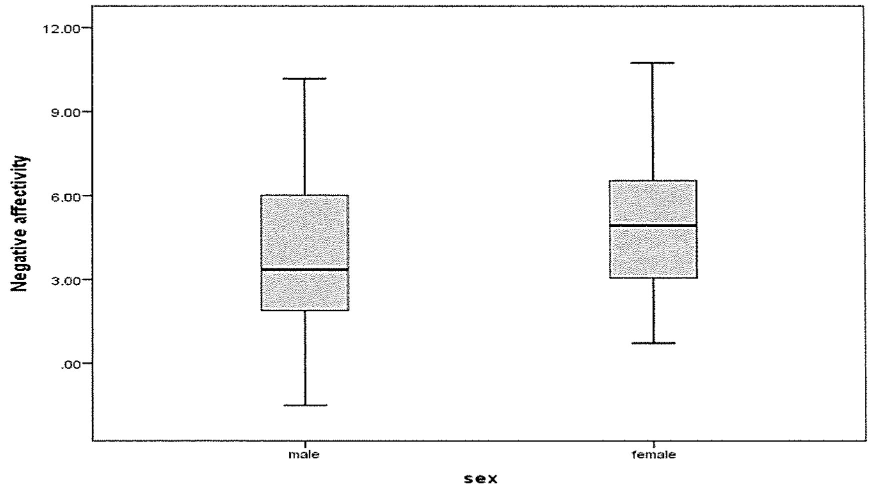


Figure 6.3 Relationship between infant sex and the Negative affectivity factor.

6.5 Discussion

The main finding in this study was that term and preterm infants had similar temperament profiles and that the temperament of Australian infants is similar to US infants when measured with the IBQR.

6.5.1 Australian infants have similar temperament profiles as US infants

The IBQR appears to be a suitable measure for Australian infants as the trait and factor means were similar to that of the US infants in the validation of the IBQR. Temperament trait and factor scores for both term and preterm infants in the current study were very similar to that of term infants from five diverse nations including Italy, Japan, Poland, Russia and the US (Dragan et al., 2011; Gartstein et al., 2005; Gartstein et al., 2003; Gartstein et al., 2010; Montirosso et al., 2011; Parade & Leerkes, 2008). Comparisons between these published studies and the current study found similarities such as the inclusion criteria of healthy term infants, mothers who were predominantly high school or tertiary educated, in their late 20's to mid 30's in age and in stable marital relationships. Most studies were adequately powered. Mothers in the current study appear to interpret the statements describing their infants' temperaments consistently with mothers from diverse cultural milieu.

6.5.2 Infant temperament profiles are independent of GA, sex and birth weight for gestational age

In the current study preterm infants' temperaments were similar to the term infants which was not influenced by CA and similar to the term infants in the cross-cultural studies cited earlier. This is in contrast to that reported by Gennaro et al. (1990), Langkamp et al. (1998) and Hughes et al. (2002) who found that preterm infants were less adaptable, less predictable, more fussy-difficult, less regular, had more negative moods and were more challenging to parent compared with term infants.

The studies that found a difference between term and preterm infants varied from the current study in their inclusion criteria of the infants, their study designs and the temperament measures used. In these published studies, preterm infants ranged in mean GA from 29 weeks to 31 weeks, were tested at four months CA only, and in two longitudinal studies at three months and six months CA, and at six weeks, six months and 12 months CA (no term comparison group but were compared to standardised norms). Sample sizes were smaller than in the current study. One group of preterm infants were predominantly African-American and born to young mothers with less education (Gennaro et al., 1990). The combination of these social factors increases the risk of difficulties during infancy which may be reflected in the temperament scores, although the study was strengthened by having two testing periods and finding stability between the two time points.

The parent-report temperament questionnaires used in the earlier studies were the Infant Characteristics Questionnaire (ICQ) (Gennaro et al., 1990), the Early Infancy Temperament Questionnaire (EITQ) (Langkamp et al., 1998) and the EITQ and the Revised Infant Temperament Questionnaire (RITQ) (Hughes et al., 2002). The current study used the IBQR as it is considered to have advantages over other parent-report temperament questionnaires. It asks parents to report on their infants' behaviours during routine everyday activities, in contrast to the other questionnaires that ask a parent for a global response to a described situation or to compare their infant's behaviour to that of term infants or for the parent's subjective interpretation of their infant's response to an environmental situation (Montirosso et al., 2011).

Other reasons proposed as to why preterm infants may have more difficult temperaments compared with term infants is that mothers may be expecting more of their preterm infants as they perceive them to be "older" and are comparing them to term infants at the same chronological age (Gennaro et al., 1990). This was not evident in the current study as the association between factor scores and CA showed strong positive correlations between CA and the SE factor only. This is another strength of the IBQR as the mother described her infant's behaviours without reference to the infant's age or comparisons to other infants of the same age, but to the infant's response to environmental stimuli.

It has been suggested that mothers of preterm infants may rate their infants more negatively than term infants because they conform to preterm stereotyping (Stern, Hildebrandt Karraker, Meldrum Sopko, & Norman, 2000). There is a risk that the negative stereotype may predispose mothers to lower their expectations for their infants' developmental outcomes, which become self-confirming (Stern, Karraker, McIntosh, Moritzen, & Olexa, 2006). This does not appear to be the case with this cohort of preterm infants and mothers.

Another suggestion as to the previously reported differences between term and preterm infants is that preterm infants have changes in their CNS organisation as a function of preterm birth, the effects of medical care and a stressful life course for both infant and parents (Hughes et al., 2002). While the primary definition of temperament is that it is an expression of behaviour shaped by inherent characteristics, another view is that infant temperament is a mix of heredity, biology and experience. Therefore, the preterm infant who is described as having a difficult temperament may be the infant's response to biological and medical problems and not related to the infant's inherent characteristics, that is temperament. The current study findings suggest that while some term and preterm infants may have a stressful neonatal course, for example being born SGA or early gestation, these factors alone do not appear to predispose parents to describe their infants as having difficult temperaments. Also, preterm infants in the current study were healthy and low risk so may have required less medical care with parents experiencing less stress.

Similar to the findings in the current study, an Australian study found no differences in temperament between term and preterm infants. Using the RITQ modified for Australian infants, Oberklaid et al. (1986) found that term and preterm infants scored similarly on maternal global rating of temperament, individual dimensions and clinical categories of temperament (Oberklaid et al., 1986). There were some similarities and differences between the Australian study and the current study. Oberklaid et al. (1986) included preterm (n = 126) infants from 26 to 36 weeks GA, ranging in age from four to eight months CA (mean 5.5 months CA) and compared them with term (n = 150) infants, but used an Australian version of the Infant Temperament Questionnaire by Carey and McDevitt. The current study included the same GA, but a wider age range, a higher mean age at the time of testing, a smaller sample and the IBQR. Similarities between studies might be cultural.

Two other studies, using a select number of traits from the IBQ (US term and preterm infants) and the IBQR (Austrian term and preterm infants), found no differences between groups. Factor scores could not be calculated as all traits comprising each of the factors were not measured (Halpern et al., 2001; Langerock et al., 2013).

Male and female infants scored the same for SE and OR, but female infants had higher negative responses. There is mixed evidence in the literature with some studies showing a difference in some temperament traits between male and female infants (Casalin et al., 2012; Crockenberg & Acredolo, 1983; Gartstein, Gonzalez, et al., 2006; Gartstein et al., 2010; Montirosso et al., 2011) while others report no sex differences (Dragan et al., 2011; Gartstein et al., 2003; Nasreen et al., 2013; Oberklaid et al., 1991; Parade & Leerkes, 2008). When sex differences have existed, boys are reported to have higher activity levels than girls, and girls to be more fearful and to be better at regulating behaviour. Overall there are minor and inconsistent differences in some temperament characteristics during infancy that may be due to differences in temperament questionnaires used, variations in samples and in cross-cultural studies the sex differences are only evident in culture-sex interaction.

In the validation study on the IBQR, Gartstein and Rothbart (2003) did not find any sex differences for the factor scores, unlike the current study. However, a tendency to exhibit more negative temperament has been shown in preschool (Shankman et al., 2011) and adolescent (Mezulis, Priess, & Hyde, 2011) girls.

Increasing infant age was strongly associated with higher SE that is likely a reflection of the development of infant behaviours. The expression of temperament traits change and are considered to be most labile during infancy (Anzman-Frasca et al., 2012). Therefore, mothers are more likely to observe and rate their 12 month old infant as being more active than their three month old infant, but this is consistent with the increasing repertoire of motor skills and not necessarily a change in temperament traits. With increasing age, not only are infants exposed to a wider range of experiences but they have more choices when making decisions. Longitudinal follow-up of temperament traits shows relative stability both situationally and over time, meaning that infants are likely to behave in certain ways irrespective of the environmental conditions (for example, at home or out shopping and visiting) and as they grow (for example, between infancy and toddlerhood) (Rothbart et al., 2000).

6.5.3 Summary

In summary, the IBQR appears to be a suitable tool for measuring temperament in Western Australian infants. In this sample of term and healthy low risk preterm infants temperament profiles were similar and were not influenced by GA or BWGA but reflected developmental changes consistent with increasing age. Female infants were more likely to have higher levels of negative affectivity.

Chapter 7
Study 3 – The Measurement of Motor Practice in Infancy

7.1 Introduction

Practice is essential for typical infants to develop motor skills such as crawling and walking. The practice in which infants engage to learn these skills is apparently not structured but occurs during everyday routines and is consistent with motor learning theory (Adolph, Tamis-LeMonda, Ishak, Karasik, & Lobo, 2008; Adolph et al., 1998; Adolph et al., 2003). Practice has also been shown to promote walking in infants with motor impairments using a structured treadmill training approach (Angulo-Barroso et al., 2008; Angulo-Barroso et al., 2010). In these studies practice is related to specific tasks, but for the purpose of the current study practice is defined as the motor activities that occur when infants play independently and with their parents during care and play. This practice could be described as being incidental as it is not structured and not related to specific motor skills, but occurs during routine daily activities. There is scant evidence on the role of daily routines in understanding infant practice. The aim of this study was to describe infant practice as it occurs during daily routines and to ascertain what factors impacted infant practice.

The measurement of motor practice in infancy has included activity monitors, direct observations by independent observers and parent diaries (Angulo-Barroso et al., 2008; Angulo-Barroso et al., 2010; Tulve et al., 2007). Monitors and diaries may be used independently or to complement each other. One benefit of using both measures is that diaries provide situational context to assist in the interpretation of accelerometer counts (Eaton, McKeen, & Lam, 1988; Worobey et al., 2009).

A parent report diary has the potential to record the type, frequency and duration of infant daily activity. As infants are dependent for most of their needs, but still have opportunities for independent activity, their practice is both infant-parent dyadic and infant-independent, but differentiating between these can be problematic. Therefore, the choice of diary is essential for a thorough record of infant daily practice. The DAIS used in this study has a comprehensive list of daily activities and the capacity to record whether the infant was independent during activities or required assistance. It has been validated for preterm infants but not for term infants (Bartlett & Fanning, 2004). The instructions for completing the diary were modified for the current study to enable cross-reference with the accelerometer.

While accelerometers have been used to track activity for typical infants and infants with motor delay (Angulo-Barroso et al., 2010), evidence guided protocols are not currently available for children from birth to two years of age (Cliff et al., 2009) so the methodology for the current study required appraisal.

The literature reports that male infants are more active than female infants, older infants practice more intensely than younger infants (Angulo-Barroso et al., 2010), and infants with motor delay practice less intensely, independently of age (Angulo-Barroso et al., 2008; Angulo-Barroso et al., 2010). For the cohort of infants in the current study, the findings from Study 1 suggest no difference in GM or FM skills between term and preterm infants at CA, but whether they practice differently has not been investigated. Study 1 also showed a difference in the performance of GM and FM skills between SGA and AGA infants. Therefore, BWGA may be a factor that impacts infant practice.

The following research questions were addressed in this chapter:

- What are the characteristics of infant motor practice when measured using a parent report diary and accelerometer?
- Does motor practice differ depending on infant age, GA, sex and BWGA?

7.2 Data management

7.2.1 Daily Activities of Infants Scale

The DAIS was the parent-report diary that was used to ascertain the daily routines of infants and to add context to the activity monitor data. Of the 180 infants in the original cohort, 11 (three term, eight preterm) diaries were not completed correctly and a further 28 (12 term, 16 preterm) had more than 60 minutes of missing data. These 39 (15 term and 24 preterm) (21.5%) diaries were omitted, leaving 141 (78 term and 63 preterm) diaries available for analyses. Data derived from the DAIS were time of the day when an activity occurred, duration of each activity and amount of assistance required for each activity. The authors did not provide instructions on how to manage errors in recording so the following rules were applied in this sequence: (1) if an activity was recorded at the same time as sleep, sleep was retained and the other activity discarded, (2) where two activities and the same levels of support were recorded as occurring at the same time, then both activities were accepted as occurring for that time, duration was halved and scores for assistance were halved, (3) where two activities and different levels of support were recorded for the same time, then both activities were accepted as occurring for that time, duration was halved for the activities and the lower score for assistance was halved for the activities. Activity scores were then calculated consistent with the instructions provided by the authors: maximum support (level A) allocated one point, moderate support (level B) two points and minimal or no support (level C) three points. Higher scores indicate greater levels of infant independence when performing an activity. Duration of each activity and individual activity and total scores were calculated for 24 hours.

Categories were created to represent the concept of "practice" as a function of infant-independent and infant-parent practice. From the eight activities described in the DAIS, a "care" category was defined as feeding, bathing, dressing and carrying, a "play" category included quiet and active play, outings and sleep were retained as separate categories. Duration and scores were calculated for care and play by summing their constituent activities.

7.2.2 Accelerometry

All monitors worked successfully generating data for 180 participants. However, to interpret activity counts, only monitors with correctly completed diaries (n = 141) were included in analyses.

Data from the monitors were downloaded consistent with the instructions in the Actical manual to an Excel spreadsheet. Monitor counts for every 15 seconds (pre-established epoch time) were summed to generate counts for every 15 minutes over the 24 hours when the infant wore the monitor. The monitor was removed for bathing. As the monitors recorded activity in real-time every 15 minutes it was possible to extract activity counts for specific time periods matched to DAIS activity time. Monitor counts were assigned to each DAIS activity and consistent with the rules applied to the DAIS. That is, when two activities were assigned to the same time in the day, then total counts were halved and attributed to each activity. Total counts were calculated for each activity. Feeding, dressing and carrying counts were summed for "care" as the monitor was removed for bathing. Quiet and active play counts were summed for "play", "sleep" had its own category. As infants varied in the amounts of time they spent in each activity, counts per hour were calculated by dividing total counts for that category by total time spent in that category. Therefore, four variables were derived: total care counts/total care time, total play counts/total play time, total awake counts/total awake time (calculated by summing the previous two variables) and total sleep counts/total sleep time. Counts assigned to outings were not included as they were not deemed to contribute to practice.

7.3 Hypotheses

- Duration of routine daily activities will differ for term and preterm infants, independently of CA, sex and BWGA.
- The amount of assistance required during routine daily activities will differ for term and preterm infants, independently of CA, sex and BWGA.
- Intensity of activity will differ for term and preterm infants during routine daily activities, independently of CA, sex and BWGA.

7.4 Data analysis

Infants were retained (141) and omitted (39) based on the completeness of their DAIS. They were compared using independent samples *t*-test for CA, GMQ, FMQ and the AIMS percentiles-for-age for CA.

Maternal age (younger mothers < 30 years and older mothers ≥ 30 years), maternal education ("technical education or less" and "university education") and family income (lower income < $60,000 and higher income ≥ $60,000) were compared using Chi-square tests for those infants retained and those omitted.

Duration of care, play and sleep, scores for care and play and activity counts for care, play, awake and sleep for term and preterm infants were examined to ensure normal distribution by examining skewness (S), kurtosis (K) and homogeneity of variance using Levene's test. As the number of infants in the term and preterm groups were still relatively large, *z*-scores for S and K were considered non-significant if <3.29 (Field, 2009).

Mean (SD) duration and scores for each activity as well as mean (SD) total duration for care and play, and mean (SD) total scores for care and play were calculated from DAIS data for male and female, term and preterm infants. Mean (SD) care, play, awake and sleep activity counts/activity hour were derived from accelerometer data for male and female, term and preterm infants.

CA, GA, sex and BWGA were examined to determine if they were correlated with duration of care, play and sleep, scores for care and play activity counts for care, play, awake and sleep. Pearson's correlations were calculated for all factors that were continuous and point-biserial correlations for sex and BWGA as they were discrete and dichotomous.

The data were examined to ensure that the regression assumptions were satisfied. Standardised residuals and Cook's distances were checked for outliers; graphs of the standardised Studentised residuals (*SRESID) were plotted against the standardised predicted (*ZPRED) values to examine the data for linearity and homoscedasticity (Field, 2009).

Linear regression models were conducted to investigate the main effects of CA, GA, sex, BWGA and the interaction of GA by sex as predictors of:

- duration of care, play and sleep,
- activity scores for care and play,
- care counts/care hour, play counts/play hour, awake counts/awake hour and sleep counts/sleep hour.

Only factors that were correlated with the outcome variables were entered together into the multivariate model. Data analyses were conducted using SPSS, version 19 (IBM Corporation, 2013).

7.5 Results

7.5.1 Comparison between retained and omitted infants

Summary data on the infants whose DAIS was and was not completed correctly are reported in Table 7.1. On average, infants whose DAIS was retained had mean CA similar to the infants whose DAIS was omitted and these were not significantly different. The mean GMQ, FMQ and AIMS percentiles at CA were similar between both groups of infants and were not significantly different.

Maternal age, education and family income were also compared between both groups of infants. There were no significant differences in mean age between the mothers in both groups. There were more mothers with technical or less education in the omitted group and concomitantly more university educated mothers in the retained group. This difference was significant and would suggest that less well-educated mothers may have had more difficulty completing the DAIS. Family income was not different between the groups.

The same comparisons were conducted at infant chronological age with similar findings and are reported in Appendix 8.

Table 7.1 Comparisons between infant and maternal characteristics for infants whose DAIS was retained and those omitted.

	Total		Test statistic	*p* - value
	Retained	**Omitted**		
	(n = 141)	(n = 39)		
CA (wks)	32.9 (12.4)	31.0 (11.1)	.85	.39
GMQCA	97.9 (6.6)	100.1 (5.4)	-1.93	.06
FMQCA	99.4 (5.5)	100.5 (5.6)	-1.06	.29
AIMSCA	34.5 (26.1)	38.7 (28.1)	-.89	.38
Maternal age	(n = 140)	(n = 37)		
<30 years	31%	43%	-.11[a]	.15
>30 years	69%	57%		
Maternal education	(n = 139)	(n = 37)		
Tech	30%	53%	-.21[a]	.005*
Uni	70%	47%		
Income	(n = 137)	(n = 35)		
< $60,000	12%	23%	[b]	.08
> $60,000	88%	77%		

CA = corrected age, wks = weeks, GMQCA = gross motor quotient corrected age, FMQCA = fine motor quotient corrected age, AIMSCA = AIMS percentile-by-corrected age, [a]Pearson's r, [b]Fisher's exact

7.5.2 Duration of daily activities

Tests for normality of care, play and sleep duration and care and play scores were normally distributed for both term and preterm infants and there were no differences in variances between groups for these measures.

Table 7.2 reports the mean (SD) duration in each activity and in total care and total play for both groups of infants. The majority of an infant's day was spent in sleep (approximately 58%), with less time spent in play (18%), care (16%) and in outings (8%).

Table 7.2 Mean (SD) duration of routine daily activities for male and female term and preterm infants in hours over a 24 hour period.

Activity (hr)	**Term**			**Preterm**		
	M (n = 39)	**F (n = 39)**	**Total (n = 78)**	**M (n = 35)**	**F (n = 28)**	**Total (n = 63)**
Care	3.8 (1.1)	3.8 (1.3)	3.8 (1.2)	3.9 (1.3)	4.0 (0.9)	3.9 (1.2)
Feed	2.2 (0.7)	2.2 (0.8)	2.2 (0.8)	2.4 (0.9)	2.2 (0.8)	2.4 (0.9)
Bath	0.3 (0.1)	0.3 (0.1)	0.3 (0.2)	0.3 (0.1)	0.2 (0.2)	0.3 (0.2)
Dress	0.5 (0.4)	0.5 (0.4)	0.5 (0.4)	0.4 (0.4)	0.4 (0.4)	0.4 (0.4)
Carry	0.8 (0.8)	0.9 (0.9)	0.8 (0.8)	0.9 (0.9)	1.1 (0.9)	0.9 (0.9)
Play	4.3 (1.4)	4.6 (1.3)	4.4 (1.4)	4.6 (1.3)	4.5 (1.3)	4.6 (1.3)
Quiet play	2.1 (1.2)	2.1 (1.3)	2.1 (1.2)	2.4 (1.4)	2.6 (1.1)	2.5 (1.3)
Active play	2.2 (1.3)	2.4 (1.4)	2.3 (1.4)	2.1 (1.4)	1.9 (1.2)	2.0 (1.3)
Outings	1.4 (0.9)	1.5 (1.2)	1.4 (1.1)	1.3 (1.2)	1.1 (0.9)	1.2 (1.0)
Sleep	14.2 (1.4)	13.7 (1.7)	13.9 (1.6)	13.9 (1.4)	14.0 (1.4)	14.0 (1.4)

Care = feed + bath + dress + carry; Play = quiet play + active play

Table 7.3 reports the correlation coefficients for duration for care, play and sleep. There were significant negative correlations between CA with care and sleep duration, and significant positive correlations with play duration. GA, sex and BWGA were not correlated with duration of activities.

Table 7.3 Correlations between corrected age, gestational age, birth weight for gestational age with duration of care, play and sleep.

	CA	GA	Sex	BWGA
Care duration	-.324**	-.072	.016	-.150
Play duration	.542**	-.037	.057	-.066
Sleep duration	-.204*	-.015	-.092	.119

CA = corrected age, GA = gestational age, BWGA = birth weight for gestational age, *$p < .05$, **$p < .001$.

The assumptions for the regression analyses for duration of care, play and sleep, scores for play and care and counts/hour for care, play, awake and sleep were satisfied. Individual plots of *SRESID against *ZPRED were distributed randomly along the horizontal central axis for all factors indicating linearity and homoscedasticity. Cook's distances were all within the accepted range of .000 to .234. Collinearity was not a problem with the tolerance statistics above .8 and VIF close to 1. Collinearity statistics were problematic when interaction between GA and sex were added to the model, and did not improve when GA and sex were centred, so the interaction was excluded from the model.

CA was entered separately in each regression model and the results are presented in Table 7.4. Infants required less care time with increasing CA. While statistically significant, CA only contributed 10% of the change in the amount of time infants required for care. For every one week of age infants required approximately two minutes less time in care activities each day, or 14 minutes over the course of one week. This is a small fraction of daily awake time and reinforces the perception that infants have high care needs.

Older infants spent more time playing and CA significantly predicted approximately 30% of play duration. For every one week of age infants spent approximately four minutes more (.05hr) in play activities every day, or 28 minutes more each week.

Younger infants spent more time sleeping over 24 hours but CA predicted only 4% of sleep duration. Less time spent sleeping and in care for older infants appeared to be re-directed into play activity.

Regression coefficients at CA for duration of care, play and sleep were very similar to that for chronological age suggesting that mothers are responsive to their infants' needs and not to their infant's gestation. The results of the regression calculations with chronological age as a predictor are reported in Appendix 8. Infant sex and BWGA did not influence the relationship between infant age and duration of daily activities.

Table 7.4 Linear regression analyses predicting total care duration, total play duration and total sleep duration from the main effect of corrected age.

	Predictors	*B*	95% CI	*B*	sr^2 x 100
Total care duration	Corrected age	-.031	-.046, -.016	-.324	10.498
	$R^2 = .105, p < .001$				
Total play duration	Corrected age	.058	.043, .074	.542	29.374
	$R^2 = .294, p < .001$				
Total sleep duration	Corrected age	-.025	-.044, -.005	-.205	4.162
	$R^2 = .042\ p = .016$				

Units of measurement for the predictors were entered as weeks of corrected age. Outcome variables were entered as hours of care, play and sleep duration.

7.5.3 Support required for daily activities

Scores for activities and comparisons between the term and preterm infants are reported in Table 7.5. The amount of support an infant required for an activity was related to the score achieved on the DAIS: more support equates to lower scores. Infants required less support for feeding (term = 16.5 points, preterm = 16.7 points), quiet play (term = 16.9 points, preterm = 18.6 points) and active play (term = 17.9 points, preterm = 15.9 points). They needed more support for bathing (term = 2.4 points, preterm = 1.9 points) and dressing (term = 2.8 points, preterm = 2.2 points). The amount of support that the infants required for activities appeared related to the dependency of the infants to achieve the tasks (more for dressing, less for play) and the safety requirements of the tasks (more for bathing).

Table 7.5 Mean (SD) scores for routine daily activities for male and female term and preterm infants over 24 hours.

Activity (points)	Term			Preterm		
	M (n = 39)	**F (n = 39)**	**Total (n = 78)**	**M (n = 35)**	**F (n = 28)**	**Total (n = 63)**
Care	27.8 (9.9)	27.7 (10.7)	27.7 (10.3)	29.4 (11.4)	28.0 (8.7)	28.8 (10.2)
Feeding	16.3 (7.0)	16.7 (9.0)	16.5 (8.0)	18.2 (8.5)	16.9 (7.3)	17.7 (7.9)
Bathing	2.5 (1.9)	2.4 (1.8)	2.5 (1.8)	2.1 (1.5)	1.8 (1.6)	1.9 (1.5)
Dressing	2.9 (1.9)	2.6 (2.3)	2.8 (2.1)	2.2 (2.5)	2.3 (1.8)	2.2 (2.2)
Carrying	6.0 (5.8)	5.9 (5.6)	5.9 (5.7)	6.9 (6.8)	6.9 (6.2)	6.9 (6.5)
Play	34.2 (20.2)	37.2 (20.6)	35.7 (20.3)	36.9 (18.3)	32.2 (19.3)	34.8 (18.8)
Quiet play	17.1 (12.4)	17.8 (15.2)	17.5 (13.8)	18.9 (12.2)	19.1 (12.6)	19.0 (12.3)
Active play	17.1 (13.9)	19.4 (15.8)	18.2 (14.9)	18.0 (16.1)	13.1 (11.3)	15.8 (14.3)
Outings	9.1 (7.9)	10.1 (8.1)	9.6 (7.9)	8.5 (8.4)	7.1 (6.3)	7.9 (7.5)
Total	71.0 (26.9)	75.0 (27.3)	73.0 (27.0)	74.9 (24.4)	67.3 (25.1)	71.5 (24.8)

CA had a positive correlation with care and play scores. GA, sex and BWGA were not correlated with any scores (see Table 7.6).

Table 7.6 Correlations between corrected age, gestational age, birth weight for gestational age with support required for care and play.

	CA	GA	Sex	BWGA
Care score	.432*	-.036	-.034	.005
Play score	.823*	.054	-.014	.022

CA = corrected age, GA = gestational age, BWGA = birth weight for gestational age, $^*p < .001$.

Table 7.7 reports the regression models predicting care and play scores. Older infants required less assistance for care activities compared with younger infants. Age significantly predicted 19% of the care score. Even though older infants required less assistance for care, the change in care score for every one week of age was only .4 of a point and is consistent with the dependency of infants in the first 12 months of life for care.

Older infants required less assistance when playing, with CA significantly predicting 68% of the play score. The rate of change in play score was greater than for care score, with every week of age seeing an increase of 1.3 points. This change is consistent with the increasing independence in play activity with increasing age.

Table 7.7 Linear regression analyses predicting total care score and total play score from the main effect of corrected age.

	Predictors	*B*	95% CI	*β*	sr^2 x 100
Total care Score	Corrected age	.356	.231, .482	.432	18.662
	$R^2 = .187, p < .000$				
Total play Score	Corrected age	1.300	1.149, 1.452	.823	67.733
	$R^2 = .677, p < .000$				

Units of measurement for the predictors were entered as weeks of corrected age. Outcome variables were entered as points for care and play assistance.

7.5.4 Verification of DAIS and accelerometer

Prior to analysing the accelerometer data, these data were cross-referenced with the DAIS categories of care, play and sleep to help interpret the activity counts. The first step in the verification process was to calculate the percentage of infants who were either awake or asleep every 15minutes over 24 hours, independently of the accelerometer. Infants were considered to be awake if they were engaged in any care or play activity as reported by their mother. The graph of the results is presented in Figure 7.1. On visual inspection the graph shows that infants begin to wake from approximately 5.30am, with the majority of infants awake by 8.00am. In the evening, the majority of infants are awake at 6.00pm and most are asleep by 8.00pm.

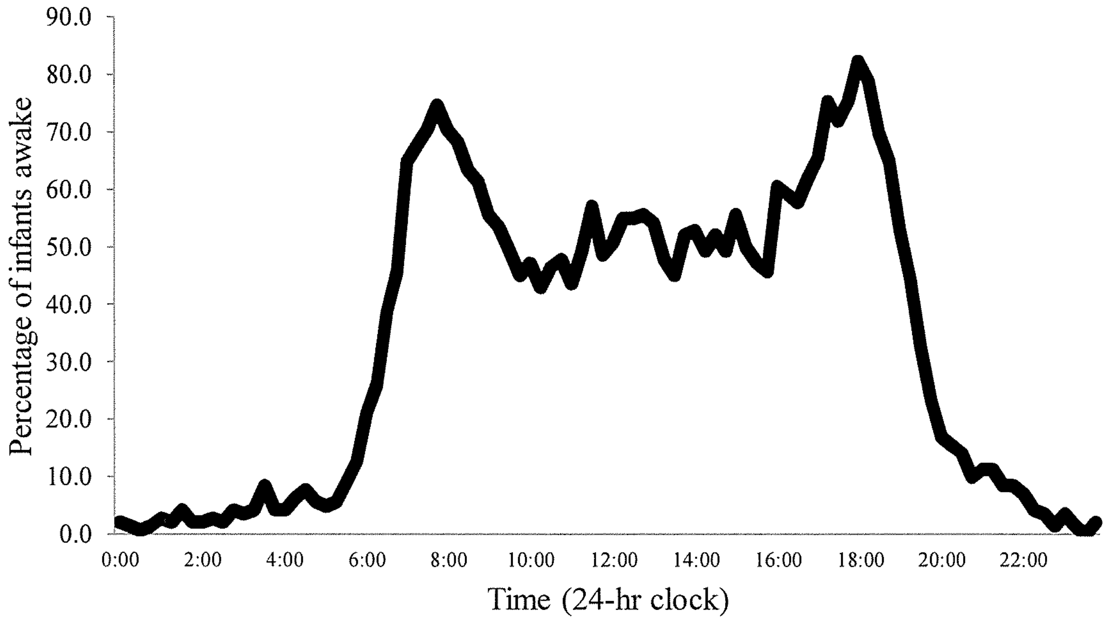


Figure 7.1 Percentage of infants who were awake during each 15 minutes epoch in the 24 hour period.

The second step in the verification process was to calculate the mean accelerometer counts every 15 minutes over 24 hours, independently of the dairy. These results are presented in Figure 7.2. This graph shows that there was a sharp increase in activity counts/hour at approximately 6.00am, with high activity counts until approximately 6.00pm, followed by a sharp decline in activity by 8.00pm.

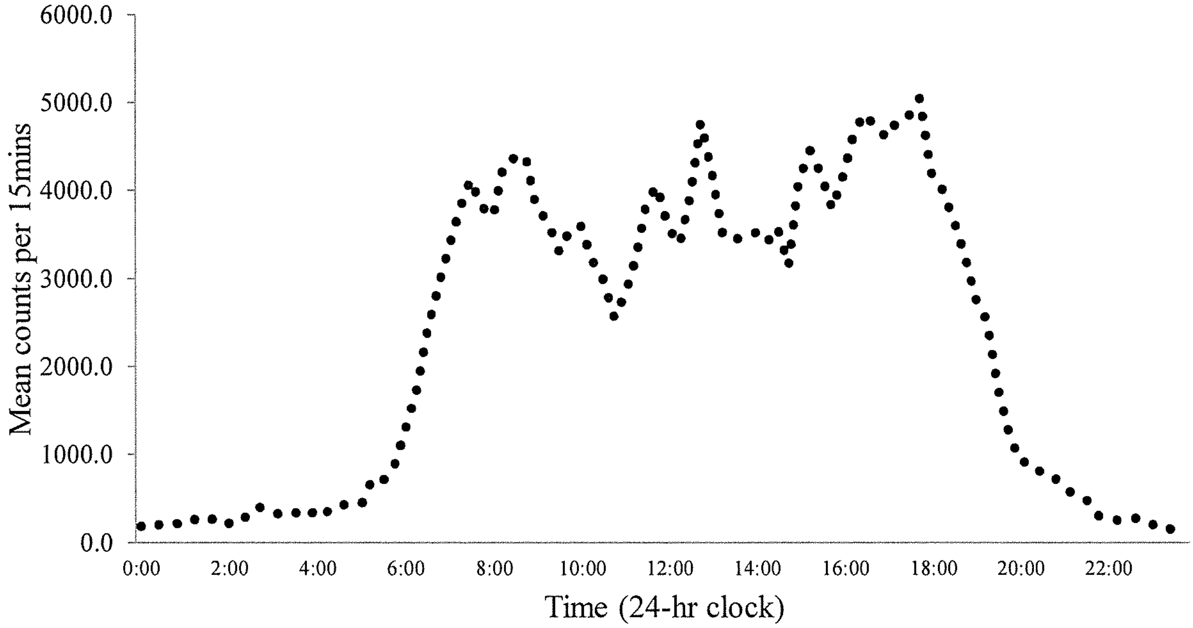


Figure 7.2 Mean accelerometer counts every 15 minutes over the 24 hour period.

The third step in the verification process was to visually compare the percentage of infants awake with the mean activity counts/hour, shown in Figure 7.3. When the graphs from Figures 7.1 and 7.2 were superimposed upon each other, on visual inspection they show close overlap, in particular the time at which infants were considered to wake and go to sleep. These graphs that were independently generated, appear to confirm that both the diary and accelerometer were independently able to measure infant activity and could be cross-referenced.

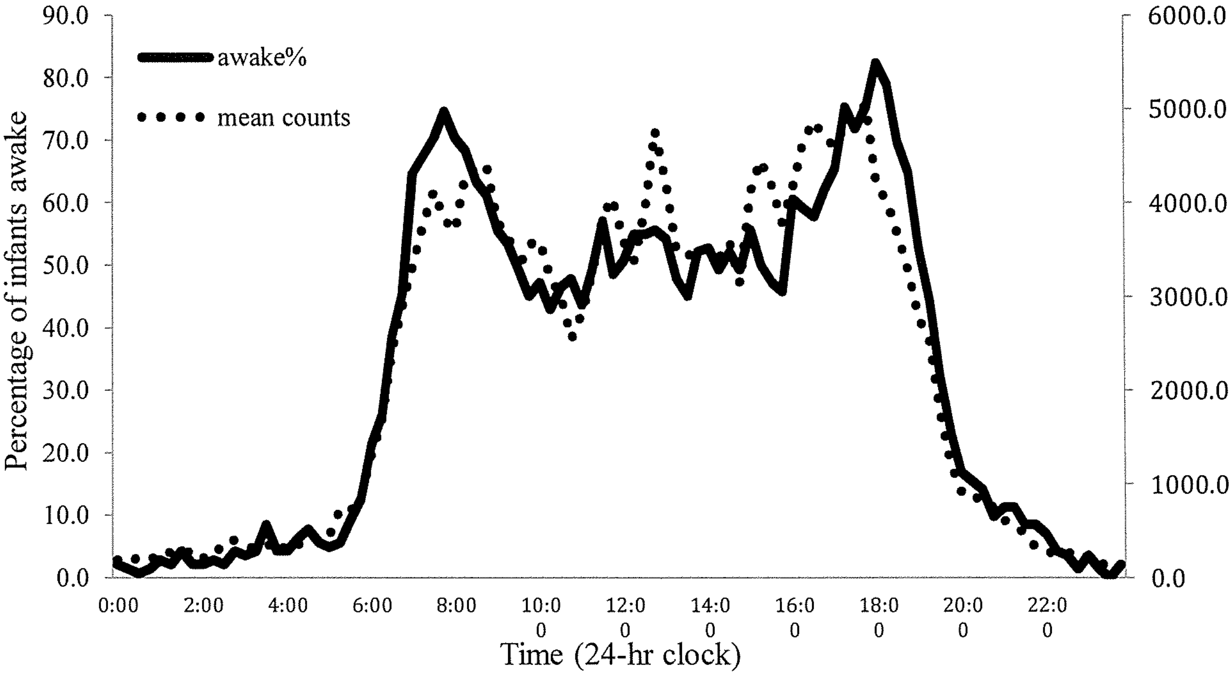


Figure 7.3. Comparison between percentage of infants who were awake with mean activity counts every 15 minutes over the 24 hour period.

7.5.5 Intensity of activity

Care counts/care hour for the term infants were not normally distributed. Skewness (S = 1.357, SE = .272, *z*-score = 4.988) and kurtosis (K = 2.585, SE = .538, *z*-score = 4.404) were significantly greater than the upper threshold (3.29) for the sample size (n = 78). Play counts/play hour were also not normally distributed for the term infants, with both S and K significantly exceeding the upper limit (S = 1.156, *z*-score = 4.25, K = 3.308, *z*-score = 6.148). As care counts and play counts contribute to awake counts, awake counts/awake hour was also not normally distributed. 5 Examination of the data showed that two female term infants aged nine months and 10 months were outliers. The nine month old infant had care counts (54858) that were >3SD above the mean for the term group (M = 17808, SD = 8848), but play counts (32063) that were within 1SD of the term group mean (M = 23444, SD = 10147). The 10 month old infant had care counts (41159) >2SD above the mean and play counts (74174) >3SD above the mean (M = 23446, SD = 10147) of the term group. As it was not possible to determine the reason for these extreme values for these two infants, their data were excluded and the care, play and awake counts/hour were re-examined. The frequency histograms for the term infants were then normally distributed with *z*-scores for skewness and kurtosis for care, play and awake counts/hour between .201 and 2.931 which were below the upper limit confirming that the distributions were normal. Therefore, the total number of female term infants was 37.

Care, play and awake counts/hour for the preterm infants were all normally distributed with skewness and kurtosis *z*-scores ranging from .196 to 2.632.

Sleep counts/hour were not normally distributed for either group of infants with a small range of low scores. Sleep counts/hour were expected to be low as infants would not be moving during sleep, with a mean of 1805 for the term infants and 2227 for the preterm infants. However, sleep counts/hour ranged from 170 to 14125 for the term infants and from 287 to 13891 for the preterm infants with the maximum sleep count/hour approximately double the minimum care and play counts/hour for both groups. There are a number of reasons why the sleep counts/hour were wide in range including (1) infant movement due to restlessness, even though the infant was asleep, (2) mothers recording "sleep" in the diary while the infant was awake and moving, and (3) the infant being moved (rocked, carried) by the parent while the infant was settling to sleep. As there was no other way of verifying the counts with activity counts attributed to sleep were accepted, despite the wide range.

There were no differences between the term and preterm infants in the variances for care, play, awake or sleep counts/hour.

Intensity of movement of the infants is reported as activity counts per activity hour during care, play, while awake and when asleep, reported in Table 7.8. The highest activity counts were generated during play, followed by care and sleep.

Table 7.8. Mean (SD) counts for care, play, awake and sleep activity quantity for term and preterm infants.

Activity (count/act hr)	Term			Preterm		
	M (n = 39)	**F (n = 37)**	**Total (n = 76)**	**M (n = 35)**	**F (n = 28)**	**Total (n = 63)**
Care	17717 (7609)	17991 (7902)	17850 (7703)	17184 (9910)	16317 (6603)	16799 (8546)
Play	24640 (9686)	23579 (10659)	24124 (10117)	21915 (7888)	21403 (8036)	21688 (7893)
Awake	42357 (14436)	41570 (16437)	41974 (15344)	39099 (15808)	37719 (12104)	38486 (14189)
Sleep	1713 (2185)	1902 (1427)	1805 (1845)	2217 (2537)	2240 (1493)	2227 (2121.3)

Correlation coefficients are reported in Table 7.9. Significant positive correlations were found for CA with play and awake counts/hour, and negative correlations with sleep counts/hour. GA and sex were not correlated with activity counts/hour. BWGA had a significant positive correlation with care, play and awake counts/hour.

Table 7.9. Correlations between corrected age, gestational age, sex and birth weight for gestational age with counts for care, play, awake and sleep.

	CA	GA	Sex	BWGA
Care count	.143	.111	-.012	.243**
Play count	.323***	.119	-.039	.377***
Awake count	.278**	.134	-.030	.365***
Sleep count	-.206*	-.093	.024	.035

CA = corrected age, GA = gestational age, BWGA = birth weight for gestational age, **p* < .05, ***p* < .01, ****p* < .000

Table 7.10 reports the regression analyses. During care, infants who were AGA were more vigorous accounting for only 6% of the variance in care counts. The regression coefficient shows that infants AGA had approximately 5000 counts/hour

more than SGA infants. AGA infants had mean (SD) care counts/hour of 17263 (8128) compared with SGA infants who had 11989 (6066).
When playing, increasing CA and AGA infants were more vigorous, together accounting for approximately 20% of the variance in play counts. CA and AGA were independently significant. Increasing CA accounted for approximately 200 counts/hour and AGA infants contributed approximately 9000 counts/hour compared with SGA infants. AGA infants had mean (SD) play counts/hour of 24937 (10020) compared with SGA infants who had 15038 (5697).

Care and play counts/hour are summed to generate awake counts/hour, therefore the awake counts followed the same pattern. Increasing CA and AGA infants together accounted for approximately 18% of the change in awake counts/hour. Awake counts/hour were influenced more by the AGA infants than CA. AGA infants contributed 14000 counts/hour compared with increasing CA that contributed 300 counts/hour.

For care, play and awake counts/hour the dominant predictor was AGA, suggesting that SGA infants move less vigorously when awake. CA did not predict sleep counts.

Table 7.10 Linear regression analyses predicting total care, play, awake and sleep counts from the main effects of corrected age and birth weight for gestational age.

	Predictors	*B*	95% CI	*β*	sr^2 x 100	*p*-value
Total care counts	BWGA	5354	1737, 8970	.243	5.905	.004
	$R^2 = .059, p = .004$					
Total play counts	Corrected age	217	106, 328	.294	8.585	.000
	BWGA	8877	5112, 12643	.353	12.320	.000
	$R^2 = .228, p < .001$					
Total awake counts	Corrected age	298	117, 479	.250	6.200	.000
	BWGA	14008	7808, 20209	.345	11.834	.002
	$R^2 = .195, p < .001$					
Total sleep counts	Corrected age	-33	-59, -7	-.206	4.244	.015
	$R^2 = .043, p = .109$					

Units of measurement for the predictors were entered as weeks of corrected age and SGA or AGA. Counts are reported as whole numbers.

7.6 Discussion

The main aims of this study were to characterise infant practice using both a diary and accelerometer and to investigate which infant factors might contribute to practice. The results of this study provide a snapshot of an infant's day: the activities in which infants engage, how much assistance they need to engage in these activities, activity duration and the intensity with which those activities are performed. The results add to the existing evidence regarding motor practice in infancy.

7.6.1 Characteristics of infant practice

Infant daily routines were measured with the DAIS, a structured parent-report diary that provided information on the duration of the major activities in an infant's day: sleep, care and play. An infant's day is divided into two broad sections – sleep and wake with sleep consuming the majority of the time. Sleep duration (approximately 14 hours/24 hours) of the current study sample of infants did not differ between term and preterm infants, or male and female infants and was comparable with that reported for English, Austrian and American term infants using non-structured diaries and parent interview (Bamford et al., 1990; Iglowstein, Jenni, Molinari, & Largo, 2003; Tulve et al., 2007).

In the current study, duration of separate categories for care (3.9 hours/24 hours) and play (4.5 hours/24 hours) were calculated, with no differences for GA or sex. These data have not been reported elsewhere in the same format. One report shows that total contact time with parents over 24 hours for English term infants aged 13 weeks to 52 weeks was approximately 6.7 hours/day with independent play accounting for on average 47 minutes/day and increasing significantly with age (Baildam et al., 2000). Much longer duration for play of 7.5 hours/24 hours was reported by Tulve et al. (2007). Their sample of five term infants included two infants aged four months, one infant at eight months and two aged 12 months and did not differentiate parent-assisted and infant-independent play. The difference in the total duration of awake activities (8.3 hours/24 hours) in the current study with the other two studies may be due to the difference in reporting procedures (structured diary versus unstructured diary and interview, respectively) and the type of information that was requested. As expected in the current study, increasing age predicted an increase in play duration and decreases in care and sleep duration. While the DAIS has predetermined, fixed activities as part of its design, the type of activities are consistent with that reported in other studies. The benefit of using the DAIS is that the same definitions were used for each activity, unlike other studies which have not used a structured approach and were reliant on parents to provide adequate descriptions of their infant's day and then interpretation from the investigator to ensure consistency between parental reports.

Another feature of the DAIS is that it was able to quantify the amount of support an infant would require during routines. Less support was needed for care and play with increasing age. This finding reinforces the developmental needs of infants as they remain dependent for feeding, bathing and dressing as well as requiring close supervision to ensure safety but still have opportunities to demonstrate motoric independence. Again, the amount of assistance infants required was not different for GA, sex or BWGA.

With increasing age infants required less support for activities which provides evidence that the DAIS was able to differentiate parent-generated infant movement (predominately required during care) from self-generated infant movement (primarily during play) to address the concerns raised by Worobey et al. (2009) and (Shao-Yu et al., 2009). While it is not possible to ascertain duration of parent-generated infant movement that might contribute to accelerometer counts, the rationale behind routines-based intervention is that handling of infants by their parents can assist infants to learn motor skills. For example, during care activities, such as carrying an infant, the parent has many options available for carrying. It might be that the infant is carried resting on the parent's shoulder, or straddling the hips, or curled within the parent's folded arm or carried in prone on the parent's forearm or carried within a baby-sling on the parent's chest or back. These variations challenge infant head and trunk control differently allowing the infant to be either an active or passive participant in the task. It is unlikely that over the whole sample of 140 infants every carrying task was entirely passive for the infant and the accelerometer counts were entirely generated by parent movement. Differences in handling are likely to also have occurred in all the other routine tasks.

Accelerometry is the most commonly used direct measure of intensity of practice as it is considered to be objective and more reliable than self-report, or in the case of infants, proxy-report by parents (Adamo et al., 2009). As recommended, accelerometer counts were interpreted with reference to the parent diary. Other studies using acclerometers with typical infants and infants with motor delay from various causes also used diaries to determine infant sleep and awake cycles, but details of these diaries were not reported (Angulo-Barroso et al., 2008; Angulo-Kinzler et al., 2002; McKay & Angulo-Barroso, 2006). In combination these two measures of infant activity, the accelerometer and diary, were comparable on visual inspection as total activity counts every 15 minutes matched wake-sleep states as reported by the parent. Further evidence that the DAIS and accelerometer matched was that the duration of activities followed a "logical sequence" (Tulve et al., 2007, p 378) from longest to shortest duration of sleep, care and play, respectively, while counts from highest to lowest was for play, care and sleep. The accelerometer and diary were able to measure different but complementary aspects of movement.

Play and awake counts increased with age as expected as the GM repertoire of the infants also increased with age supporting the premise that older infants are more active (Eaton et al., 2001). As the current study was cross-sectional with a wide age range, the effect of infant age likely had a direct effect on accelerometer counts.

There were no differences in counts between term and preterm infants for care, play or sleep in the current study. Rather, for the whole group mean sleep counts (2016) were comparable with that reported by Tulve et al. (2007) (1823) who measured activity in term infants only. However, the comparison in mean play counts (10284) for the Tulve et al. (2007) infants are considerably lower (current study mean play counts = 22906) and may be because they had only five term infants ranging in age from four months to 12 months. One study reports that preterm infants had higher mean counts for sleep, suggesting that they had less restful sleep but they only measured sleep/wake activity at 12 months of age (Asaka & Takada, 2010). While the mean sleep counts were higher for preterm infants in the current study this was not significant.

The current study did not find any differences between male and female infants for care, play or sleep counts. Campbell and Eaton (1999) however, found a small but significant sex difference of 0.2SD between male and female infants' activity levels based on a meta-analysis of parent report (diary and infant temperament questionnaires), direct observations (in natural settings) and direct measures of activity (monitors of varying sophistication). Accelerometer counts for care, play and sleep in the current study were not influenced by infant GA or sex, similar to the duration of DAIS categories of care, play and sleep that also found no differences due to infant GA or sex.

Interpreting accelerometer counts in older children and adults is based on cut-points to describe intensity of practice as sedentary, light, moderate or vigorous. However, there are no cut-points for counts in infancy. In fact there are no guidelines for cut-points to separate awake from sleep counts when using the Actical® accelerometer with infants reinforcing the need of a diary to separate wake from sleep time. McKay and Angulo-Barroso (2006) applied an arbitrary criterion value (awake count) so that 70% of an infant's activity was spent in sedentary-light activity and 30% was spent in moderate-vigorous activity. These values were based on the evidence of older children (Angulo-Barroso et al., 2008; Angulo-Kinzler et al., 2002; McKay & Angulo-Barroso, 2006). In the current study, awake accelerometer counts were used as a continuous variable. There are three indicators that support this approach. Firstly, the validity of the accelerometer was determined by graphing accelerometer mean counts every 15 minutes for 24 hours against the mean awake time as reported by the parent diary. These graphs demonstrated congruency between both measures although visual inspection alone was used to ascertain that both the diary and accelerometer were closely aligned. Secondly, when the mean counts for sleep, care and play were compared there was a logical gradient from lowest to highest. And finally, increasing age predicted increasing play counts and was not associated with care and sleep counts, independently of other infant factors.

Essentially, the duration of daily routines, the amount of assistance an infant required and the intensity of activity was similar for term and preterm infants and for both sexes.

7.6.2 Infants small for gestational age engage in less intense activity

A number of factors were investigated to ascertain whether they contributed to infant practice, including CA, sex, GA and BWGA. The only factor that affected intensity of infant practice was BWGA, such that SGA infants practiced with less intensity than AGA infants. This is a novel and important finding in infancy.

In childhood, children who were born SGA are reported to have reduced physical activity that may be due to reduced skeletal muscle mass and altered lung structure and function. During pregnancy, inadequate maternal nutrition or placental insufficiency which are associated with SGA, appear to restrict the development of skeletal muscle fibre number as blood flow and nutrient supplies are preferentially shunted to vital organs, such as the brain and heart and preferentially restricted to skeletal muscle. Even with compensatory catch up postnatal growth, the SGA infant is likely to have reduced muscle mass as there is no increase in muscle fibre number (L. D. Brown, 2014). For term infants, between 36 and 41 weeks GA, in the immediate postnatal period, lean body mass (that is less skeletal muscle) was significantly less for SGA infants compared with AGA infants (Lapillonne et al., 1997) with percentage of body fat higher for SGA infants compared with AGA infants (Hediger et al., 1998). Post-natal growth of SGA infants is altered such that body composition shows increased fat mass relative to lean body mass (Tappy, 2006). Therefore, the ratio of skeletal muscle to body fat is lower for SGA infants compared with AGA infants and might have a negative impact on the ability of SGA infants to move with vigor.

In the current study, SGA infants were both term and preterm, but preterm birth alone can disrupt normal skeletal muscle development as preterm infants tend to have decreased lean mass and increased fat mass at term compared to full term infants (M. J. Johnson, Wootton, Leaf, & Jackson, 2012). The combination of SGA plus preterm birth is likely to negatively affect the growth of skeletal muscle which in turn may reduce the ability of SGA infants to engage in vigorous movement.

Lung function may be adversely affected in SGA infants which again is attributed to inter-uterine under-nutrition. This can result in permanent changes in lung structure leading to chronic airflow obstruction in childhood. Lung function measurements are decreased in SGA infants compared with AGA infants, while preterm infants are more likely to have respiratory symptoms (Briana & Malamitsi-Puchner, 2013; Lum et al., 2001). SGA infants born <29 weeks gestation had increased need for oxygen in neonatal and early post-natal life, and at two years of age required more and frequent hospital admissions, and need for medications compared with AGA infants at the same gestation (Peacock et al., 2013). Hospital admissions and respiratory health were not investigated in the current study but it is possible that SGA infants in the current study had compromised respiratory function which may have resulted in reduced capacity for vigorous activity.

There are no studies of which the author is aware that report on the exercise capacity of SGA infants during childhood. However, there is evidence that children who were born LBW, that is <2500 grams, have lower exercise capacity compared with children who are normal BW (NBW) (Rogers et al., 2005). Exercise capacity is reported to be impaired to some degree in LBW, VLBW and ELBW childhood, adolescence and adulthood. This is attributed in part to reduced skeletal muscle mass, increased intrinsic muscle oxidative capacity (due to a higher ratio of Type I to Type II muscle fibres in preterm infants) and impaired cardiovascular function (Siebel, Carey, & Kingwell, 2012). Further, between two months to eight years muscle growth is reported to remain reduced in infants with BW <2500 grams compared with infants of NBW (Baker et al., 2010). While there is evidence for reduced exercise capacity in individuals with LBW, there is no specific evidence related to individuals who were born SGA, as the terms SGA and LBW were used synonymously and GA was not reported in either of these studies.

No direct link was found between skeletal muscle mass, lung structure and function and physical activity in infancy, but reduced exercise capacity seen in childhood and beyond may have its origins in infancy (Clemm et al., 2012), as found in the current study.

7.6.4 Summary

Infants who were AGA engaged in more vigorous activity than SGA infants, independently of infant age, GA and sex. Accelerometry is a feasible method for measuring activity in infants and should be accompanied by a diary to give context and to help with interpretation of accelerometer counts. Accelerometry was better than the diary at differentiating between infants in terms of their practice characteristics.

Chapter 8

Study 4 – The Effects of Infant Temperament and Motor Practice on Term and Preterm Infants' Motor Skills

8.1 Introduction

Typical infants develop motor skills through practice which occurs through the interplay of the infant's abilities and the interaction between the infant and parent (Adolph, Tamis-LeMonda, et al., 2008; von Hofsten, 2009b) such that parent handling and positioning during everyday tasks appear to influence infant motor development (Lobo & Galloway, 2012). Therefore motor skill practice embedded into daily routines is advocated for infants with motor delay and described as a routines based intervention strategy (Cripe & Venn, 1997). As reported in chapter 7, older infants practiced more intensely than younger infants, but importantly infants who were SGA practiced less intensely.

Infants who engage in more practice may also have a more active temperament. Activity level is a major descriptor of infant behaviour and has been measured using parent-report infant temperament questionnaires and compared against direct observations and activity monitors (Eaton & Dureski, 1986). However, activity level is only one temperament trait and is defined as gross motor activity of arms and legs and includes locomotion (Gartstein et al., 2003; Montirosso et al., 2011), so it would appear that some infants are inherently more active than others.

In measures of temperament of children and adults those with a high extraversion temperament had a predilection for movement (Agras, Hammer, McNicholas, & Kraemer, 2004; Anderson, Bandini, Dietz, & Must, 2004; Fernandez-Aranda et al., 2014; Kjelsas & Augestad, 2004; Rhodes & Smith, 2006). Adults who are extraverted tend to be energetic and to seek excitement and novelty (Brunes, Augestad, & Gudmundsdottir, 2013). This description is consistent for children between three to seven years of age (Rothbart, Ahadi, Hershey, & Fisher, 2001). Extraversion in children and adults is associated with higher levels of physical activity (Anderson et al., 2004; Brunes et al., 2013) which could be interpreted as practice. Infants with a high extraversion temperament may practice more than infants with low extraversion but this has not been investigated.

The relationship between practice and motor skills in children has been demonstrated consistently but the relationships between temperament, practice and motor skills have not been investigated. Infant temperament has been described as an organiser of development (Marshall et al., 2000) but there is limited evidence showing a link between infant temperament and motor development. Although not measuring temperament directly, a "motivation to move" scale has shown that infants with high motivation to move had better motor development than infants with low motivation (Atun-Einy, Berger, & Scher, 2013). Conversely, infants with a fussy, unadaptable temperament appear to have delayed motor development (Nasreen et al., 2013). Nasreen et al. (2013) speculated that mothers with difficult infants may not interact as constructively with their infants as mothers with infants with easier temperaments, therefore not providing the same opportunities for practice through play. Also, the infants themselves were less likely to engage in independent exploratory play if they did not feel secure with their mother (Nasreen et al., 2013). These few studies suggest that the process of acquiring motor skills may be related to temperament but work through the effects of practice. It is possible that practice acts as a mediator in the relationship between infant temperament and motor skill acquisition.

This chapter addressed the following research questions:

- Does practice have positive effects on an infant's motor development?
- Do infants who practice with higher intensity have different temperament profiles to infants who practice less intensely and is the relationship different for term and preterm infants, male and female infants and SGA and AGA infants?
- Is the relationship between infant temperament and GM skills influenced by intensity of practice, and is this relationship the same for term and preterm infants, male and female infants and AGA and SGA infants?

A meditational model was proposed with temperament having direct and indirect effects through practice on motor skills. Specifically, infants with high surgency/extraversion (SE) would have better gross motor skills. There would also be an indirect effect as infants with high SE would practice more either independently or with parental assistance and therefore have better gross motor skills. From the previous chapters, male infants and SGA infants had lower FM skills, and SGA infants practiced less than AGA infants and these factors should therefore be adjusted. CA was not entered in the model as GMQ was age standardised. Figure 8.1 shows the conceptual model and path diagram for the main variables with the direct path from surgency/extraversion to motor skill and the indirect paths from SE to practice to motor skill.

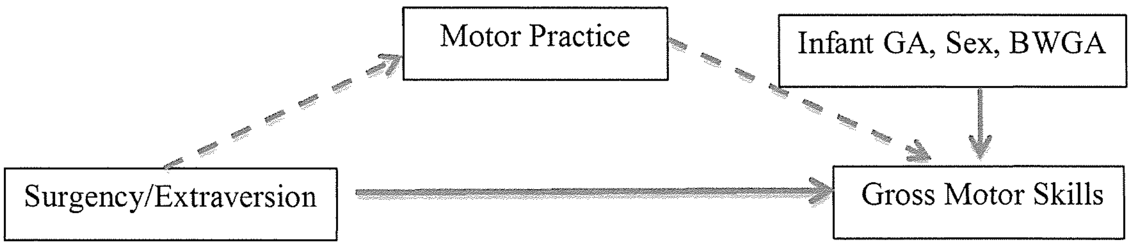


Figure 8.1 Conceptual model and path diagram showing relationships between infant temperament, motor practice and gross motor skills, controlling for infant GA, sex and birth weight for gestational age.

8.2 Data management

8.2.1 Sample size

Infants were included in this study if they had full data for GM and FM skills, temperament factor scores and accelerometer counts. There were 141 infants who met these criteria, 78 term (39 males) and 63 preterm (35 males). For the simple one-mediator model being proposed, the recommended sample size is between 100 to 150 participants (Hair, Black, Babin, Anderson, & Tatham, 2006) so this sample size is adequate.

8.2.2 Hypotheses

- Infants with higher SE will engage in more practice which will not be influenced by infant characteristics of CA, GA, sex and BWGA.
- Infants who are more vigorous when awake will have better motor development than less active infants, independently of sex, GA and BWGA.
- Infant practice will mediate the relationship between SE and motor skills, independently of infant GA, sex and BWGA.

8.3 Data analysis

GMQ, SE, NA, OR and awake counts have previously been tested and found to be normally distributed.

To test for the relationship between temperament and practice, correlations were examined between SE, NA, OR and awake activity counts with CA, GA, sex and BWGA. Factors that were correlated with awake counts ($p < .05$) were entered into step one of the hierarchical linear regression model and temperament factor scores were entered in step two.

The relationship between practice and motor skills was examined with correlations between GMQ and AIMS percentiles with GA, sex, BWGA and awake activity counts. Factors that were correlated with the motor outcomes were entered into step one of the hierarchical linear regression model and awake counts in step two.

The final analyses tested the correlations between SE, NA, OR, awake counts, GA, sex and BWGA with GMQ and AIMS percentiles.

8.4 Results

8.4.1 Relationship between infant temperament and motor practice

CA, AGA and SE were all positively correlated with awake activity counts. The other infant characteristics and temperament factors were not correlated with awake activity counts and are reported in Table 8.1.

Table 8.1 Correlations between infant characteristics, infant temperament factors and awake activity counts.

	CA	GA	Sex	BWGA	SE	NA	OR
Awake activity	.277*	.125	-.018	.374*	.349*	.097	-.108

CA = corrected age, GA = gestational age, BWGA = birth weight for gestational age, SE = surgency/extraversion, NA = negative affectivity, OR = orienting/regulation,
*$p < .001$

Table 8.2 presents the findings of the regression model. CA and BWGA were entered in the first step in the model and SE entered in step two. Assumptions for the model were met with tolerance and VIF statistics being close to 1, Cook's distances being <1 and the graph confirming linearity and homoscedasticity.

In the first step of the model, CA accounted for a significant but small number of awake counts. For every one week of CA, there was an increase of approximately 300 counts. BWGA was also significant in the first step with AGA infants recording approximately 14,000 counts more than infants who were SGA. Together CA and AGA accounted for a significant 20% of the variation in the awake activity counts. In step two of the model CA was no longer significant but the effect of BWGA remained. SE was significant showing that for every 1 point increase there was an increase of 900 awake counts. The addition of the SE factor together with BWGA accounted for a further 5% of the variation in awake counts that was significant. Together they accounted for 25% change in awake counts, with AGA contributing 14,000 counts and SE 900 counts.

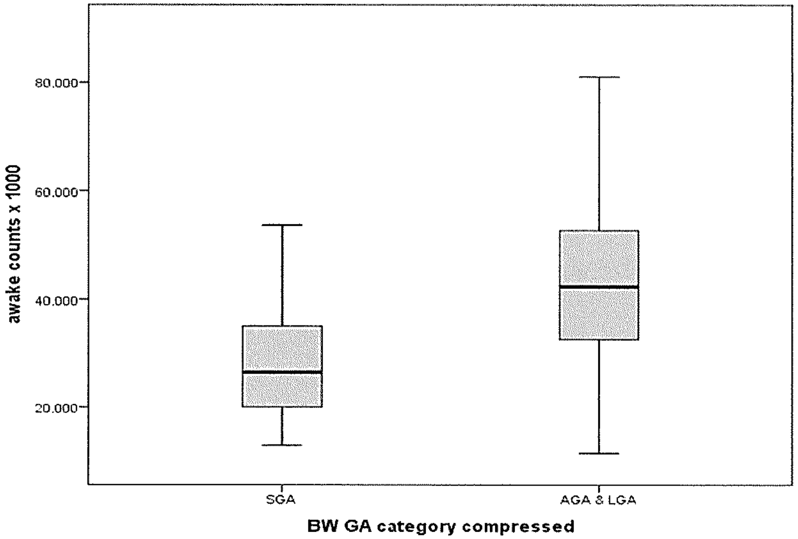
The relationship between BWGA and SE to activity counts is shown graphically in Figure 8.2

Table 8.2 Multiple linear regression analysis predicting practice from surgency/extraversion controlling for infant corrected age and birth weight for gestational age.

Awake counts x 1000	**Predictors**	**B**	**95% CI**	***β***	***sr^2* x 100**	***p*-value**
	Step 1					
	CA	.293	.112, .473	.248	6.101	.002
	BWGA	14.242	8.096, 20.387	.354	12.461	.000
	$R^2 = .201, p < .001$					
	$\Delta R^2 = .050, p = .003$					
	Predictors	**B**	**95% CI**	***β***	***sr^2* x 100**	***p*-value**
	Step 2					
	CA	.103	-.112, .318	.087	.504	.344
	BWGA	14.069	8.097, 20.041	.350	12.110	.000
	SE	.916	.313, 1.519	.276	5.062	.003
	$R^2 = .251, p < .001$					

CA = corrected age entered as weeks of age, BWGA = birth weight for gestational age with entered as SGA = 1 and AGA = 2, SE = Surgency/extraversion entered as points

(A)



(B)

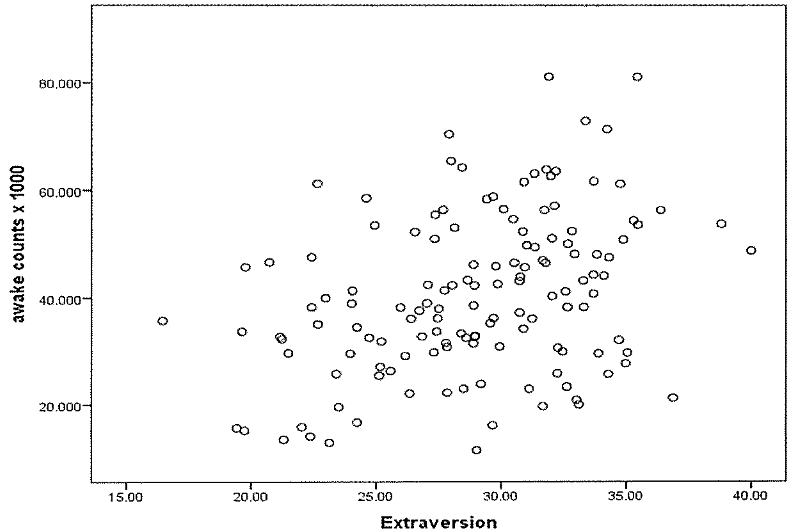


Figure 8.2 Box plots showing difference in activity counts between appropriate and small for gestational age infants (A) and the scatterplot showing the relationship between activity counts and surgency/extraversion score (B).

8.4.2 Relationship between infant motor practice and motor skills

The Pearson's correlation coefficients and levels of significance are reported in Table 8.3. GA was not correlated with GMQ, FMQ and AIMS percentiles confirming that CA adjusted for the effect of GA on quotients. There was a positive correlation between female sex and FMQ and positive correlations between AGA and FMQ and AIMS percentiles. Awake counts/hour were positively correlated with all motor outcomes.

Table 8.3 Correlations between gestational age, sex, birth weight for gestational age and awake counts with age standardised gross and fine motor quotients and AIMS percentiles.

	GA	**Sex**	**BWGA**	**Awake counts**
GMQCA	.142	.152	.165	.227**
FMQCA	.123	.204**	.181*	.168*
AIMSCA	.086	.103	.177*	.283***

GA = gestational age, BWGA = birth weight for gestational age, GMQCA = gross motor quotient corrected age, FMQCA = fine motor quotient corrected age, AIMSCA = AIMS percentile for corrected age, *$p < .05$, **$p < .01$, ***$p < .001$.

Assumptions for all regressions were met and the results are presented in Table 8.4.

As no infant characteristics were correlated with GMQ, only awake counts were entered into the linear regression model. Awake counts predicted 23% of the change in GMQ. For every 1000 awake counts/hour there was an increase of 0.1 point in the GMQ. This small change in the GMQ while statistically significant is unlikely to be clinically significant. However, this finding suggests that infants who are more active have better GM skills, independently of infant GA, sex and BWGA.

BWGA accounted for a significant 18% of the change in the AIMS percentile in step one of the model. AGA infants scored 12 percentiles higher than SGA infants for every 1000 activity counts. The addition of activity counts in step two increased the variance in the AIMS percentile significantly to 29%. BWGA was no longer significant, but for every 1000 activity counts there was an increase of 0.4 percentiles. The change in AIMS percentiles in both steps of the regression model should be interpreted cautiously as the percentiles do not increase linearly.

Importantly, activity counts predicted an increase in GM skills consistently, based on both the GMQ and the AIMS percentiles, but not the FMQ.

Table 8.4 Hierarchical linear regression analyses predicting gross and fine motor quotients and AIMS percentiles for corrected ages from the main effects of infant characteristics and awake activity counts.

Gross motor quotient	**Predictors**	***B***	**95% CI**	***β***	***sr^2* x 100**	***p*-value**
	Awake counts x 1000	.102	.028, .176	.227	5.153	.008
	$R^2 = .227$ $p = .008$					
Fine motor quotient	**Predictors**	***B***	**95% CI**	***β***	***sr^2* x 100**	***p*-value**
	Sex	2.141	.341, 3.946	.910	3.802	.040
	BWGA	2.569	.118, 5.021	1.240	2.958	.020
	$R^2 = .267$, $p = .007$					
	$\Delta R^2 = .013$, $p = .165$					
	Sex	2.190	.395, 3.985	.200	4.000	.017
	BWGA	1.870	-.766, 4.506	.125	1.346	.163
	Awake counts x 1000	.046	-.019, .112	.125	1.322	.165
	$R^2 = .290$ $p = .008$					
AIMS percentile	**Predictors**	***B***	**95% CI**	***β***	***sr^2* x 100**	***p*-value**
	BWGA	12.461	.683, 24.238	.177	3.133	.038
	$R^2 = .177$, $p = .038$					
	$\Delta R^2 = .058$, $p = .005$					
	BWGA	5.808	-6.577, 18.193	.082	5.777	.355
	Awake counts x 1000	.442	.134, .749	.252	5.476	.005
	$R^2 = .293$, $p = .002$					

8.4.3 Relationship between infant temperament, motor practice and gross motor skills

None of the temperament factors were correlated with GMQ (in bold in Table 8.5). The significant correlations are consistent as reported between temperament factors and awake counts and between awake counts and GMQ.

Because a direct effect between temperament and GM skills was not established, examination of the meditational model was not justified.

Table 8.5 Correlations temperament factors, awake counts, gross motor quotient, infant sex and birth weight for gestational age.

	BWGA	GMQ	SE	NA	OR	Awake counts
Sex	.048	.152	-.023	.155	.039	-.018
BWGA		.165	.064	-.041	.165	.374**
GMQ			**-.027**	**.113**	**-.027**	.227*
SE				.104	.224*	.349**
NA					-.255*	.097
OR						-.108

BWGA = birth weight for gestational age, SE = surgency/extraversion, GMQ = gross motor quotient for corrected age, *$p < .01$, **$p < .001$

8.5 Discussion

The main finding of this study was that infant temperament did not have an indirect effect on motor skills through motor practice. This three-way relationship was not demonstrated, although other original findings were revealed.

8.5.1 Intensity of practice promotes gross motor skills

Infants who practice more had better GM skills independently of infant GA, sex and BWGA. However, it is not the type of activities in which infants engage nor the amount of support they require nor the duration of the activities, but the intensity of their movement during those activities that appears to have positive benefits on their GM skills.

This is a novel finding as there are no studies of which the author is aware that report a relationship between intensity of practice and development of GM skills in infancy. Specific practice of crawling and gait in typical infants is described as being intense, variable and random, with practice parameters of frequency, duration, distance travelled, physical environments and errors noted as being important for typical infants learning (Adolph et al., 1998; Adolph et al., 2003) but the intensity of the practice has not been quantified. This is the first study to also report on the practice parameters for preterm infants, noting that there were no differences between term and preterm infants.

High activity counts were associated with both measures of GM skills, the PDMS2 and the AIMS. These measures are discrete and independent of each other, so confirm that the relationship between intensity of activity and GM skills is plausible.

Differences in intensity of practice have been shown in a small number of studies of treadmill training for infants at risk of neuromotor delay (Angulo-Barroso et al., 2010) and infants with Down syndrome (Angulo-Barroso et al., 2008; Lloyd, Burghardt, Ulrich, & Angulo-Barroso, 2007) where a relationship between higher intensity of walking practice was associated with earlier walking achievement. Specific GM skills training for term infants at two months of age for 15 minutes/day over three weeks had positive effects on GM skills compared with an age and sex matched group who did not receive this training (Lobo & Galloway, 2012). The differences between these studies and the current study is that the earlier studies found a positive combined effect of task specific practice (gait training and practice of specific discrete motor skills) with higher intensity practice on the development of gait and motor skills. The current study measured practice that occurred as part of daily routines and suggests that non-specific, incidental practice if performed with higher intensity is beneficial for the development of a range of gross motor skills and over the course of infancy.

Term and preterm infants in the current study were not exposed to specific GM training but interacted with their parents during routine tasks as well as during opportunities for independent and supported play. The current findings are consistent with the notion that routines based interventions could promote learning of motor skills in infants with motor delay (Cripe & Venn, 1997). The findings further suggest that infants and parents should engage actively in their interactions.

The procedure and tools for measuring infant practice appear adequately robust to support this original finding. However, in this cross-sectional sample, causation cannot be inferred between intensity of practice and GM skills. It is possible that infants who practice with more vigour develop better GM skills but the converse is equally possible that as infants acquire GM skills they have an increased repertoire with which to practice. Associations between motor ability and physical activity have been studied extensively in children, adolescents and adults with one view suggesting that the relationship is dynamic, cyclical and changes with developmental time such that at different times in an individual's life, motor ability may drive physical activity while at other ages the converse is true (Stodden et al., 2008). The current study finding is that practice occurs during infant-parent interactions as well as during infant independent play. Therefore, using awake activity counts appears rational as both types of activity are captured.

8.5.2 Infants with a high surgency/extraversion temperament engage in more practice but there is no relationship with gross motor skills

Infants with high SE practiced more intensely than infants with lower SE. This association is independent of infant GA, CA and sex, although infants born AGA practiced more intensely as discussed in the previous study. Other temperament factors of negative affectivity and orienting/regulation were not associated with intensity of practice.

SE as a predictor of practice is an original finding in infancy, but has been reported for children and adults. Girls aged eight to 12 years with a high activity temperament had increased energy expenditure that appeared to be related to "fidgetiness" and was discrete from structured and unstructured physical activity (PA) measured using accelerometry (Anderson et al., 2004). Adult women with high extraversion and the novelty seeking trait, described as having an energetic attitude and exploratory behaviour, participated in higher amounts of moderate-vigorous PA (Fernandez-Aranda et al., 2014; Kjelsas & Augestad, 2004). Finally, a meta-analysis of 23 studies (n = 50721) measured personality (composite factor or traits) and PA (monitors as well as questionnaires) and found a correlation between extraversion and increasing PA with a small-medium effect (Rhodes & Smith, 2006).

A few studies have confirmed that infants with a high activity temperament, that is a predilection for gross motor activity, have higher activity levels measured using monitors (Eaton & Dureski, 1986; Eaton et al., 2001). In the current study, the composite SE factor was examined as it provides a more comprehensive picture than the activity trait alone to explain why some infants are more intensely active. SE includes the activity trait and five other traits, which are vocal reactivity, high pleasure, smiling and laughter, approach and perceptual sensitivity. The authors of the IBQR provide definitions for each trait which when combined can define the SE factor. An infant with high SE could be described as showing anticipation and pleasure from both low intensity and novel environmental stimuli by increasing their gross motor activity and smiling and laughter (Gartstein & Rothbart, 2003). Some of these features are consistent with the description of extraversion for adults.

One of the advantages of using the SE factor to interpret infant activity is that it provides an opportunity to further understand the contribution of infant-independent and infant-parent movement. Infants in the current study were reported by their parents as responding to people, objects and events in their environment with gross motor activity, therefore scored high in SE and had high activity counts. This activity was likely to be infant generated. An in-depth look at the items that comprise the six traits and therefore the SE factor affords a better understanding of the infant's behavioural response. There are 72 items in the SE factor of which 64 are purely infant response during feeding, bathing, play, and other daily activities. The remaining eight items are infant movement during interaction, for example, the infant's response to being tickled, tossed playfully or being bounced. Therefore, it would seem that the SE factor is a legitimate way of understanding infant-independent movement.

In contrast, infant-parent movement could more likely be reflected by the other two temperament factors, negative affectivity and orienting/regulation. Higher proportions of infant-parent movement could be measured with higher OR factor scores as this included the infant being carried and rocked but this factor was not associated with higher activity counts. NA was also not correlated with activity counts, as the items included in this factor did not involve movement by the infant or parent.

While the SE factor appears better able to differentiate infant-independent from infant-parent activity compared with the OR and NA factors, nevertheless as infants are dependent, the likelihood is that the activity counts include movement from both infant and parent. Furthermore, infants who respond positively and enthusiastically to environmental stimuli of any form may evoke positive responses in their parents, thereby increasing activity counts.

Li, Pawan and Standbury (2014) reported that infants at 12 months of age who had high OR were provided with more assistance and coaching during daily activities, by their mother. The authors did not attribute maternal assistance as practice (I. Li, Pawan, & Stansbury, 2014). The current study did not find any relationship between OR and practice.

Infant sex did not influence the relationship between SE and intensity of practice in the current study, nor was it related to temperament profiles or practice parameters. This is in contrast to the sex differences in the activity trait that were found in a meta-analysis (Campbell & Eaton, 1999). Male infants were significantly but only slightly more active than female infants measured using activity monitors, but parent report temperament questionnaires found no sex differences (Campbell & Eaton, 1999). The activity trait only was measured in this meta-analysis, not the SE factor. It is possible that the current study might have found sex differences if the relationship between the activity trait and activity counts was investigated, rather than the wider SE factor.

The current study hypothesised an association between SE and GM skills as infant temperament is described as an organiser of development across multiple domains (Marshall et al., 2000) but there was no correlation in the current study. In contrast, a longitudinal study of impoverished infants (n = 652) from two to eight months in rural Bangladesh found that infants who were fussy and unadaptable and whose mothers had depression had lower GM scores at eight months (Nasreen et al., 2013).

This study used the Infant Characteristics Questionnaire (ICQ), which generates different descriptors of infant temperament, so comparison with the current study is difficult. It is also possible that the combination of poor ante- and post-natal nutrition of the mother and infant and lack of maternal education and social support might all contribute to delayed infant GM skill acquisition. While these were acknowledged in the study, their effects on GM skills were not tested.

As gross motor skills develop in a stage-like, irregular progression (Adolph, Robinson, et al., 2008), it is possible that SE might drive an increase in practice that reaches a critical point at which time a motor skill emerges. The emergence of motor skills is likely to be masked in cross-sectional studies, such as the current one. While temperament is considered to be stable longitudinally, its effects on behaviours may vary depending on the other factors that might contribute to those behaviours.

It might be that the use of the SE factor in the current study concealed a possible association between the activity trait and GM skills, as this trait is defined by the infant's gross motor activity in response to environmental stimuli. There are no studies which have looked at the relationship between the activity trait and GM skills in infancy. Longitudinal studies have, however, shown that some infants with a high activity trait show a range of adverse behaviours in childhood, such as externalizing behaviours, hyperactivity, poor adjustment to child care and school, and conflict and negativity with siblings and peers (Saudino, 2012). What is not reported is the severity of activity or scores for other temperament traits that might predispose some children to show mal-adjusted behaviours in childhood. While the current study did not find any association between the SE factor and GM skills, this relationship may be important for understanding the long term effects of an active, outgoing temperament in infancy on all domains of development in childhood.

8.5.3 Summary

Infants with high SE engaged in more motor practice independently of GA, sex and BWGA. Infants who practiced more intensely had better GM skills, again independently of GA, sex and BWGA. There was no association between SE and GM skills. The proposed model to test if motor practice mediated the relationship between SE and GM skills could not be tested.

Chapter 9 – Final discussion

9.1 Introduction

The main aim of this thesis was to examine the effects of motor practice and infant temperament on GM and FM skills and to determine if these relationships differed for CA, GA, sex and BWGA. Four studies were conducted generating discrete results.

In summary, the first study confirmed that comparisons between term and preterm infants' GM and FM skills should be based on CA, and unlike many other studies, preterm infants' motor performance was similar to term infants. Male infants and SGA infants had poorer FM skills. The second study found that temperament profiles were similar for term and preterm infants, measured using the IBQR. The mean scores for traits and factors for all infants were similar to those of US infants. In the third study, unstructured practice that occurred during daily routines was similar for term and preterm infants in its duration, rhythmicity, assistance required and vigor. Accelerometry was better able to measure intensity of practice than the parent report diary. SGA infants were less intense in their practice than AGA infants. In the final study, infants who had higher surgency/extraversion (SE) engaged in more vigorous practice as measured by the accelerometer, and infants who practiced more intensely had better GM skills. However, there was no three way relationship between infant temperament, practice and motor skills.

The results of these studies, when viewed together yielded a number of original findings.

9.2 Preterm infants' motor skills, temperament and motor practice were similar to term infants

Preterm birth alone was not associated with delayed motor skills, negative temperament profiles or less practice compared with term birth. Specifically, at CA the preterm infants had similar GM and FM skills, were equally extraverted and self-regulated, spent the same amount of time in routine activities and engaged in as much practice when awake as the term infants. Overall, this cohort of healthy, low-risk preterm infants at CA, were more like the term infants behaviourally than different to them. While GA differentiated term from preterm infants, early gestation did not result in motor delay, negative temperament traits or reduced motor activity.

Preterm birth is associated with deficits in a number of body systems, such as the neurological, muscular and cardiopulmonary systems (Committee on Understanding Premature Birth and Assuring Healthy Outcomes, 2007). These systems were not assessed in the current study and do not appear to have had an adverse affect on the preterm infants who participated in the study. However, longitudinal follow-up may expose deficits in body systems that impact motor function later in childhood.

According to the dynamic systems theory of motor development, environmental factors interact with infant characteristics to promote or delay motor development (Thelen & Smith, 1994). There are a number of environmental factors that might explain why the preterm and term infants in the current study had similar GM and FM skills. Social environmental context describes the place in which infants are raised including physical environment or the distal factors and social environment or proximal factors (Messer et al., 2008). Distal factors include the neighbourhood (e.g. footpaths, street lighting, parks and playgrounds) and access to health services (e.g. child health nurse, general practitioners) and proximal factors such as maternal education, family structure, family income, and stable living arrangements (Davey, Cameron, Ng, & McClure, 2015). In the current study, the majority of the mothers of preterm infants were university educated. Maternal education is one factor that appears to impact infant outcomes in two ways. Davey et al. (2015), in a large population (n = 1914) based study of urban Australian mothers and their infants, found that university educated mothers had better health habits during pregnancy, such as not smoking, low risk of alcohol and drug use, nutritious diet and low psychological distress, compared with mothers with high school or lower levels of education. The authors go on to suggest that mothers' positive ante-natal health practices are likely to continue post-natally as these mothers are more likely to breastfeed, immunise their infants and access health services for their infant (Davey et al., 2015). Pregnancy, birth history and post-natal care were not obtained from the mothers in the current study. Davey et al. (2015) also found that infants of mothers with a secondary school education or a trade were significantly more likely to have had a medically diagnosed infection or respiratory condition or sustained an injury compared with infants with university educated mothers (Davey et al., 2015). Again, this information was not gathered from the mothers in the current study, although if the preterm infants required medical intervention it was more related to their prematurity. Other social factors that are considered to be protective and were evident in both groups of infants were living in a two parent nuclear family, being in the highest income level, and having mothers who were in their mid 30's (Davey et al., 2015).

The majority of the preterm infants in the current study also had protective distal factors such as access to regular health services (preterm infants were recruited through a physiotherapy conducted playgroup) and attended playgroups (preterm infants were recruited through the Miracle Babies® playgroup). A combination of positive social and physical environment context factors may have ameliorated the effects of early gestation and contributed to better outcomes for the preterm infants.

Temperament profiles for the preterm infants in the current study were similar to term infants. This might be because the expectations of parents of the preterm infants were congruent with the capabilities of the infants in what is described as "goodness of fit" (Chess & Thomas, 1977). Additionally, Vasquez (1995) explains that parents of preterm infants work through a process whereby they first gather resources to cope with their preterm infant then use these resources to affirm their family unit (Vasquez, 1995). Both these strategies may explain why mothers in the current study perceived their preterm infants to be similar in temperament to term infants.

The transactional relationship between preterm infants and their mothers is evidenced in the construction of daily routines. Arnott and Brown (2013) suggest that educated mothers are better able to establish routines (Arnott & Brown, 2013). In the current study daily routines may have provided a framework to assist preterm infants to learn motor skills. Learning of motor skills is more likely to occur during daily routines as routines allow an infant to practice regularly, frequently, have in-built reinforcement and reward for success and enable practice within context (Cripe & Venn, 1997). For infants to benefit from routines, infants and parents need to work cooperatively to establish the routine and work within its structure (Woods, Kashinath, & Goldstein, 2004). In the current study there is no direct evidence that mothers and preterm infants worked constructively to shape their daily routine. However, preterm infants appear to have benefitted as they had comparable GM and FM skills, had moderate temperament traits, that is, were not excessively extraverted or negative in affect or poorly regulated, and had daily routines with adequate time spent in care, play and sleep.

While the social and physical environments appear to have had positive effects on preterm infants, the same was also true for the term infants. In the current study term infants may have benefitted from the protective effects of their social environment. Term infants lived in two-parent nuclear families with high income and had mothers who were predominantly university educated. They may have derived the same benefits as the preterm infants. On all indications, the preterm and term infants were very similar. An alternative question might be: Independently of GA, what biological, social and environmental factors differentiate infants who are delayed in motor skills from those developing appropriately?

9.3 Infants who are small for gestational age require close monitoring

In the current study infants who were SGA had a higher risk of FM delay and practiced with less intensity compared with AGA infants. SGA was defined as BW < 10^{th} percentile for GA (WHO, 2011) and was not used interchangeably with LBW, that is, BW < 2500g. Many studies use the terms interchangeably hence potentially hiding some of the consequences of SGA.

A number of body systems are compromised due to intra-uterine growth restriction (Rogvi et al., 2015) which might explain the FM delay. When performing FM skills the infant is required to do more than just use their hands and fingers. The items included in the PDMS2 that test FM skills, for example holding one block in each hand and banging them together, have underlying components that include but are not limited to GM skills such as sitting balance (Hadders-Algra, 2013), visual control (Barrett et al., 2008), kinesthesis (Cabral, da Silva, Tudella, & Martinez, 2015), visuo-spatial and visuo-motor control (van Braeckel & Taylor, 2013), graded muscle control of the hand and fingers and motor planning (Claxton, Keen, & McCarty, 2003). All or some of these aspects may be limited in an infant who is SGA.

Consistent with the dynamic systems theory, one body system is not more important than the others and the SGA infant may not be able to organise their body systems adequately to achieve FM tasks. Recognition of FM delay in SGA infants is important as it is appears to persist into childhood (Bos et al., 2013).

SGA infants practiced significantly less intensely than AGA infants but this did not cause delay in their GM skills. A reduction in intensity of practice may be due to reduced development of the chest and respiratory muscles as well as altered fetal lung development (Briana & Malamitsi-Puchner, 2013). They may also have lower skeletal muscle mass (Ahmad et al., 2010) which may negatively impact their ability to move with vigor. The lack of an association between less intense practice and GM delay in SGA infants does not preclude the possibility that an association might exist as the infants reach preschool or school age.

The implications of reduced intensity of activity may be an increased risk of overweight and obesity for children and adolescents who were born SGA (Huang, Mori, & Beilin, 2012). Infants who were born SGA also have a higher propensity for cardiovascular and metabolic disorders which tend to manifest when the child is exposed to environmental factors, such as high caloric foods and reductions in physical activity (Tappy, 2006). This is referred to as the "thrifty phenotype hypothesis" (Hales & Barker, 1992) but has not been demonstrated in infants. Reductions in intensity of activity for SGA infants may be a precursor for later inactivity in childhood.

9.4 Intense motor practice is important for learning gross motor skills

Angulo-Barroso and colleagues in 2008 and 2010 demonstrated that high intensity practice using treadmill training for infants with Down syndrome and infants with neuromotor delay, respectively, was beneficial for infants learning to walk and to increase their levels of physical activity compared with infants who did not engage in the training. The current study adds to these specific training protocols by showing that some infants practice more intensely during everyday activities and the higher intensity promoted GM skills. This novel finding in infancy reinforces the significance of interventions being embedded into everyday routines for infants with motor delay. The challenge for parents and clinicians is to ensure that the practice is of sufficient intensity to develop GM skills.

The current study found that infants who practiced with higher intensity had higher SE but this was not associated with motor skills in infancy. The association however, has been reported for children (Anderson et al., 2004) and adults (Fernandez-Aranda et al., 2014). It might be that infants with high SE are supported to play and explore their environment by their parents, but are not able to engage in independent activity in the same way that older children and adults do. There are potentially other factors that may affect the intensity of infant practice, apart from infant temperament, such as parenting styles, older siblings, and environmental stimulation.

9.5 Strengths

There were a number of strengths of the thesis. Firstly, both groups of infants were well matched for health status, accounting for preterm GA, maternal and paternal characteristics and family SES. Therefore, the main difference between groups was infant GA.

Secondly, all studies were adequately powered to detect differences in GM and FM skills, temperament profiles and motor practice. In particular, when measuring activity using accelerometers the sample size in this thesis is one of the largest (n = 140), compared with Tulve et al. (2007) with five typical infants, McKay and Angulo-Barroso (2006) with eight and Saudino and Eaton (1991) with 120. The feasibility of measuring infant activity using both accelerometers and diary is confirmed and this study's procedures and findings therefore, could be of interest to other researchers investigating activity in infancy.

Thirdly, GM skills and practice were measured using two independent tools. GM skills were assessed using the PDMS2 and the AIMS both of which generated similar findings. Likewise, the DAIS and the accelerometer were complementary but also independently measured motor practice.

Finally, the IBQR has not been used with Australian infants but appears to be a suitable measure of temperament.

9.6 Limitations

There were a number of limitations to the thesis, some of which are related but converse to the strengths. The main limitation is the lack of generalizability of the findings to other groups of term and preterm infants. Henrich et al. (2010) suggest that using a homogenous WEIRD sample reduces its applicability. WEIRD is defined as – Western, Educated, Industrialised, Rich and Democratic (Henrich, Heine, & Norenzayan, 2010). GM and FM outcomes were based on Western norms and applicable to Australian infants, but may not be applicable to other cultures or societal groupings. Measurement of temperament of infants who are at risk of adverse health outcomes due to social and environmental factors could provide a range of trait and factor scores that are wider and may reflect unusual behaviours. Trait and factor scores in the current study are within a small range so may not be useful for determining if infants are at risk of adverse outcomes as they grow. The majority of mothers who participated were university educated and the family socioeconomic status favoured advantage. This is not an unexpected bias when a study has high commitments as in the current study, and has been noted elsewhere (Davey et al., 2015). Again, this limits the application of the study findings to mothers who are less well educated or who have post-natal depression or other reasons that compromise maternal competence.

The cross-sectional study design might have masked motor delay of infants from either group, as motor development is non-linear and the progression with its peaks and troughs of skills from three to 12 months requires further investigation. Adolph and Robinson (2015) suggest that longitudinal study designs consider the differing time frames of the components of motor development. Measuring developmental change in body systems to explain behavioural outcomes, for example kinematics of movement, will differ to the time frames for measuring the change in motor behaviour and will again be different if measuring the impact of motor development on other domains of development, such as language (Masten, 2006). Careful consideration should be given to the variables of interest when designing longitudinal studies.

Use of the accelerometer for 24 hours only was not ideal but was considered practical for the purpose of the study and was consistent with the protocols for monitoring effects of treadmill training for infants at risk of neuromotor delay (Angulo-Barroso et al., 2010) and infants with Down syndrome (Angulo-Barroso et al., 2008). Further research could include longer periods of accelerometry but with a less detailed diary to reduce the inconvenience to parent participation. Alternatively, direct observation of infant behaviour occurring concurrently with accelerometer use would help with validation of activity counts.

A high proportion of diaries had to be omitted due to inaccuracies and further, the omitted diaries were primarily those of mothers with lower levels of education. It is possible that mothers and their infants who were omitted from the analyses might have influenced some of the relationships, especially as there is an association showing that mothers with higher levels of education are more likely to use routines for their infants (Arnott & Brown, 2013). Omission of mothers with lower educational attainment limits the generalizability of the findings in the current study to other mother-infant dyads. This is an important group from which to obtain and retain accurate information as infants with mothers who are less educated are at a higher risk of developmental problems. A less complex diary might ensure better accuracy and completion.

Interpretation of accelerometer counts is problematic for infants even with the use of a diary. The current study found wide ranges of counts for care, play and sleep when referenced against the diary. It might be that there was a mismatch between what the mother interpreted as an activity and what the accelerometer was recording. For example, the mother might have placed her infant to sleep and recorded sleep in the diary, but the infant was still awake and moving in his/her bed with the accelerometer recording activity counts. Mis-match between accelerometer and diary were also reported by Tulve et al. (2007). One solution to this mis-match is to engage in direct observation of infant behaviour and so establish ranges of counts for different categories of activities. However, counts are specific to the make and model of accelerometer and are limited in their generalizability. Alternatively, the use of an algorithm to confirm diary report of sleep and wake states could be designed (Galland, Kennedy, Mitchell, & Taylor, 2012).

9.7 Clinical implications and future directions

The majority of the preterm infants in this study were competent on all measures, which may be the result of regular monitoring by physiotherapists, in a playgroup setting, of motor development during infancy to ensure that they are not at risk of motor delay. Longitudinal tracking through toddlerhood and into childhood of healthy low risk preterm infants might assist in a better understanding of the factors that might result in later delay.

SGA infants may benefit from closer monitoring during infancy to ensure their motor skills are appropriate and form a platform for subsequent development. Parents should be educated to ensure that their SGA infant is spending adequate time in daily activities of varying intensity to benefit GM development. Furthermore, practice could potentially improve their cardiopulmonary capacity, muscle strength and postural control. These infants should also be provided with a rich play environment that fosters FM skill development. Clinicians who work with infants who are SGA should be advised to monitor infants' motor development from infancy through childhood.

In the current study, preterm infants were lighter in weight compared with term infants. Preterm girls were the shortest, lightest and had the smallest head circumference. The mean weight for age for the preterm infants at CA in this study was on the 3rd centile consistent with that reported in the literature (Bertino et al., 2012). Currently no growth charts exist to monitor postnatal growth of infants born preterm after they reach term age. One protective factor for SGA infants appears to be post-natal growth. Infants with catch-up growth are reported to have better GM outcomes than infants who remain small for age (Black et al., 2004; Hediger et al., 2002; Latal-Hajnal, von Siebenthal, Kovari, Bucher, & Largo, 2003).

Future research could explore whether term and preterm infants who are delayed practice with less frequency, duration and intensity. In particular, male infants in this cohort were at an increased risk of FM delay so monitoring male infants who present with risk factors related to their birth or social environment should be considered.

Longitudinal studies across infancy and into early childhood exploring the change in practice and development of GM and FM skills are recommended.

9.8 Conclusion

This thesis achieved its aim to investigate the role of motor practice and infant temperament in the development of motor skills in term and preterm infants. Intense motor practice was found to have positive effects on GM development for infants, therefore parents and clinicians should ensure that term and preterm infants engage actively in varying duration and intensities of motor practice. Particular attention should be given to SGA infants as they practice with less intensity. Although a direct effect of temperament on GM skills was not found in the age group studied, parents with infants with quieter or more fearful or irritable temperaments may need help to play creatively with their infants, particularly infants with motor delay. The benefits to infants for development of cognition, language and social skills may be enhanced through preventing or ameliorating motor delay with motor practice.

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Every reasonable effort has been made to acknowledge the owners of copyright material. I would be pleased to hear from any copyright owner who has been omitted or incorrectly acknowledged.

Appendix 1: Curtin University Ethics approval

Curtin University

Memorandum

To	Professor Jan Piek, School of Psychology and Speech Pathology
From	Assoc/Prof Stephan Millett, Chair, Human Research Ethics Committee
Subject	Protocol Approval **HR 148/2010**
Date	16 December 2010
Copy	Mrs Lynn Jensen, School of Physiotherapy Dr Jennepher Downs, School of Physiotherapy Graduate Studies Officer, Faculty of Health Sciences

Office of Research and Development

Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for your application submitted to the Human Research Ethics Committee (HREC) for the project titled "*Factors that affect motor development in infants with and without motor delay*". Your application has been reviewed by the HREC and is **approved**.

- You have ethics clearance to undertake the research as stated in your proposal.
- The approval number for your project is **HR 148/2010.** *Please quote this number in any future correspondence.*
- Approval of this project is for a period of twelve months **14-12-2010** to **14-12-2011**. To renew this approval a completed Form B (attached) must be submitted before the expiry date **14-12-2011**.
- If you are a Higher Degree by Research student, data collection must not begin before your Application for Candidacy is approved by your Faculty Graduate Studies Committee.
- The following standard statement **must be** included in the information sheet to participants:
  This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HR 148/2010). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. Its main role is to protect participants. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au.

Applicants should note the following:

It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.

The attached **FORM B** should be completed and returned to the Secretary, HREC, C/- Office of Research & Development:
When the project has finished, or

- If at any time during the twelve months changes/amendments occur, or
- If a serious or unexpected adverse event occurs, or
- 14 days prior to the expiry date if renewal is required.
- An application for renewal may be made with a Form B three years running, after which a new application form (Form A), providing comprehensive details, must be submitted.

Regards,

A/Professor Stephan Millett
Chair Human Research Ethics Committee

Subject: "Factors affecting motor development in infants with and without motor delay" project.
Date: Friday, 14 October 2011 3:38:42 PM AWST
From: Welch, Anne
To: Lynn Jensen
CC: Sprigg, Lyn, Ablett, Lorraine, Wright, Suella, King, Keith

Dear Lynn

I am writing to advise you that your research request has been endorsed by the Child and Adolescent Community Health (CACH) Executive.

As detailed in the Site Authorisation Form, you may display recruitment posters at all Child Health Centres and Child Development Centres in the metropolitan area and relevant CACH staff may draw parents' attention to the posters and encourage them to contact the researcher.

For your information, follow this link to a list of all CACH sites.
http://www.health.wa.gov.au/services/category.cfm?Topic_ID=18

Please contact the Directors of North Coastal, South Coastal and Inland Zones (for Child Health Centres) and the Director of the Child Development Service for advice on organising poster display etc. They may be reached by email and their phone numbers are listed below.

A/Director – Inland Zone Lyn Sprigg Tel: 9224 7064 Fax: 9224 1612	**Director – North Coastal Zone** Lorraine Ablett Tel: 9224 1664 Fax: 9224 1612	
Director - CDS Keith King Tel: 9224 3732 Fax: 9224 1612		

It would be appreciated if you could provide me with an electronic copy of the Executive Summary of your PhD when completed and references to any publications which may arise from your research.

Kind regards

Anne
Anne Welch
Senior Research and Evaluation Officer
Strategic Support Unit
Child and Adolescent Community Health

T: 9224 8510
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PO Box S1296
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Note: I work P/T, Tues and Fri

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PARTICIPANT INFORMATION SHEET

Project title: Factors affecting motor development in infants with and without motor delay

Investigator: Lynn Jensen
Project Supervisor: Prof Jan Piek
Co-Supervisor: Dr Jenny Downs

Purpose of Research

Infants learn movement by practicing during play by themselves or with the help of their parents. They also practice during daily routines when their parents help them to feed, bath and get dressed. Some infants seem to be more active than other infants and this might be due to the infant's temperament or personality. What we are interested in knowing is whether an infant's temperament affects their development of movement.

Parents vary in how confident they feel about playing with their baby and helping their baby learn to move. The confidence of the mother, as the main care-giver, may be related to the baby's temperament and development of movement.

The purpose of this research is to measure the type and amount of movement infants do each day, to see if the infant's temperament affects how much movement they do and to find out how mothers feel about themselves as a parent. This information would help in our understanding of infants and their families so that physiotherapy treatment for infants who are delayed in their movement can be improved.

Your role in this research

This study has two-parts. First, an appointment will be scheduled at a time convenient to you for me to visit you at home. You can attend to your baby's needs at any time during my visit. During the visit I will:

- look at your baby's development of movement while he or she is playing. This will take between 30-40 minutes.
- measure your baby's length, weight and head circumference using the same equipment that the child health nurse uses.
- explain to you how to complete the three short questionnaires about your baby, about you (mum) and your family. These questionnaires take about 30 minutes to complete. You can do them while I am with you or later in your own time.

The second part of the study is to measure how much movement your baby does during 24-hours. To do this you will be asked to complete a diary and put an activity monitor on your baby's ankle. The diary contains pictures of routine infant activities and boxes for you to record the time that the activity happened. The activity monitor is a small box about 3cm square and weighs 15gm. The diary and activity monitor have been used in research with infants and do not have any risks.

I will visit you again 2 days later to pick up the questionnaires, diary and activity monitor if that is convenient for you or you can post them back to me at Curtin University using a pre-paid envelope which I will provide.

Risks and Discomforts

It is unlikely that there will be any risk or discomfort involved, as this study only involves observation of your child. However, the study does take some of your time during the home visit and also for you to complete the questionnaires.

Benefits

By taking part in this study, you will be helping us to better understand the daily routines of infants with and without delay in development of movement. You can request the results of your child's assessments. The study will benefit therapists who work with infants with delayed movement development, by providing them with information that will enable them to improve their treatment.

Confidentiality

Personal details about you and your child will be kept separately from questionnaires and other data collected about you and your child. All data collected will be coded so that you or your child cannot be identified. In accordance with ethical procedures, data collected may be used in scientific presentations and articles but will be presented collectively, so that individual participants cannot be identified. All information will be stored in a secure location within the School of Physiotherapy, Curtin University for 25 years before being destroyed. No information will be released to any third party.

Refusal or Withdrawal

You have the right to refuse to take part in this study and withdraw from the study at any time without prejudice. Refusal or withdrawal will not affect the therapy your child receives. All information relating to you and your child will be destroyed if you withdraw.

For any queries about the study please contact Lynn Jensen on 0487 412 985 or L.Jensen@curtin.edu.au. Alternatively, you may contact Prof Jan Piek (Principal Supervisor, 9266 7990 or J.Piek@curtin.edu.au) or Dr Jenny Downs (Co-Supervisor, 9266 4644 or J.Downs@curtin.edu.au).

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HR148/2010). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. Its main role is to protect participants. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University of Technology, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au.

This study has been approved by the Women and Newborn Health Service Ethics Committee (Approval number 1864/EW). If you have any concerns or complaints regarding this study, you can contact the Director of Medical Services at KEMH (Telephone: (08) 9340 2222). Your concerns will be drawn to the attention of the Ethics Committee who is monitoring the study.

This study has been approved by the Disability Services Commission's Research and Confidentiality Committee, March 2011. If you have any complaints you can contact the Manager, Planning, Research and Reporting on 9426 9250.

Thank you for considering participating in this study.

Government of **Western Australia**
Department of **Health**

WOMEN AND NEWBORN HEALTH SERVICE

Mrs Lynn Jensen
School of Physiotherapy
Curtin University of Technology
GPO Box U1987
PERTH WA 6845

Dear Mrs Jensen

REGISTRATION NUMBER: **1864/EW**

TITLE: **Factors that affect motor development in infants with and without motor delay**

MEETING DATE: **5 April 2011**

RGO and Ethics requirements satisfied 5 April 2011

The WNHS Ethics Committee has recommended approval be given for you to undertake the abovenamed research study. This recommendation has been ratified by the Women's and Newborn Health Service.

The Ethics Committee does however wish to be informed immediately of:

I. any untoward effects experienced by any participant in the trial where those effects in degree or nature were not anticipated by the researchers, and steps taken to deal with these,

II. substantial changes in the research protocol together with an indication of ethical implications, and

III. other unforseen events.

The Ethics Committee has been charged with the responsibility of keeping the progress of all approved research under surveillance. A copy of the final result must be forwarded to the Committee upon completion of the research or if the research is not completed within twelve months you are asked to submit a progress report and annually thereafter. This information should include:

Government of **Western Australia**
Department of **Health**

WOMEN AND NEWBORN HEALTH SERVICE

c) The status of the project (completed/in progress/abandoned/not commenced). In the event that a project does not commence within 12 months of being approved by the Ethics Committee the study must be resubmitted to the Committee for approval.

d) Compliance with conditions of ethical approval, including security of records and procedures for consent.

c) Compliance with any special conditions stated by the Ethics Committee as a condition of approval.

d) Results from the study to date, including outcome.

Please note that approval for studies is for **three years (your expiry date will be 5 April 2014)** and if the research is not completed within that period of time, a request for an extension of time should be submitted for consideration. In the event that a project does not commence within **12 months** of being approved by the Ethics Committee, the study must be resubmitted to the Committee for approval.

Please quote the above registration number on all correspondence.

Yours sincerely

Dr Mark Salmon
Executive Director
Medical Services

7 April 2011

The Ethics Committee is constituted, and operates in accordance with the National Health and Medical Research Council's National Statement on Ethical Conduct in Research Involving Humans

Government of **Western Australia**
Department of **Health**

WOMEN AND NEWBORN HEALTH SERVICE

Ms Lynn Jensen
Lecturer/Paediatric Physiotherapist
School of Physiotherapy
Faculty of Health Sciences
Curtin University
GPO Box U1987
PERTH WA 6845

Dear Ms Jensen

REGISTRATION NUMBER:	**1864/EW**
TITLE:	**Factors that affect motor development in infants with and without motor delay**
MEETING DATE:	**06 March 2012**

The WNHS Ethics Committee has recommended approval for the amendments requested to the abovenamed study. This recommendation has been ratified and confirmed by Women and Newborn Health Service.

The Chief Investigator seeks permission to attend the pre-term follow up groups in the Physiotherapy Department at KEMH to distribute the information sheets in person.
It should be noted that all other aspects of the approval remain unchanged. This is so, in particular, in relation to the progress reports required and regarding any further amendments to the protocols.

Please quote the above registration number on all correspondence.

Yours sincerely

Dr Mark Salmon
Executive Director
Medical Services

09 March 2012

The Ethics Committee is constituted, and operates in accordance with the National Health and Medical Research Council's National Statement on Ethical Conduct in Research Involving Humans

Demographic information

Today's date	**Measure 1**	**Measure 2**	**Measure 3**
Length (cms)			
Weight (gms)			
Head circumference (cms)			

Please give me some information about your child

Please put a circle around your response or fill in the boxes.

Is your child: Male Female Age of Child: ______ months / ______ weeks

Date of Birth ____/____/_____ Birth Weight: _________

Was your child born at term: Yes No

If possible, Gestational Age:________

Did your child need ventilation (breathing support) when born? Yes No

What type of ventilation (breathing support) did your child need?

How long did your child need ventilation (breathing support)? days

Did your child need oxygen when born? Yes No

How long did your child need oxygen after birth?

Is your child well at this time: Yes No

Does your child attend childcare? Yes No

How long has your child attended childcare?	Less than 3 months	3 – 6 months	7 – 12 months	Longer

Does your child attend playgroup? Yes No

Does your child attend:

Baby swim?	How often?	How long is a class?

Baby gym?	How often?	How long is a class?
Baby music?	How often?	How long is a class?
Other? (PleaseList)	How often?	How long is a class?

Is your child currently receiving therapy? Yes No If Yes, please proceed to Part A.

If No, did your child receive therapy in the past? Yes No If Yes, please proceed to Part B.

If No, please proceed to the section on family information on the next page.

Part A

What type of therapy was it?	Speech Pathology	Occupational therapy	Hydrotherapy	Physiotherapy
	Other (Please List)			
How often does your child attend?				
When did your child start therapy?				
Where are the sessions held?	Home	Childcare	Centre	*Other* (Please List)
What type of session is held?	Group	Individual	Both	

Part B

What type of therapy was it?	Speech Pathology	Occupational therapy	Hydrotherapy	Physiotherapy
	Other (Please List)			
How often did your child attend?				
When did your child start sessions?				
Where were the sessions held?	Home	Childcare	Centre	*Other* (Please List)

What type of session was held?	Group	Individual	Both	
When was the last time your child attended the sessions?				
How long did your child undergo therapy?				

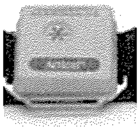
Please give me some information about you and your family

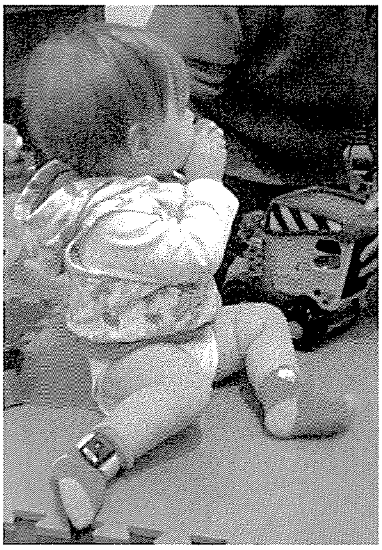
Do you have other children? Yes No If Yes, please list their ages:					
What was the mother's highest level of education?	High School or Less	High School graduate	Some university credits or TAFE	University Graduate	Post Graduate Degree
What is the mother's occupation?					
What is the mother's age?	<20yrs	21 – 30yrs	31 – 40yrs	41 – 50yrs	>50yrs
Is the mother Indigenous? Yes No					
Where was the mother born?					
How would you describe the mother's ethnic background?					

What was the father's highest level of education?	High School or Less	High School graduate	Some university credits or TAFE	University Graduate	Post Graduate Degree
What is the father's occupation?					
What is the father's age?	<20yrs	21 – 30yrs	31 – 40yrs	41 – 50yrs	>50yrs
Is the father Indigenous? Yes No					
Where was the father born?					
How would you describe the father's ethnic background?					

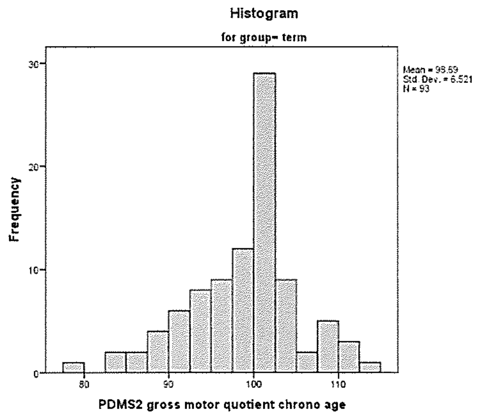
What is the combined family income pre-tax?	0 – $29,999	$30,000 - $59,999	$60,000 - $124,999	$125,000 +

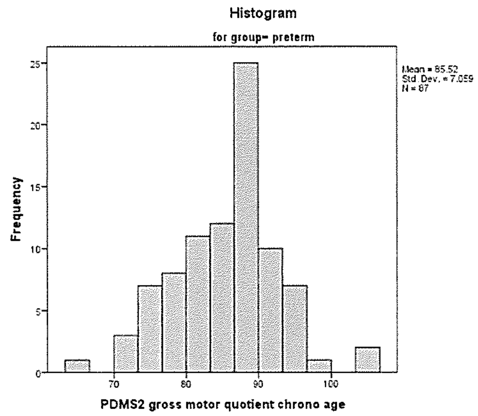
Appendix 6: Actical® accelerometer and placement on the infant's right leg.

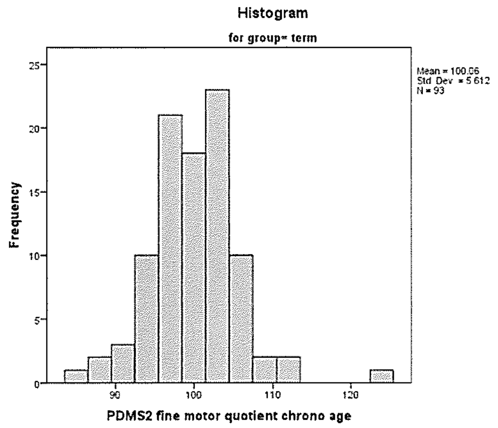


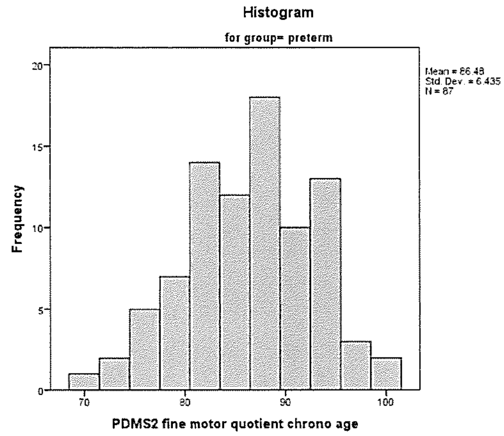


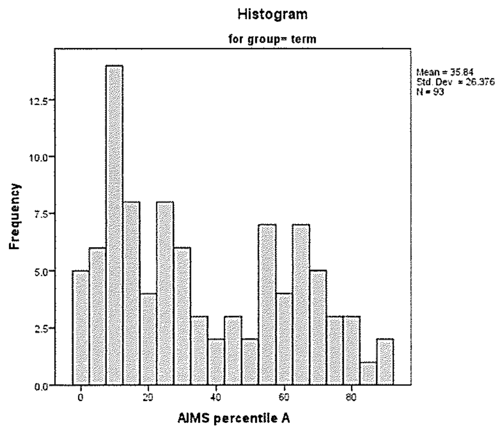
Appendix 7: Histograms of normality for gross motor quotient, fine motor quotient, percentiles for chronological and corrected ages for term and preterm infants.

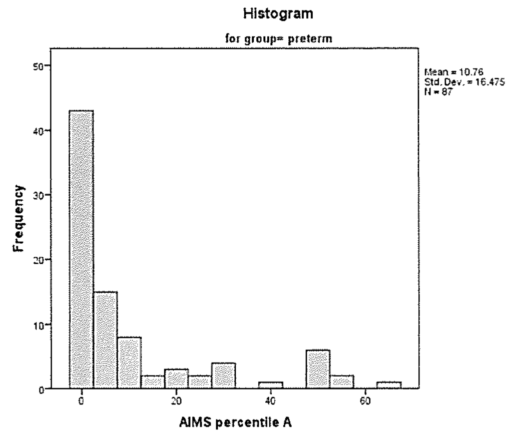




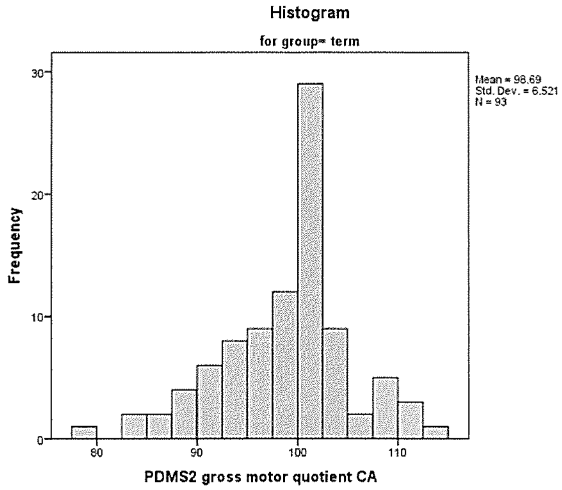


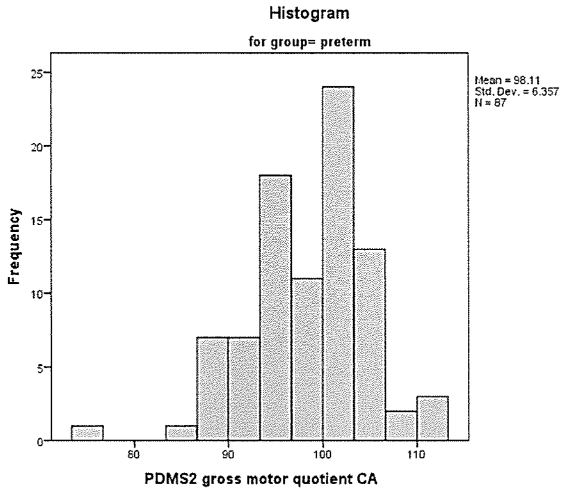


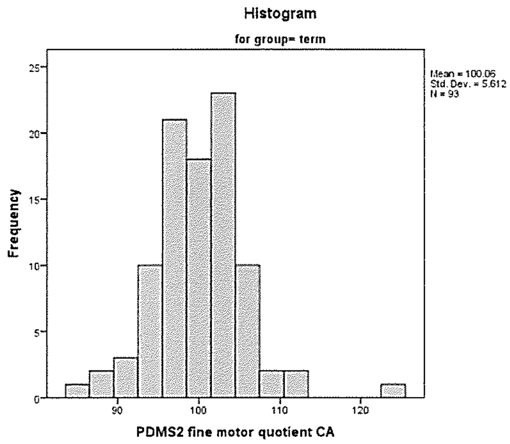


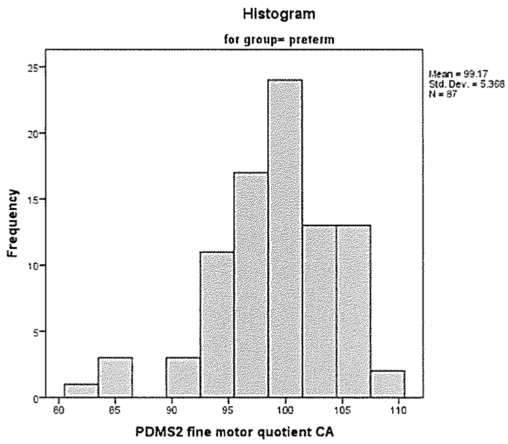


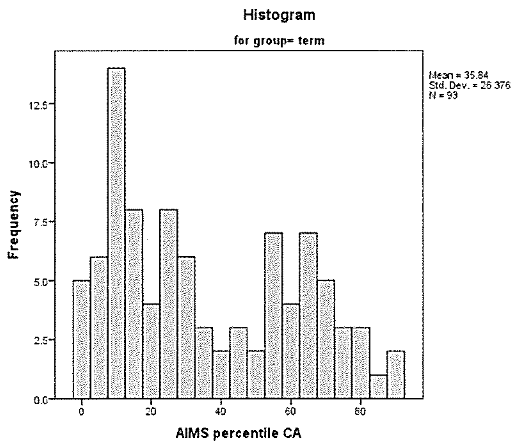
Appendix 7 continued

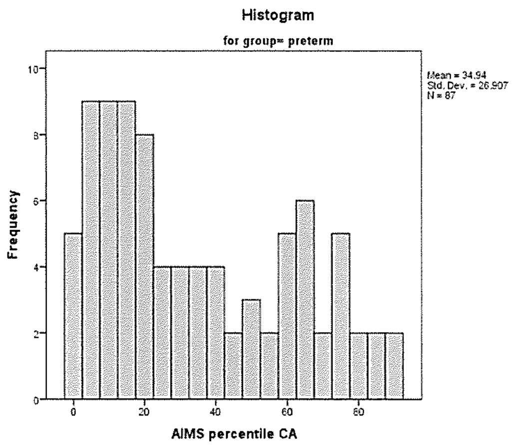












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Subject No.

CONSENT SHEET

Project title: **Factors affecting motor development in infants with and without motor delay**

Investigator:	**Lynn Jensen**
Project Supervisor:	**Prof Jan Piek**
Co-Supervisor:	**Dr Jenny Downs**

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HR148/2010), the Women and Newborn Health Service Ethics Committee (Approval number 1864/EW) and the Disability Services Commission.

I, ____
(Given names) (Family name)

of ____ Postcode__________

Phone (H)________________________ Mobile _____________________

Parent / Guardian custodian of

____
(Given names of child) (Family name)

- I understand the purpose and procedures of the study.
- I have been provided with the participant information sheet.
- I understand that the procedure itself may not benefit my child or me.
- I understand that my child and my involvement are voluntary and I can withdraw at any time without problem.
- I understand that no personal identifying information like our names and address will be used and that all information will be securely stored for 25 years before being destroyed.
- I have been given the opportunity to ask questions.
- I agree and consent to my child and my participation in the study outlined to me.

I am willing to be contacted in the future for a possible follow-up study: Yes / No
(Please circle)

Signature ____________________ Date______________________

Witness Signature ______________________ Date______________________

I have explained the research procedures to which the subject has consented to participate and answered all questions to his/her satisfaction.

Investigator's name______________________

Signature_____________________________ Date______________________

Appendix 9: Comparisons based on chronological age

Table 7.1 Comparisons between infant and maternal characteristics for infants whose DAIS was retained and omitted. (Results for corrected age on page 136)

	Total		Test statistic	*p* - value
	Retained	**Omitted**		
	(n = 141)	(n = 39)		
Age	37.8 (13.3)	38.2 (12.9)	- .19	.85
GMQA	92.4 (9.4)	92.2 (9.9)	.07	.95
FMQA	93.8 (8.8)	92.4 (10.0)	.87	.39
AIMSA	23.6 (25.5)	24.0 (25.2)	-.09	.93
Maternal age	(n = 140)	(n = 37)		
<30yrs	31%	43%	-.11[a]	.15
>30yrs	69%	57%		
Maternal education	(n = 139)	(n = 37)		
Tech	30%	53%	-.21[a]	.005
Uni	70%	47%		
Income	(n = 137)	(n = 35)		
< $60,000	12%	23%	[b]	.08
> $60,000	88%	77%		

A = chronological age, GMQA = gross motor quotient chronological age, FMQA = fine motor quotient chronological age, AIMSA = AIMS percentile-by-chronological age, [a]Pearson's r, [b]Fisher's exact

Table 7.3 Correlations between chronological and corrected ages with duration of care, play and sleep. (Results for corrected age on page 138)

	Age	CA
Care duration	-.278**	-.324**
Play duration	.524**	.542**
Sleep duration	-.182*	-.204*

Age = chronological age, CA = corrected age, $*p < .05$, $**p < .001$.

Table 7.4 Linear regression analyses predicting total care duration, total play duration and total sleep duration from the main effect of chronological age. (Results for corrected age page 139)

Care duration	**Predictors**	***B***	**95% CI**	***β***	**sr^2 x 100**
	Chronological age	-.025	-.039, -.010	-.278	7.728
	$R^2 = .077, p < .000$				
Play duration	**Predictors**	***B***	**95% CI**	***β***	**sr^2 x 100**
	Chronological age	.053	.038, .067	.524	27.458
	$R^2 = .275, p < .000$				
Sleep duration	**Predictors**	***B***	**95%CI**	***β***	**sr^2 x 100**
	Chronological age	-.020	-.039, -.002	-.182	3.312
	$R^2 = .033, p = .032$				

Units of measurement for the predictors were entered as weeks of corrected age. Outcome variables were entered as hours of care, play and sleep duration.

Table 7.6 Correlations between age and corrected age with support required for care and play. (Results for corrected age page 141)

	Age	**CA**
Care score	.413*	.432*
Play score	.752*	.823*

Age = chronological age, CA = corrected age, $*p < .001$.

Table 7.7 Linear regression analyses predicting total care score and total play score from the main effect of chronological age. (Results for corrected age page 141)

	Predictors	***B***	**95% CI**	***β***	**sr^2 x 100**
Total care score	Chronological age	.318	.199, .436	.413	17.057
	$R^2 = .170$,				
	$p < .000$				
Total play score	Chronological age	1.109	.945, 1.273	.752	56.550
	$R^2 = .566$,				
	$p < .000$				

Units of measurement for the predictors were entered as weeks of chronological age. Outcome variables were entered as points for care and play assistance.

Table 7.9. Correlations between chronological and corrected age with counts for care, play, awake and sleep. (Results for corrected age page 146)

	Age	CA
Care count	.090	.143
Play count	.259**	.323***
Awake count	.210**	.278**
Sleep count	-.148	-.206*

Age = chronological age, CA = corrected age, *p < .05, **p < .01, ***p < .000.

Table 7.10 Linear regression analyses predicting total play and awake counts from the main effects of chronological age and birth weight-for-gestational age. (Results for corrected age page 148)

	Predictors	*B*	95% CI	*β*	sr^2 x 100	*p*-value
Total play counts	Chronological age	173	69, 278	.251	6.300	.001
	BWGA	9345	5536, 13154	.371	13.764	.000
	$R^2 = .205, p < .001$					
Total awake counts	Chronological age	225	53, 396	.202	4.080	.011
	BWGA	14659	8397, 20920	.361	13.032	.000
	$R^2 = .174, p < .001$					

Units of measurement for the predictors were entered as weeks of chronological and corrected ages and SGA or AGA. Counts are reported as whole numbers.