Physical activity in infancy: assessment of an intervention to increase physical activity in infants.

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"No survey without service"

Prof. Archie Cochrane

This thesis is dedicated to the POI.nz families who gave freely and generously towards better health for future generations.

Abstract

Physical activity (PA) in infancy is an under researched area despite the known relevance of PA to health. This thesis combines three distinct studies to achieve a positive contribution to knowledge in the area of PA and its measurement in the first year of life. The aims were to: (1) determine if accelerometers could measure PA in six month old children and (2) to determine if behavioural intervention could increase (a) tummy time at four and six months of age and (b) physical activity as measured by accelerometer at twelve months of age.

In the validation study three accelerometers were placed on six month old infants (n = 34) at the wrist, waist and ankle. Four activities were then performed by the infants and their caregivers. Accelerometer output was compared with that obtained from a doll wearing similarly placed accelerometers performing the same activities to clarify how much activity was attributed to the infant and how much was derived from the caregiver. Comparison with the accelerometers on the doll indicated that movement of the caregiver accounted for 23% to 55% of the infants' activity counts during some activities. The accelerometer counts from site of placement differed for all comparisons ($P<0.05$). Accelerometer use at this young age may be restricted to sleep/wake cycles due to the lack of independent mobility of the infant.

Participants in the Prevention of overweight in infancy study (POI.nz) activity intervention groups Feeding Activity and Breastfeeding (FAB) and Combo (FAB and Sleep), (n=401) were offered group activity education sessions where the focus was on encouraging parents to be active with their children. Basic activities were suggested that could be carried out with the infant, such as tummy time, to enhance both infant activity and participation with the family. The other two groups received usual well child care (Control) or another intervention focussing on the establishment of health sleep patterns (Sleep). Parental questionnaires were administered when infants were 19 weeks, 27 weeks, and one year old to assess the effect of the activity intervention. The two outcome variables of interest in this thesis were the amount of tummy time per day offered at 19 and 27 weeks, and PA measured using accelerometry at 12 months. Tummy time was used by 95% of families in the study however the intervention groups used it more frequently at both time periods (19 weeks IRR 1.15 95% CI 1.03-1.28, $P = 0.012$, and 27 weeks IRR 1.15, 95% CI 1.02-1.30, $P = 0.027$). Total tummy time was significantly related to milestone achievement for crawling (19 weeks OR 1.14 95% CI 1.08-1.20, $P<0.001$; 27 weeks OR 1.06 95% CI 1.02-1.09, $P = 0.001$), and walking assisted (19 weeks OR 1.36 95% CI 1.13-1.63, $P = 0.001$; 27 weeks OR 1.15 95%CI 1.07-1.24, $P<0.001$). The POI.nz study was successful in achieving a large database of valid accelerometer data at 12 months of age (n=408). Intervention group effects were evident for the outcomes PA counts per minute (CPM), and time restrained. The COMBO group had significantly higher CPM on three of the five days measured and less time restrained in car seats or strollers ($P = 0.041$). Of most significance to the literature in this area was that there were significant differences in CPM between walking and non-walking infants ($P<0.001$), highlighting the difficulties observed in the validation study of using objective measures of PA at this age when infants' movement is dependent on caregivers if they are not walking independently.

Conclusion: Measurement of PA in infancy is difficult due to developmental immaturity and objective measures used to date do not accurately capture infants' PA. Intervention to increase PA appears to have been effective on some levels and may have wider application in the public health arena.

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Publications relevant to this thesis

Journal Publications

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Conference abstract

Spencer C, Taylor R, Gray A, Dale K, Taylor B. Use of accelerometry to measure physical activity in 6 month old infants. *Australia New Zealand Obesity Society Conference (ANZOS) 2012: For our children's children*. Auckland, New Zealand.

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Introduction to the thesis

Obesity is having deleterious effects on the health of our children (1, 2). The causes are multifactorial with prevention suggested to be the feasible option (3), which has precipitated intervention research to inform preventive action. Interventions beginning early in life, even prenatally, and in the family environment are in progress (4, 5). Physical activity (PA) starting early in life is posited to offer some alleviation from the childhood obesity epidemic (6). Because measurement of physical activity in infants is an under researched field, little is known about how much PA infants are obtaining, and therefore it is unknown whether intervention to increase activity can be effective.

Physical activity plays a part in obesity prevention because of its role in energy balance (7), and consequently, intervention studies in this area focus resources on equipping parents with skills and knowledge on enhancing their own and their child's participation in PA. In Australasia, the EPOCH collaboration (Early Prevention of Obesity in Children) involves four studies on early intervention towards obesity prevention, one of which is the Prevention of Overweight in Infancy study (POI.nz) based in Dunedin, New Zealand. Such research requires PA outcomes that are easily interpreted, a factor that is less of an issue in research on older children and adults. However the activity of young children is not yet well understood as measurement of PA during this unique stage of development requires further elucidation (6). Several methods of assessing infants' and young children's activity are available to researchers however all methods have inherent problems (8, 9).

While there is no easily administered criterion or "gold standard" measure of PA in early childhood (10), research continues to reveal methods that can be used in the field, (i.e., used in the normal family environment) which will offer precise yet simply collected data (11, 12). Accelerometers are becoming increasingly accepted to offer these advantages, however their use in this young age group remains the topic of some debate (13, 14).

Clarification around both measurement of PA, and the effect of early intervention to prevent obesity are addressed in this thesis, which is divided into six chapters.

Chapter 1 provides a review of the literature on the benefits and measurement of PA, as well as reviewing intervention studies that have encouraged PA as a method of obesity prevention.

Chapter 2 outlines the methods used in the Prevention of Overweight in Infancy (POI.nz) study, the RCT from which the majority of data for this thesis was derived. In this study, families were randomised to one of four groups, with half the families receiving intervention involving anticipatory guidance on encouraging child and family activity from very early in life.

Chapter 3 describes a validation study which was undertaken prior to analysis of the POI.nz data to assess whether it would be feasible to assess PA in 6-month old infants using accelerometry. As accelerometers were being used to measure sleep in this age in the POI.nz study it was thought this may also allow assessment of PA. Therefore this study was designed to assess the use of accelerometer derived PA data in this age group.

Chapter 4 details analysis of the questions asked of POI.nz families in 19 and 27 week questionnaires around how much tummy time they offered their infant at those times. This is important because there have been some changes observed in developmental milestone achievement since the early 1990s when health professionals began encouraging parents to lie their infants supine to sleep. Quantifying the use of tummy time was considered important because its use was being encouraged in the POI.nz study as part of the PA intervention.

Chapter 5 also presents data from the POI.nz study. At 12 months accelerometers were used to assess infant activity. As the use of accelerometers in infants at 12 months is a new area of PA research, the considerable process of data reduction is presented. Given this is an under-researched age group, issues such as the number of hours to constitute a valid day, and the number of minutes to constitute non-wear required some consultation prior to data reduction. Data from accelerometers were reduced to amount of activity in counts per minute (CPM). Data were then analysed across a range of demographic and milestone variables and compared with the few existing studies in this area.

Chapter 6 This chapter summarises the results of the three presented studies and outlines their contribution to the body of knowledge on infant activity measurement.

Candidate's contribution to the studies in this thesis:

Chapter 2 – This study was designed by the candidate, in consultation with supervisors. Ethical consent was applied for, and consultation with the University of Otago Māori advisor undertaken. Recruitment, consenting, and all activities involved in visiting and collecting data from families with 6 month old infants was involved. This was complicated by the requirement to use infants who were not in the POI.nz study, which was successfully recruiting in the area (59% of all eligible children in the local population). All accelerometer initialising, downloading, and selection of relevant data and analysis from the accelerometer data and direct observation of videoed play were undertaken, and results presented. The study was written up by the candidate for publication, and presented at a conference in poster format.

Chapter 4 - Several 3 month activity sessions hosted by sport Otago educators were attended and videoed by the candidate. Meetings were attended regularly with the POI.nz group where progress of the study was discussed. Tummy time data were requested, analysed, and written as a paper to be presented for publication.

Chapter 5 - Anthropological measurement of infants at 6, 12, and 18 months was undertaken by the candidate along with other measurers employed by the POI.nz study. At the measurements, accelerometers were given to the families. A significant part of the work in this thesis was downloading and calibration of accelerometers from up to 800 infants at both 6 and 12 months. A small amount of data from the 6 month accelerometers were reduced and analysed by the candidate and examined with the parent diaries before the decision was made by the POI.nz group not to analyse the activity data at this age. Data collected from accelerometers at twelve months were reduced using a macro programme to remove sleep from the data. Prior to this, various methods of data reduction were trialled before consensus was reached regarding appropriate parameters for this data. Times of wake periods were entered into Meterplus* to produce outputs of counts over periods of wakefulness across the day. Data from diaries kept by parents during accelerometer use were also entered into Meterplus* for later analysis. Accelerometer data were further reduced to CPM for analysis for daily activity and comparison across a range of demographic and milestone variables.

Definitions and abbreviations

BMI - body mass index

CARS - Children's activity rating scale

COMBO - combined FAB and sleep group

CUP - counts per minute

DLW - doubly labelled water

FAB group - Feeding, Activity and Breast feeding group

HDL - high density lipoprotein

HR - heart rate

IBQ - Infant Behavioural questionnaire

Infant - child from birth to 12 months

IPAQ - International Physical Activity questionnaire

LMC - lead maternity carer

MPA - moderate physical activity

MVPA - moderate to vigorous physical activity

OSCRAC-P - Observational system of recording physical activity in children- preschool version

PA - Physical activity

POI.nz - Prevention of overweight in infancy New Zealand

Pre-schooler-child from 24 months to 6 years

QMMU - Queen Mary Maternity unit

RCT - Randomised controlled trial

SIDS - sudden infant death syndrome

TEE - Total Energy Expenditure

Toddler - child from 12 months to 24 months

VPA - vigorous physical activity

Chapter 1. Literature Review

1.1 Benefits of physical activity in childhood

1.1.1 Introduction

Concern is evident in the public health literature that children are not receiving enough physical activity (PA) to produce health benefits (15-17). This is compounded by the observation that PA levels appear to decrease markedly across childhood and into adolescence (16, 18). Despite PA being a crucial component of health, questions exist as to whether the early adoption of an active lifestyle will improve population, and individual health. While PA has been found to enhance the health of older children (19), evidence that adoption of an active lifestyle from early childhood is effective in improving health outcomes is limited (20). However some suggest health benefits from early activity are apparent both in the immediate and longer term (21). These benefits include increased motor competence(20), maintenance of energy balance (21, 22), enhancement of cardiovascular fitness (23), as well as benefits to psychological (24, 25) and skeletal health (26). The research supporting each of these areas is considered below.

1.1.2 Enhanced motor competence

Motor competence is enhanced by PA. Physical development is seen as a progressive process with abilities at one age increasing the potential for ability at later ages (27). When a 2 month old infant experiences prone positioning, the ensuing increase in muscular control is carried over to subsequent activity, increasing their competence in that activity (28). Practice at such skills allow rewards of enhanced competence which, in a circular fashion, encourages the individual to pursue the activity (27). Evidence of this sequential development can be found at several ages across childhood and into adulthood. Early walking has been positively associated with the number of sports played ($P = 0.003$) and frequency of participation in sport at adolescence ($P = 0.043$) (29). Cross sectional observational studies have established a relationship between motor skill competence and accelerometer measured activity in 4 year olds (20, 30). Motor proficiency was also higher in 5 to 6 year old children who were more active (31). In older children, Wrotniak and colleagues found that 8 to 10 year olds with the highest motor proficiency spent more time in MVPA per day than those in the lower quartiles. Improved skill was a reinforcing factor (32). Longitudinal research indicates that children classified as low motor competence at age 9 continued to show less skill at age 12 than those classified as high motor competence at baseline (33). This indicates that motor competence does not “catch up” with age, suggesting early achievement of competence is important. Adding to this evidence in children is research showing that higher skill levels in school sports is associated with higher activity levels in adulthood (34). Therefore, interventions improving motor competence at an early age may encourage children to participate in PA, even into adulthood.

The use of prone position or tummy time is an important early activity that can enhance motor competence from infancy. The developmental principles of cephalocaudal and proximodistal development imply development is from the head down and midline to limbs. Tummy time allows the nervous and muscular system to develop, strengthening the neck muscles and allowing more control of the head as the infant has the opportunity to lift its head and push with its arms against gravity. This antigravity extension appears to enhance the achievement of motor milestones such as rolling and sitting (35). The importance of this activity is evident in the supervised floor based play time from birth to one year of age now advised in recent government recommendations for activity for children in the first year of life included in the recommendations for children aged 0 to 5 years in Australia (36) and Canada (37). With the move since the 1990's to place babies on their backs to sleep it appears some parents have been reluctant to place their infants prone during the day (172, 173). More time spent prone has been found to be correlated with advanced achievement of motor milestones in the first year (54), although all infants reached milestones within normal WHO parameters. Reaching motor milestones sooner and increasing competence with motor abilities could have implications for later involvement in PA as there is evidence in older children that motor competence and PA are positively correlated (60).

To date, few studies have implemented interventions to determine whether enhancing motor development in infancy leads to improved motor competence later in life. However there is some intervention evidence from studies of older children. An Australian longitudinal study, the Tooty Fruity Vegie in Preschools intervention, gave 4 year old children instruction in locomotor and object control skills in 10 sessions over two terms (38). Teachers were trained and given resources to present the activity-based program, and workshops were also held where health professionals presented the material to parents. Six locomotor skills, (e.g. run, gallop) and 6 object control skills, (e.g. kick or bounce a ball) were assessed by trained observers prior to the intervention at 4 years old, then at follow-up at 5 and 8 years of age. While later locomotor skills did not differ between intervention and control groups, girls' object control skills did show an effect even three years later. Boys' object control skills did not improve from the intervention. This is postulated to be because school physical education in Australia caters particularly for skilled boys (38). Considerable caution should be exercised in interpreting these results as this study was not initially intended as a longitudinal assessment and, therefore, ethical consent for follow up testing was not available for all participants. Consequently, the follow-up rate was relatively low with only 137 (29%) children completing the study. Data from those tested at 8 years old had significantly greater object control skills at baseline than those not followed up, which may affect the difference in skills at follow-up. Despite these factors, the need to consider intervention to strengthen girls object control skills is an important result, particularly given that previous work in elementary school children has established that early object control skills are predictive of cardiorespiratory fitness (39). The authors propose that the relationship between object control skills and fitness may be because object control skills are necessary for most MVPA sports. Further to this idea, there is evidence that acquiring and refining gross motor skills is best initiated at an early age because the plasticity of motor development makes the young child more responsive to new experiences (40). Early introduction to PA may therefore allow the physical and mental skills which encourage the individual to participate at a later age.

1.1.3 Energy balance

Although some controversy exists (41), it has generally been thought that modern sedentary lifestyles have resulted in decreased daily energy expenditure (6), and thus, increased the likelihood of overweight and obesity (42). This makes intuitive sense given that PA plays a large part in energy balance (7), although increased consumption of energy dense food may also contribute to the energy imbalance (43). While the contributing factors may be debated, children are more overweight and obese than in the past (1, 44). Whether the same energy expenditure issues apply in infancy and childhood is uncertain. This is because the physiological aspects of energy balance in early life are not fully understood (45, 46). Research into the relative importance of energy input and output in infants concludes that in the first 12 months of life it is excess of energy input that contributes to excess weight (47, 48). Given that in the first few months of life energy output is limited, due to immature motor development, this should not be surprising. Therefore, the motivation to encourage activity in infancy is not necessarily to prevent obesity at this age, rather it is to prevent obesity through educating parents on how to engage their children in PA both to enhance their child's motor skills, and so that it becomes a part of an active family lifestyle (49), and thus a lifelong habit. The importance of this is evident in a recent qualitative study from Australia where parents of infants, and pre-schoolers were asked about their ability to influence their child's PA and screen time (50). Parents in this study generally believed children are naturally active. This belief did not change across age groups, however parents of pre-schoolers (age 3-5 years) were less optimistic about their ability to positively influence their child's activity than were the parents of infants (age < 12 months). This implies parent's confidence to enhance their child's PA appears to decline rapidly. Education from health professionals may form part of the answer to increasing their confidence.

While there is evidence of a dose response pattern of PA to bodyweight in children as young as 2 to 4 years of age (51), the cross sectional nature of studies makes it unclear whether being overweight causes, or is a result of, less PA (52). While longitudinal evidence using objective measurement of activity has been suggested to clarify the issue (21), the results from such studies so far have failed to do so. In a longitudinal study observing children from 4 to 11 years, the most active children had lower levels of adiposity at follow up (53). Conversely, in a study of children 5 to 10 years, PA at 5 years was not predictive of later percentage body fat. In this study, activity and obesity were not correlated at age 5 but were correlated at age 10, prompting the conclusion that obesity precedes a decrease in PA (54). This pattern has also been observed in older children (55). Irrespective of the direction of the relationship it is generally agreed that diet and activity, as key factors in the energy equation, need to be approached together when planning health care, education, and research (56).

1.1.4 Cardiovascular health

The importance of PA to cardiovascular health in adults is well documented (57), but less is known about its effects in children and adolescents. Similar to research in adults, cross-sectional evidence suggests moderate to vigorous intensity PA is required to improve cardiovascular health in children (58). Consequently guidelines have been established in some countries recommending regular amounts of daily PA for children (59). The European Youth Heart Study, a large cross-sectional study of children aged 9 to 15 years, used objectively measured PA and showed that children in the top quintile of PA in both age groups had reduced cardiovascular risk indicator scores compared to those in the bottom three quintiles (60). Although a positive association was found in this study, it was notable that although leisure time activities increased across time points, much of the activity was reportedly of insufficient intensity and duration to reduce cardiovascular risk. The authors subsequently suggested that PA guidelines are too low for health benefits to be realised. In contrast, recent evidence suggests even modest amounts of PA (15 to 30 minutes a day) can lead to substantially reduced HDL cholesterol and triglyceride values in youth (61). Part of this discrepancy may be due to different categorisation of activity intensity as accelerometer cut points for activity intensity varied between studies.

1.1.5 Psychological health

Research on the psychological benefits of PA in infants and pre-schoolers is limited (62, 63). However, research on older children indicates that increased aerobic fitness appears to benefit cognition (24) and mental health in school age children (25). Aerobic fitness has also been positively associated with some aspects of recognition memory (64). In a group of Canadian children, aged 12 to 18 years, surveys were used to gauge the effect of PA on several aspects of mental health, specifically body esteem, depression, and anxiety. A dose-response result was evident, where increased intensity of PA correlated with decreased psychological distress. Vigorous activity of 15 minutes duration, several times a week, was indicated to improve mental health. Boys and girls show positive but differential effects regarding anxiety and depression, with boys showing more positive effects from moderate and vigorous PA on depression, but not anxiety; while for girls, vigorous PA was inversely correlated with anxiety and not correlated with depression (25). This study had a large sample size (n=1259), however the age group of 12 to 18 years (mean age 14.8 years) is wide and details of results by age and sex are not reported. It would be useful to have analysis by age and sex as these six years involve puberty, and this may be relevant to whether there is any differential effect of high intensity PA on mental health between sexes by age. The emergence of any differences could be of interest in prevention and treatment. While it may be the case that feeling less anxious or depressed leads adolescents to undertake more vigorous PA, the direction of causation is not clear from this cross sectional study. Meta-analysis of the effects of PA on mental health in children has, however, also indicated that children experience improved mental health and self-esteem from increased PA with effects significant across BMI (63), suggesting the benefits could be applied without consideration of body weight. No studies have assessed the relationship between PA and mental health in pre-schoolers, both concepts being somewhat difficult to measure. However given this research, the adoption of a habit of PA from an early age may well enhance mental health in the long term.

1.1.6 Skeletal health

Health benefits from PA on the skeletal system are evident and indications are that early PA may have lasting positive effects on bone mass (26). Only one study has investigated the effects of PA in relation to musculoskeletal health in infancy (65). Six-month old (n=58) infants were randomised to receive 15 minutes of gross or fine motor activity five days a week over one year. Interestingly, the type of activity had no effect on bone accretion, the measure of skeletal health, when calcium intake was high, whereas the gross motor group had lower bone accretion when calcium intake was low. However, this study was insufficiently powered to be able to determine interaction effects with a sample size of only 58. In addition, a similarly designed study by the same group in children aged over 3 (n=239) found bone mass changes from PA only in the high calcium intake group but greater diameters of the membrane covering the inner and outer aspect of bone (periosteum and endosteum respectively) in the gross motor group, irrespective of calcium intake, an effect that persisted for a year after intervention (66). Supporting the independent effect of PA on skeletal health, the Iowa Bone Health study found children in the top quartile for MVPA (moderate to vigorous PA) at 5 years of age had significantly greater bone mineral content at 8 and 11 years (67).

1.2 Tracking studies

Research on whether PA tracks across the lifespan is important in assessing the degree to which early intervention may contribute to later engagement in PA, and to determine where opportunities might exist to intervene before habits become entrenched (68). Tracking refers to the maintenance of relative rank or position within a group over time (69). Generally speaking, strong tracking is indicated by correlations of greater than 0.6, with correlations of 0.3 to 0.6 described as moderate and below 0.3 as low (70).

There are no reported studies relating physical activity during infancy and at a later age. However, several studies have examined the tracking of PA across early childhood. Moderate correlations of r = 0.53 to r = 0.63 were observed in a small study of 47 pre-schoolers followed from 3 to 6 years of age, using percentage of time heart rate (HR) was 50% or more above resting HR (PAHR-50 index) as the objective measure (71). Lower correlations (r = .22 to r = .32) were observed in a larger study (n = 300) in pre-schoolers that measured activity using direct observation (68). One of the difficulties with these studies is that they tend to only measure PA for a few hours per day. This highlights the limitations of using a single point in time to measure activity in pre-schoolers, whose activity tends to be intermittent and variable (11, 72). Two longitudinal studies using accelerometers to record activity have reported moderate correlations for PA in early childhood. The SPARKLE project used three days of PA measurement by accelerometer and found rank order correlations of r = .41 from ages 3 to 4 years, while the FLAME study found correlations for total active time of r = .32 between 3 and 4 years and r = .41 between 4 and 5 years (73).

Future research using measures that are more indicative of the full range of PA of infants and pre-schoolers is required for tracking to be fully understood. To date, the low to moderate tracking observed implies there is not yet a clear relationship between activity measured at one point in early childhood and activity levels at a later age. The question remains, however, whether this is indicative of an actual absence of tracking or that the measures used are not yet refined enough to detect it. Added to this is the issue of measurement of PA in children when physical development appears to occur in distinct stages, and can be affected by the environment (74). Much is unknown about the trajectory of development and it is not clear whether achievement at one stage has a bearing on achievement at a later stage, although there is evidence that independent walking is related to later gross motor functions (75).

Attempts to establish whether tracking relates to future PA participation has proven a problem due to the use of different measures of PA (76). Objectivity of activity measurement has improved with the use of new measurement methods, particularly accelerometers (76). The reporting of evidence from studies using accelerometers appears to be in an exploratory phase with some studies finding it necessary to adjust activity data for sources of variation, such as season of the year. For example, the European youth heart study has used accelerometers to measure activity in a cross-sectional study in children 8 to 10 years, and 14 to 16 years of age (77). In this study, the younger children were more active in Spring months than Winter and Autumn, and in both age groups, weekend activity was lower than weekday activity. When these authors investigated the longitudinal data to assess the tracking of activity of 208 eight to ten year olds, followed up six years later, they examined the tracking correlations with and without these sources of variation (78). Without adjustment, correlations were r = .18 for boys and r = .19 for girls, indicating low levels of tracking over the six years from middle childhood to adolescence. Adjustment of correlations for season, day of the week, activity overnight, and instrumental measurement error raised the correlations to r = .53 and r = .48 for boys and girls respectively. Thus, adjustment of data for potential measurement confounders can substantially affect the outcome and the validity of adjusted variables needs to be established for future studies.

When a behavioural variable such as activity is being measured for tracking across the lifespan, the fact that the definition of PA intensity is going to differ with age is an important consideration. It must be considered, for example, that what represents vigorous activity at age 2 is different from vigorous activity at age 10 (69). Whether activity at one age is related with activity at another age may be more complex than correlations of objective PA measurement.

Taken together, the evidence presented for tracking of PA across the lifespan beginning in infancy is not conclusive. Evidence from children and adults suggests that PA does appear to track in the short term, but over longer periods the relationship is less certain (69, 76, 79). Further research is required and should take into account the many variables affecting PA such as season (78) and life stage (69).

Despite low to moderate levels of tracking of activity as evident so far, the fact that PA has immediate and on-going benefits remain, and the adoption of an active lifestyle at any age may benefit health.

1.3 Physical activity in infancy: factors and influences

In order to effectively encourage activity from infancy, it is necessary to understand what factors might influence activity such as sex, age, parental influence, and environmental factors. As little data exists in young children, the evidence available from older children will be examined.

1.3.1 Sex and age

Factors such as sex and age have been shown to affect PA. Boys are consistently found to be more active than girls both in infancy (80), and later childhood (81-84). There appears to be a positive correlation between age and PA in school age children, although many studies are cross-sectional and measurement of PA using different tools makes comparisons between studies difficult (82, 83). A negative relationship between age and PA is evident in studies on older children (82, 85), with activity decreasing noticeably at puberty. However, more recent research in both cross sectional (86) and longitudinal studies (73) suggest that PA decline may begin as early as the preschool years.

1.3.2 Parental influence

It is evident from studies in older children that parents exert some influence on their children's participation in PA whether it be by role modelling PA, psychological encouragement, or more practical support such as transport to activities (87-89). For infants and toddlers, parental factors might exert even more influence on their activity due to the increased level of dependence on their parents, however little research exists to support or refute this suggestion. With the aim of modelling the relative importance of parental influences on activity in children, Loprinzi and Trost (2010) used a path analysis of data from 156 parent-child dyads (87). Parental activity, and parental perception of the child's physical competence showed low but positive correlations with parental support ($\beta = 0.23$ and $\beta = 0.18$, respectively), which in turn was positively correlated with infant home PA ($\beta = 0.16$) (87). Physical activity was measured objectively at preschool and by proxy at home. The authors note this may have influenced results as social desirability cannot be ruled out when using proxy report. Parental report of children's activity is commonly found as the measure of PA in such studies. Reviewing correlates of PA in children and adolescents, Gustafson and Rhodes (2006) found only three cross sectional studies on parental influences on pre-schoolers PA, all using parental report (89). Parental report was also used in a Canadian study which was interested in the social learning that may influence pre-schoolers PA levels by parents' role modelling PA. They found parents' support, and their own level and enjoyment of PA predicted their pre-schoolers' PA (90). This study did not measure PA levels of children while in childcare, and the authors point out that parents assumed their children were getting the two hours per day that preschools are obliged to offer in Canada. Research on children's PA in preschools indicates that this is variable across preschools so this assumption may not be accurate (91). It appears that parents do influence their children's PA, however measurement is an on-going issue when assessing the nature and degree of influence.

1.3.3 Environmental factors

A range of environmental factors have been suggested as being related to limiting young children's PA. Gunner (2005) suggests restriction to infant seats in cars or strollers, small play spaces, and an increase in television viewing time as contributing factors (49). Two factors that research has implicated as determining amounts of children's PA are time outdoors and socio-economic status. Time spent outdoors has consistently been found to be positively correlated with children's level of PA even at preschool age (92, 93). While this association may lead to the conclusion that the answer to getting children active and meeting recommended activity levels would be more outdoor time, recent evidence indicates this might not be the case. In a study directly observing pre-schoolers, with each child observed in 10 to 12 sessions, outdoor play activity level declined over a twenty minute observation period, so long periods of time outdoors may not contribute as expected to children's overall PA (94). Measuring children's outside play using another objective measure would be a useful adjunct to the literature so that if patterns, such as a decrease in play over time in a session, can be recognised, this information could be used to inform teachers and parents. It may be that, due to their physiological immaturity, multiple short periods of outdoor time are useful for young children.

Generally the socioeconomic status of the family does not appear to be correlated with the physical activity level of the children, however this may be due to inconsistent measurement across studies (82, 83). Several measures have been used for socioeconomic status including factors such as postcode (95) and maternal education (96, 97). When using maternal education, Gubbels et al (2009) noted the narrow range of educational level in their sample as a possible source of bias (98). Other studies in this area also report high percentages (≈60%) of parents with college (97) or university education (87). While it may be that better educated parents are willing to participate in such research, it leads to the question of the generalizability of the results.

1.4 Physical activity measurement in infants and toddlers

1.4.1 History of physical activity measurement in infancy

Accurately measuring the PA of infants and toddlers is proving a challenge to researchers. While this is a relatively unexplored field there have been some attempts to quantify PA in infants, however these have not been measures of PA exclusively. Instead, PA is an indicator of an aspect of behaviour such as temperament (99). Measures of temperament in infancy have employed a questionnaire, the Infant Behavioural Questionnaire (100), which uses PA as one aspect of temperament. The PA section of this questionnaire requires coding of activity of the arms and legs and locomotor activity to indicate activity level. Apart from a comment that activity increases across infancy (99) there is no attempt to measure PA as a distinct entity in these studies.

Physiological studies looking at energy balance, but concerned more with input than output, have looked at PA as Total Energy Expenditure (TEE) measured using doubly labelled water (DLW) and sleeping metabolic rate (SMR) using respiratory calorimetry (101). The conclusion reached in this study was that infants from 6 to 12 months had increased energy needs as a result of increased PA across this time however the focus is on the energy input and feeding recommendation rather than PA recommendations. The use of this measure of PA is valid in this age group although lacks the requirement for ease of application essential in large population studies (102).

Actometers, an early form of the accelerometer, have been used in 30 week old infants in one study to compare questionnaire acquired information in order to examine the activity level of twins and define the level of genetic determination of activity level and found activity level did appear to have some level of genetic determination (103). Since this study in the early 1990's accelerometers have been employed widely to study PA in pre-schoolers however their use in infants and toddlers is more current and little is yet documented on this important research area. More research is required to quantify PA in this young age group as recommendations are being produced by governments for time spent active per day from the first year of life. Recommendations for amounts of time at certain levels of activity have been extended to toddlers and pre-schoolers with 180 minutes of activity at any level recommended now by three countries, Australia, Canda, and the UK (59).

The nature of infants' and toddlers' activity is different to older children and adults, therefore extrapolating methods used in older people are not always useful when measuring PA in this age group. Movement may be dependent on another person and rapid development is occurring, therefore what is possible to measure may be different from what would be considered rigorous research in older children and adults (104). The confounding effect of caregiver movement in infants (105), and the need to account for nap times in infants and toddlers (14) are examples of the unique features that must be accounted for in PA measurement in this age group. Various direct and indirect methods of assessment are currently used in the first year of life and will be discussed below.

1.4.2 Indirect methods of PA measurement

Indirect reporting of activity, whether self or proxy, has been used in studies of adults' and children's PA. Self report involves the participant recalling or recording activity. Questionnaires have been created such as the International Physical Activity Questionnaire (IPAQ) (106) which was introduced in the 1990's to standardise PA reporting. While it has been useful for assessment of PA in adults and older children, over reporting of activity has been established as an issue (107). Children are known to over report PA to appear socially desirable, therefore it is not recommended as a method of assessing PA in children 10 years old and under (8). Proxy reporting of children's activity by teachers and parents is commonly used in research on pre-schoolers, toddlers, and infants (9). In one study, Wen and colleagues found low positive correlations between a 7-day activity diary completed by parents of children aged 3 to 5, and accelerometer derived walking activity ($r = .25$) or moderate and vigorous activity (r = .23) (108). Only 31 families completed the study, reducing power to assess correlations between measurement tools. Also, families in this study were recruited from pre-schools, however no information is given on how parents assessed their child's activity while they were not with them. Absentee reporting has been established as a problem with proxy reporting (109).

Offering parents a checklist with suggested amounts of time to record the time their child spent playing outdoors at home/neighbourhood and in public areas/preschool while their child wore an accelerometer resulted in a higher correlation with accelerometer derived activity than asking them to recall a typical day of outdoor PA (checklist r = .33, P <0.001, recall r = .20, P = 0.003) (n = 250, mean age 44 months) (92). This indicates that it may be possible to improve the value of proxy reporting by making the process more immediate and easier for parents and/or teachers to record activity. Tulve et al (2007) placed considerable burden on parents by asking them to record activity every 30 minutes for four days while infants aged 4 to 17 months (n = 9) wore accelerometers (110). While they claim 100% diary entry, they note this was because the diaries were checked when picked up by the researchers. This implies some retrospective completion which could be prone to recall difficulties. This study also categorized activity as "active" and "quiet" and the authors note that parents found it difficult to categorize activity in their infants, whose movements were often variable. One useful aspect of this study, however, was that the parents' videoed representative examples of different activities so the researchers could clarify parents coding of activity. Consistency of coding could be assisted by videoing; however this is time consuming and thus may not be possible in large studies. While low to moderate positive correlations are evident between objectively measured PA and parent or teacher report, more research on proxy reporting is required (11, 108, 111), and further refinement can only enhance the process.

1.4.3 Direct measures of PA measurement

There is no measure of PA in infants and toddlers that is accepted as precise enough to be considered a criterion measure (11). Direct observation has been accepted as sufficiently accurate to be the criterion measure in older children and adults (9). Direct observation involves an observer focussing on the activity of an individual for a period of time and then recording the observed activity on a previously determined scale. The commonly used children's activity rating scale (CARS) (112) involves classification of activity into one of five categories of activity (Table 1.1). In order to establish these categories, energy expenditure was measured in 25 five to six year old children using indirect calorimetry while undertaking a series of graded activities in a laboratory setting. Extensive direct observations (389 paired observation periods) of 3 to 4 year old children were also made using CARS criteria to establish the tool as reliable, and able to discriminate between PA intensity levels. Observer agreement was 84.1% which the authors conclude established the tool as reliable (112). Reactivity of children to being observed is reported to be short term and not lead to any significant change in activity (112). Accelerometer validation studies have used CARS as the criterion measure when assessing PA in pre-schoolers and this use will be discussed further in this section (11, 113, 114).

Table 1.1. Operational definitions used for Children's Activity Rating Scale (CARS)

Observed activity code	Operational definition	Representative activity
1	Stationary-no movements	Lying, sitting
2	Stationary with movement	Standing/colouring/ball activity
3	Translocation slow/Easy	Walk 2.5mph 0 grade
4	Translocation medium/moderate	Walk 2.5mph, 5% -10%grade
5	Translocation fast/very fast/strenuous	Walk 2.5mph 15% grade

From Puhl, Greaves, Hoyt and Baranowski (1990) (112).

A modified version of CARS, the observational system of recording PA in children, preschool version (OSRAC-P) has been designed to take into account contextual aspects of the activity of children aged 3 to 5 (115). The original version allowed five seconds for observing and 25 seconds for recording activity and contextual elements around the activity. It has been used to compare activity with accelerometer measured PA in pre-schoolers (116) and toddlers (117). In both cases, the coding time was adjusted to be compatible with the short accelerometer epoch time required to capture toddlers' and pre-schoolers' activity, illustrating the modifications required when working with younger children. In a toddler study (117), OSRAC-P is stated to have been used as a criterion measure however it's use as such has never been validated (11).

Two methods of activity measurement, indirect calorimetry and doubly labelled water (DLW), have been considered "gold standard" tools to measure energy expenditure related to PA (9, 10). Indirect calorimetry measures energy expenditure as a function of oxygen consumption and carbon dioxide production, and thus requires the wearing of a mouthpiece or mask to capture expired gases (118). While energy expenditure and PA are related, they are not the same construct and their association is less clear in children (9). Despite this, portable monitors have been used in children to validate measures of activity such as accelerometry (119). While DLW meets the validity and reliability criteria required for research, it also has several drawbacks when considering its use with infants and toddlers. Firstly, it is expensive, and secondly, the "heavy water" required is difficult to obtain (111). Thirdly, this method requires obtaining a baseline urine sample and the subject then drinking a quantity of DLW. The following morning two further urine samples are obtained 20 minutes apart. Approximately two weeks later, two further urine samples are obtained 20 minutes apart (120). Thus, DLW is considered not to be useful in large studies, particularly with children (111).

Two further direct activity measurement tools are heart rate monitoring and pedometry. Heart rate monitoring of activity involves using a portable telemetry monitor with a transmitter that is attached to the chest using electrodes and a receiver, which is often worn on the wrist, that records the heart rate over a specified time period (121). Heart rate (HR) is useful to measure adult PA, however issues around determining resting heart rate mean it is more difficult to measure HR in young children (11, 121). Furthermore, HR may not be a useful measure of activity as children's HR and energy expenditure do not appear to be strongly correlated. (8, 111). While Loprinzi and Cardinal's 2011 review found pedometers to be valid and reliable measure of PA in children, Oliver et al (2007) suggest they may be better for measuring general activity, outside of research assessment (11). Pedometers are also reliant on the child being capable of walking, therefore are of limited use in children under 18 months.

There is little doubt that direct objective measurement of activity has been enhanced by the use of accelerometers (122, 123). Accelerometers are small devices with a piezoelectric acceleration sensor which produces an output voltage signal proportional to the acceleration which, after a series of conversions, results in a count of PA over a pre-set time period (124). Several brands of accelerometer are available with different features such as uni or omni directional motion detection. A review of comparisons with other methods indicated moderate to strong correlations with other measures such as PA recall, treadmill walking, indirect calorimetry, and heart rate monitoring in children, youth, and adults (12). Validation studies have been performed to assess the usefulness of accelerometers in pre-schoolers. Comparison has been made using VO_2 measured by a portable metabolic system. In these studies, the widely used Actigraph accelerometer indicated a correlation of r = 0.82 across all activities (125). Under the same conditions, the smaller Actical accelerometer showed a correlation of r = 0.89 (119). Both models are therefore accepted as valid tools for measuring PA in pre-schoolers (126).

Comparison between direct observation and accelerometers has been undertaken as it is postulated that accelerometers may be more cost effective than direct observation in field studies (113). When comparing the Actigraph accelerometers with CARS measurement while children played at preschool, correlations ranged from r = 0.03 to r = 0.92, with the median correlation at r = .74 (113). Correlations were noted to be higher when the child was more active, however because children spent a great deal of the day inactive overall correlations were reduced. Two studies since have aimed to correlate PA intensity measured by accelerometry with CARS (114, 127). The first study found correlations of between r = .46 and r = .70 for the Actigraph and a modified CARS. There were two parts to this study, the first involved 3 to 5 year old children (n =16) in a calibration study performing structured CARS activities while wearing accelerometers. The second part of the study involved 281 children wearing accelerometers while their activity was coded using a modified CARS in the preschool environment for up to 10 days, the aim being to categorize activity by intensity using the activity cut-points established in the first part of the study. Observers identified the highest level of activity that occurred during each 15 second observation interval. This measure is noted by the authors to be quantifying a different aspect of the child's activity than the accelerometer, which is recording accumulated activity for that period (114). While this can be controlled in laboratory settings, it may have an effect on activity measurement in the field where activity intensity is more varied (114). In the second study, 3 to 4 year old children (n = 6) were videoed playing outdoors. Play was then coded using CARS criteria resulting in a correlation of $\kappa = .22$ with the Actical accelerometer. In this study, video footage of play was coded by trained observers and the video rated on a second by second basis averaged over 15 seconds for comparison with the 15 second epoch of the accelerometer (127). The lower correlation could have arisen due to the use of less structured activity, however the authors also note the use of 15 second time sampling may not have captured the activity of the children. Also, accelerometers do not recognise the vertical component of activity, such as climbing, which was observed to have consumed 18% of the activity time. The use of a more conservative correlation coefficient (kappa) may also have led to the comparatively lower correlation (128). The authors conclude that accelerometer data alone is not sufficiently accurate to measure the full extent of pre-schooler's activity, and that two methods of assessment are required until more reliable classification of activity is established (127).

Three studies have employed accelerometers on infants 2 years and under and are therefore relevant to this thesis.are Two European studies have studied small groups of toddlers (117, 129). While the Belgian study reported toddlers in their study reached the 180 minutes of activity of any intensity per day recently recommended by health authorities in some countries (59), the study from the Netherlands did not support this level of activity. As is often considered to be an issue in such comparisons, the cut off points for the accelerometer derived activity were different between these studies making it difficult to compare the contrasting results. The other study using accelerometers in toddlers was from Australia (96). The InFANT study is an RCT which used encouragement of activity as an intervention in a study centered around obesity prevention from infancy. This study found no intervention effect on PA in 19 month old toddlers so examined their results as one group. The accelerometer data were used to examine the activity pattern of the toddlers across the day rather than considering counts per minute of activity which would allow better comparison with the POI.nz study reported in this thesis. This analysis showed that the majority of children reached the 180 minutes of activity recommended (58) however it was mostly of light intensity.

1.4.3.1 Considerations when using accelerometers

Despite this caveat, accelerometers are becoming accepted as the way forward in obtaining reasonably accurate objective measurement of PA in infants, toddlers, and pre-schoolers (13). However, as with all methods, there are advantages and disadvantages with this technique. The advantages of accelerometers include their small size and light weight. These factors are especially relevant when research involves this young age group as they can be worn without obstructing activity. Some models are also waterproof so can be worn for water-based activity which offers the added advantage that they will not be forgotten to be refitted after removal for such activities. Disadvantages include initial and on-going costs such as researcher time in ensuring units are calibrated, distributed, and returned, and sundries such as straps or belts. While accelerometers have been considered to be expensive, the price per unit is decreasing making them more desirable for large longitudinal studies where multiple units may be required over a long period of time. Accelerometer brands are not considered to be inter-changeable (130, 131), so one brand should be selected.

The responsibility of the researcher when using accelerometer derived data is to determine parameters around settings and data reduction. Areas where decisions must be made prior to research include the site of wear, number of days to be worn, and the epoch length used to collect data. Before data can be reduced to counts, further decisions must be made around the amount of time worn to constitute a valid day, the interpretation of zero counts, and intensity cut-points relevant to the brand of accelerometer and age of the participants.

As accelerometers register the movement of the part of the body they are worn on (124), adults and independently mobile children generally wear them on a belt around the waist, closest to the body's centre of mass (12). Recent research comparing wrist and hip worn accelerometers for measuring total sleep time in 10 year old children found a high correlation (r = .97) between these two sites, supporting the usefulness of the hip site to measure sleep and activity over 24 hour periods, although the paper analysed only sleep data (132). When using accelerometers on adults and children, they are usually placed at either the left or right iliac crest, or the back (14). Where to place an accelerometer on a toddler or non-walking infant remains the subject of research. A thorough review of methodology in accelerometer use in children states the site of placement is an area where further research is required, particularly given the developmental differences evident in children from 0 to 5 years (14). In a pilot study comparing accelerometer derived activity to caregiver diary, accelerometers were placed on the ankle of infants < 6 months (n = 2) and the waist of those > 6months (n = 7). As this study was looking at individual correlations with diary recorded activity, placement of the accelerometer was not discussed, however examination of the data does not indicate any differences in trends for counts by placement site (110). Movement at this age is intermittent (10, 11), and the one minute epochs used for data collection in this study may have been too long to capture any differences by site of placement.

Issues can arise when accelerometers are given to parents to place on children at home. With some units it is necessary to have the accelerometer unit in the correct orientation as it will pick up movement along a specific axis (133). The Actical accelerometer, for example, can be attached to a belt in either orientation depending on the site of wear but it is important that it is worn in the position and orientation directed by the manufacturer or the data may become skewed (134). However, variation in measurement has been reported in children even between different waist placements. A small study using 11 pre-schoolers in free living conditions reported significantly higher counts per minute at the umbilicus than at the right hip (135). This is of particular significance when researchers are leaving the units with parents to supervise. These authors also caution against the use of attaching accelerometers to elastic belts in children, favouring a more fixed method for free living conditions given the large differences evident in results from small differences in placement. They go so far as to speculate that differences in measurements in one study that failed to validate the Actiwatch accelerometer against DLW could be attributed to "wandering" accelerometers, although there is no mention of this being an issue in the validation study (136).

Research into the time an accelerometer should be worn to give an accurate indication of the pattern of PA has established some guidelines. Trost and colleagues (137) examined the question of length of wear required and found children aged 6 to 10 years old required four to five days to give a reliability of 0.8. Further research on younger children has supported this conclusion (138). In the latter study (mean age 5.6 years), reliability increased with days of wear but peaked at 80% for 10 hours per day for seven days. However, reliability of over 70% was evident for as little as three hours of wear time over five days, while periods longer than 11 hours showed decreasing reliability. This unusual result led these authors to suggest fewer hours might be representative in children of this age, which is useful when considering participant burden. Regarding hours per day, to constitute a valid day for toddlers, 7.5 hours per day has been suggested as a reasonable time to monitor activity using accelerometers (117). Supporting this figure, the InFANT study examined data from 250 19 month old infants and concluded that at this age, four days of valid data (7.4 hours per day) returned reliability of over 70% (96). Acceptable wear time would appear to be somewhat dependant on the age of the child, however seven to 10 hours per day for five days would be reasonable to meet the considerations of researchers and participants across age groups. In the study reported in this thesis 8 hours per day for 3 to 5 days was used in the final analysis.

Accelerometers allow researchers to choose the epoch (time) interval for measurement of PA. As they are battery powered, longer epoch intervals allow more days of recording. As toddlers' and pre-schoolers' movement is variable, shorter epochs are recommended for accurate measurement of their activity (114). Laboratory-based validation research suggests that 15 second epochs captured the sporadic nature of children's activity (119). In contrast, Oliver (2009) found that the 15 sec epoch used in their study of 3 to 4 year olds engaged in free play did not capture the variety of less than 15 second activities and recommend the shortest epoch possible to be used in child studies (127). The shortest epoch allowed by some accelerometers is one second while others have a lower limit of 15 seconds. In studies of pre-schoolers, shorter epochs appear to result in more time spent in MVPA and are therefore thought to be better for detecting the intermittent activity of this age group (139, 140). In one study of 4 to 5 year old children (n = 76) using 15 second epochs, only 7% were found to be moderately to vigorously active 60 minutes a day, and only 26% met the recommendation of at least 120 minutes of activity at any intensity per day (141). In contrast, another study in a sample aged 3 to 5 years old (n = 30), found all participants met the 120 minutes of activity per day recommendation when using 3 second epochs (142). This discrepancy may be due to the younger age group in the study by Obeid et al (2011), but other research has shown that longer epoch lengths can lead to underestimation of time spent in MVPA (13, 142). While the epoch length may be determined by the type of accelerometer used, it would seem that when measuring PA in infants, toddlers, and pre-schoolers, shorter epochs can give a better indication of movement.

Accelerometer data cleaning and processing can be achieved using commercial software such as MeterPlus (**http://www.meterplussoftware.com/about.html**). Use of such software requires users to define parameters for the minimum number of hours of wear time required for the day to constitute a valid day, and the number of consecutive zero counts to constitute non-wear time. While little research is available in this area minimum wear time to constitute a valid day has been suggested to be 7.5 hours when measuring toddlers' activity (117). Defining non-wear is more problematic and a consensus has not been reached on the appropriate level of zero counts required to describe non-wear in pre-schoolers. The reasoning that is used in decision making in older children and adults is that any activity will register movement therefore zero counts should be removed (14). Research has shown that in school aged children, around 17 minutes was the longest time spent inactive (143) and supports the use of more than 20 minutes as non-wear in this age group (16). Some researchers have suggested that consecutive zero counts should not be removed from the dataset in order to include as much data as possible even though this will alter intensity interpretation by diluting mean counts. Given the uncertainty, researchers must decide given the evidence that best fits the age of their participants. Researchers measuring activity on children under 3 years old appear to prefer a shorter time period to account for movement being intermittent and variable at this age, with 10 minutes of zero counts defined as non-wear in two such studies (117, 129).

It has been thought that assessing PA in order to recommend amounts for optimum health benefits requires raw counts to be reduced to time spent at different intensity levels (126). Accelerometer output can be categorised by reducing counts per minute (CPM) to the amount of time spent at different intensity categories, for example, low, moderate, or high intensity. Categorisation of activity by intensity levels has become the focus of accelerometer-based research, even in young children (144). A number of cut point systems for this purpose have been proposed (114, 119, 145, 146). The variation in cut points results from the different types of accelerometers being used, and the amount of structure imposed during the calibration activities (126, 145, 147). Using different cut-points consequently leads to variation in the conclusions around amounts of time spent at different intensity levels. Therefore, the achievement or non-achievement of recommended levels of PA can be conflicting (13). In two previously mentioned studies, both using the Actigraph AM-7164 accelerometer, one study used a cut point of 2000 CPM to indicate moderate activity (60), while the other used a cut-point of 3000 CPM as moderate to vigorous activity (61). Andersen et al (2009) studied 9 and 15 year olds and found that the least active quintiles spent over 30 minutes per day in MPA, while the most active quintiles spent over two hours at this level of activity level (60). Le Blanc et al (2010) used a higher threshold of 3000 CPM and found that only 4.1% of participants reached 60 minutes per day of MVPA, with 71.1% of the girls accumulating less than 15 minutes per day in MVPA (61). Using different PA definitions and thresholds thus results in different conclusions, and given the importance of this research, consistency would be useful.

Research on the appropriate cutpoints to use on toddlers is sparse, however recently cut points have been developed for this young age group. In this recent study, Actigraph accelerometers were compared to direct observation using OSRAC-P in 2 year old infants. Positive correlations between mean OSRAC-P activity intensity levels and Actigraph recorded PA were reported as r = .66; P = <.001; n = 31 (117). Cut points developed by Pate et al (2006) of sedentary ≤ 37, light 38-419, and moderate to vigorous ≥ 420 counts per 15 seconds (125) were reported to show the least bias in classifying sedentary versus non sedentary behaviour in toddlers in this study. More specific classification at this age was not clear, and this is postulated to be due to the activities carried out by this age group such as vertical climbing not being detected by the accelerometer. Another study on pre-schoolers compared accelerometer measured activity with a four item modified CARS coding schedule (144). Children in this study were 2 years old (n = 22) and wore an Actigraph accelerometer while their play was videoed for a 20 minute period. In contrast to the study by Van Cauwenberghe et al (2011) (117), Trost and colleagues concluded that the cut points developed by Pate et al (2006) were valid for identifying MVPA, but not sedentary time (135). Sedentary behaviour was over estimated by all five cut point classifications (114, 117, 125, 144, 148) used in this study, however the commonly used 100 counts per minute, or 25 counts/15seconds, was found by the authors to have the least bias and is supported for use in classifying sedentary behaviour in toddlers (144). In comparing accelerometers, Trost et al (2012) also found that both the Actigraph and Actical overestimated sedentary activity when compared to direct observation. While the actigraph was useful at classifying MVPA at around 420 counts/15 seconds, the Actical did not successfully classify MVPA (Trost 2012, personal communication, March 2012). While it is evident some headway is being made in classification of PA intensity, variation in cut points is a result of the range of methods and equipment used and therefore standardisation of these factors is required before conclusive decisions can be made around cut points for children's activity (13).

Consideration of consistent data reduction has been suggested by multiple authors over some years (179, 13,135). Issues surrounding the inconsistency in PA measurement in infants and pre-schoolers are yet to be resolved; however two researchers have offered solutions to aspects of the problem. Oliver et al (2011) have proposed alternative methods of data reduction which are said be more sensitive to the specific nature of movement of pre-schoolers (149). This method uses a generalized estimating equation (GEE) model to assess average daily PA rates per second for participants resulting in a continuous global measure of PA. Oliver notes the calculation in this method is time consuming and it does not allow cut point consideration of intensity of PA. In an attempt to ensure some repository of knowledge in this area, a database of research employing accelerometers in measuring PA in children (122) has been created to enable greater communication and, potentially agreement, so that knowledge in this area can move forward and inform recommendations.

In infants who are not independently mobile, dependant activity from a parent carrying the infant may confound measured PA using accelerometers, according to the single study that has evaluated this issue (105). Accelerometers were used in this single subject study with a doll and researcher mimicking the 3 month old infant and parent activity. In this study by Worobey and colleagues (2009) the doll and infant wore a micro mini motion logger around the ankle for a 24 hour period. The researcher carried out the same activity with the doll as the mother did with the infant so that the accelerometer on the doll was picking up the researchers activity and any extra activity on the infant's accelerometer was the infant's alone. The results indicated that overall the infant activity was only 45% more than the doll. The majority of movement therefore was from the mother, indicating a large amount of interference in activity measurement in this age group. The researchers therefore recommended caution in the use of accelerometers in this young age group given the amount of "maternal enhancement" of activity, and recommend concurrent measurement of the caregiver activity with the infant may make the level of interference clear (105). Dependent activity could therefore be an issue in studies of infants' PA. However, the parameters for the attainment of independent walking are wide; some children do not walk until 18 months (150), therefore research into PA before this age, while necessary for the elucidation of infant activity, is complicated by walking achievement.

1.5 Early intervention studies

Early intervention for obesity prevention research is evident in the literature since the 1970's (151) and has focussed on feeding. More recent interventions place less emphasis on diet alone and include other factors involved in obesity such as PA and sleep (4 , 95, 152), however there remains little rigorous research on infants and pre-schoolers (153, 154). The dearth of intervention research is indicated in a 2010 review of interventions to prevent obesity in the 0 to 5 age group (154) where only 23 papers were found in a search covering 1995 to 2008. However, 17 of these papers were from 2003 onward, indicating the recent increased research interest in this area. Five studies involved children under 1 year old and four of these did not have obesity as their intervention focus, nor any measurement of weight or obesity. Since this 2010 review, further intervention studies are evident in the literature from the USA and Australasia (4, 5, 95, 155-158). These studies are relevant to this thesis and will consequently be considered in more detail.

In the last five years several early intervention RCT studies have published protocols (4, 5, 95, 158, 159) indicating the shift in emphasis towards a greater understanding of the early life factors on obesity. Despite the evidence that PA is beneficial to health and that, with nutrition, should be included in early intervention research (160), not all of the recent research has included an intervention and outcome measure of PA. Early intervention of PA is the focus of this thesis, however studies that did not include a measure of PA will also be discussed in this review to give a thorough picture of the research around early intervention for obesity prevention, given the relatively limited evidence base.

Three early intervention studies have been reported from the United States. The first study focussed on a Native American population where active parenting education was presented (155). During home visits, half the participants received information on PA and nutrition while the other half received parenting support without the focus on obesity prevention. Entry criteria included maternal BMI greater than 25kg/m^2 and the mean age of the 43 infants was 21 months. Despite there being no significant difference in weight for height scores between groups following the intervention, the authors described the results as promising for obesity prevention in the high risk population studied, presumably on the basis of the trend in between group difference in weight for height nearing significance (p = 0.06). More participants may have allowed the study the power to detect this difference more conclusively. Despite tabled information depicting infants' activity in both groups *decreasing* from baseline to follow-up by around 10%, accelerometer count analysis is not discussed in the results or discussion. Reference to this would have been useful, given the direction of the results, and because few studies that have used accelerometers in this age group (155).

In a further study in the USA which is described as a pilot study (n =160) a 2x2 design was used to give education around infant sleep and the introduction of solids (156). Maternal pre-pregnancy BMI (BMI<25 and BMI≥25) was stratified when randomising to groups. The hypothesis in this study was that infants receiving sleep and nutrition interventions would have lower length-for-weight percentile at 12 months. All groups received a home visit two to three weeks after birth where the infant was weighed and measured and standard infant parenting information was given, with the control group receiving no added information. In the "Soothe/Sleep" condition, a research nurse taught parents methods to intervene when their infant woke that did not include feeding as the first option. Information on soothing techniques was given and a video detailing the information left with the family. The "Introduction of Solids" group received information at the first home visit around breast feeding exclusively for the first 4 months, and then how to recognise hunger and satiety cues as well as being instructed to delay complementary feeding until at least four months. The second visit was initiated by the parents contacting the researchers when they felt their infant was ready for solid food and the research nurse visited within two weeks of this call. At this time the feeding intervention group regularly received premade foods (commercially available vegetable purees) and were instructed to try each one three times before offering cereal or milk alternatives. All infants were measured again at one year. Fifty families dropped out of the study (31%) and these mothers differed significantly from completers in a range of factors such as being younger in age and having less years of education. Weight for length results at one year indicated the hypothesised difference between groups was supported. Infants in the multiple intervention group had mean weight for length in the 33rd percentile compared to the other groups which were at or over the 50th percentile (P = 0.009). There was also slower weight gain in the Soothe/Sleep group between the first and second measurement (P = 0.02), which was attributed to a reduction in the number of night and day breast feeds (156). There are several limitations to this study, some of which are mentioned by the authors, such as the homogeneity of the sample and the fact that positive results were confined to dyads who continued to breastfeed, which at 16 weeks comprised only 51% of those completing the study. Those not breastfeeding beyond this time may have differed in some way from those that continued breastfeeding. The relatively high drop-out rate also provided less power for examining interactions between interventions. While not reaching significance (P = 0.06), the introduction of solids was delayed until after 4 months by 87% of those receiving the nutrition support compared to 71% not receiving this intervention. It may be that the protocol asking mothers to call the research nurse when they were ready to introduce solids could potentially bias the results due to the social desirability effect when they were specifically "instructed" to delay feeding solids. A standard time for the second visit for all groups would create less bias.

Another pilot study from the USA started with 292 participant families in a randomised cluster trial, however retention by the third visit at 12 months was only 57%. The MOMs project (159, 161) recruited families with an eligible infant 2 months old or younger in a low income area of Ohio through primary care clinics. Three clinics were used, each offering anticipatory guidance around either the mother's role in modelling good nutrition (MOMS), infant nutrition (OP), or normal well child care (BF) which had less detail regarding portion size and food introduction. Maternal nutrition messages were designed to address the mother as the role model of good nutrition habits to her children. Mothers were asked to incorporate healthy eating habits into their diet such as five servings of fruit/vegetables, drinking milk daily, eating with the family, and avoiding fast foods. The infant nutrition clinic focused guidance on how to introduce solids and awareness of the infant's ability to determine hunger and satiety. Although the infant's nutrition condition had written information that included a "Be Active" section, PA was not the focus of the study. At a 12 month follow up there were no differences in infant growth, however the mother's nutrition group offered infants less juice and more vegetables (161). Limitations of this study include the high dropout rate which left two groups with less than the 63 participants (required to give power of 0.80 with 61 and 59 in the MOM and OP groups respectively). The average BMI of mothers in this study was 28, 62% of mothers were overweight, and there were some significant differences in eating and feeding practices between clusters at baseline. After controlling for these factors it was concluded that this pilot study offers encouragement for a low cost intervention at a "teachable moment" in a family lifecycle. This conclusion appears to be based on a relatively small change in nutrition behaviour in a group with previously high obesogenic behaviour, and no evidence of change in infant growth parameters. This seems to be little evidence on which to base such a recommendation.

Australasian research groups in early obesity intervention across a variety of research centres have collaborated to increase the precision of interventions involving early obesity prevention. The resulting group has been called the Early Prevention of Obesity in Children (EPOCH) collaboration (162). This thesis presents evidence from one study involved in this research group while the other three studies currently underway will be discussed below.

The EPOCH collective comprises three research groups in Australia and one in New Zealand. The NOURISH study is an Australian component of the EPOCH collective which involves an RCT focussed on early feeding practices and their effect on later obesity. This study recruited in two sites, Adelaide and Brisbane, with the intention of following first time parent participants for 5 years (158). The study used anticipatory guidance to deliver education on factors established to be related to parental feeding practices and infant feeding behaviour. Physical activity was not included, reportedly due to the lack of nationally accepted guidelines for PA in pre-schoolers, and also the need for more validation of tools for measuring PA in infants, toddlers, and pre-schoolers (158). The control group received normal well child care, the content of which is not well explained but reported to be self-directed and targeted at high risk families. Sessions were held in clinics starting when children were 4 to 6 months old and comprised 1-1.5 hour sessions. While on average parents attended only half of the sessions, significant differences were reported between groups in parental response to satiety and food refusal at the 14 months follow-up (163). Outcome results at this time indicated significant differences in BMI-for-age z-score (P = 0.009) and weight gain in the nine month follow-up period (OR 1.5, p = 0.014). This study did not target low-income families as some other studies have, choosing instead to gather a consecutive sample of women who had given birth within specific hospitals in the region. The retention figures indicate that older (median 31years completed, 27years did not complete), better educated mothers (University educated 61% completed, 34% did not complete) and those living with partners (96% completed, no partner 90% not completed) tended to complete the study, however these factors did not vary between groups. The lack of a comparable education program for the control group is also a limitation in this study as it is not clear what education, if any, the control group received given the self-directed nature of the control conditions clinic visits. The authors allude to the fact that providing 18 hours of content that differed sufficiently without encroaching on topics covered by the intervention, and did not somehow enter the obesity prevention field, was not feasible so there was potentially some cross over in information given to the control group (163).

The Healthy Beginnings randomised cluster trial in Sydney initiated a home based intervention to prevent childhood overweight/obesity. Healthy feeding/eating and PA strategies in the first two years of life were promoted to an economically disadvantaged population who received eight home visits by specially trained community nurses. First time mothers were given education focussed on feeding behaviour and problem solving activities which included encouragement of early intervention of activity such as “tummy time”. The control group was provided with the usual well child care which included one home visit and possible clinic visits (4). Nutrition and activity outcomes have been published from the one year follow-up which indicates success in lengthening breastfeeding time, delaying the introduction of solids, and the earlier use of tummy time (P = 0.03 for trend) (164). Two year follow-up results indicate the primary outcome of significantly lower BMI in the intervention group was achieved (16.53 compared with 16.82. P = 0.04) (165). Secondary outcomes, including maternal time spent active, were also significantly different at follow-up with intervention mothers more likely to spend 150 minutes or more a week on PA than the control group (48% v 38%, P = 0.04). Infant activity was not measured, however television watching for more than 60 minutes a day was significantly lower at follow up in children in the intervention group compared with those in the control group (14% v 22%, P = 0.02). This study was based in the most economically and socially disadvantaged areas of Sydney. While these results are encouraging, the sample was not representative, however they do indicate how successful a targeted health promotion activity can be. The input by nurses was high with an hour at each visit, therefore the expense of such an intervention is considerable, particularly given routine well infant care in New South Wales involves voluntary clinic visits. Cost effectiveness analysis is being completed and will give an indication as to the benefits of such an intervention (165).

The last of the Australian EPOCH studies, the InFANT study in Melbourne also offered early intervention for obesity prevention to first time mothers, reducing costs by incorporating their intervention into existing new mothers groups using a cluster-randomised controlled trial design (5). First-time parent groups were contacted and invited to participate and if the majority of participants consented, the group was randomised to intervention or control conditions. The control group received usual care from their Maternal and Child Health nurse (MCH) which included 10 scheduled clinic visits, however the content of these visits and how they differ from the intervention is not clearly outlined. For the intervention groups, six anticipatory guidance based education sessions were offered with a dietician at three month intervals which included a variety of teaching strategies and follow-up methods. The content of the sessions included weaning, the introduction of solids, parental modelling of eating, and infant food rejection. The role of the family in sedentary and physical activity was also included in these sessions. Demographic data from the InFANT study indicates mothers in both groups had high levels of education with 54.2% reporting a university degree or higher. This compares to 25% of the general population in Australia having a University degree (166). The reported maternal factor results for the InFANT study (167) indicate the recruitment and retention to be high in the InFANT study with 86% of women agreeing to participate and only 9% lost to follow-up. The protocol document, however, states that to achieve the desired outcome 300 participants were required in each group in order to account for 40% attrition (5). The numbers Lioret and colleagues used for final analysis were 178 and 179 in the intervention and control groups respectively, from the 542 randomised to two groups of 271 at baseline (167). While there may have been only 9% lost to follow-up, final results account for only 66% of participants and the study did not achieve the 300 in each group required to account for such attrition. Viewed with recruitment and retention figures for the NOURISH study, it seems that when families have new babies, the complexities of research may be underestimated in the planning stages as neither study appears to have met the targets set to achieve the power stated in their protocol documents.

Despite these issues, recent publications from the InFANT study allow some elucidation in the area of patterns and predictors of early life PA. Follow-up at 19 months has been reported and, while some dietary effects are evident, there have been no beneficial effects reported at 18 months regarding maternal PA or TV viewing time (167). Activity minutes per week for the mothers declined at follow up in both the intervention and control groups. Reasons for this are suggested to be the lack of power in the study to detect change in this variable, and the use of a low precision self-report questionnaire to measure PA (167). Further published results from the InFANT study have included the assessment of infant activity at 19 months of age (96). While the protocol papers suggested parental report would be the outcome measure of infant PA at 19 months (5), accelerometer (Actigraph) derived PA has been reported (96). The inclusion of a direct objective measure makes the activity aspect of this study more comparable with its EPOCH partner the, POI.nz study. There was no differences in PA between the intervention and control groups in this study, with both having similar mean CPM so the data was examined as a whole rather than by intervention. Using the intensity parameters suggested by Trost et al (2012) (144) this study found 90.5% of the 19 month olds met the suggested PA guidelines of ≥180 minutes of LPA/MVPA per day. It appears that 80% of this activity was at the LPA level, and this is perhaps why a subsequent paper from the InFANT group does not emphasise the point that the majority of children achieved the 180 minute recommendations, instead noting that generally young children are at risk of not meeting such targets (168). The aim of this more recent paper was to assess predictors of toddler PA using a regression model with PA at 19 months and predictor variables. The variables that were positively correlated with PA at 19 months were spending time with babies of a similar age at 4 months, and time spent being active with their mother at 9 months. The authors note that the effect size was small and multiple variables were tested, therefore there is some possibility the effects are by chance. Of further importance was that adjustment to the model had to be made for the length of time the infant had been walking, as infants who had been walking longer prior to accelerometry measurement at 19 months were more active. At 19 months, 40 minutes more activity per day was observed in infants who walked at 8 months compared to those walking at the later time of 18 months. Ten months of bipedal experience evidently offers greater walking skill. This quantifies what is easily observable; infants become increasingly confident in their balance and movement with increased bipedal experience. It is useful to have such information when looking at recommendations of PA for health in young children, and for evidence of the benefits of encouraging PA in infancy.

1.6 Conclusion

Physical activity is an important aspect of the energy input and output cycle and as such contributes to the maintenance of health (7). This is evident across a range of body systems and it appears likely that early adoption of an active lifestyle can only enhance health in the short and long term (169). The obesity epidemic and consequent metabolic diseases that are evident in developed nations are a looming problem and calls for obesity prevention intervention involving education around both nutrition and physical activity (1). Activity intervention beginning early in life would seem to hold promise for long term health benefits (49, 170). While evidence for the sustained effect of early PA from tracking studies could be considered not to support high levels of tracking, it may be that factors such as measurement inconsistencies are an issue, and thus require further research (69). This issue is especially evident in the literature on infant and child PA, as not only are physiological measurements of energy expenditure more difficult to obtain than in adults, other commonly used methods, such as self report, are not useful in studies of infants and pre-schoolers (107).

The future of PA measurement generally seems to be the use of accelerometers, particularly so with children, given that alternative indirect methods pose potential accuracy issues (122). While some headway is being made, consistent procedures need to be followed for comparable research and thus become useful in assessing the true nature of young children's activity (13). When this is achieved, infants' and children's PA will be able to be quantified and it will be evident whether activity recommendations are being met. In the meantime, studies are increasingly employing accelerometers as the best objective measure of activity (81, 144).

This thesis reports on aspects of the randomised controlled trial, the Prevention of Overweight in Infancy study (POI.nz) (95). The POI.nz study aimed to determine if additional guidance and support around feeding, sleep, and PA could reduce the rate of excessive weight gain from birth to 2 years of age. Accelerometry was included as the outcome measure of PA at 6, 12, and 24 months of age. Parental report has also been used for a range of infant activities such as the use of tummy time and milestone achievement. Analysis of the POI.nz data for infant activity at 12 months is reported, with the aims of thesis as follows:

1) To determine whether accelerometers are useful for measuring PA in 6 month old infants. A study was undertaken separate from the POI.nz study to determine whether the accelerometer data collected at 6 months of age to assess whether sleep was also suitable for evaluation of PA. This validation study raised questions around the use of this data at 6 months of age so the 12 months accelerometer data were considered for reporting in this thesis. The results of the validation study are presented and discussed.

2) To determine whether the activity intervention delivered prenatally and at 3 months of age had any effect on parental offering of tummy time to their infants at 19 and 27 weeks post natal.

3) To quantify activity at 12 months from accelerometer recorded activity and determine whether the intervention influenced the activity of the infant's at 12 months of age.

Chapter 2. Validity of Accelerometer Measured Physical Activity in 6 Month Old Infants.

2.1 Introduction

The child obesity epidemic has multiple causes and therefore effective prevention remains a difficult target. However, promoting physical activity (PA) in children from infancy is considered an important goal (171). Being able to quantify PA at this young age would provide multiple benefits, both for researchers determining how PA develops from very early in life, and for health professionals in providing suitable anticipatory guidance to parents. Accelerometers are small motion-sensors commonly used in PA measurement in adults and older children. Given the good correlations with time-activity diaries (110) and portable metabolic systems (r = 0.82) observed in older (3-5 years) children (125), there is promise for their use in the measurement of PA in infants.

The use of accelerometers to assess PA is complicated in infants and toddlers by the intermittent nature of their activity (11). At this age, activity is often not purposeful or independent, and measurement of PA may be confounded by the activity of the caregiver. In the only published study using an accelerometer to measure PA in this young age group a novel method was employed to gauge how much of the activity measured by the accelerometer was due to the infant moving independent of any caregiver movement. A researcher with a doll was employed to mimic the activity of a mother and her 6 month old infant (105). Twenty four hours of activity output from accelerometers worn on the ankle of the infant and doll were compared. The doll, which did not move independently at all, spent 44% of the time "awake", meaning activity was detected by the accelerometer when obviously the doll was not moving independently. Worobey and colleagues conclude that confounding may represent up to half of the measured PA in infants who are not moving independently (105). Given this is a single subject study the results may be more variable than this study revealed.

Accelerometry is being increasingly used to measure sleep in infants (172). As measures are typically obtained over 24-hour periods, this provides the opportunity to determine whether PA could be measured as well. Recently 5-day accelerometer data (24-hour) was collected from over 400 infants involved in the Prevention of Overweight in infancy study (POI.nz)(95). The current study was designed to assess the degree of caregiver confounding that might be expected in these measurements, as well as determining the best site of placement of the accelerometer for the measurement of activity in non-ambulant infants. In this study, short sessions of activity typical of daily activity of an infant and caregiver were chosen and the activity of the infant and a doll doing the same activities were measured using accelerometers. Three accelerometers were worn by both the infant and the doll (the waist, one ankle, and one wrist) to allow examination of differences in PA measurement by site of placement.

2.2 Methods

2.2.1 Participants and procedure

Mothers with infants between 5 and 7 months old were recruited by advertisement and word of mouth from the lower South Island, New Zealand. Ethical approval was obtained from the University of Otago Ethics Committee (09/212) and all mothers gave written informed consent. Sample size was calculated as 10 participants for each variable to be examined which in this case was the three activities carry, stroller and ball.

Each infant was weighed and measured on a combined weight/length board (SECA 334-Germany) in duplicate wearing only a singlet and no nappy, and means calculated. A solid vinyl doll (40 cm long, 0.8kg weight) was used by the researcher to mimic activity of the mother and infant. Six Actical accelerometers (Mini-Mitter, Respironics, Oregon, USA), three for the infant and three for the doll, were initialised by entering relevant weight and length data into the Actical setup program (Respironics Inc. Version 2.12). A 15-second measurement interval (epoch) was selected as recommended to capture infants' intermittent movement (11). Before use, the output of each accelerometer was checked at a low, medium, and high activity level on an "in house" mechanical calibrator.

One accelerometer was then placed on the wrist, one around the waist, and a third on the ankle of each infant, and in similar positions on the doll. Left or right side placement (same for all three accelerometers) was randomly assigned for each infant using the corresponding side for the doll within each pairing. The mother and infant then undertook four activities (described below), in a randomly assigned order. For three of these activities (i-iii below), the researcher used the doll to mimic all activities of each mother/infant pairing. Where possible, five minutes of activity was carried out for activities i-iii, and up to 10 minutes for the mat activity.

Stroller activity involved the caregiver pushing the baby in the stroller.

Carrying involved the parent carrying the baby in whatever position was comfortable (usually on the side at the hip) but simulating normal household activities.

Swiss ball activity involved the caregiver rolling the prone infant on the Swiss ball, an activity which has been promoted to encourage prone positioning by active movement educators (173).

For the fourth activity, mat play, the infant was placed supine on a mat equipped with hanging toys and left to play freely. This activity continued for 10 minutes, or until the baby was no longer compliant. Video recording time was synchronised with the accelerometer-measured episodes using a digital clock to ensure video recorded activity and accelerometers recorded activity were corresponding. The video recorder was hand held so that the limbs wearing accelerometers were in frame at all times. If infants became unsettled, the activities were concluded early.

2.2.2 Researcher coded activity

Previous studies with older children have used the Child Activity Rating Scale (CARS) (113) or a modified version of CARS (127) which classifies movement as 1 (*stationary/motionless*), 2 (*stationary/movement of limbs or trunk*), 3 (*translocation-easy*), 4 (*translocation-moderate*), and 5 (*translocation-strenuous*). The present study found these to be unsuitable for pre-walking infants due to the lack of a classification of smaller body activity being included in the coding. Therefore, a three level coding system, specific to this age group, was created and comprised the following:

1 - zero or minimal movement - may include slight movement of fingers, toes or head.

2 - movement of one to three limbs without movement of the trunk.

3 - movement of four limbs and/or trunk - includes crawling.

The two observers, the researcher, and a research nurse were trained for two hours in coding infant activity. Videoed recording of six infants' activity while they played on the mat was coded every three seconds independently by each coder to ensure reliability. The researcher coded all videoed mat play activity twice, two months apart.

2.2.3 Data reduction and analysis

Data were downloaded from each of the three accelerometers from the infant and the doll. Epochs were matched between the doll and the infant. The first five minutes of recordings were used to analyse activities i-iii. Accelerometer counts were totalled to create a total activity count for the first five minutes of activities i-iii for each participant. The mat activity was recorded for as long as the infant remained active and all available recorded minutes were used in analyses, giving up to 10 minutes of activity (range 4 to 10 minutes). Data were analysed using Stata 11.0 (StataCorp. 2009. Stata Statistical Software: Release 11. College Station, TX: StataCorp LP). To determine the amount of caregiver interference, ratios were calculated using the mean activity counts for the doll relative to the infant for each activity, and each site of accelerometer placement. Pearson product-moment correlations were calculated for the mat play data from the activity counts (accelerometer) in comparison with the observer coding.

2.3 Results

Thirty four mother/infant pairs participated overall but the number of infants in each activity varied as infants were not compliant for the entire range of measures and no single infant completed all four activities. As infants were randomly assigned to order of activities, reasonably even numbers of infants were involved in each activity. Twenty-seven participant pairs completed the stroller activity and 23 completed each of the carrying and ball activities. Twelve infants completed the mat activity. Infants ranged in age from 5 months 3 days to 7 months 6 days (median = 6 months, 10 days). All infants were born after 36 weeks gestation with no congenital abnormalities. Sixteen infants were female. Mothers' ages ranged from 20 to 39 years.

Table 2.1. Average accelerometer counts for the infant and doll by specific activity and according to site of accelerometer placement.

	Infant Mean (SD)	Doll Mean (SD)	Ratio doll/Infant	95% CI
Stroller				
Wrist	462 (4.1)	133 (5.0)	0.29	0.15-0.55
Waist	46 (4.6)	111 (3.9)	3.5	1.12-11.26
Ankle	920 (4.4)	92 (3.0)	0.09	0.04-0.19
Carry				
Wrist	1844 (3.6)	417 (3.5)	0.23	0.11-0.35
Waist	353 (8.3)	445 (4.4)	1.38	0.05-3.83
Ankle	1061 (4.5)	638 (4.5)	0.52	0.23-1.15
Ball				
Wrist	2901 (2.4)	722 (3.0)	0.28	0.17-0.45
Waist	376 (6.2)	900 (4.4)	2.5	1.28-5.02
Ankle	4548 (1.8)	971 (3.1)	0.21	0.13-0.39

Table 2.2. Ratios for activity counts according to site of placement on infant for each of the three activities.

	mean of ratio	95% CI	P value
Stroller			
wrist/waist	12.8	5.3-30.6	<0.001
wrist/ankle	0.48	0.28-0.83	0.005
waist/ankle	0.03	0.02-0.07	<0.001
Carry			
wrist/waist	5.98	2.57-14.2	<0.001
wrist/ankle	1.65	0.89-2.76	0.02
waist/ankle	0.28	0.12-0.69	0.003
Ball			
wrist/waist	7.92	3.8-16.3	<0.001
wrist/ankle	0.64	0.43-0.96	0.015
waist/ankle	0.08	0.03-0.19	<0.001

2.3.1 Stroller/carry/Swiss ball activities

Table 3.1 presents the ratios of the geometric means of the accelerometer counts for the doll relative to the infants. Due to the positive skew of the data, geometric means were used as a better indication of the true mean. This data indicates that 29% of the arm movement and 9% of the leg movement of the baby in the stroller could be accounted for by the stroller moving rather than from the physical activity of the infant. Caregiver interference was observed when the infant was being carried, with 23% of the arm movement and 52% of the leg movement of the baby being attributed to physical activity of the mother. During the Swiss ball activity, 21% (ankle) to 28% (wrist) of the activity was due to the mothers' movement. In contrast, the waist accelerometer yielded consistently *higher* measures of movement counts on the doll compared with the infant for all three activities. The accelerometer counts from each site of placement differed for all comparisons ($P<0.05$) however the confidence intervals are wide (Table 3.2).

2.3.2 Mat activity

Mat observation data were coded twice by the same researcher, two months apart for all participants, and by a second researcher for six participants to assess internal consistency. When rater coding was averaged over 15 seconds, intra-rater reliability was high (ICC = 0.80), while inter-rater reliability was lower (ICC = 0.50). However, when aggregated at the individual participant level both were high (intra-rater-ICC = 0.92, inter-rater-ICC = 0.95). The researcher's first coding was used for all analyses. For the mat activity, correlations between observer coding of activity and mean accelerometer recorded activity by placement site indicated that stronger correlations were observed for the ankle ($r = 0.675$, $P = 0.016$) and waist ($r = 0.624$, $P = 0.030$) than were obtained at the wrist ($r = 0.173$, $P = 0.590$).

2.4 Discussion

Although measurements of sleep have been shown to be valid using accelerometers (172), the current study suggests that assessment of physical activity using accelerometers at this age is largely confounded by caregiver interference in a group of non-ambulatory infants. Our results demonstrate that 23% (wrist) to 52% (ankle) of the activity counts indicated by the infant-worn accelerometer can probably be attributed to movement by the caregiver during activities when the infant is being held. Measurement of infant activity was not as adversely affected when the child was not directly held by the caregiver, such as when being pushed in a stroller. This was particularly evident when the accelerometer was worn around the ankle. However, when children play on a Swiss ball, an activity promoted for infant development (173), most (72-79%) of the activity measured by the accelerometer occurs due to infant movement.

Placement of the accelerometer also proved important in this study. For the three dependent activities, placement of the accelerometer at the waist did not produce a valid measure of activity, given that activity counts were greater on the "stationary" doll than that observed in the infant who was free to move at all times. During free play on the mat, the waist and ankle placements were more strongly correlated with observed activity than the counts from the wrist worn accelerometer. Overall it would appear that the ankle or wrist provide the best site of placement at this age when substantial amounts of movement are dependent on the caregiver. This is consistent with the greater independent movement of the limbs than the trunk in this age group (27).

While it might seem intuitive that assessment of physical activity would be difficult at this age, it is important to refine methodology in this age group and to confirm previous reports of caregiver interference on PA in non-ambulatory infants. We found a similar level of confounding to that found in the study by Worobey et al (105) when an infant is being carried, but considerably less for the other activities measured. However, the confidence intervals evident in Table 3.1 indicate considerable variability in caregiver confounding.

Further examination of restraint of infants and its influence on PA measurement using accelerometers would clarify some of the issues raised in this study. Accelerometer recorded PA from the stroller activity indicated a moderate amount of arm and leg movement by the infant while restrained, however minimal PA measured by the waist worn accelerometer. Thus, infants were moving their limbs in the stroller but their body was largely immobile. Restraint in a stroller is of interest because caregivers may think they are being active walking with the infant in a stroller when in fact the infant's movement is minimal.

The mat "free play" measurement was used to determine whether the accelerometers could detect independent activity in infants. Moderate correlations were observed between the accelerometer measured activity and observer coding for the waist and ankle worn accelerometers, correlations which compare favourably with similar studies in older children (117). By contrast, a wrist worn accelerometer seemed less able to detect full body activity when it did occur. This may be due in part to difficulties faced in designing a coding schedule suitable for this age group. The play gym used in this study had a toy hanging above the baby's shoulders and all babies played with the toy at some point. If the child used only the accelerometer-wearing arm to play with the toy, this would be coded as 1 (minimal body movement). If they moved the three other limbs but not the arm with the wrist accelerometer, less movement would be detected, but the activity would be coded as 2. Therefore whole body infant movement is more likely to be detected by the waist and ankle accelerometers which might explain their higher correlation with coded activity. Interestingly, while the waist worn accelerometer was not appropriate during activities when movement is dependent on other the caregiver (e.g., being carried), it appears to be a valid site at times when the infant is moving independently.

One of the strengths of this study includes the range of activities undertaken, including the assessment of "free play", to examine independent infant PA. However, assessment of this free play was complicated in this age group by having to use a modified version of the Children's Activity Rating Scale. Unfortunately, not all babies completed all activities as the assessment stopped when the infants were no longer compliant. Methodological issues with the video timer were also not discovered until the analysis stage, limiting the number of subjects with mat play data. Furthermore, we encountered difficulties trying to select an appropriate type of doll that would closely resemble the weight of an infant. We used a solid vinyl doll rather than one with a cloth body and vinyl limbs, as used by Worobey et al (105), as it was believed this would more appropriately limit extraneous limb movement from the doll. However the doll only weighed 0.8kg and in practice it was observed the doll moved around a lot in the stroller, presumably due to its relatively light weight. Adding weight to the doll to make it a similar weight to the infant would be advisable in future studies to truly estimate the effect of confounding from external movement.

In conclusion, measurement of PA in 6 month old infants is complicated by caregiver interference, suggesting that use of accelerometers at this age may be restricted to analysis of sleep/wake cycles. If the degree of this interference could be accounted for, it may be possible to successfully measure infant PA, although this is complicated by the high variability observed between individuals. At this point, when movement is dependent on an external person, ankle or wrist worn accelerometers appear to provide more useful measurement of infant PA than waist worn accelerometers. However, the waist site may be more useful when an infant's activity is independent of their caregiver.

Further research in this area is warranted. To fully explore the degree of interference from caregiver movement further studies such using doll/researcher mimicking with more participants could be done however this would entail considerable time and thus expense. Alternatively a larger study of caregiver/infant pairs using video observation over several hours, synchronized with accelerometer measured infant PA could be employed. Such research would further elucidate the utility of accelerometers use in measuring PA in non-walking infants.

Chapter 3. General Methods

3.1 The Prevention of Overweight in Infancy study

The Prevention of Overweight in Infancy (POI.nz) study was a randomised controlled trial (RCT) encompassing two different interventions to prevent excessive weight gain from birth to 2 years of age. All four groups received the standard Well Child care offered in New Zealand. The intervention groups were also offered extra guidance and support through one of three different interventions. One intervention aimed to improve infant's sleep (Sleep). The second intervention aimed to improve the rate of exclusive breastfeeding (FAB), dietary patterns, and participation in physical activity. The third intervention was a composite of the Sleep and FAB groups (COMBO), as they received both interventions. The four arm RCT used a 2-year intervention phase and planned follow up for five years. Ethical approval to conduct this study was granted by the New Zealand Lower South Regional Ethics Committee (project Key: LRS/08/12/063). The full study protocol has been published elsewhere (95) and this thesis focuses on outcomes of the PA intervention up to 12 months of age.

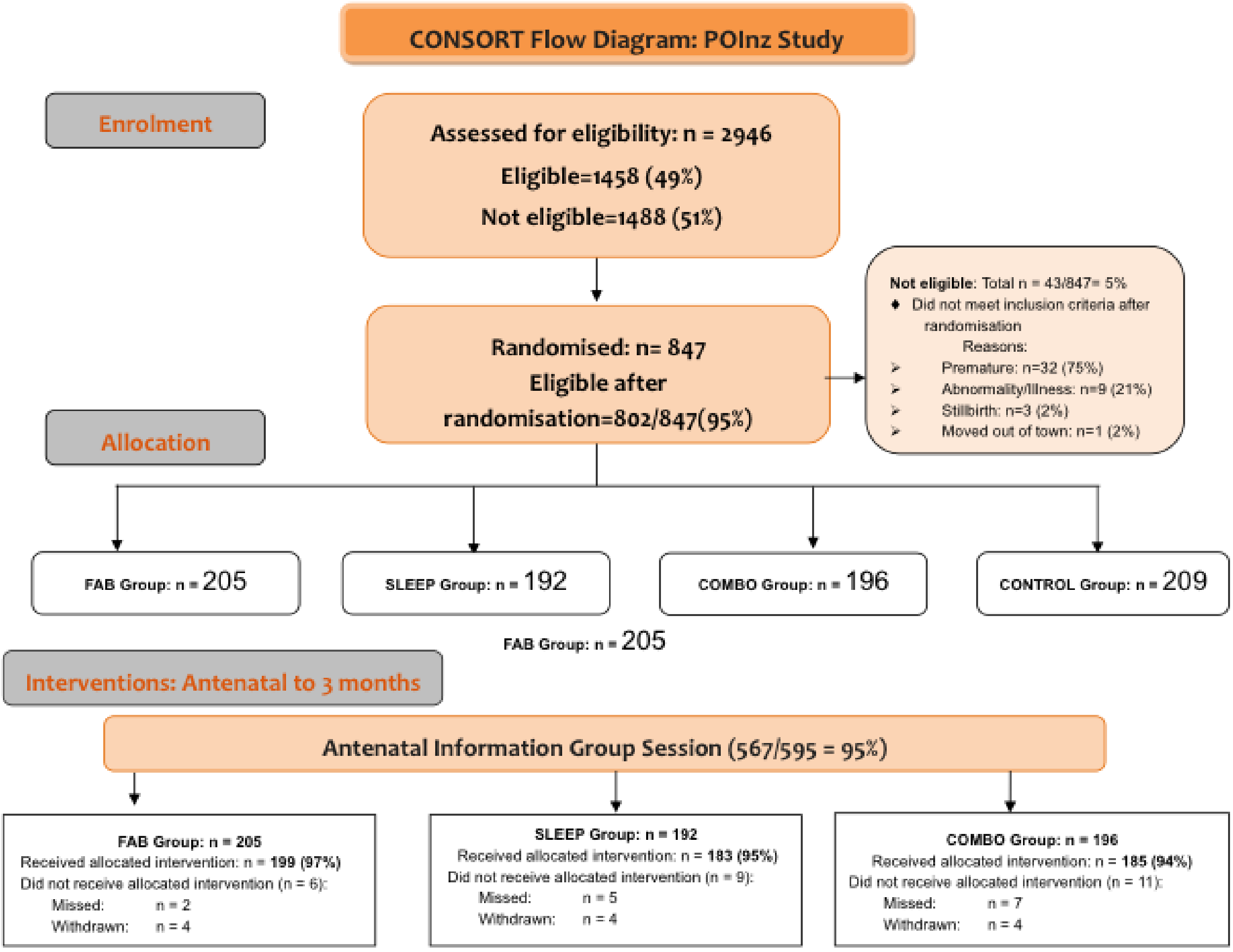
3.2 Recruitment

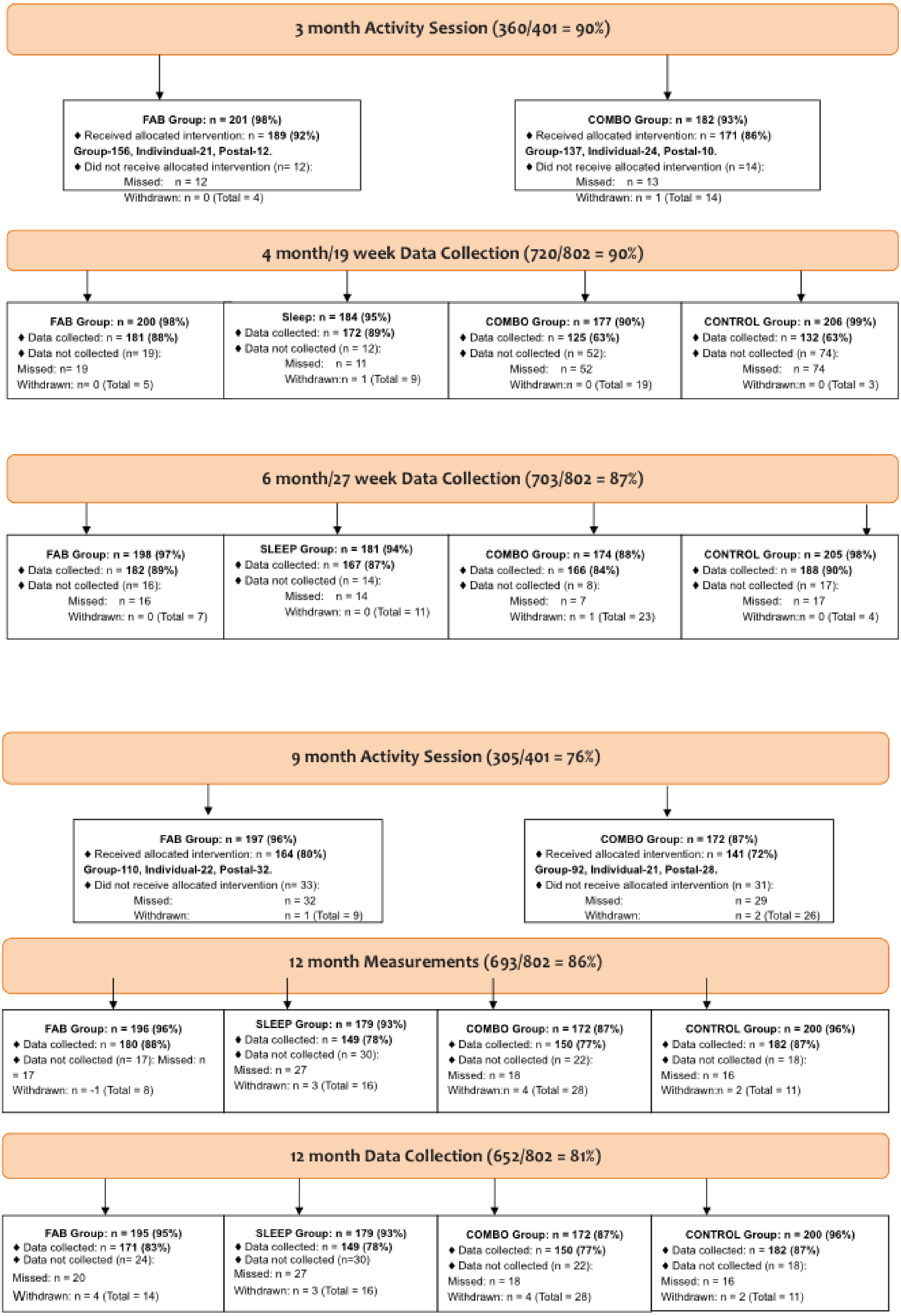
Pregnant women were recruited once they had booked into Queen Mary Maternity Unit (QMMU) in the city of Dunedin, New Zealand, between April 2009 and October 2010. Dunedin is a city with a population of approximately 120,000, and QMMU is the only maternity unit in the city, with > 97% of all pregnant women in the city giving birth in the unit. The remaining <3% are planned home births and these women were given a letter of invitation by their Lead Maternity Carer (LMC). At 28 weeks gestation, ethical approval was obtained to send each woman a personalised letter of invitation which contained information on how to opt out of further contact if they chose not to participate. Those who did not use this opt out system (answerphone) were phoned by a research nurse within two weeks to explain the study, and to establish eligibility and interest in participation. If interested, an appointment was made to meet and obtain written consent. Eligibility criteria included; being 16 years of age or older, booked into QMMU or study notified of the pregnancy by LMC before 34 weeks gestation, were able to communicate in English or Te Reo Māori (indigenous language), and planned to live in the local area at least until their infant was 2 years old. Exclusion criteria applied after birth included prematurity (babies born before 36.5 weeks gestation) or having any medical condition likely to affect feeding, physical activity, or growth.

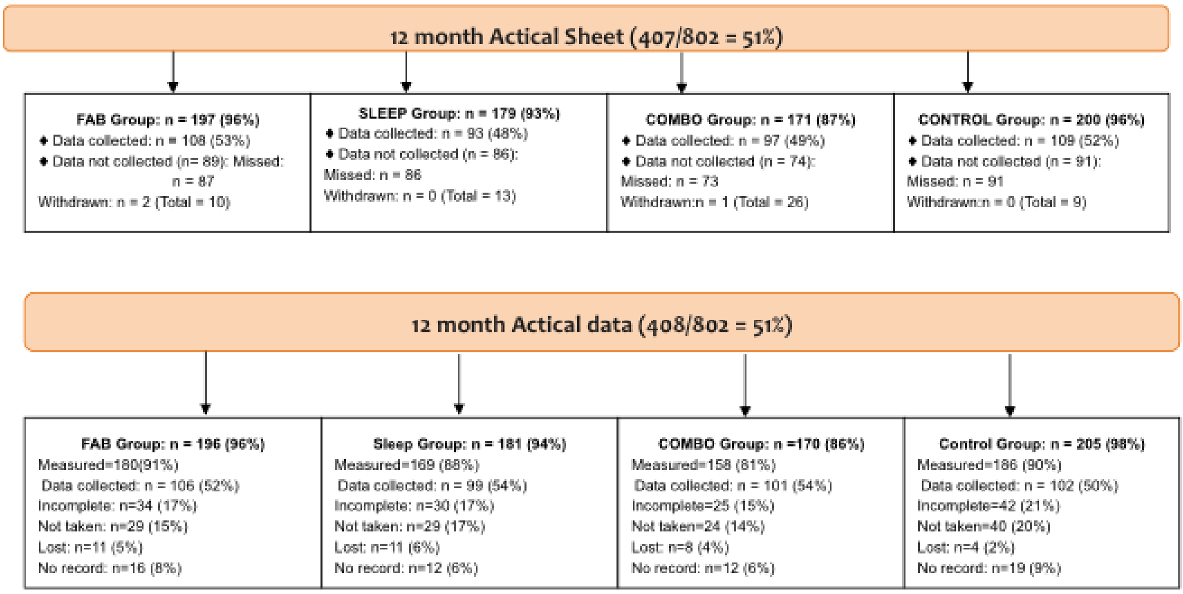
3.1.1 Randomisation

Allocation was by computerised random number, stratified by socioeconomic status (SES), and parity, as these factors could affect the primary outcome, development of overweight. The 2006 New Zealand Index of Deprivation (174) was used to categorise SES with high deprivation being low SES and low deprivation being high SES. Cut offs used were lowest 30% = low deprivation, middle 40% = medium deprivation, and top 30% = high deprivation. Parity was defined as 1 pregnancy vs >1 pregnancy. Participants were given a plain envelope with their group allocation at their consent interview which occurred in late pregnancy. The baseline questionnaire was also completed at this time. The Consort Statement (175) which outlines the requirements of RCT studies, notes that while demographic and clinical baseline measurements are necessary, rigorous randomisation will account for any known and unknown confounders in outcome assessments. While some researchers may consider that a baseline measurement of an outcome measure such as tummy time is required to assess whether any between group differences in tummy time are a result of a PA intervention, Consort states that the use of randomisation of participants to groups will account for any potential bias. However the inclusion of a baseline measurement does add power to the analysis.

Full details of group allocation, intervention, and retention are given below for the sections relevant to the studies in this thesis.




3 month Activity Session (360/401 = 90%)
FAB Group: n = 201 (98%)
♦ Received allocated intervention: n = 189 (92%)
Group-156, Indivindual-21, Postal-12.
♦ Did not receive allocated intervention (n= 12):
Missed: n = 12
Withdrawn: n = 0 (Total = 4)
COMBO Group: n = 182 (93%)
♦ Received allocated intervention: n = 171 (86%)
Group-137, Individual-24, Postal-10.
♦ Did not receive allocated intervention (n =14):
Missed: n = 13
Withdrawn: n = 1 (Total = 14)
4 month/19 week Data Collection (720/802 = 90%)
FAB Group: n = 200 (98%)
♦ Data collected: n = 181 (88%)
♦ Data not collected (n= 19):
Missed: n= 19
Withdrawn: n= 0 (Total = 5)
Sleep: n = 184 (95%)
♦ Data collected: n = 172 (89%)
♦ Data not collected (n = 12):
Missed: n = 11
Withdrawn:n = 1 (Total = 9)
COMBO Group: n = 177 (90%)
♦ Data collected: n = 125 (63%)
♦ Data not collected (n = 52):
Missed: n = 52
Withdrawn:n = 0 (Total = 19)
CONTROL Group: n = 206 (99%)
♦ Data collected: n = 132 (63%)
♦ Data not collected (n = 74):
Missed: n = 74
Withdrawn:n = 0 (Total = 3)
6 month/27 week Data Collection (703/802 = 87%)
FAB Group: n = 198 (97%)
♦ Data collected: n = 182 (89%)
♦ Data not collected (n= 16):
Missed: n = 16
Withdrawn: n = 0 (Total = 7)
SLEEP Group: n = 181 (94%)
♦ Data collected: n = 167 (87%)
♦ Data not collected (n = 14):
Missed: n = 14
Withdrawn: n = 0 (Total = 11)
COMBO Group: n = 174 (88%)
♦ Data collected: n = 166 (84%)
♦ Data not collected (n = 8):
Missed: n = 7
Withdrawn: n = 1 (Total = 23)
CONTROL Group: n = 205 (98%)
♦ Data collected: n = 188 (90%)
♦ Data not collected (n = 17):
Missed: n = 17
Withdrawn:n = 0 (Total = 4)
9 month Activity Session (305/401 = 76%)
FAB Group: n = 197 (96%)
♦ Received allocated intervention: n = 164 (80%)
Group-110, Individual-22, Postal-32.
♦ Did not receive allocated intervention (n= 33):
Missed: n = 32
Withdrawn: n = 1 (Total = 9)
COMBO Group: n = 172 (87%)
♦ Received allocated intervention: n = 141 (72%)
Group-92, Individual-21, Postal-28.
♦ Did not receive allocated intervention (n = 31):
Missed: n = 29
Withdrawn: n = 2 (Total = 26)
12 month Measurements (693/802 = 86%)
FAB Group: n = 196 (96%)
♦ Data collected: n = 180 (88%)
♦ Data not collected (n= 17): Missed: n = 17
Withdrawn: n = -1 (Total = 8)
SLEEP Group: n = 179 (93%)
♦ Data collected: n = 149 (78%)
♦ Data not collected (n = 30):
Missed: n = 27
Withdrawn: n = 3 (Total = 16)
COMBO Group: n = 172 (87%)
♦ Data collected: n = 150 (77%)
♦ Data not collected (n = 22):
Missed: n = 18
Withdrawn:n = 4 (Total = 28)
CONTROL Group: n = 200 (96%)
♦ Data collected: n = 182 (87%)
♦ Data not collected (n = 18):
Missed: n = 16
Withdrawn:n = 2 (Total = 11)
12 month Data Collection (652/802 = 81%)
FAB Group: n = 195 (95%)
♦ Data collected: n = 171 (83%)
♦ Data not collected (n= 24):
Missed: n = 20
Withdrawn: n = 4 (Total = 14)
SLEEP Group: n = 179 (93%)
♦ Data collected: n = 149 (78%)
♦ Data not collected (n=30)
Missed: n = 27
Withdrawn: n = 3 (Total = 16)
COMBO Group: n = 172 (87%)
♦ Data collected: n = 150 (77%)
♦ Data not collected (n = 22):
Missed: n = 18
Withdrawn: n = 4 (Total = 28)
CONTROL Group: n = 200 (96%)
♦ Data collected: n = 182 (87%)
♦ Data not collected (n = 18):
Missed: n = 16
Withdrawn: n = 2 (Total = 11)



Missed = participants not withdrawn however not contactable or chose not to participate in this activity.

Figure 3.1. POI.nz consort diagram relevant to this thesis.

3.2 Group details

3.2.1 Control group

This group received usual care from the government funded "Well Child" care service which typically includes seven visits beginning from 2 to 4 weeks until 2 years of age. The nurses in this service offer standard growth and development assessments and support and guidance on breast feeding, nutrition, parenting, safe sleep environments, smoking cessation, safety, immunisation, and family health issues. (http://www.health.govt.nz/our-work/life-stages/child-health/well-child-services)

3.2.2 Intervention groups

The three intervention groups also received Well Child care plus additional support and education, depending on their group allocation.

3.2.2.1 Sleep

Those in the sleep group attended a prenatal group session which outlined normal sleep in infants and what to expect in the first few months. Techniques for preventing the development of sleep problems were also discussed and included; detecting early signs of tiredness, placing baby to bed awake (just before they are about to go to sleep), maximising night and day differences, and avoiding bed sharing. A researcher then visited them at home at 3 weeks to assess how things were going and to offer additional advice if requested. From 6 months onwards, a more intensive sleep intervention was offered to those parents who identified their infant's sleep to be a problem and who had requested assistance with this. This involved assessment of the baby's sleep by a researcher, including a full history, which was brought back to the sleep team and discussed. A possible plan was then presented to the family and, if agreed upon, assistance was given in implementing the plan. The interventions used were matched to each family with the following modified techniques designed to extinguish the awake behaviour and encourage sleep, being in order of preference; Parental Presence, Camping Out and Controlled Comforting.

3.2.2.2 FAB Group (Feeding, activity, and breastfeeding)

This group focused on three aspects of early infant care; breastfeeding, introduction of solids, and PA. An education session focusing on breastfeeding was offered with a lactation consultant at approximately 34 weeks gestation. In addition to the breastfeeding information, a brief presentation of approximately three to four minutes on the importance of PA for infants, including tummy time, was conducted. Two further group sessions with a local sports facilitation group (Sport Otago) were offered when the infant was 3 and 9 months old. These latter sessions focussed on the importance of active play with the infant and included discussions on the benefit of indoor and outdoor play. Family-based activities were also emphasised. Advice was also given on limiting television viewing prior to 2 years old. Activity sessions were approximately an hour long with the first 30 minutes being allocated to presenting information and demonstrating types of activities. The final thirty minutes was available to parents to interact with their infant and the activity equipment. Further detail on the background and the actual intervention advised are included in Section 5.2.3 and Tables 5.1 and 5.2 in Chapter 5.

3.2.2.3 COMBO Group (Sleep and FAB)

The Combo group received both FAB and Sleep interventions.

A local sports facilitation group, Sport Otago, was contracted to deliver PA education sessions, using Koringa Hihiko Active Movement, a concept of Sports and Recreation New Zealand (SPARC ihi Aotearoa). Education and practical demonstrations of a variety of methods of achieving active play with infants was included in the program. Tables 3.1 and 3.2 outline the content of the 3 and 9 month activity sessions offered by Sport Otago.

Table 3.1. Three month activity session content: background and intervention.

Topic of interest	Specific intervention
Reflexes-specifically palmar and plantar-stimulation related to later patterned activity such as pencil holding	Massage infants hands and feet
Vestibular and proprioceptive development	Function and development of vestibular system in balance and proprioception discussed in detail in relation to movement of the infant by the caregiver with and without

Topic of interest	Specific intervention
	equipment, e.g., the use of change in posture such as holding the infant upside down for short periods to allow them to experience the effect of gravity shift, and the use of moving objects to be tracked visually allowing movement of the eyes and visual stimulation. Equipment used; Scooter board, Swiss ball, towel, bubbles, feathers, scarves.
Motor development	Tummy time at least daily for as long as the infant will tolerate it, using parent or equipment to lie on if necessary as aim is to allow the upper body to experience pushing against gravity and enhancing upper body strength. Equipment used; Scooter board, Swiss ball. Lengthy periods of restraint in car seat, stroller or walkers were discouraged.

Table 3.2. Nine month activity session content: background and intervention.

Background	Intervention
Neuromuscular development	Brain and nervous system development discussed in relation to the importance of experiencing opposite arm and leg movement and the consequent transfer of information across the corpus callosum to the opposite side of the brain. Suggested games such as songs with actions, assisted climbing, and vertical crawling. Tummy time still important even though infant will be moving independently, play with infant on tummy to give motor skills and upper body strength. Sedentary time discouraged. Avoid restraint in car seats, strollers, walkers and walking aids. Equipment used; Swiss ball, outside play on grass, tunnel.
Vestibular and visual system development	Actions that lead to increased depth perception, eg., moving objects or moving the infant.

Background	Intervention
	Concept of 'ocular lock' presented which can develop from prolonged TV watching. Equipment used; Scooter board, bubbles, scarves, feathers, balloons, and fly swats
Principles of development and fine motor skills	Proximo-distal and cephalo-caudal development discussed and the need to develop strength of hand and finger muscles. Equipment used; Water, play dough, posting boxes

3.3 Outcome measures

The questionnaires were administered face to face by a research nurse at baseline and at 19 weeks, 27 weeks, and 12 months postnatal. Questionnaires were also used to collect milestone achievement outcome data at 27 weeks and 12 months. The nurse was not blinded to the intervention group of the family as she was required to deliver some interventions.

3.3.1 Milestone achievement

Developmental milestone achievement was assessed at 27 weeks and 12 months using parental report of achievement for six gross motor development milestones (176, 177). Examples of the milestone questions used in the questionnaire are included in Appendix A.

Table 3.3. Demographic and milestone content of questionnaires at baseline, 19 weeks, 27 weeks and 12 months relevant to present studies.

Time	Baseline	19 weeks	27 weeks	12 months
Data obtained by questionnaire (main questionnaire to primary care giver)	Date of birth Years of education Ethnicity Employment Postcode (for NZ Deprivation score) Parity	Breastfeeding/ Feeding/ solids Depression index Infant/mother sleep Family financial concerns Smoking Alcohol use	Infant restraint Active play Maternal work/study Maternal TV/dvd use Childcare use Measures of attachment, infant temperament, maternal confidence	Maternal and infant health problems in first year. Smoking Alcohol use Feeding/solids Infant/mother sleep

Time	Baseline	19 weeks	27 weeks	12 months
	Smoking Alcohol use Stress Parenting		Infant behaviour control methods Maternal PA (light, mod, vig/week) Smoking Alcohol use Feeding/solids Infant/mother sleep	Infant restraint Active play Maternal work/study Maternal TV/dvd use Maternal PA (light, mod,vig/week)
Developmental Milestones obtained by questionnaire			Sit Crawl	Sit Crawl Stand assisted Stand unassisted Walk assisted Walk unassisted Bottom shuffle Pincer grip

3.3.2 Anthropometry

Infants were weighed wearing their singlet and a clean nappy provided by the measurer (dry nappy weight known). Electronic scales that were regularly calibrated (Tanita WB-100 MA/) were used for infant and parent weight. When the infant was 6 and 12 months of age the mother was weighed, her weight recorded, and the scales zeroed. The infant was then handed to the mother while she was still standing on the scales and the infant weight recorded. The infant's length was measured using a Rollameter 100c length board (Harlow healthcare, UK), head circumference was measured using a Seca 212 measuring tape (Seca, Germany), and abdominal circumference using a Rosscraft Anthropometric tape (Rosscraft Innovations Inc., USA). Maternal heights were measured using a Harpenden stadiometer (Holtain Ltd., UK) in the clinic, or a Leicester Height Measure (Harlow healthcare, UK) in the home. All measurers were blind to group allocation and trained in measurement techniques and protocols established by the WHO (178). Measurements were all completed twice in a set sequence and a third measurement taken if weights were not within 0.1 kg, height 0.5cm, length 0.7cm, waist circumferences 1.0cm, and head circumference 0.5cm.

3.3.3 Physical activity measurement

Actical accelerometers (Mini-Mitter, Respironics, Oregon, USA), were used to assess PA at 6 and 12 months of age. The actical accelerometer was chosen as they were readily available to the research team. Parents were asked to complete a diary of sleep and wake times for five days of measurement. A more detailed description of the methodology for accelerometer use and data reduction is included in Chapter 5.

3.3.4 Statistical analysis

This thesis involves three distinct but linked studies. Each study uses statistical analysis specific to the requirements of the data and analysis used is discussed fully in the method sections of each chapter.

Chapter 4. Parental Use of Prone Positioning in Infancy: Does Anticipatory Guidance Increase the use of Awake "Tummy Time"?

4.1 Introduction

The "Back to sleep" message has been an important feature of parental education in New Zealand and other developed countries since the 1990s when a successful campaign aimed at reducing the number of infants dying from sudden infant death syndrome (SIDS) was introduced (179-181). Parents were encouraged to place their babies supine (on their back) for sleep rather than prone (on their front). Since parents have followed this advice it has been observed that long periods in the supine position, and too little time spent prone, can lead to physical abnormalities and a delay in reaching motor developmental milestones (181, 182). It appears that knowledge of the dangers of prone sleeping has also made some parents reluctant to place their infants prone for play when they are awake (183, 184).

Prone positioning is recommended to allow flexion and extension of the muscles involved in holding up the upper torso and head (184). This antigravity extension appears to enhance the achievement of motor milestones such as rolling and sitting (35). While children not given tummy time still achieve milestones within normal parameters (28, 185), increased tummy time has been found to result in earlier acquisition of motor milestones. Dudek-Shriber and Zelazny (28) observed that four month old infants having more than one hour of tummy time per day were more advanced in their achievement of early milestones compared with infants receiving less tummy time. While the long-term advantage of this early boost in motor competence has not been established, it could lead to later benefits, as increased motor competence in older children has been related to increased physical activity (33).

Research on this topic is limited, but there is some evidence to suggest that the use of awake tummy time can be improved through nurse-led education interventions that increase the awareness of the benefits of tummy time (164). The Healthy Beginnings Trial in Australia offered an education intervention beginning at birth, with home visits from a community nurse which included resources on tummy time and active play. Although one-quarter of parents reported not using any tummy time, significant intervention benefits were observed in terms of starting tummy time at an earlier age and spending more awake time prone (164).

Given the lack of research on tummy time, the aims of the current study were to:

Quantify the current use of tummy time in a modern New Zealand population.

Observe whether an education intervention can increase the number of parents offering tummy time to their infants or the amount of time offered.

The POI.nz study included education around encouraging infant activity such as tummy time as part of the four arm RCT. Thus, data were examined for both the amount of tummy time offered by those receiving the PA intervention (FAB and COMBO groups) and those not receiving the PA intervention (Sleep and Control groups).

4.2 Methods

4.2.1 Participants

As previously presented in Chapter 2, the POI.nz study is a randomised controlled trial investigating whether additional education and support around sleep, breastfeeding, food, and physical activity could slow the rate of excessive weight gain from birth to two years of age. In brief, 847 women were recruited for the study in late pregnancy. Participants were randomised to one of four groups; Control, FAB (feeding, activity and breastfeeding), Sleep, and Combo (Sleep and FAB), on an intention to treat basis. A full description of the methodology is given in Chapter 2.

4.2.2 Interventions

4.2.2.1 Three-month activity session

Parent(s) and infants attended a one-hour group session run by Sport Otago, a local physical activity (PA) service provider who use the Koringa Hihiko Active Movement programme, a concept of Sports and Recreation New Zealand (SPARC ihi Aotearoa). Content of the session included discussions on active movement, movement and brain development, factors around increased sedentary behaviour in our current lifestyle, and how development can be enhanced through increased PA. Education and practical demonstrations of a variety of ways to incorporate tummy time into daily life represented approximately 10 minutes of the 60 minute session (content in Table 3.1 of Chapter 3). This included discussion with parents on the fact that while some babies do not like to lie prone for extended periods, even short periods could be used effectively. Ways to encourage tummy time were offered such as using a scooter board (a plastic/wooden board with four castor wheels), on which the baby was placed prone and moved around gently, allowing a change in posture. The importance of such activity for vestibular and muscle development was discussed. Tummy time was presented as an important part of physical and cognitive development which parents should attempt to provide every day for as long the infant would tolerate it. Material written specifically for the POI.nz study promoting tummy time was also provided to intervention participants as well as two publically available pamphlets promoting tummy time.

4.2.3 Outcome variables

At 19 and 27 weeks postnatally, a research nurse administered a questionnaire to the infant's caregiver in the family home. Questions on sleep position, parental smoking status, maternal education, and parity were included in the questionnaires. Tummy time was assessed using two questions:

Thinking about the last week,

How many times each day, did you usually place [baby's name] on his/her tummy for play ("tummy time")? ___________ times.

How long did each ‘tummy time’ usually last? ________ minutes.

Outcome variables Maternal PA, and achievement of milestones crawling, standing, walking assisted and walking unassisted were also included in analysis. Questions used to assess these aspects are included in Appendix A.

4.2.4 Statistical analysis

All analysis was carried out using the 19 and 27 week data. Times per day (frequency) of tummy time was analysed for between group differences and negative binomial regression was used due to unequal variance dispersion. Tummy time in minutes per day (duration) was modelled using linear regression on the log transformed outcome to correct for skew/heteroscedasticity. Frequency and duration were multiplied to find total tummy time per day in minutes, resulting in a continuous variable (total tummy time). Multiple linear regression was used on log transformed data to examine the effects of a range of predictor variables on total tummy time. The influence of total tummy time on milestone acquisition was modelled using logistic regression on the binary variables achievement and non-achievement of crawling, standing, both assisted and unassisted, and walking, both assisted and unassisted, with a goodness of fit test used to ensure the predictive value of the model. In these cases total tummy time at 19 and 27 weeks was divided by 15 so that odds ratios related to a larger unit of time. At 27 weeks a small number of parents claimed to offer up to 16 hours of total tummy time, possibly as a result of misinterpreting the question as weekly rather than daily. Given that sleep should account for over 12 hours per day in this age group, these figures seemed unlikely (186). It was decided to use data from participants reporting up to and including 600 minutes per day which resulted in four participants being excluded at 27 weeks. All statistical analyses were by intention to treat and were performed using Stata 11.0 (StataCorp. 2009. Stata Statistical Software: Release 11. College Station, TX: StataCorp LP).

4.3 Results

Table 4.1. Baseline characteristics of POI.nz study participants.

	FAB	Combo	Sleep	Control
N	205	196	192	209
Sex n (%)	F 98 (48)	F 100 (51)	F 82 (43)	F 111 (53)
Ethnicity				
European	185	182	171	187
Māori	3	4	4	7
Other	17	10	17	15
Gestational age	40.0 (1.4)	39.9 (1.5)	40.1 (1.2)	40.0 (1.4)
Mothers age at infant birth	32.1 (5.3)	30.9 (5.4)	31.6 (5.2)	31.5 (5.0)

Min	17.6	17.4	16.7	18.8
Max	44.2	43.3	45.5	45.7
Maternal education n (%)				
5th form/less	17 (8.4)	13 (6.7)	18 (9.3)	14 (6.8)
6th from	9 (4.4)	19 (9.8)	14 (7.3)	13 (6.3)
7th form	14 (6.9)	18 (9.3)	17 (8.8)	28 (13.6)
Post HS	27 (13.4)	31 (16.0)	28 (14.6)	29 (14.1)
University	135 (66.8)	113 (58.2)	115 (59.9)	122 (59.2)
Maternal BMI prepregnancy	25.2 (5.4)	24.7 (4.7)	24.5 (4.1)	25.2 (5.1)
Maternal Weight status n (%)				
Underweight	3 (1.5)	4 (2.0)	2 (1.0)	7 (3.4)
Normal	99 (48.3)	109 (55.6)	93 (48.2)	107 (51.2)
Overweight	46 (22.4)	44 (22.5)	52 (26.9)	48 (23.0)
Obese	27 (13.2)	21 (10.7)	15 (7.8)	26 (12.4)
Parity				
1	97	96	89	98
2	67	63	62	65
3	29	32	34	28
4+	12	6	8	18
NZ deprivation index n (%)				
Low	70 (34)	67 (35)	65 (34)	74 (35)
Medium	86 (42)	87 (45)	85 (44)	93 (45)
High	47 (23)	39 (20)	43 (22)	39 (19)
Mother Smoking daily n (%)				
Baseline	14 (6.5)	20 (9.6)	18 (8.6)	15 (7.0)
19weeks	8 (4.4)	17 (9.9)	11 (6.4)	17 (8.7)
27weeks	8 (4.2)	15 (9.1)	10 (6.0)	17 (9.1)
Infant Sleep position 19 weeks				
Supine	164	150	152	176
Prone	5	9	4	5
Side	11	13	16	15

Means and SD (in parenthesis) are shown for continuous variables

Demographic variables were similar between intervention groups (Table 4.1). Attendance at both the antenatal and 3 month information sessions was high in both FAB (97% and 86% respectively), and

COMBO (93% and 83% respectively) participants (Consort diagram, Figure 3.1, Chapter 3). Missing questionnaire data was also relatively low; 713 (88%) of parents provided information on tummy time at 19 weeks and 691 (86%) at 27 weeks. Completion of the tummy time question did not differ between groups with 86% to 91% responding at 19 weeks (P = 0.573), and 81% to 87% responding at 27 weeks (P = 0.120).

Table 4.2. Comparisons of demographic variables for responders and non-responders to tummy time questions at 19 and 27 weeks

	19 weeks			27 weeks		
	Responders	Non- responders	P value	Responders	Non-responders	P value
N	689	113		621	181	
Mothers age at dob m (SD)	31.8 (4.9)	29.9 (6.5)	P<0.001	32.0 (4.9)	29.9 (6.0)	P<0.001
Mothers with post high school education	79%	52%	P<0.001	78%	59%	P<0.001
SES in 4 highest deprivation levels	29%	45%	P<0.001	29%	40%	P=0.002
Mother smoking at baseline	5.5%	23%	P<0.001	6%	21%	P<0.001
Gestation m (SD)	40.1 (1.4)	39.7 (1.4)	P=0.003			P=0.232

However, differences in some demographic variables were observed between those who responded and those who did not respond to the tummy time questions (Table 4.2). At 19 weeks, participants who completed the tummy time questions were more likely to be older, have some post high school education, be of higher SES, and be non-smokers at baseline. Differences remained significant at 27 weeks for these variables. Although gestational age was statistically significant at 19 weeks, this was by only 2 days, a difference not likely to be clinically important.

Interestingly, it appears that tummy time is a popular and well received activity amongst parents as 95% of parents at 19 weeks offered tummy time at least once a day and 90% of parents offered tummy time at least once a day at 27 weeks. Total tummy time of more than 60 minutes per day was offered by 14.4% of parents at 19 weeks and 34% of parents at 27 weeks.

Table 4.3. Frequency and duration of tummy time and total tummy time per day at 19 and 27 weeks.

	FAB	COMBO	Sleep	Control	P value
19 weeks					
N	177	169	169	192	
Frequency mean (SD)	3.8 (4.1)	3.7 (2.7)	3.2 (2.6)	3.4 (2.8)	0.648
Duration (min) mean[a]	8.7 (7.9-9.5)	7.9 (7.1-7.8)	7.8 (7.1-8.6)	8.3 (7.5-9.1)	0.120
Total tummy time	22.9	21.6	18.6	20.4	0.442
27 weeks					
N	179	160	164	183	
Frequency m (SD)	5.2 (4.6)	4.4 (4.8)	3.8 (3.1)	4.8 (4.3)	0.058
Duration (min) mean[a]	10.9	8.6	9.4	9.6	0.053
Total tummy time	39.0	28.6	26.7	30.9	0.137

*mean (SD), [a] geometric mean.

No significant group differences in frequency, session duration, or total tummy time were observed at 19 or 27 weeks (Table 4.3).

When the intervention groups (FAB and COMBO) were combined and compared to the non-intervention (Sleep and Control) groups, analyses revealed that the intervention groups offered more frequent tummy time at 19 weeks (IRR 1.15 95% CI 1.03-1.28, P = 0.012), and 27 weeks (IRR 1.15, 95% CI 1.02-1.30, P = 0.027). However duration and total tummy time were not significantly different between the intervention and non-intervention groups at either time period.

Table 4.4. Multivariate analysis of total tummy time at 19 and 27 weeks.

	19 weeks			27 weeks		
Variable	Ratio[b]	95% CI	P value	Ratio[b]	95% CI	P value
Group			0.587			0.139
Control						
Sleep	.90	.70-1.1		.76	.54-1.1	
FAB	1.1	.83-1.3		1.1	.79-1.6	
COMBO	.99	.78-1.3		.87	.61-1.2	
SES	.98	.95-1.0	0.294	.99	.93-1.0	0.538
Ethnicity			0.533			0.738
European						
Māori	1.1	.74-1.6		.81	.48-1.4	

Other	.86	.63-1.2		1.0	.65-1.6	
Maternal PA						0.039
Regular						
Regular-began last 6 months				.60	.41-.87	
Some, not regular				.71	.54-.96	
No intent next 6 months				.94	.62-1.4	
Not regular, no intent				.53	.18-1.5	
Sleep position			0.113			
Supine						
Side	1.6	.96-2.7				
Prone	1.2	.87-1.6				
Smoking status at time of			0.042			0.066
Never smoked						
Quit some time ago	.93	.76-1.1		.76	.57-1.0	
Quit since baby	.59	.26-1.3		.26	.04-1.64	
Occasionally	.49	.26-.89		.79	.38-1.6	
Daily	.69	.48-.95		.53	.31-.90	
Maternal Education			0.240			0.037
University						
Post High school	1.0	.79-1.3		.92	.64-1.3	
7TH form	.87	.64-1.2		.88	.58-1.3	
6TH form	1.4	1.0-2.1		.61	.37-1.0	
5th form and less	.94	.62-1.4		1.9	1.1-3.4	
Infant sex	1.0	.85-1.2	0.856	.92	.70-1.2	0.493
Parity			0.064			0.021
1						
2	.85	.70-1.0		.83	.62-1.1	
3	.82	.64-1.1		1.24	.87-1.8	
4+	.63	.42-.94		.52	.29-.93	

[b=]Ratio of geometric means

Table 4.4 shows that in the multivariate adjusted model smoking status was significantly associated with total tummy time at 19 weeks showing that those who had never smoked offered more total tummy time than those that smoked daily (P = 0.029) or occasionally (P = 0.025). Pairwise comparisons for maternal education and parity indicated levels of these variables were also significantly associated with total tummy time. Those at the educational level of 6th form (4 years of high school) offered more total tummy time than those with 7th form education (ratio 1.65, 95%CI 1.07-2.56, P = 0.025), and those with a University education (ratio 1.44 95%CI 1.0-2.1, P = 0.047). At 19 weeks, having only one infant compared to having four or more children resulted in significantly more total tummy time offered (ratio 1.59, 95%CI 1.1-2.4, P = 0.024).

Similar associations were observed at 27 weeks. Maternal education, smoking status, and parity indicated significant differences to the comparison group (Table 4.4), and pairwise group differences. Mothers with 5th form education (3 years of high school) offered more total tummy time than all other groups; 6th form (ratio 3.1, 95%CI 1.5-6.5, P = 0.002), 7th form (ratio 2.2, 95%CI 1.1-4.2, P = 0.015), Post High School (ratio 2.1, 95%CI 1.1-3.9, P = 0.024), and University (ratio 1.9, 95%CI 1.1-3.4, P = 0.032). Those who had never smoked offered more tummy time than those who smoke currently (ratio 0.53, 95%CI 0.31-0.90, P = 0.018). Those with only the infant in the study again offered more tummy time than those with four or more children (ratio 0.52, 95%CI 0.3-0.9, P = 0.028), while those with three children offered more tummy time than those with 2 (ratio 1.5, 95%CI 1.0-2.2, P = 0.032), and those with four or more children (ratio 2.4, 95%CI 1.3-4.4, P = 0.006).

Maternal physical activity was included in the model at 27 weeks. Significant differences in tummy time offered emerged with those currently active offering more tummy time than both those starting regular exercise in the last six months (ratio 0.60, 95% CI 0.4-0.8, P = 0.008), and those doing some, but not regular, exercise (ratio 0.72, 95% CI 0.54-0.96, P = 0024).

The developmental milestones of crawling and walking assisted were examined using two predictor variables; total tummy time, and intervention group. Cases in one aspect of these variables were too low to use more predictors (n = 43 were crawling at 27 weeks, and n = 84 were not walking assisted at 12 months). Means for crawling indicated the average tummy time at 19 weeks for the 43 crawling infants was 99 minutes compared with 34.6 minutes for the 622 infants not crawling. Total tummy time at both 19 and 27 weeks was a significant predictor of both crawling (19 weeks OR 1.14 95% CI 1.08-1.20, P<0.001; 27 weeks OR 1.06 95% CI 1.02-1.09, P = 0.001), and walking assisted (19 weeks OR 1.36 95% CI 1.13-1.63, P = 0.001; 27 weeks OR 1.15 95%CI 1.07-1.24, P<0.001). Standing alone at 12 months and walking unassisted at 12 months were modelled using total tummy time at 19 and 27 weeks and the variables in Table 4.4. At 12 months, standing alone was significantly associated with total tummy time at 19 weeks, socio economic status, and parity. Infants offered more total tummy time at 19 weeks were significantly more likely to be standing unassisted at 12 months (OR 1.08 95%CI 1.02-1.16, P = 0.007). At 12 months, 78% of infants in the highest and 68% in the second lowest socioeconomic group were standing, however only 51% of infants in the lowest socioeconomic group had achieved this milestone (OR 1.08 95%CI 1.00-1.15, P = 0.037). Infants in two child families were standing in 67% of cases compared to 58% of singletons (OR 1.58 95% CI 1.05-2.37, P = 0.027). Total tummy time at 27 weeks, was also associated with standing unassisted at 12 months (OR 1.04 95% CI

1.01-1.07, P = 0.006) and was the only significant predictor of walking alone at 12 months (OR 1.04 95% CI 1.02-1.07, P = 0.002), with offering 15 minutes more tummy time increasing the odds of both standing unassisted and walking by 4%.

4.5 Discussion

This study sought to quantify the use of tummy time by a large cohort of New Zealand parents and to determine whether an education intervention could increase the amount of tummy time offered. In comparison to previous studies, where approximately 75% of parents reported the use of daily tummy time (164, 184), this study found over 90% of parents reported at least daily tummy time at both 19 and 27 weeks. Given that the control/sleep groups, who were not given any extra education or information on the use of tummy time, also offered tummy time for a similar amount of time, it would appear that in New Zealand the public health message about tummy time is well received and understood by parents.

Duration of episodes and total tummy time were not different between groups, indicating the message on frequent tummy time may have been effective and further education could focus on the benefit of longer periods of tummy time rather than frequency. The increased frequency of tummy time offered by the intervention groups may have been because the information given to this group encouraged even short periods of tummy time, utilising novel methods and equipment to increase the enjoyment, such as the scooter board. It could also be possible that the frequency of tummy time is easier to recall for parents than the duration. Future research could identify specific techniques parent’s utilise to enhance enjoyment of tummy time.

When the Sleep, FAB, COMBO, and Control groups were compared, frequency of tummy time was significantly lower at 27 weeks in the Sleep group. While the reason for this is unclear, it is worth considering that the Sleep group also had extra guidance on positioning for safe sleep (supine) and this may have discouraged parents from offering prone awake time. This relationship has been noted before in an Australian study where knowledge of sleep recommendations and avoidance of tummy time were significantly associated (183).

There is limited research to compare to the current study as quantifying the amount of tummy time is difficult and previous research has not controlled for potential confounders. Dudek-Shriber and Zelazny (2007) have previously emphasised the importance of controlling for factors such as birth order and maternal education (28). These, and a range of other demographic variables thought to be relevant to infant activity, were included in the current study to elucidate their impact on total tummy time offered. The pattern of results was similar at both 19 and 27 weeks periods with multivariate analysis indicating smoking, maternal education, parity, and maternal PA as factors influencing tummy time. Non-smoking, physically active parents offered more total tummy time, which would be consistent with parents who are conscientious about their own health. Whether such care for one’s own health carries over to the care of ones children’s health is a useful area for future research in the transfer and teaching of healthy behaviours.

Having more children made parents less likely to use tummy time. This is consistent with comments from the parents at education sessions that having older children around was both a time and safety issue for parents. The pattern of results was less easily explained for maternal education where mothers with more education offered more tummy time. Maternal education has been observed to be positively correlated with health enhancing behaviour (187). In our study, a negative correlation was evident, however a similar pattern of results regarding heath enhancing behaviours and maternal education was found in a sample of white American mothers (188). This was suggested by Eisenhower et al (2013) to be related with return to work by those with more education, limiting the time available for interaction with the mother (177). This is a factor that should be considered and accounted for in future research.

Although total tummy time offered was related to a range of demographic variables that can also be related to increased PA, it is not clear if tummy time can be an effective tool to improve motor competence, although some evidence should be considered. In our study, infants who were crawling at the age of 27 weeks had experienced significantly more tummy time at 19 weeks. World Health Organisation standards for the milestone achievement notes hand–knees crawling to begin at 23 weeks and end around 54 weeks (176), suggesting that the infants in the current study who were crawling at 27 weeks were achieving this milestone at the early normal level and more tummy time may have contributed to that. Additionally, while over 60 minutes of tummy time was offered by only 14% of parents at 19 weeks and 34% at 27 weeks, infants crawling at 27 weeks received on average 99 minutes of tummy time per day at 19 weeks, indicating that longer periods of tummy time offered a noticeable effect on milestone achievement as has been evident in a previous study (28). Results in our study for standing and walking milestones also indicated earlier achievement by infants given more tummy time, posing the possibility that upper and lower body strength was enhanced by early tummy time. Evidence suggests even children given less than an hour of tummy time per day will achieve milestones within accepted parameters (185). This study offers evidence that encouraging early tummy time can enhance milestone achievement. However whether this enhancement is sustained beyond 18 months is not known (184).

The main limitation to this study was how tummy time was defined by the parents. By 27 weeks some infants were rolling over and parents may have been confused as to whether to include this “spontaneous” tummy time despite the wording of the question which was “How many times each day did YOU usually place [baby’s name] on his/her tummy for play?” The confusion between the spontaneous time and the purposeful time may have resulted in the high tummy time minutes evident at 27 weeks. Future studies would benefit from more clear definition of tummy time activity. It should also be noted that milestone achievement was measured by parent report rather than direct researcher observation. However, milestone achievement questionnaires were frequent and timed to coincide with normal milestone achievement, reducing the error that may occur with retrospective reports.

In conclusion, it would appear from this study that tummy time activity is relatively popular in this population, suggesting that additional interventions to increase this behaviour could be focused on lengthening tummy time periods rather than the frequency of tummy time. Another consideration is that the POI.nz study population was not representative of the New Zeland population so further research on tummy time use in subsets of the population is warranted. This would indicate if tummy time use is as prevalent in other population groups.

The Well Child care in New Zealand appears from the research to be doing well in educating families. With the recent introduction of paid parental leave there may be an opportunity to introduce group education sessions available publicly, where not just tummy time but time spent active with parents and children could be approached as part of a healthy lifestyle.

Chapter 5. Measurement of Activity in Infants Following Activity Intervention as Part of a Randomised Controlled Trial.

5.1 Introduction

Effective interventions to prevent obesity at the individual and community level are still required and it is thought the earlier in life that these can occur to prevent early weight gain the better (189). Physical activity, while accepted as an integral aspect of obesity management (171), is seldom included in early intervention studies, presumably due to the difficulties in measuring PA in infancy.

Measurement of PA in older children is frequently conducted using accelerometers (13). Their validity has been established against calorimetry in older children ages 3 to 8 years (111, 117, 136), and their size and weight make them suitable for use with young children (190). However, further research into their use in measuring activity in children less than two years of age is required.

Only three studies appear to have measured PA in children less than 24 months of age and in all of these studies participants were asked to place the accelerometer on their toddlers only during waking hours. Van Cauwenberghe et al. (2011) recently conducted a study where accelerometers were worn for six days by 1 to 2 year old children in child care centres (n = 47). Inclusion criteria stipulated that children were walking independently and direct observation was compared to accelerometer measured activity (117). The authors determined that accelerometer measured activity was feasible and valid in this small group of toddlers. However, important points were raised concerning protocols for data reduction. Children were required to wear the accelerometer for a minimum of three days, which resulted in 36% of participants being excluded from the study. This large rate of non-compliance was greater than in previous reports from the same group of researchers when they studied older children (147, 191), and was thought to be due to the teachers and parents being responsible for placing the accelerometers on the children. One solution to this issue is to leave the accelerometer on for naps as one way of obtaining more valid hours. The high level of non-compliance could also have been due to the conservative data reduction methods requiring 3 valid days of weartime.

The Melbourne based InFANT group (96) have also published results from a study using accelerometers with toddlers. Here the participants had a mean age of 19 months and were walking independently when they wore an Actigraph accelerometer for seven consecutive days. At least four days of wear time were required for inclusion. The authors estimated that four days of wear time offered reliability of over 0.7 while retaining a large enough sample size (n = 295). Again collecting data using accelerometers in this age group proved difficult, with sixty-nine toddlers (17%) with no data and 53 (12%) with insufficient data. However results from the valid data were promising, showing that, using intensity cut-points validated for toddlers (144), the infants reached activity guidelines established by the Australian Department of Health of 180 minutes a day. Unfortunately the InFANT study only examined the daily pattern of PA in terms of MVPA and did not include the average CPM which would have been useful for comparison with future research.

A recent study in the Netherlands monitored toddlers (25 months) for only two days, one weekend and one weekday, using Actigraph accelerometers (129). These researchers supported this short measurement period, saying they expected little variation in PA in this age group, however they hypothesised variation might occur from week day to weekend day. The toddlers in this study did not meet national recommendations for total PA in contrast to the results from the InFANT study. However, the discrepancy between these studies may be due to the different cut point utilized as Wijtzes and colleagues used Sirard's cutpoints (114) which were approximately 1000 CPM different from the Trost cutpoints used in the InFANT study (144). Such intensity cut-point variation between studies is seen as a major concern when assessing toddlers' and pre-schooler's PA (127).

In addition to the problems associated with determining valid intensity cut points the chosen valid hours per day and valid number of days required to meet satisfactory reliability estimates is an issue of some debate. A balance between reliability and retaining enough valid data needs to be considered (192). Some studies have implemented a 70/80 rule in which a day is defined as the hours where at least 70% of the participants have PA data recorded, and 80% of these hours are taken to constitute a valid day (193). In the InFANT study, the study by Wijtzes and colleagues (2013), and Van Cauwenberghe and colleagues studies this 70/80 rule would have resulted in a valid day defined as 7.5 hours (450 minutes) (range 444 to 464 minutes) (96, 117, 129).

The 70/80 rule has been implemented by a small number of studies and it is not yet clear if this is the most valid way of determining how many days and hours per day are required to obtain a valid estimate of habitual activity. Therefore methods from studies on older children may offer insight. Trost et al (137) reported children (aged 6 to 12) showed less variability in their activity than adolescents and therefore required less days of monitoring to achieve acceptable reliability, advising four to five days to achieve 80% reliability. Penpraze et al (138) reported that in children aged 5 to 6 years, more days of measurement resulted in higher reliability, with the peak at seven days and 10 hours per day providing 80% reliability. However, fewer days and hours per day did not reduce reliability significantly and the accepted level of 70% was achieved with five days and as little as three hours per day of monitoring. This is particularly relevant when trying to reduce participant burden.

Non-wear time must also be accounted for when measuring PA by accelerometry in any age group, however in infants and pre-schoolers it is more of a problem as the accelerometer may be removed for naps or bathing. Criteria are therefore required regarding how much time activity is below a minimal count cut point so that non-wear time can be excluded. While various rules have been applied by researchers in this area, periods of zero activity for over 10 minutes is commonly used (117, 129). Hnatiuk et al, whose participants are the youngest to have been studied to date, chose 20 minutes of zeros as non-wear time. However they also required 30 minutes of activity in an hour for the hour to be valid to avoid underestimation of the toddlers activity (96). Thus, it is clear that the parameters with which wear time and activity intensity are defined varies across studies, making comparison of outcomes difficult.

An area of accelerometer use that does seem to have met with agreement amongst users is that of epoch length. Epochs are periods of time that accelerometer counts are added over. Longer epochs preserve battery life and allow the unit to measure for longer periods, however longer epochs also mean that a greater number of low and high points are aggregated into an average. This may be particularly important in infants and toddlers for whom activity is very sporadic in nature.

Many issues surround the measurement of infant activity; however it is essential to further develop methods in this area to determine the most accurate way to measure activity at this young age. Research on PA in children under 3 years of age using accelerometers indicates that while parents perceive their toddlers as active, much of their time is spent in sedentary (129) or light PA (96), and clarification as to whether this is an artefact of measurement methods, or if in fact children are not active enough, is needed.

Sedentary behaviour (SB) is an issue in PA measurement in older children with seen as distinct from inactivity (19). This issue has not been addressed in infants however restraint in car seats and strollers is an area where infant activity is limited and therefore requires quantification and is addressed in this study.

To date research into the use of accelerometers in children as young as 12 months of age is lacking. Using data from the Prevention of overweight in infancy (POI.nz) study physical activity in infants was examined.

The aims of this chapter were to:

1) Determine if a family-based activity intervention increased PA levels and resulted in less use of restraints (car seats and strollers) at 12 months of age.
2) Examine day to day variation in physical activity at 12 months of age to assess the reliability of the data.
3) Determine if objectively measured PA differs between walking and non-walking toddlers.
4) Examine whether the family-based activity intervention affected the time at which children achieved motor milestones such as walking and crawling.

5.2 Methods

5.2.1 Study design

The POI.nz study was a randomised controlled trial designed to prevent excessive weight gain during the first two years of life. The complete study protocol has been explained in detail in a protocol paper (95) and in Chapter 2. Only the relevant information is summarised here.

5.2.2 Participants

Over an 18 month period, 847 families were recruited in mid to late pregnancy and randomised to one of four groups; Control, FAB (feeding, activity and breastfeeding), Sleep or COMBO (Sleep and FAB). Eight hundred and two families (802) made up the study group after exclusions and those who withdrew after randomisation were accounted for. The demographic details of the participants are presented in Chapter section 4.4 Table 4.1, and the Consort diagram for the POI.nz study up to one year is included in Chapter 3, section 3.1.1, Figure 3.1.

5.2.3 Activity intervention

Three activity sessions were offered to COMBO and FAB families at ages 3, 9, and 18 months.

5.2.3.1 Activity education

A local sports facilitation group, Sport Otago, was contracted to deliver PA education sessions, using Koringa Hihiko Active Movement, a concept of Sports and Recreation New Zealand (SPARC ihi Aotearoa). Education and practical demonstrations of a variety of methods of achieving active play with infants was included in the program. Tables 3.1 and 3.2 outline the content of the 3 and 9 month activity sessions offered by Sport Otago.

5.2.4 Outcome variables

5.2.4.1 Activity Measurement

Objective measurement of activity was obtained using Actical accelerometers (Mini-Mitter, Phillips Respironics, Oregon, USA), attached to a waist belt and worn for five consecutive 24-hour periods. When the parent and infant met with the researchers at their one year anthropometric visit accelerometers were initialized with the child's participant number, height, and weight, and set to collect data in 15 second epochs. Parents were instructed verbally and in writing (Appendix A) to place the belt around the waist of the child before bed the first night of the measurement period. From the time of waking the following day, parents were asked to complete a diary of sleep and wake times for the five days the infant wore the accelerometer. Parents were instructed that while the accelerometer was waterproof it should be placed over the child's clothing and taken off for bathing. Any removal of the accelerometer for more than 15 minutes was requested to be recorded on a diary sheet, as was any sedentary time (Appendix A), so that gaps in accelerometer data could be accounted for. A parent diary was provided attached to the instructions to record this relevant information as illustrated in Appendix A.

Accelerometers were picked up after use by a research nurse or returned by courier. Upon return accelerometer data were downloaded and saved using the participant identification code. Accelerometers were calibrated between use by participants using a custom made calibration tool made to ensure devices could detect activity of low, medium and high intensities. If the accelerometer was performing as expected it was prepared for another participant, if not measures were perfumed to fix any obvious issue (e.g. batteries replaced), and the unit retested. Failure to measure correctly in two consecutive calibration tests meant the unit was deemed unreliable and it was put aside for return to the manufacturer or disposal. The time filtering software Meterplus 4.3* (Santech. San Diego, CA.) was used to clean and analyse accelerometer data.

5.2.4.1.1 Defining accelerometer output

Accelerometer data reduction is an important consideration and includes defining periods of wear time, removing times of non-wear, and defining minimal wear time for a valid day. In this study there were four issues to be resolved before accelerometer data could be analysed. Although the accelerometer was worn for 24 hours, in order to analyse awake activity, time periods of sleep needed to be removed from the 24 hour file. Time filters for sleep onset and offset were inputted into Meterplus for each day of wear. The resulting analyses included only periods of time where the toddler was deemed to be awake. Once sleep periods were removed from the file, definitions for minutes of consecutive zeroes for non-wear time, and hours required for a valid day needed to be established.

5.2.4.1.2 Defining counts for sleep/wake

Rules defining sleep and wake onset in this age group have not previously been reported. Generally research in this area employs accelerometry during awake hours if it is concerned with activity and during sleep hours if it is concerned with sleep. Separating out activity from 24 hour accelerometer data in infants, where multiple sleeps per day are likely, is an understudied field. The following section outlines the process of testing that occurred in order to determine the most appropriate method of excluding sleep from the activity data. Initial data was collected in 15 second epochs. Although previously published algorithms exist, such as those developed by Sadeh et al (194), these algorithms have not been validated for use in infants. Therefore, we tested and adapted the rules developed by Sadeh (1995) with visual inspection in order to identify rules for sleep onset and offsets that would best fit this age group. In order to use the Sadeh algorithm as a basis for our visual determination, files were reintegrated into 1 minute epochs. Once reintegrated, files were visually inspected using twenty counts or more per minute (CPM) as the criteria for "awake" and less than 20 CPM for "sleep". This cut-point was established after examination of the sleep research (172, 195, 196) and cut points found in previous PA studies, for example Evenson's (2008) cut-points(145), where sedentary activity was defined as less than 44 CPM. Accelerometer output was compared with diaries for ten participants with parent dairies that appeared complete and it was decided that a $<20/\geq 20$ CPM cut off seemed feasible to define sleep/wake states in infants.

During the initial development of the sleep and wake cut-points various "rules" were tested:

Rule 1. Counts equal to or above 20 CPM were required to be *sustained* for 3 minutes or more to be classed as an "awake" time, and below 20 CPM for 30 minutes or more to be classified as "sleep".

Although this thesis is concerned with activity data collected from the accelerometer, other researchers required the sleep data. Therefore, as overnight waking was required by the sleep researchers, another rule was established:

Rule 2. Once a sleep period was defined, the sleep state could be interrupted by counts greater than 20 CPM without the "state" changing. If counts greater than 20 CPM were sustained for more than 3 consecutive minutes within a 10 minute block the state changed to awake.

We analysed a few files using rules 1 and 2, and it became clear that the rules could not be applied to both "daytime" and "night time" sleep, because when we compared the results we obtained to the parent diaries for the same day significant discrepancies were identified for day sleep, but not night sleep. Therefore Rule 3 was established.

Rule 3. To identify periods of sleep that occurred during the day versus those which occurred at night "day" and 'night' periods were defined. "Day" was defined as 7am to 7pm and the rules were adjusted so that counts greater than 20 CPM, sustained for more than 10 minutes (rather than 3 minutes) would be considered "awake" during night time hours. At "night" or 7.01pm to 6.59am, counts greater than 20 CPM, but sustained for less than 10 minutes would be considered "sleep".

A further five files were analysed and then discussed by the group. Problems identified were that different day/night rules still did not ensure recognition of sleep and awake time as a significant amount of "real" sleep (long periods of low to zero counts) was being incorrectly coded as "awake" time when rules 1-3 were used. Therefore, in order to reduce the amount of sleep that was incorrectly coded as awake time a fourth rule was developed, and rule #3 was removed.

Rule 4. Awake was defined as a sustained period of 5 or more minutes of counts greater than or equal to 20 CPM and sleep was defined as a sustained period of 15 minutes or more of counts less than 20 per minute. A further 5 files were tested using these new rules and compared against parent diaries. A final problem identified was that infants in this age group spend a considerable amount of their time constrained (high chair, car seat, stroller etc.) while awake and this rule resulted in a considerable discrepancy between the visual determination of sleep and parent diary recording of sleep. The advisory group then decided that rule #4 was also invalid for our age group.

The final rules to determine sleep and awake for this data set resulting from this testing process were:

Sustained periods of 5 minutes or more of ≥20 CPM were defined as "awake" and sustained periods of 30 minutes or more of CPM <20 were defined as sleep. The rules did not vary with time of day.

During the initial development of these definitions for sleep and wake, files were examined visually by a research assistant who recorded sleep onset and offset times. Due to the large dataset an automated macro for Microsoft Excel was developed to identify sleep onset and offset using the final rules developed above. The macro was subsequently compared to a visual check on 10 files and found to have 100% reliability.

5.2.4.1.3 Consecutive zero's required to define non-wear

Previous research using accelerometers to measure children's PA has defined non-wear time using periods of zero counts. These periods vary from 10 minutes of consecutive zeroes (117, 129) to 60 minutes (191). Given the absence of known criteria for this age group we chose to use 20 minutes of consecutive zeroes as non-wear time. To test this assumption we analysed eight files using 10 minutes and 20 minutes of consecutive zeroes to define non-wear time. We found that 10 minutes resulted in less valid hours (on average 6.7 hours per day). Therefore to maximise data inclusion twenty minutes of consecutive zeroes was used to define non-wear time.

5.2.4.1.4 Valid hours per day/valid days

The number of hours per day to define a valid day was set at 8 as at this age there can be up to 15 hours per day of sleep (186). Previous research has indicated that validity remains high with even short (3 hour) periods of monitoring in pre-schoolers(138). At least 3 valid days were required for the data to be included in the study. While weekdays and weekend days may differ in amount of activity (197) it was not considered as a variable in this study given the age of the infants.

5.2.4.1.5 Cut points for level of activity

The use of accelerometer output cut points to assess activity intensity is commonplace when reporting on the activity of adults and older children. Depending on the cut points used the amount of time in various levels of activity can vary. As there are currently no published reports on appropriate cut points for this age group, correspondence between leading researchers in this area was sought. Consensus advice was that using cut points to define intensity would not be a valid analysis, but that total counts per minute would be of interest (S. Trost and E. Cauwenberghe, email correspondence 2013).

5.2.4.1.6 Accelerometer data analysis

Periods of time identified as sleep were removed from the data by creating filters in Meterplus*(Santech. San Diego, CA.) which used time of sleep offset to time of sleep onset to filter in periods identified as awake for analyses. Subsequent time filtered files were then merged into a spreadsheet and files with less than three valid days of accelerometer measurement removed (n=131). In two cases this was due to malfunction of the accelerometer.

5.3.2.1 Restraint, Maternal PA, and Active time with mother are included in Appendix A.

5.3.2.2 Milestone achievement

Milestone achievement outcomes including hands-knees crawling, standing unassisted, and walking unassisted were asked at 12 months. Below is an example of the format of the milestone questions which used the WHO categorisations (176). Other milestones included were standing assisted and unassisted, walking assisted and unassisted and bottom shuffling is included in Appendix A.

Can [infant's name] stand without assistance? (Infant can stand in an upright position on both feet, holding onto a stable object e.g. furniture with both hands without leaning on it. Stands for at least 10 seconds).

☐ Yes

☐ No [go to question 59]

At what age did [infant's name] stand without assistance?

____________ months or

☐ Don't know

5.3.2.3 Data analysis

A summary measures approach was taken to deal with repeated measures and to give each participant an independent variable, mean counts per minute (CPM). To reduce data to CPM, total epochs for each awake period were divided by four to obtain total minutes as data were collected in 15 second epochs, therefore four epochs for each minute. Counts per minute were then calculated by dividing the counts for each awake period by the minutes in that time. Counts were averaged across all awake periods per day to give an average for each day of measurement, and mean CPM across all measured days. Logistic regression was used to assess differences in the binary variables accelerometer data/no data against demographic variables, achievement or non-achievement of walking, and by mean CPM. Descriptive statistics were calculated for CPM by intervention group. Log transformation was required on the variable mean CPM to meet the assumption of normality for regression analysis. Geometric means are thus reported. Linear regression was used to assess between group differences in CPM, time in restraint, and time since the infant began walking. Spearman's rho was used to assess correlations between time in active play with the mother and mean CPM. All statistical analyses were by intention to treat and were performed using Stata 11.0 (StataCorp. 2009. Stata Statistical Software: Release 11. College Station, TX: StataCorp LP).

5.4 Results

At least 3 valid days of accelerometer data were available for 408 participants (408 with 3 days, 399 with 4 days, 358 with 5 days) and were used for analysis. One hundred and thirty-one families were given accelerometers but some were not worn (n =110) or had insufficient valid days (n = 21). Accelerometers were lost or not returned by 34 families.

Demographic variables of POI.nz study participants with (n = 408) and without valid accelerometer data (n = 394) are presented in Table 5.3.

Table 5.1. Characteristic comparisons for POI.nz study and those participants with and without accelerometer data.

	POI study	Accelerometer Data	Incomplete or no accel. Data	P[1]
Male (%)	51	51	52	0.766
Group				0.864
FAB	205	106	99	
SLEEP	192	99	93	
CONTROL	209	101	108	
COMBO	196	102	94	
Maternal education %				
5th form/less	7.8	3.5	12.4	<0.001
6th from	6.8	6.4	7.2	
7th form	9.7	10.9	8.5	
Post HS	14.5	13.1	16.0	
University	61.1	66.2	55.8	
SES %				
Low	21	18	24	0.050
Medium	33	34	33	
High	46	48	43	
Mother in paid work	59.5	62	56	0.125
Maternal age m(SD)	31.6	32.4	30.65	<0.001*

[1] Comparison between accelerometer and no accelerometer.

There was no difference between groups for the number of valid accelerometer data files, with the 408 valid files spread evenly across groups (P = 0.864) possibly due to the large number of participants in the study and randomisation allowing possible confounders to accelerometer use to be limited. Mothers with accelerometer data were older, and had more years of education than those without accelerometer data (Table 5.1). More families with data were of high SES compared to those without, while fewer families with data were of low SES compared to those without (P = 0.05).

Table 5.2. Total minutes of activity recorded each day by group allocation.

	COMBO	Sleep	Control	FAB
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Day 1	587 (124)	579 (96)	567 (130)	598 (99)
Day 2	615 (116)	570 (112)	574 (138)	575 (112)
Day3	603 (119)	580 (116)	596 (121)	589 (110)
Day 4	607 (121)	589 (104)	570 (152)	595 (111)
Day 5	595 (111)	590 (99)	558 (128)	594 (98)

The activity data, or time awake when activity within the defined parameters was detected ranged from 558 minutes (9 hours 18 minutes) to 615 minutes (10 hours 15 minutes) per day. Mean total minutes for the 408 participants were 585 minutes (SD 83) or 9 hours 45 minutes.

Table 5.3. Mean[b] and 95% CI for CPM for each day, and in total, by group allocation.

	COMBO	Sleep	Control	FAB	
	Mean	Mean	Mean	Mean	P
	95% CI	95% CI	95% CI	95% CI	
Day 1	[c]N=100	N=99	N=103	N=106	0.038
	210	170	171		
	182-222	159-183	155-190	158-187	
Day 2	200	176	167	178	0.051
	180-222	163-191	153-182	163-195	
Day 3	195	170	168	185	0.396
	178-213	158-184	153-183	170-201	
Day 4	N=98	N=97	N=99	N=105	0.153
	202	180	170	186	
	182-225	166-195	154-188	170-203	
Day 5	N=98	N=91	N=88	N=93	0.015
	210	177	177	174	
	187-237	165-190	162-195	158-191	
Total	206	179	175	182	0.133

[b] = geometric mean [c]=N for days 1 to 3 as minimum 3 valid days

Significant differences were evident by group allocation for average CPM for days 1 and 5. On those days, the COMBO group had significantly higher CPM than the other three groups (Table 5.3).

Time spent restrained in car seats or strollers differed significantly by group with the COMBO group having significantly less time restrained per day than any other group (P = 0.041). The mean time restrained for the COMBO group was 31 minutes (95% CI 27-35), compared with Sleep having 42 minutes (95% CI 36-48), Control having 44 minutes (95% CI 38-50), and FAB having 38 minutes (95% CI 33-44). Active play with the mother at 6 and 12 months did not vary significantly between groups (P = 0.841 and P = 0.229 respectively) or show any correlation with mean CPM at 12 months (r = 0.08 and r = 0.14 respectively).

Table 5.4. Mean CPM across days 1 to 5.

Day #	CPM Mean (SD)
Day 1 n=408	202 (151)
Day 2 n=408	203 (165)
Day 3 n=408	197 (106)
Day 4 n=399	210 (155)
Day 5 n=358	211 (209)
Total	204 (133)

Table 5.4 indicates the range of mean counts per minute over the 5 days was only 14 CPM; however variation is large in proportion to the mean. The intraclass correlation (ICC) value was 0.662 (95% CI 0.62-0.70). The Spearman-Brown prophecy formula was used to predict the number of measured days required to achieve satisfactory reliability, accepted to be 0.7 (198). In this case, 2 days allowed a prediction of 0.8, and 5 days 0.9, therefore only 2 days of data indicated satisfactory reliability.

Table 5.5. Mean CPM days 1 to 5, and total mean CPM for walkers and non-walkers.

Day #	Walkers	Non-walkers	P
	Mean (SD)	Mean (SD)	
Day 1	230 (132)	181 (162)	0.001
Day 2	235 (120)	181 (176)	0.001
Day 3	233 (134)	171 (71)	<0.001
Day 4	251 (197)	179 (111)	<0.001
Day 5	235 (129)	194 (255)	0.073
Total	237(125)	180(137)	<0.001

Data were available on walking status at 12 months for 646 participants, indicating 267 (41%) of the entire sample were walking. The same percentage of infants who had valid accelerometer data was walking (164 of the 408 participants). Walkers were significantly more active than non-walkers on days 1 to 4 and for total mean CPM (Table 5.5). The age at which an infant started walking did not result in a significant difference in mean CPM (P = 0.683).

Overall boys were more active than girls (P = 0.009) (Geometric means CPM - boys 195, 95% CI 184-206, girls 176 95% CI 176-186) although this difference may have little or no clinical significance. Although more boys (143, 44%) than girls (124, 39%) were walking at 12 months of age, there was no significant difference in activity (CPM) between boys and girls who were walking (P = 0.198), or between boys and girls for those not walking (P = 0.103).

No significant differences were found between groups for the variables achievement or non-achievement of the milestones hand-knees crawling, standing unassisted, and walking unassisted (Figures 5.1, 5.2 and 5.3). However there was a consistent trend for the FAB group to have the highest percentage of infants achieving these milestones earlier than infants in the other groups.

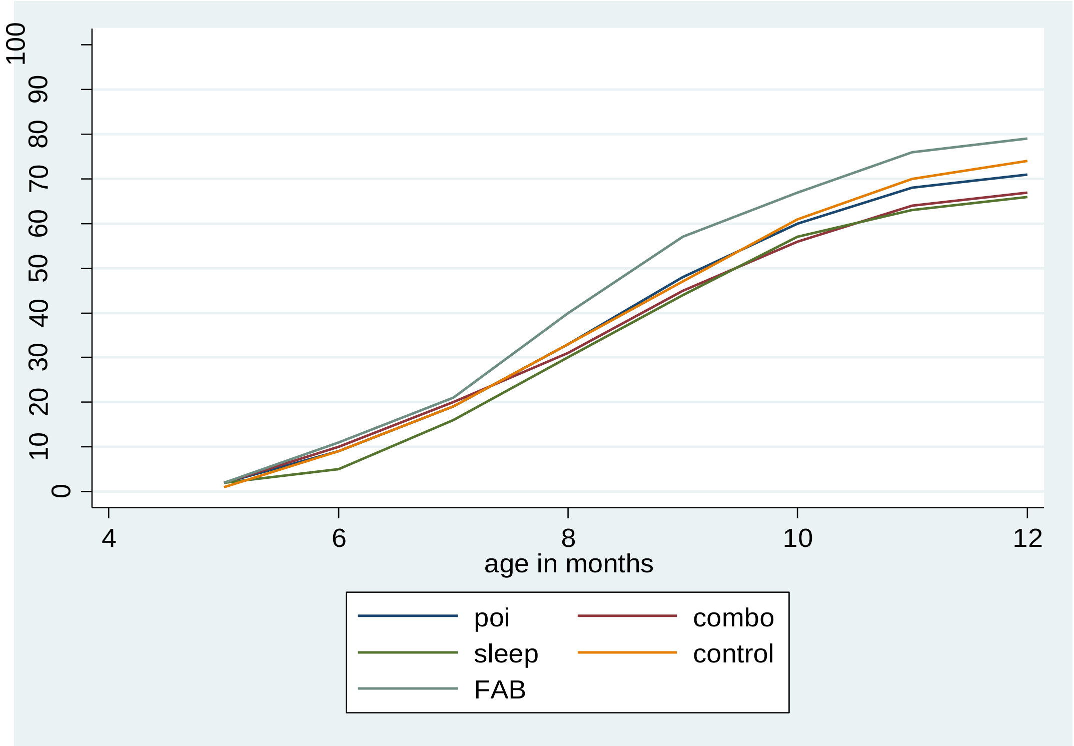


Figure 5.1. Line graph showing the percentage of infants at each age (months) who were doing hands-knees crawling, stratified by group. Note POI.nz group represents the entire group, irrespective of group allocation.

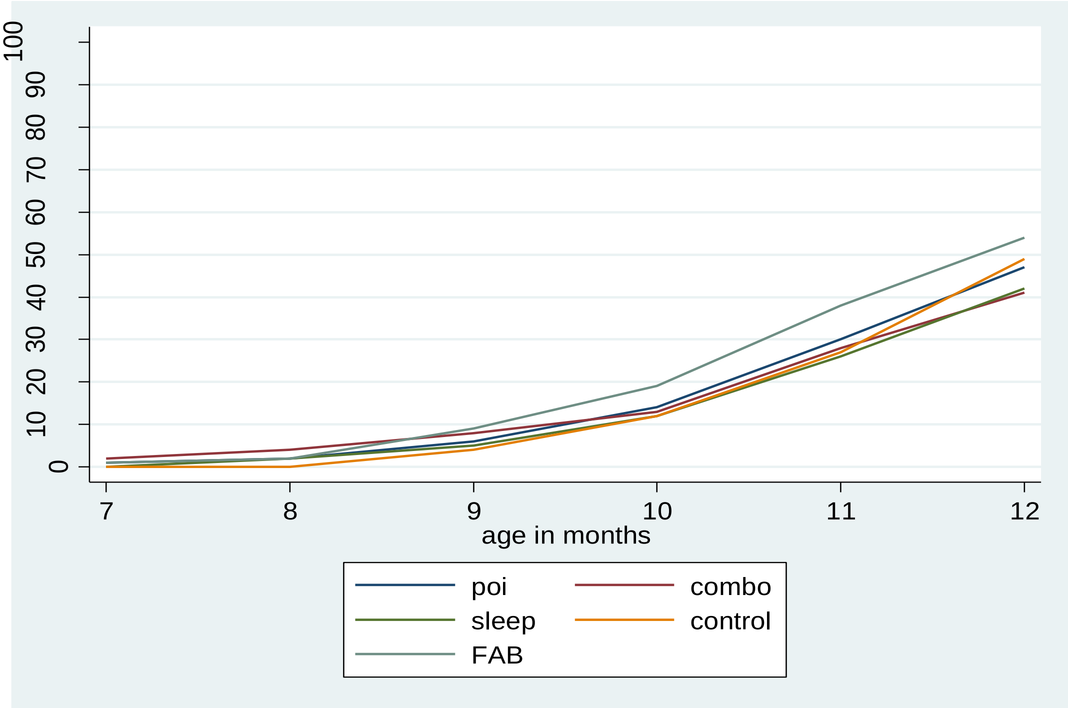


Figure 5.2. Line graph showing the percentage of infants at each age (months) who were standing unassisted, stratified by group. Note: POI group represents the entire group, irrespective of group allocation.

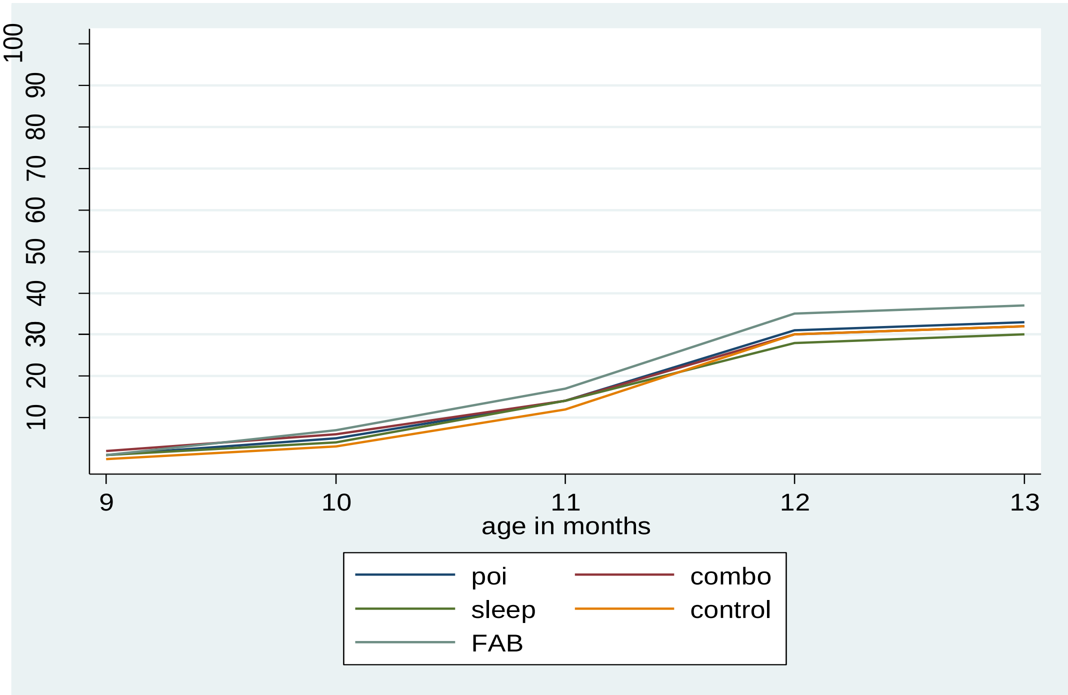


Figure 5.3. Line graph showing the percentage of infants at each age (months) who were walking unassisted, stratified by group. Note POI group represents the entire group irrespective of group allocation.

Fig. 5.1 shows from 8 months onwards 7% to 13% of the infants in the FAB group achieved crawling sooner than those in the other groups. By 12 months of age 66% (Sleep) to 80% (FAB) of infants were reported to be hands-knees crawling however it is not clear why up to 34% of infants were not reported to be crawling by this age. This discrepancy may have been because some parents reported their infant's did not "hands-knees" crawl, but rather moved around by shuffling their bottom along the floor. This "bottom-shuffling" could not account for all of the infants not reported to be crawling by 12 months as the numbers who reported this were relatively small; 6% in the COMBO and Sleep groups, 7% in the FAB group, and 11% in the Control group. And in total only 22% of the babies who bottom shuffled were not reported to have crawled. It is possible that asking parents in retrospect about milestone achievement when they have multiple children leads to recalling less clearly each child's achievement.

Fig 5.2 indicates that the FAB group also achieved standing unassisted 5% to 13% sooner than the other groups and had 54% of infants standing unassisted at 12 months however these differences were not significant.

5.5 Discussion

Measurement of PA in infants of 12 months is a largely unexplored field. This study was fortunate to obtain valid accelerometer data from a large group of infants to enable four research aims to be addressed. While participation in the PA intervention education session was high with 90% attendance at 3 months, and 76% at 9 months, PA intervention alone does not appear to have resulted in significant differences in the outcomes measured. The COMBO group had significantly higher mean CPM than the other three groups, and less time restrained in car seats suggesting that the education given to the COMBO group had some positive effect on activity, and time in restraint. It is possible that because the COMBO group had the most total education (receiving both the PA feeding and sleep interventions), they responded more effectively to the messages they received. However despite these positive results the rate of withdrawal by 12 months for the COMBO group (13% compared with Sleep -7%, FAB -5% and Control -4%), was the highest of the four groups suggesting participant burden was a contributing factor.

The greater response by the COMBO group for activity did not extend to time spent active with the mother, which might have been expected given the PA intervention encouraged active play with the parents. This result is in contrast to Hnatuik (2013) and colleagues who found that time spent active with their mothers at 9 months was a predictor of infant activity at 19 months (168). Hnatuik et al (2013) note the multiple comparisons made in their study could have resulted in some false positive results. The lack of relationship between time spent activity with the mother and CPM in our study may have been due to the fact that in our study active play was one variable rather than aspects of play activity such as floor play and outdoor play which created multiple comparisons, therefore only one comparison was made, limiting the chance of error.

The amount of hours of activity measured was consistent across days with between 9.25 and 10.25 hours of activity data per day (Table 5.2). Sleep time of up to 15 hours can be expected at this age (186) therefore it would appear that sleep was successfully removed from the 24 hour data using the parameters set during data reduction. The InFANT study reported wear minutes of 586 minutes (SD 65minutes) or 9.8 hours in the group of 19 month old infants wearing accelerometers only while awake (96). Our study shows similar mean total hours (9.75), however greater variation (SD 83 minutes) which may be a result of the requirement for 24 hour wear as the accelerometer is consequently not put on at the same time each day. This may be a more accurate representation of the hours of activity of children at this age.

Intraclass correlation analysis (ICC) revealed that despite some variation in mean CPM, as seen in Table 5.4, only 2 days of measurement resulted in an ICC of 0.8 or 80% reliability which is useful information for children of this age and supports Trost's observation of older children in that activity may be less variable than in adolescents(137). Van Cauwenberghe and colleagues (117) noted that had 2 valid days been required they could have included 17% more participants in their study. In the present study while only 12 participants had only 2 valid days of data this would have increased the number with valid activity data to 420, 52% of the 802 participants, and 60% of those measured at 12 months (n=693) and eligible for an accelerometer.

Consistency in mean CPM across days is indicated in Table 5.5, however variation is large, making trends in activity difficult to assess. Some of this variation may be accounted for by the walking status of the child. This is the first study to place accelerometers on infants at 12 months, a time when not all the infants are walking. Consequently some differences can be expected in our results from research using walking infants (96, 129). As discussed in Chapter 3 accelerometer data is compromised by caregiver movement and quantification of caregiver interference with measurement is required before more can be understood about the awake activity of non-walking infants.

The family-based activity intervention did not result in differences in timing of achievement of developmental variables such as crawling, standing or walking. For all milestones examined the FAB group, which received the feeding and activity intervention, had the highest percentage of infants achieving the milestone after 10 months while the COMBO group which also received these interventions were consistently later in achievement. None of these differences were significant however there was evidence of earlier achievement in the attainment of standing and walking by the early crawlers compared to the later crawlers. It must be noted that the timing of milestone achievement was reported by the parent and not observed by the researchers. Previous research to develop milestone achievement parameters asked parents to observe infants and record changes after first teaching the physical indications of the milestone (177). While parents have been found to accurately assess sitting, crawling, and walking milestone achievement (199) this was when the reporting was close in time to achievement rather than more retrospectively as in the present study. Two issues could limit the reliability of parental report of milestone achievement in this study. The first is memory decay given the retrospective nature of the questioning, although milestones achieved around 12 months would be expected to be accurately recalled at the 12 month questionnaire. The other is the demand characteristic from group allocation. Those receiving interventions obviously encouraging activity could look to please the interviewer, who was not blinded to the intervention group of the family, by appearing to be more interested and active in their infant's activity.

The use of accelerometers in this age group is novel, therefore knowledge gained around use and return has few comparisons. The InFANT study reports the amount of accelerometer data collected was 70%, or 295 of the 417 infants that wore accelerometers. They note there was 17% malfunction of accelerometers and 13% had no data (96). Wijtzes et al. reported 14% of the children did not wear the accelerometer after saying they would and there was loss or malfunction of 10% of their accelerometers (129). In the present study 59%,or 408 of 693 participants measured at 12 months returned useable data, 131 (19%) were incomplete, while 34 (5%) were lost. Malfunction accounted for few in the present study, possibly due to the calibration process carried out between participants. Loss was an issue however with some families contacted multiple times for return of the units, which in some cases did not result in the return of the accelerometer. In the POI.nz study uptake and use of the accelerometers may have been lower because families had been asked to use the devices at 6 months and some families had found it burdensome so may have refused at 12 months or continued to find it a problem and not completed the accelerometer use as requested.

Differences in demographics between participants that completed the accelerometer measures and those that did not may be of interest to future investigations. Those with accelerometer data had a higher level of education, with 66% mothers reporting having a University education compared to the national average of 40% with post High School education (200). The issues involved with gaining a representative sample in such studies will be discussed in a later section of this thesis.

Strengths of the present study include the number of families receiving the activity education, and the retention rate of the POI.nz study. The Consort diagram indicates that at 3 months 92% of the FAB and 87% of the COMBO groups received the information while at 9 months these figures were 80% and 72% respectively. Compared to the 50% attendance rate reported in the NOURISH study this is a promising result. The InFANT study did not publish attendance rates for their intervention (163). In the POI.nz study multiple education sessions were offered and research nurses and administration staff were vigilant in ensuring as many participants as possible attended sessions. To encourage retention in the study, families were given greeting cards on important occasions and small gifts for continued participation. A regular newsletter was also sent to families updating them on relevant topics related to the study.

Given that recent public health measures to reduce the level of obesity in children and adulthood are focussed on prevention of excess weight gain from an early age (189) early measures of PA infant activity are of interest. The POI.nz study offered the opportunity to collect PA data at 12 months of age in an attempt to elucidate questions about PA measurement at this young age. While there were significant differences between groups for restraint use and some evidence of higher CPM in the COMBO group on two of the five days that could be related to the activity intervention, there was no significant differences between groups for most of the outcomes examined. Given that accelerometer use to measure PA prior to walking appears not to be a useful measure of activity at this age it may be that if there were differences between groups this measure is not sensitive enough to elucidate them. Also the activity education focussed on the family being active not just the infant so this may lead to the infant being put in a stroller while the parent or family are active in walking or running, thus the infant is in fact not active while the other members of the family are. Further use of the accelerometer measure at older ages will give more conclusive evidence of the effect of the activity interventions on PA in the child. While no differences in mean CPM were evident between early and more recent walkers in this study all were relatively recently walking. This is an area that could benefit from further research, given the indications from previous studies that early motor competence is predictive of later participation in PA (33).

Chapter 6. Discussion

6.1 Overview

Physical activity guidelines for children under 3 years of age have been introduced by some countries in an attempt to address the decrease in PA noted to occur with age (59). These guidelines suggest children under 3 require 3 hours per day of PA of any intensity. In order for guidelines to be useful to health professionals and parents it is essential to identify the current levels of PA in toddlers and pre-schoolers. Although historically little research is available recently several studies have published reports on infant based activity such as tummy time and objectively measured activity in walking infants (96, 129, 164, 168). This thesis contributes to this knowledge having examined both the use of tummy time in a large cohort, and the use of objectively measured PA in children at ages 6 and 12 months. Both indirect measurement using parent report, and objective measurement using direct observation and accelerometers have been discussed. Methods commonly applied to research in older children but not yet clearly identified as useful in infancy have been examined. Thus this thesis is novel as it is the first attempt to examine PA in the first year of life using a range of methods. Aspects of the results of this thesis could be applied to apprise future research and clinical practice.

6.2 Tummy time

Parents in the POI.nz study reported using tummy time more than has been the case in previous studies (164, 184) with almost 90% of families attempting tummy time with their infant. However while daily use was high the length of each tummy time session may have been too short to enhance motor skill and potentiate early milestone achievement (28). Future research could assess the effect of a targeted intervention to lengthen the use of prone positioning on milestone achievement to fully understand what benefits, if any, tummy time may offer.

Tummy time interventions could also be targeted toward certain segments of society as this study revealed relationships between demographic variables and the amount of tummy time offered. Non-smoking parents and those who were more physically active used more tummy time suggesting that parental health behaviours may indicate family health behaviours and thus improving parental health may be a practical goal when considering enhancing children's health. Recent evidence that smoking rates in New Zealand are declining could be an indication that the time is right to increase education on health enhancing behaviours for families (200). Anticipatory guidance around early activity such as increasing tummy time duration and early play activity with parents are examples from this study of areas where such education could be focussed.

Further research could reveal the reasons that those with more children offered less tummy time. Studies which used only first time parents would be a useful comparison to assess the effect of more children on the use of health enhancing behaviours. Discussion with parents at activity education sessions indicated that safety was an issue, with older children posing a danger by not being cognisant of an infant on the floor. Awareness of this potential barrier may inform future anticipatory guidelines on tummy time and offer strategies and solutions (such as playpens) for parents and health professionals to cope with these potential barriers. Strategies such as offering playpens for hire at a small cost in the same way as infant car seats are at present may be implemented in order to reduce barriers for parents. In 1986 the Ottawa charter outlined moves to encourage signee countries to ‘make the healthy choice the easy choice’(201). This document is no less relevant today (202), perhaps more so given the current obesity epidemic. While the focus of the ‘choice’ seems to have been placed on food choice (203), and larger environmental aspects such as healthy cities (204,) it is imperative this should extend to creating an environment for families to be active with their children from birth and equipment and facilities made available for this to happen.

6.3 Accelerometer derived PA measurement

Two aspects of accelerometer derived PA measurement were examined in this thesis. Firstly the use of accelerometers as an objective measure of PA in six month old infants was explored and secondly their use in a large RCT where an early intervention to encourage PA at a family level was being assessed. Waist worn accelerometers were shown in the validation study to produce the lowest counts of the three sites of wear tested when the infant was being carried by the caregiver and being pushed in a stroller but to have moderate correlation with observer coded activity in free play on a mat. Therefore results from the validation study informed accelerometer use in the POI.nz study as accelerometers were worn at the waist to measure activity at 12 months of age.

Overall, although wear time was similar, activity was lower in the POI.nz study compared to other studies in young children (96, 129). This low level of activity could be explained by the fact that only 41% of the infants were walking unassisted when measures were obtained at 12months. Comparison of CPM between walking and non-walking infants showed significantly greater CPM in walking than non-walking infants. This may be explained by results shown in the validation study which showed that using waist worn accelerometers on infants who were not independently mobile resulted in significantly lower CPM than using a wrist worn or ankle worn accelerometer. The higher CPM reported in the InFANT study may have been related to the age of their sample as all of the children involved were walking at the time of measurement.

Restraint in car seats or strollers is also a factor when considering PA measured by waist worn accelerometers. Daily restraint of between 30-45 minutes per day was reported by the POI.nz study groups. Given the indications from the validation study of low counts registered on waist worn accelerometers while infants are restrained it could be anticipated that in the POI.nz study the COMBO group, which had significantly less time restrained, would have generally higher mean CPM. While this was the case for two of the five days of measurement it was not observed across all five days of activity and therefore the relationship remains to be clarified.

The validation study also showed that carrying infants led to low levels of accelerometer measured activity. Non-walking infants would presumably be carried more that those walking, leading to lower counts, consistent with the current study results.

Taken together the results of the POI.nz study reveal that education about such activity as tummy time is widely available and well received by parents, however targeting time spent prone rather than increased frequency, could be considered. Also increased attention by policy makers to demographic variables and health behaviours shown to affect family health behaviours is warranted. Secondly future research on accelerometer measured activity at in infancy needs to allow for the level of independent movement of the child.

6.4 Strengths and limitations

The strengths and limitations of the studies in this thesis have been mentioned in each chapter however some comment is warranted on aspects of the POI.nz study not explored in the chapters. A factor that limits the application of the POI.nz study results to the general population is the lack of representative education level and socioeconomic status compared to the general population. However, this is common for research in this area, with maternal education higher than the population average noted in other studies in this area (87, 97) and in both the studies that used accelerometers in children under 2 years old (96, 129). To counter-act this selection bias the InFANT study controlled for maternal education within the analyses because it has been indicated to be a covariate of older children's PA (96). The Nourish study did not recruit selectively and had high proportions of parents with higher educational qualifications than the national norm (158). The POI.nz study used random allocation to groups but controlled for socioeconomic status within the analyses (95). One study in the EPOCH group, the Health Beginnings study, selectively recruited in a low socioeconomic area (4) because overweight and obesity are more prevalent and more difference to health outcomes can be made in this group.

Obtaining a representative sample is made more complex by the demographic composition of the population the study is drawing participants from. In Dunedin city the University of Otago students and faculty make up a high proportion of the population thus increasing the average educational level . Figures from the 2006 census (200) indicate that 40% of New Zealand adults over 15 years old at that time had post high school qualifications. As data from the 2013 census on educational levels are not yet available it could be assumed that this figure had risen since the previous census but it would be unlikely to be as high as the 76% of mothers and 73% of the fathers in the POI.nz study who had this level of education. In the POI.nz based studies reported in this thesis mothers with higher education were more likely to report tummy time and obtain accelerometer data than those with lower levels of education. Future research should control for maternal education and SES as they both have the potential to affect conclusions (96).

Social desirability is a well-known limitation of self reported PA (107). It may have also affected the current study as participants, consciously or unconsciously, may have answered questionnaires in ways that were pleasing to the researcher, such as over reporting activity such as tummy time. In the POI.nz study, research nurses delivered the 6 month and 12 month questionnaires to the primary caregiver after having visited them previously and discussed aspects of the study. The Control group, on the other hand, had little contact with the nurse other than for delivery of the questionnaires, therefore less opportunity to form a relationship where amenability to recommendations could be considered to alter the answers given to questions. However, if social desirability was an issue, effects by group on PA reported concepts such as tummy time and time spent active with the infant might be expected. While some group differences were found between groups, the research reported in this thesis did not indicate large effects of the interventions and therefore social desirability is unlikely to have been an issue in this study.

A major strength of the POI.nz study is the high retention rate with 94% of the families remaining in the study at 12 months. This high retention rate meant we could obtain objective measures of PA in a large sample. Our compliance rates for accelerometry of 70% compare favourably with the InFant study where the same percentage of parents returned complete data. However, these compliance rates are low in comparison to studies on older children using accelerometers which report higher rates of compliance. The FLAME study for example obtained accelerometer data for 93% of 3 year olds, 86% of 4 year olds and 96% of 5 year olds (73). Reasons that the accelerometer was not worn were recorded anecdotally on the parent diary and in only a few cases did parents report that their child would not wear it. Given that the compliance rates were similar in the InFANT study it would seem that the lower compliance rates may be related to the age of the child and the significant burden placed on parents to attend to the accelerometer. At 6 months of age 455 accelerometer diary sheets were returned compared to 407 diaries at 12 months. While diary return is not always indicative of use of the accelerometer it would appear less parents used accelerometers at 12 months than 6 months. Anecdotally, the decrease in parents agreeing to use an accelerometer at the 12 month measurement may have been because some parents found the accelerometers burdensome and difficult to use when they tried them at 6 months of age and would not try them again at 12 months. If repeated use of such a measure, particularly one that requires considerable participant effort, is to be used in such studies ease of use should be considered. In this case families had at least one young child and there were already considerable demands on their time. While diaries of time in and out of bed were generally completed record of removal of the accelerometer for bathing and time spent sedentary were not, indicating parents were willing to do what was required within the bounds of their time and energy. This could be considered to be part of the reason the COMBO group, which had the highest level of participation of any group, had considerably higher dropout than other groups.

While this study is focused on the activity aspect of obesity prevention this was just one part of one arm of the POI.nz study and did not evaluate the effect of feeding or sleep interventions. The examination of

PA in combination with breastfeeding/feeding and sleep outcomes will potentially elucidate obesity intervention in an attempt to curb the obesity epidemic in New Zealand.

6.5 Conclusion

In rounding off this work I return to Professor Archie Cochrane's quote, "No survey without service" in asking "What does this body of work contribute to the knowledge of infant activity in the first year of life and the effect an activity intervention might have on that activity?"

The validation study indicated it is difficult to accurately gauge activity when an infant is not walking without assistance with much activity being due to the caregiver. Examination of the POI.nz 12 month accelerometer data supported this finding in that walking infants were significantly more active than non-walking, implying when the infant is walking the accelerometer records more of the infant movement. Future research could attempt to quantify the amount of interference from caregiver movement on an infant's activity in a study with more participants than the validation study reported in this thesis however the need for the range of activities used in this study is not necessary to examine this issue.

The activity intervention, designed to increase the use of parental interaction with their children towards increased PA, could be considered to be successful on a number of levels. Firstly tummy time is seen to be used widely in this cohort compared to other similar overseas studies which indicates that New Zealand parents are aware of health enhancing behaviours. Although the PA intervention did not increase the total tummy time offered by parents it did increase the frequency of tummy time and this knowledge in itself is useful to health professionals as it indicates where intervention can be effect change in behaviour. The greater activity and less restraint used in the intervention group also offer some support for the use of anticipatory guidance in PA enhancement. While activity and milestone achievement was not enhanced in the PA intervention group's follow-up of these participants at a later stage of development, when they are all walking will make objective measurement more reliable.

How important it is to have a measure of PA in infants and toddlers? This is a question raised by this thesis. Given the continued increase in childhood obesity in New Zealand (205) there is obviously a need to clarify issues such as the current level of activity of infants and toddlers. Measuring the PA of infants is difficult, as this theis has established, however the measurement PA of toddlers using accelerometers has more potential. Once the current level of toddler activity is established health professionals could use the knowledge to target education to parents. The POI.nz will establish this in a large cohort allowing examination of the level of support required to encourage PA in the family context.

The most important aspect of this thesis that must be considered in closing is the contribution made to the body of knowledge on the measurement of infant activity in the first year of life. The methods employed such as parental report, direct observation, and accelerometry were all used effectively, taking into consideration the age of the participants by altering measures such as CARS to fit the motor skills, and repeating observer coding to ensure reliability of observations. While other similar studies have chosen to wait until all the infants were walking (96, Wijtzes, 2013 #824) we chose to measure PA at 12 months of age in a large group of infants. Quantifying the problems associated with measuring PA in ambulatory and non-ambulatory infants using accelerometers was a major contribution to the literature and reinforces that more work is required to understand infant PA. Further use of accelerometers in the POI.nz study at 2 and 3.5 years will be of interest and add to the body of knowledge in the area of toddler's and pre-schooler's activity. It is clear from this study that the data will be more easily interpreted when the children are independently mobile.

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Appendix A. Milestone and parent and infant activity questions from POI.nz 19 and 27 week and 12 month questionnaire

Thinking about the last week,

How many times each day, did you *usually* place [baby's name] on his/her tummy for play ("tummy time")? ___________ times

How long did each 'tummy time' *usually* last? ________ minutes

Over the last week

How many times did you put [baby's name] in a 'jolly jumper' or equivalent? ________times

How long did each session *usually* last? __________ minutes

Still thinking about the last week,

How many times each day would you usually place [baby's name] in a a car seat or pram/stroller? _______________ times

How long did each time in a car seat or pram/stroller usually last? _________ minutes

In the last week

How many times each day would you usually place [baby's name] in a play pen or bouncinette? ___________ times

How long did each time in a play pen or bouncinette usually last? __________ minutes

Again, in the last week,

How many times each day did you usually do some active play with [baby's name]? (active play could be lying on the floor with baby on your legs and lifting, dancing with your baby, flying and lowering your baby so they are upside down) ___________ times

How long did each 'active play time' usually last __________ minutes

Being an active parent is an important part of who I am?

[USE SHOW CARD 17]

1	2	3	4	5
No, definitely not				Yes, definitely yes

I think of myself as being a physically active parent?

[USE SHOW CARD 18]

1	2	3	4	5
Completely false				Completely true

Can [baby's name] sit without support? (child sits up straight with head straight up for at least 10 seconds. Child does not use arms or hands to balance body or support position)

☐ YES ☐ NO

Does your baby crawl?

☐ YES ☐ NO

a. At what age did [infant's name] do hands-knees crawling?

____________ months or

☐ Don't know

2. Can [*Infant's name*] walk with assistance? (Infant is in upright position, makes sideways or forward steps by holding onto a stable object eg furniture with one or both hands. Infant takes at least 5 steps in this manner)

☐ Yes

☐ No [go to question 61]

a) At what age did [Infant's name] walk with assistance?

____________ months or

☐ Don't know

3. Can [Infant's name] stand alone? (Infant stands in upright position on both feet, the legs support 100% of the Infant's weight. There is no contact with a person or object. Infant stands alone for at least 10 seconds)

☐ Yes

☐ No [go to question 62]

a) At what age did [Infant's name] stand alone?

____________ months or

☐ Don't know

4. Can [Infant's name] walk alone? (Infant takes at least five steps independently in upright position- there is no contact with a person or object)

☐ Yes

☐ No [go to question 63]

a. At what age did [Infant's name] walk alone

____________ months or

☐ Don't know

5. Does [Infant's name] shuffle on his bottom when he is moving around the room? (If the Infant is now walking- ask whether they used to bottom shuffle)

☐ Yes

☐ No

☐ Don't know

Physical activity

The next questions are about the time you spent being physically active in the last 7 days to yesterday. Do not include activity you have done today. By 'active' I mean doing anything using your muscles. Think about activities at work or home, getting from place to place, and any activities you did for exercise, sport, recreation or leisure. We are going to ask you separate questions about brisk walking, moderate activities, and vigorous activities.

Walking

During the last 7 days, on how many days did you *walk at a brisk pace* – a brisk pace is a pace at which you are breathing harder than normal? This includes walking at work, while getting from place to place, at home and at any activities that you did solely for recreation, sport, exercise or leisure.

Think *only* about brisk walking done for at least 10 minutes at a time.

________ days per week (GO TO 35a)

☐ None (GO TO 36)

How much time did you typically spend walking at a brisk pace on each of those days?

________ hours ________ minutes

Moderate physical activity

During the last 7 days, on how many days did you do moderate physical activities? ‘Moderate’ activities make you breathe harder than normal, but only a little – like carrying light loads, bicycling at a regular pace, or other activities. Do not include walking of any kind.

Think *only* about those physical activities done for at least 10 minutes at a time.

________ days per week (GO TO 36a)

☐ None (GO TO 37)

How much time did you typically spend on each of those days doing moderate physical activities?

________ hours ________ minutes

Vigorous physical activity

During the last 7 days, on how many days did you do vigorous physical activities? ‘Vigorous’ activities make you breathe a lot harder than normal (‘huff and puff’) – like heavy lifting, digging, aerobics, fast bicycling, or other activities.

Think only about those physical activities done for at least 10 minutes at a time.

________ days per week (GO TO 37a)

☐ None (GO TO 38)

How much time did you typically spend on each of those days doing vigorous physical activities?

________ hours ________ minutes

Thinking about all your activities over the last 7 days (including brisk walking), on how many days did you engage in:

At least 30 minutes of moderate activity (including brisk walking) that made you breathe a little harder than normal, OR

At least 15 minutes of vigorous activity that made you breathe a lot harder than normal (‘huff and puff’)?

________ days per week

☐ None

Describe your regular physical activity over the past six months. Regular physical activity means at least 15 minutes of vigorous activity (makes you ‘huff and puff’) or 30 minutes of moderate activity (makes you breathe slightly harder than normal) each day for 5 or more days each week. Include brisk walking.

[USE SHOW CARD 19]

☐ I am not regularly physically active and do not intend to be so in the next 6 months

☐ I am not regularly physically active but am thinking about starting in the next 6 months

☐ I do some physical activity but not enough to meet the description of regular physical activity

☐ I am regularly physically active but only began in the last 6 months

☐ I am regularly physically active and have been so for longer than 6 months

Currently, on average, how many hours per day or per week do you spend sitting watching television, videos, DVDs, playing computer or video games, or surfing the internet for pleasure?

_________ hours per day

_________ hours per week

☐ Rarely or never

☐ Don't know

☐ Do not wish to answer

The next questions are about [baby's name]

On how many days during a usual week does [baby's name] watch TV, videos, DVDs?

☐ ______days

☐ None [go to question 44]

☐ No TV/video/DVD/computer at home [go to question 44]

☐ Don't know

☐ Refused

On these days how much time does your child spend doing these activiti

☐ _______hours per day

☐ _______minutes per day

Does [baby's name] watch DVD's designed for babies such as 'Baby Einstein'?

☐ Never/rarely

☐ Sometimes

☐ Often

Over the past week

How many times have you played music specifically for [baby's name]? ________times

How long did each session usually last? ___________ minutes

POI.nz 12 month questionnaire activity and milestone achievement questions

ACTIVITY

Over the last week

How many times did you put [*infant's name*] in a 'jolly jumper' or equivalent? ________times

How long did each session *usually* last? __________ minutes

Still thinking about the last week,

How many times each day would you usually place [*infant's name*] in a a car seat or pram/stroller? _______________ times

How long did each time in a car seat or pram/stroller usually last? _________ minutes

In the last week,

How many times each day would you usually place [*infant's name*] in a play pen? ___________ times

How long did each time in a play pen usually last? __________ minutes

Again, in the last week

How many times each day did you usually do some outside active play with [*infant's name*]? ___________ times

How many times each day did you usually do some active play (include inside and outside active play) with [*infant's name*]? (active play could be crawling on the floor with your infant, rolling around on the floor with your infant, playing at the park, dancing with your infant, chasing your infant) ___________ times

How long did each 'active play time' usually last __________ minutes

Can [*infant's name*] sit without support? (Infant sits up straight with head straight up for at least 10 seconds. Infant does not use arms or hands to balance body or support position)

☐ Yes

☐ No [go to question 58]

Can you recall at what age [*infant's name*] could sit without support?

____________ months or

☐ Don't know

Can [infant's name] stand without assistance? (Infant can stand in an upright position on both feet, holding onto a stable object eg furniture with both hands without leaning on it. Stands for at least 10 seconds.)

☐ Yes

☐ No [go to question 59]

At what age did [infant's name] stand without assistance?

____________ months or

☐ Don't know

Can [infant's name] do hands-knees crawling? (Infant alternately moves forward or backward on hands and knees. The stomach does not touch the supporting surface)

☐ Yes

☐ No [go to question 60]

At what age did [infant's name] do hands-knees crawling?

____________ months or

☐ Don't know

Can [*Infant's name*] walk with assistance? (Infant is in upright position, makes sideways or forward steps by holding onto a stable object eg furniture with one or both hands. Infant takes at least 5 steps in this manner)

☐ Yes

☐ No [go to question 61]

At what age did [Infant's name] walk with assistance?

____________ months or

☐ Don't know

Can [Infant's name] stand alone? (Infant stands in upright position on both feet, the legs support 100% of the Infant's weight. There is no contact with a person or object. Infant stands alone for at least 10 seconds)

☐ Yes

☐ No [go to question 62]

At what age did [Infant's name] stand alone?

____________ months or

☐ Don't know

Can [Infant's name] walk alone? (Infant takes at least five steps independently in upright position- there is no contact with a person or object)

☐ Yes

☐ No [go to question 63]

At what age did [Infant's name] walk alone

____________ months or

☐ Don't know

Does [Infant's name] shuffle on his bottom when he is moving around the room? (If the Infant is now walking- ask whether they used to bottom shuffle)

☐ Yes

☐ No

☐ Don't know

Did you regularly prop your Infant to sit (for example with cushions holding them in a sitting position)?

☐ Yes

☐ No

Don't know

Have you noticed [Infant's name] using their thumb and index finger to pick up small objects? (also called the pincer grip)

☐ Yes

☐ No [go to question 66]

At what age did you notice [Infant's name] using their thumb and index finger to pick up small objects?

____________ months or

☐ Don't know

Does your infant do any of the following behaviours and if yes, which ones?

Bye-Bye waving

Clapping

Kissing

Others (please list) _____________________

Appendix B. Accelerometer Instructions

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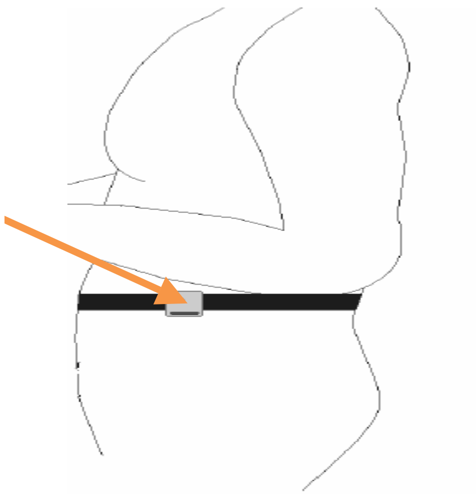
!

ACCELEROMETER)

As!part!of!the!POI!study,!we!want!to!collect!data!on!the!amount!of!sleep!and! activity!your!infant!undertakes!over!five!days!and!nights!(five!24?hour!periods).!! We!are!collecting!this!data!using!accelerometers.!

USING)YOUR)ACCELEROMETER)

The!accelerometer!should!be!worn!around!your!infant's!waist(see!photo).!If!it!is! not!worn!correctly!then!it!will!not!be!able!to!measure!sleep!and!activity!levels! properly.!The!accelerometer!can!be!worn!against!the!skin!OR!over!clothing!OR! something!like!a!'stretch!and!grow',!whichever!is!preferred.!The!strap!should!be! fitting,!but!comfortable.!Ensure!the!accelerometer!is!worn!with!the!arrow!facing! **UP)**towards!your!infant's!head.!



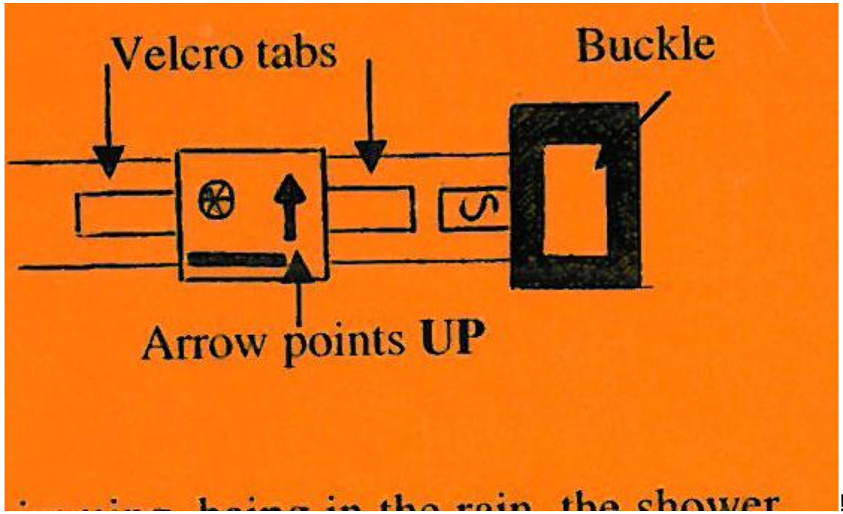
!

! ! !!!!!!! !

The!accelerometer!is!waterproof,!and!can!withstand!a!bath!or!shower,!swimming,! being!in!the!rain!etc.!However!the!damp!strap!may!be!uncomfortable!to!wear!so! we!have!provided!you!with!two!belts!so!you!can!change!the!belt!when!necessary.! There!is!a!section!on!the!'activity!sheet'!where!you!can!make!a!note!of!this.!When! putting!the!accelerometer!on!to!a!new!dry!strap,!ensure!that!it!is!put!on!with!the! arrow!pointing!**UP**!as!shown!on!the!diagram.!If!you!have!any!questions!about!the! accelerometer,!please!contact!the!POI!office!4793033.!

We!would!also!like!you!to!complete!the!sleep!diary!for!a!48!hour!period!while! your!baby!is!wearing!the!accelerometer.!!**<u>THANK)YOU</u>)**

)



!

Poi Activity monitoring:….weeks/months

Please place the monitor on your child this evening, before you put your child to bed for the night. Then please start filling out the tables below first thing tomorrow morning, when your child wakes for the day.

Date	Time out of bed	Time put to bed
Day 1		
Day 2		
Day 3		
Day 4		
Day 5		

If for any reason the monitor is removed please note the date, time frame that it was removed and why (e.g. 24/10/2010, 6.15-6.30, removed for nappy change)

Date	Time off/time back on	Reason

If your child watches TV or a DVD for at least 15 minutes at one sitting whilst wearing the monitor can you please record the details below.

Date	Time started	Time finished

Please record when your child is placed in a buggy/pram or car seat (only record if this is for at least 15 minutes) whilst wearing the monitor

Date	Time started	Time finished

When wearing the belt the arrow should always be pointing