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Correlates of tummy time in infants aged 0-12 months old: A systematic review

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Abstract

Background: Tummy time, defined as an infant being placed on their stomach whilst they are awake and supervised, has been shown to have a positive effect on infant development and head shape. Tummy time can be influenced by a number of factors. Using a social ecological model, categories of potential variables can be examined to determine their influence on behaviours such as tummy time. The purpose of this systematic review was to examine potential correlates of tummy time in infants from birth to 12 months old.

Methods: Electronic databases were originally searched between March to December 2016. Included studies needed to be peer-reviewed, written in English, and meet a priori study criteria. The population was apparently healthy infants aged from birth to 12 months old. The article needed to contain an objective or subjective measure of tummy time as a dependent variable and examine the association between a demographic, psychological, behavioral, and/or environmental variable and tummy time. For this study, tummy time could include the ability of the infant to move whilst being positioned on their stomach, for example, the infant's ability to roll from back to front, or lift their head when lying on their stomach (prone positioning ability), or the capacity, time spent, age started, or parent attitudes/ behaviours regarding the infant being placed on their stomach. The outcomes were the relationships between potential correlates and tummy time. Risk of bias was assessed at the individual study level using the Cochrane risk of bias assessment for observational studies.

Results: 15 articles representing 2372 unique participants from 7 countries were included. Correlates that were positively correlated with tummy time were age, prone sleeping, spending greater than 15 minutes whilst awake in tummy time when 2 months old, amount of time in the bath, order of achievement of prone extension and prone on elbow positions and parents/carers setting aside time for tummy time. Risk of bias of the included studies ranged from low to high.

Conclusions: Specific demographic, environmental and behavioral variables were found to be positively and negatively associated with tummy time. This evidence could assist future research regarding interventions to promote tummy time, enhance motor development, increase infant physical activity and contribute to future tummy time recommendations for parents and health care providers.

Disciplines

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Conclusions: Specific demographic, environmental and behavioural variables were found to be positively and negatively associated with tummy time. This evidence could assist future research regarding interventions to promote tummy time, enhance motor development, increase infant physical activity and contribute to future tummy time recommendations for parents and health care providers.

Keywords: tummy time, prone positioning, infant, correlate, behavioural, demographic, environmental, variable, physical activity, motor development

Background

Tummy time, defined as awake and supervised positioning on the stomach, is included in the National Academy of Medicine (IOM, 2011) and both the Canadian (Tremblay et al., 2012) and Australian Early Years (Australian Government Department of Health, 2014) physical activity recommendations for infants. As tummy time has been included in these recommendations it can be assumed that it is an important component of physical and motor development in infancy. These recommendations suggest that tummy time should be provided daily to an infant less than 6 months of age. Identifying factors that influence tummy time is therefore important in assisting parents/carers, health professionals, and early childhood educators meet these guidelines

Tummy time provides an opportunity for the infant to stimulate and enhance their motor development. Infants can be placed on their tummy from birth for short periods of supervised play. When an infant is on their tummy they are given the opportunity to practice lifting up their head, lifting up and turning their head, moving their legs and pushing up with their arms. Tummy time strengthens the infant's head, neck, shoulder and trunk muscles they will need to master motor skills such as rolling, sitting, crawling and pushing up to sit. There are some studies that have demonstrated a positive effect between tummy time and motor development (Russell et al., 2009, Salls et al., 2002b, Majnemer and Barr, 2005, Monson et al., 2003, Dudek-Shriber and Zelazny, 2007, Salls et al., 2002a). However, studies that have explored factors that influence tummy time are limited. Some potential examples of tummy time correlates may be age, sex, sleeping position, type of positioning and handling from carer, home set up, amount of time placed prone, low birth weight, gestational age, mental health issue of the carer and tolerance by the infant. In addition, studies that investigate an infant's ability to move when on their stomach (prone

positioning ability) have not been systematically reviewed. This could include the ability to roll from front to back, ability to lift their head, ability to push up with their arms, and ability to move their arms and/or legs, Combining tummy time and prone positioning ability in the search strategy will be important to ensure as many studies as possible are captured. A study using the combination of these terms is yet to be conducted. As such, both the infant's ability to move in prone (prone positioning ability) and the infant's capacity, time spent, age started, or parent attitudes/behaviours regarding the infant being placed on their stomach will be defined in this study as 'tummy time'. A number of systematic reviews have been conducted addressing the correlates of pre-school-aged children's physical activity (Hinkley et al., 2008) and sedentary behaviour (Hinkley et al., 2010). In contrast, reviews investigating correlates of infant behaviour or positioning practices are limited. Identifying what influences tummy time will be important for the development of evidence-based interventions. In addition, it will also highlight how these correlates relate to infant health indicators. Therefore, the purpose of this systematic review is to examine the correlates of objectively and subjectively measured tummy time in infants (aged 0 to 12 months) across observational study designs.

Methods

Protocol and Registration

This review was registered with the international prospective register of systematic reviews PROSPERO network (http://www.crd.york.ac.uk/prospero/): Registration no. CRD42016036931. This review followed the PRISMA statement for reporting systematic reviews and meta-analyses (Moher et al., 2009).

Inclusion and Exclusion Criteria

For an article to be included in this review, it had to be peer-reviewed, published or in press, written in English, and meet *a priori* determined population, intervention/exposure, comparator/control, and outcome (PICO) study criteria (Schardt et al., 2007) from the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework (Guyatt et al., 2011a, Guyatt et al., 2011b). Conference abstracts, book chapters, and dissertations were excluded.

Population: The population was apparently healthy (i.e., general population, including overweight/obese, but not studies that only included infants with a diagnosed medical condition with the exception of studies relating to prematurity, sudden infant death syndrome or low birth weight) infants from the ages of 0 to12 months. For studies using a longitudinal design, the age criterion applied to at least one measurement time point during the study. Observational studies and only the control group (i.e., not experienced any form of intervention) from experimental studies were reviewed and were required to have a minimum sample size of 20 participants. An article was included if it: (1) included human infants aged from birth to 12 months old; (2) contained quantitative research and had been published in an English-language, peer-reviewed journal; (3) contained a measure of tummy time and/or prone positioning ability as a dependent variable (all defined in this study as tummy time); (4) examined the association between a demographic, psychological, behavioral, and/or environmental variable and tummy time.

Intervention (exposure): Tummy time could be measured objectively (e.g., direct observation, validated measurement tool) or subjectively (e.g., proxy-report, questionnaire).

Comparator: Various levels of demographic (e.g., Age, gender), behavioral (e.g., Sleeping position, type of positioning and handling from carer, tolerance by infant), environmental

(e.g., Home set up, amount of time placed prone), or psychological factors (e.g., Depression or mental health issue of carer).

Outcomes (indicators): The outcomes were subjectively or objectively measured amount of time spent prone or tummy time or stomach or abdomen or front or belly or position*, age at which started tummy time and/or ability to move whilst on the stomach.

Information Sources and Search Strategy

Computerised searches were completed in April 2016 using MEDLINE, CINAHL, Scopus and PsycINFO. A search top-up was conducted in April 2017 to capture any articles that were not yet indexed in the search engines in April 2016. The following search terms were used: "tummy time" OR "prone" OR "position*" OR "abdomen" OR "stomach" OR "belly" OR "front" AND "correlate*" OR "determin*" OR "predictor*" OR "relationship*" OR "associate*" OR "difference*" AND "infant* OR "baby" OR "babies" OR "newborn". In addition, studies from the author's own libraries were also assessed for possible inclusion. After duplicates were removed, two researchers independently reviewed the titles of the articles to determine if they met the criteria for the systematic review. Abstract and full-text articles were then referred to clarify and confirm eligibility. Any differences in articles selected by the two researchers were discussed to reach a decision regarding inclusion. Discrepancies that could not be resolved by the two independent reviewers were resolved by discussions with a third reviewer. Reference lists of relevant reviews identified during screening were also checked for relevant studies. To capture registered clinical trials, two trial registries (https://clinicaltrials.gov/ and http://www.who.int/ictrp/en/) were searched in May 2017 using search terms for tummy time and the infant age group.

Data Extraction

The data extracted included; authors name, publication year, country, study design, sample size, characteristics of participants, tummy time measure and/or prone positioning ability measure, the correlate and type of correlate and the risk of bias. A finding was deemed to be statistically significant if $p<0.05$ was reported even if statistical significance was defined differently in the article. One reviewer completed data extraction for each included article and a second reviewer checked all data.

Quality Assessment

Risk of bias was assessed at the individual study level using the Cochrane risk of bias assessment for observational studies (Higgins, 2011). Selection bias, performance bias, selective reporting bias, detection bias, attrition bias, and other biases (e.g., inadequate control for key confounders) were assessed (Guyatt et al., 2011c). For all studies, risk of bias was assessed by one reviewer and checked by a second reviewer. Overall quality of evidence was evaluated by one reviewer and verified by the larger review team.

Results

Description of studies

After de-duplication, 1840 titles, 466 abstracts and 41 full-text articles were screened (see Figure 1). It was determined that 15 articles met the inclusion criteria. Reasons for excluding articles are summarized in Figure 1.

The 15 articles involved 2372 participants from seven different countries. An experimental study design was used in two articles; this included a randomized controlled trial (n=1) and a non-randomized intervention (n=1). An observational study design was used in the remaining 13 articles, including longitudinal (n=6), prospective cross-sectional (1), prospective cohort (1) and cross-sectional (n=5).

Time spent, tolerance of, age when first experienced and parent attitudes/knowledge of tummy time was not measured objectively in any articles and subjectively in nine articles, primarily by proxy-report questionnaire, log, or interview (Carmeli et al., 2009, Davis et al., 1998, Hesketh et al., 2015, Jennings et al., 2005, Moir et al., 2016, Ricard and Metz, 2014, Salls et al., 2002a, van Vlimmeren et al., 2007, Zachry and Kitzmann, 2011). The ability of the infant to move whilst on the stomach was only measured objectively in seven articles, primarily by validated assessment tools (e.g., prone AIMS scale, Chailey level of abilities scale, prone position) (Bartlett and Fanning, 2003, Bell and Darling, 1965, Bridgewater and Sullivan, 1999, Majnemer and Barr, 2006, Rocha and Tudella, 2008, Salls et al., 2002a) and direct observation (Horowitz and Sharby, 1988). Further information on the study design, sample size, tummy time outcome measure and correlates identified from each study are summarized in Table 1. Rules for classifying the strength of the correlate to tummy time are reported in Table 2. All correlates that are reported to have a positive or negative association with tummy time were statistically significant ($p<0.05$) and are reported in Table 3.

Demographic variables

There were four demographic variables that correlated with tummy time from 10 articles (Table 3). Age had a positive correlation with tummy time from six studies (Rocha and Tudella, 2008, Majnemer and Barr, 2006, Hesketh et al., 2015, Carmeli et al., 2009, Bridgewater and Sullivan, 1999, Salls et al., 2002a) and an unclear association in two studies (Davis et al., 1998, Moir et al., 2016). Older parents and low parent education level was found to have a negative correlation (van Vlimmeren et al., 2007, Majnemer and Barr, 2006). One third of the studies investigating a demographic variable had a high risk of bias (Table 4).

Behavioral variables

There were 16 behavioral variables that correlated with tummy time from 10 articles (Table 3). Prone sleeping (Majnemer and Barr, 2006, Davis et al., 1998, Salls et al., 2002a), the order of achievement of prone extension and prone on elbows position (Horowitz and Sharby, 1988) and parents setting aside time for tummy time (Ricard and Metz, 2014) were all positively correlated with tummy time. Interestingly, knowledge, a fearful attitude (Ricard and Metz, 2014) and receiving information from a pediatrician (Jennings et al., 2005) about tummy time had no effect. The frequency and duration of hand-mouth behaviors decreased as the ability to move whilst on the stomach improved (Rocha and Tudella, 2008). Despite these findings, almost half of the studies that had a behavioral variable had a high risk of bias (Table 4).

Environmental variables

There were 15 environmental variables that correlated with tummy time from four studies (Table 3). Among these studies, spending greater than 15 minutes in tummy time at two months of age (Salls et al., 2002a) and amount of time in the bath (Bridgewater and Sullivan, 1999) was positively correlated with tummy time. Amount of time spent awake supine (Bridgewater and Sullivan, 1999) was negatively correlated. Equipment and minutes spent exercising had no effect (Bridgewater and Sullivan, 1999, Bartlett and Fanning, 2003). Interestingly, time spent in tummy time (minutes per day) at 4 and 6 months had an indeterminate effect on the ability to move whilst on the stomach, with one study reporting a significant positive effect (Majnemer and Barr, 2006) and the other reporting no effect (Salls et al., 2002a). Both were longitudinal studies with less than 100 participants. However they used different assessment tools (AIMS prone subscale vs Denver II Gross Motor Sector) and overall the risk of bias for Salls, Silverman et al. 2002 was high whereas it was moderate for Majnemer and Barr 2006. Approximately, almost half of the studies with an environmental variable had a high risk of bias (Table 4).

Discussion

In this systematic review, evidence from 15 articles were synthesized to examine the correlates of tummy time in infants aged from birth to 12 months old. From these observational studies and control groups from experimental studies, age and prone sleeping has the strongest positive correlation with tummy time. It is not unexpected that as an infant grows older, their tummy time practices improve. However, this information can provide evidence for health professionals and encouragement to parents who report that their infant does not enjoy tummy time when they first begin to experience it. Fifty percent of parents from the study completed by Ricard and Metz 2014 reported that their infant cried, rolled/squirmed or appeared frustrated during tummy time. Anecdotally, health professionals assist parents to provide tummy time to their infants a few minutes at a time and gradually increase the demand and duration. The knowledge that tummy time improves, as the baby gets older can be a powerful tool in the early stages to persevere. Prone sleepers also had a positive correlation with tummy time. There was no indication from studies that had the correlate of prone sleeping as to why parents were not complying with the back to sleep recommendations. One study, even gave parents brochures and advised them to adhere to supine sleep positioning according to the American Academy of Pediatrics recommendation prior to entry into the study (Davis et al., 1998). However, as the sample size for the prone sleeping groups was smaller than the supine sleeping group it can be suggested that the majority of those enrolled in these studies were complying with the recommendations. The number of parents in this sample of participants who did not follow the sleep recommendations was consistent with other studies that found that approximately one third of parents who are aware of the recommendations continue to put their babies prone to sleep (Taylor and Davis, 1996, Rainey and Lawless, 1994). Despite this, parents should be

encouraged to adhere to the 'back to sleep' campaign recommendation (AAP, 1992). For safety, increasing the amount of time prone whilst the infant is awake and supervised would be recommended rather than changing the infant sleeping position. This view is supported by Pin, Eldridge et al. 2007 who reported that it is important to educate parents to continue placing their baby to sleep supine but to change their position during play time when they are awake (Pin et al., 2007).

The frequency and duration of hand-mouth behaviors decreased as the ability to move when on the stomach improved (Rocha and Tudella, 2008). To explain this, Rocha and Tudella 2008 suggest that as infants start to use their arms for support in prone they begin to visually explore their environment around them rather than exploring just their own body. Order of achievement of a prone extension position was reported by one study to be head extension, then leg extension, then arm extension and the prone on elbows position to be head extension then leg extension (Horowitz and Sharby, 1988). This correlated positively with the infant's ability to move when on the stomach. This information could be helpful to Physiotherapists and Occupational therapists assisting infants with motor development delay. Motor development interventions could be structured to achieving head extension, then leg extension and then arm extension. This is not to say that therapists cannot progress until the first one is achieved, but that motor development training could be ordered and progressed as tolerated by the infant. This information could also be helpful to parents. Being aware of the stages of achieving tummy time may assist in relieving the pressure of achieving "text book" tummy time (i.e. Head up, arms extended, happy baby on tummy) immediately or in the first few attempts.

Amount of time in the bath (Bridgewater and Sullivan, 1999) and setting aside time for tummy time (Ricard and Metz, 2014) were also positively correlated to tummy time. To our knowledge, this is the first link between bath time and tummy time. This may be a result of bath time promoting positive interactions between parents and infants, however this finding requires further investigation. The infant's position in the bath was not mentioned however increased time in the bath was associated with more mature responses from the infant of being able to lift their head in prone ($p<0.0001$) (Bridgewater and Sullivan, 1999). Having the attitude of "setting aside time for my baby to spend on his/her tummy is important" correlated with setting aside time for awake prone positioning ($p<0.01$) (Ricard and Metz, 2014). The most common factor influencing this decision for parents in this study was "helping their infants develop". Ricard and Metz 2014 suggest providing education to parents on how, when, and the significance of setting aside time for tummy time may improve daily practice of tummy time.

Variables that were detrimental to tummy time were found to be amount of time spent supine whilst awake (Bridgewater and Sullivan, 1999), having older parents (Majnemer and Barr, 2006), having less educated parents (van Vlimmeren et al., 2007) and spending less than 15 minutes per day at 2 months of age in awake and supervised tummy time (Salls et al., 2002a). From this information, health professionals could be extra vigilant in their tummy time instructions with parents who are older and/or less educated. Parents could also be informed that a minimum of 30 minutes per day spent in awake and supervised tummy time when the infant is two months old is a positive step towards starting tummy time. In addition, avoiding prolonged supine positioning could be beneficial to the infant's motor development. Some of the risk factors for deformational plagiocephaly at 7 weeks of age is experiencing tummy time less than 3 times per day and slow achievement of motor milestones (van Vlimmeren et

al., 2007). This information could be combined with the results from this study to assist parents with a more prescriptive approach to tummy time. For example, when your baby is two months old, they could be receiving tummy time more than 30 minutes per day. This could be broken up into small amounts (for example, more than 3 times per day) adding up to more than 30 minutes. Proclaiming a specific goal to reach could be helpful to assist parents to determine if their baby is getting enough tummy time and exposes tools or equipment that would assist to meet it. For example, using a timer or diary to record their sessions, having a space, play mat and suitable toys ready.

A number of research gaps and limitations to address in future research also warrant attention. For instance, as all included articles were observational studies, they lack the rigor of a randomized controlled trial and will all score high on risk of bias. The final outcomes found in this study (positive and negative correlates described in Table 3) are drawn from only 11 studies. As such, findings from this review should be interpreted with caution. In addition, there were no objective measures of the time spent in tummy time. All were based on parent questionnaires or position logs. Future research into objective measures of tummy time using real time measurement devices is yet to be conducted. The majority of studies (75%) had a high selection bias. As such, information from these studies may not be generalizable to other cultures and/or socio economic groups. As there were no psychological variables found, further research could be conducted examining the effect of depression or mental health issue of the parent or carer with the aim to further target populations more in need of specific interventions. As tummy time and prone positioning ability were used as combined terms in this study, it is important to note that the correlates found are from studies investigating tummy time and/or prone positioning ability, further analysis would be required to separate out these two terms. Lastly, having English language limits for feasibility was

also a limitation as it is possible that studies published in other languages may have provided additional correlates not discovered by this review.

Conclusions

This review synthesized low quality evidence from 15 studies on the correlates of tummy time. Age, prone sleeping, greater than 15 minutes daily of tummy time at two months, amount of time in the bath, order of achievement of prone extension and prone on elbows position, parent education level and setting aside time for tummy time were all positively correlated. Time spent supine, age of the parent and duration and frequency of hand mouth behaviors were all negatively correlated to tummy time. This information could be used to assist health professionals target intervention groups and specify intervention techniques. Good quality studies would be beneficial to strengthen the evidence base and inform future research aimed at improving motor development and physical activity for infants.

List of Abbreviations

IOM: Institute of Medicine; PROSPERO: International Prospective Register of Systematic Reviews; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PICO: Population Intervention Control Outcome; GRADE: Grading of Recommendations, Assessment, Development, and Evaluation; MEDLINE: Medical Literature Analysis and Retrieval System Online; CINAHL: Cumulative Index of Nursing and Allied Health Literature; Scopus: Bibliographic database for academic journal articles; PsycINFO: Psychological Information Database; HRE: Head righting - extension; AWBTS: Active weight bearing through shoulders; AIMS: Alberta Infant Motor Scale; AAP: American Academy of Pediatrics.

Declarations

Ethics Approval and Consent to Participate: Not applicable.

Consent for Publication: Not applicable.

Availability of Data and Material: Not applicable.

Competing Interests: The authors declare that they have no competing interests.

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Authors' Contributions: LH led the design and coordination of the review. ADO conceived of the study. ADO, RS and LH conducted the screening of the records, and appraised the quality of evidence. LH extracted the data, analyzed, interpreted the data and drafted the manuscript. All authors were responsible for revising the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

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Table 1. Descriptive information of included studies (Ordered alphabetically)

Author	Country	Sample size	Sex (B, G)	Age at measurement	Design	Tummy time outcome measure	Correlates of tummy time identified	Type of correlate (Social Ecological Framework Domain Association)
(Bartlett and Fanning, 2003)	Canada	60	28, 32	8.08 months (corrected)	Observational	Prone AIMS subscale	- Amount of equipment use (jolly jumper, walker, exersaucer, seat, swing, backpack, carried, other, total equipment), n.s	- Environmental
(Bell and Darling, 1965)	USA	75	41, 34	Birth to 4 days old	Observational	Prone Head Reaction (PHR) by an 11 point scale	- Sex, n.s - Method of feeding (Breast or bottle fed)	- Demographic - Behavioural
(Bridgewater and Sullivan, 1999)	Australia	26	13, 13	14 to 18 weeks	Observational	Movement Assessment of Infants (MAI): Head righting (Extension) and active weight bearing through shoulders	- Age, $p<0.001$ - Bath time, $p<0.001$ - Amount of time spent supine, negative correlation, $p<0.05$ - Exercise, n.s. - Capsule/cuddle, n.s	- Demographic - Environmental - Environmental - Environmental - Environmental - Environmental
(Carmeli et al., 2009)	Israel	80	80, 0	Birth to 26 weeks	Longitudinal	Position log completed by parents	- Age, $p=0.03$ - AIMS percentile, prone subscale, n.s	- Demographic - Behavioural
(Davis et al., 1998)	USA	400	49%, 51%	1 week to 6 months	Longitudinal	Position log completed by parents	- Prone sleeping ($p <0.003$) - Age, no p value given	- Behavioural - Demographic
(Hesketh et al., 2015)	Australia	542	285, 257	4 and 9 months	Longitudinal	Questionnaire to the Mother	- Age, $p<0.001$	- Demographic
(Horowitz and Sharby, 1988)	USA	20	10, 6	8 to 28 weeks (every 2 weeks)	Longitudinal	Direct observation, prone positioning ability	- Order of achievement of prone extension posture (head and limb positions) was head, lower extremity, upper extremity ($p<0.001$) - Order to achieve prone on elbows position was head and lower extremity ($p<0.01$) - Upper extremity extension not required to achieve prone on elbows position (n.s) - Prone on hands position not correlated with head, lower or upper extremity extension (n.s)	- Behavioural
(Jennings et al., 2005)	USA	27 *control group only	Not given	6 months	Non-randomized intervention	Parent survey	- Parent receiving positioning information from the paediatricians office, no p value	- Behavioural

(Majnemer and Barr, 2006)	Canada	72	32, 40	6 months	Longitudinal	- Prone AIMS subscale - Motor milestones (AIMS) (% achieved): Rolling prone to supine - Prone AIMS subscale	- Prone sleeping, p<0.005 - Prone sleeping, p<0.02 - Mean daily exposure to prone position (minutes/day), p<0.01	- Behavioural - Behavioural - Environmental
(Majnemer and Barr, 2006)	Canada	83	42, 41	4 months	Longitudinal	Prone AIMS subscale	- Prone sleeping, p<0.002 - Mean daily exposure to prone position (minutes/day), p<0.05 - Older parents, negative, p<0.01 - Age, p<0.0001	- Behavioural - Environmental - Demographic - Demographic
(Moir et al., 2016)	New Zealand	209 *control group only	98, 111	4 and 6 months	Randomized controlled trial	Parent questionnaire	- Age, no p value	- Demographic
(Ricard and Metz, 2014)	USA	87	Not provided	3 months	Observational	Parent questionnaire	- Knowledge of prone positioning, p>0.05 - Fearful attitude towards prone position, p>0.05 - Setting aside time for prone positioning, p<0.01	- Behavioural - Behavioural - Behavioural
(Rocha and Tudella, 2008)	Brazil	40	16, 24	Newborn, 1, 2, 3 and 4 months	Prospective cross-sectional study	Chailey level of abilities scale, prone position	- Frequency of hand-mouth behaviour, negative, p<0.001 - Duration of hand-mouth behaviour, negative, p=0.005 - Age, p<0.001	- Behavioural - Behavioural - Demographic
(Salls et al., 2002a)	USA	66	Not provided	2, 4 and 6 months	Longitudinal	Parent questionnaire Denver II Gross Motor Sector, (head up 45deg, head up 90deg, chest up-arm support	- Age, no p value, unknown if significant - Awake time in prone >15mins at 2 months old, p<0.05 - Awake time in prone <15 minutes at 2 months old, p<0.05 - Awake time in prone < or > 15 minutes, 4 and 6 months, p> 0.05 - Sleeping position at 2 months - Sleeping position at 4 months	- Demographic - Environmental - Environmental - Environmental - Behavioural - Behavioural
(van Vlimmeren et al., 2007)	Netherlands	380	178, 202	7 weeks	Prospective cohort study	Parent questionnaire, gave their infant tummy time for the first time at >=3 weeks of age	- Low education level, negative, significant but no p value given	- Demographic
(Zachry and	USA	205	42%, 52%	2 weeks to 24	Observational	Parent questionnaire	- Tolerance of tummy time in	- Behavioural

Kitzmann, 2011)	months (range)	minutes, ?, no p value - Intolerance of tummy time in minutes, ? no p value - Caregiver awareness of tummy time, ? no p value	 - Behavioural - Behavioural

Table 2. Rules for classifying variables regarding strength of association with tummy time

Studies supporting association (%)	Summary code	Explanation of code
0-33	0	No association
34-59	?	Indeterminate/inconclusive association
60-100	+	Positive association
60-100	–	Negative association

Note: When an outcome was found four or more times, it was coded as: 00 (no association); ?? (indeterminate); ++ (positive association); or – – (negative association) (Tonge et al., 2016)

Table 3. Summary of reported correlates – tummy time

Correlate	Investigated an association with tummy time (reference)	Association (0, ?, – or +)	Summary coding for studies with an association (n/N; %)	Summary code for association (– /+)
Demographic variables				
Age	(Rocha and Tudella, 2008) (Majnemer and Barr, 2006) (Hesketh et al., 2015) (Davis et al., 1998) (Carmeli et al., 2009) (Bridgewater and Sullivan, 1999) (Bridgewater and Sullivan, 1999) (Moir et al., 2016) (Salls et al., 2002a)	+, p<0.001 +, p<0.0001 +, p<0.001 ?, no p value given +, p=0.03 +, p<0.001 (HRE) +, p<0.01 (AWBTS) ?, no p value given ?, no p value given, unknown if significant	6/9 (67%)	++
Male infant	(Bell and Darling, 1965) (Bell and Darling, 1965)	0, n.s but no p value given +, p<0.01	1/2 (50%)	?
Low parent education level	(van Vlimmeren et al., 2007)	-, significant but no p value given	1/1(100%)	–
Older parents	(Majnemer and Barr, 2006)	-, p<0.01	1/1, (100%)	–
Behavioural variables				
Method of feeding (breast or bottle)	(Bell and Darling, 1965)	?	1/1 (100%)	?
AIMS percentile, prone subscale	(Carmeli et al., 2009)	0, n.s	0/1, (0%)	0
Prone sleeping	(Majnemer and Barr, 2006) (Majnemer and Barr, 2006) (Majnemer and Barr, 2006) (Davis et al., 1998) (Salls et al., 2002a) (Salls et al., 2002a)	+, p<0.002 +, p<0.02 +, p<0.02 +, p<0.003 +, p<0.05, 2 months old 0, p>0.05, 4 months old	5/6 (83%)	++
Order of achievement of prone extension posture (head and limb positions) was head, lower extremity, upper extremity	Horowitz and Sharby 1998	+, p<0.001	1/1 (100%)	+
Order to achieve prone on elbows position was head and lower extremity	Horowitz and Sharby 1998	+, p<0.01	1/1 (100%)	+
Upper extremity extension not required to achieve prone on elbows position	Horowitz and Sharby 1998	0, n.s	0/1 (0%)	0

Prone on hands position not correlated with head, lower or upper extremity extension	Horowitz and Sharby 1998	0, n.s	0/1 (0%)	0
Parent receiving positioning information from the paediatricians office	(Jennings et al., 2005)	0, no p value	0/1 (0%)	0
Knowledge of prone positioning	(Ricard and Metz, 2014)	0, p>0.05	0/1 (0%)	0
Fearful attitude towards prone position	(Ricard and Metz, 2014)	0, p>0.05	0/1 (0%)	0
Setting aside time for prone positioning	(Ricard and Metz, 2014)	+, p<0.01	1/1 (100%)	+
Frequency of hand-mouth behaviour, negative	(Rocha and Tudella, 2008)	-, p<0.001	1/1 (100%)	–
Duration of hand-mouth behaviour	(Rocha and Tudella, 2008)	-, p=0.005	1/1 (100%)	–
Tolerance of tummy time in minutes	(Zachry and Kitzmann, 2011)	?, no p value	1/1 (100%)	?
Intolerance of tummy time in minutes	(Zachry and Kitzmann, 2011)	?, no p value	1/1 (100%)	?
Caregiver awareness of tummy time	(Zachry and Kitzmann, 2011)	?, no p value	1/1 (100%)	?
Environmental variables				
Awake time in prone >15mins at 2 months old	(Salls et al., 2002a)	+, p<0.05	1/1 (100%)	+
Mean daily exposure to prone position (minutes/day), 4 months	(Majnemer and Barr, 2006)	+, p<0.05	2/4 (50%)	?
Mean daily exposure to prone position (minutes/day), 6 months	(Majnemer and Barr, 2006)	+, p<0.01		
Awake time in prone (< or > 15minutes per day), 4 months	(Salls et al., 2002a)	0, p>0.05		
Awake time in prone (< or > 15minutes per day), 6 months	(Salls et al., 2002a)	0, p>0.05		
Amount of time spent supine	(Bridgewater and Sullivan, 1999)	-, p<0.05 (AWBTS)	1/1 (100%)	–
Amount of time in the bath	(Bridgewater and Sullivan, 1999)	+, p<0.001	1/1 (100%)	+

Minutes spent experiencing exercise	(Bridgewater and Sullivan, 1999)	0, n.s	0/1 (0%)	0
Amount of time in capsule/cuddle	(Bridgewater and Sullivan, 1999)	0, n.s	0/1 (0%)	0
Amount of time in jolly jumper	(Bartlett and Fanning, 2003)	0, n.s	0/1 (0%)	0
Amount of time in walker	(Bartlett and Fanning, 2003)	0, n.s	0/1 (0%)	0
Amount of time in exersaucer	(Bartlett and Fanning, 2003)	0, n.s	0/1 (0%)	0
Amount of time in seat (e.g., highchair, infant seat, bouncer seat, car seat – other than for meals)	(Bartlett and Fanning, 2003)	0, n.s	0/1 (0%)	0
Amount of time in swing	(Bartlett and Fanning, 2003)	0, p=0.24 *excludes outlier	0/1 (100%)	0
Amount of time in backpack	(Bartlett and Fanning, 2003)	0, n.s	0/1 (0%)	0
Amount of time carried	(Bartlett and Fanning, 2003)	0, n.s	0/1 (0%)	0
Amount of time in other equipment not mentioned above	(Bartlett and Fanning, 2003)	0, n.s	0/1 (0%)	0
Amount of time use total equipment	(Bartlett and Fanning, 2003)	0, n.s	0/1 (0%)	0

n.s: not significant

Table 4. Risk of bias of included studies

Author	Were the participants likely to be representative of the chosen population? (Selection bias)	Did an adequate proportion of those consenting to participate in the study have complete data (i.e. no more than 20% of data missing from a cross sectional study and no more than 30% for a longitudinal study) (Attrition bias)	Did the study report the sources and details of the type of tummy time measurement tool used in the study? AND did the study report adequate reliability and/or validity of this measurement tool used in the study (Detection bias)	Did the study report the sources and details of the type of correlate measurement tool used in the study? AND did the study report adequate reliability and/or validity of this measurement tool used in the study (Performance bias)	Did the study have incomplete or absent reporting of some outcomes and not others on the basis of the results? (Selective reporting bias)	Other sources of bias
(Bartlett and Fanning, 2003)	High	Low	High	Low	Low	Low
(Bell and Darling, 1965)	High	High	Low	Low	High	Low
(Bridgewater and Sullivan, 1999)	High	Low	Low	High	Low	Low
(Carmeli et al., 2009)	High	Low	Low	High	Low	High
(Davis et al., 1998)	High	Low	High	Low	Low	Low
(Gajewska and Sobieska, 2015)	High	Low	Low	Low	Low	Low
(Hesketh et al., 2015)	Low	Low	Low	Low	Unclear	Low
(Horowitz and Sharby, 1988)	High	Low	Low	Low	Low	Low
(Jennings et al., 2005)	High	High	High	Low	Low	Low
(Majnemer and Barr, 2006)	High	Low	Low	High	Low	Low
(Moir et al., 2016)	Low	Low	High	Low	Low	Low
(Ricard and Metz, 2014)	High	High	High	High	Low	Low
(Rocha and Tudella,	Unclear	Low	Low	Low	Low	Unclear

2008)						
(Salls et al., 2002a)	High	High	High	Low	High	High
(van Vlimmeren et al., 2007)	High	Low	High	Low	Low	Unclear
(Wen et al., 2011)	Low	Low	High	Low	Low	High
(Zachry and Kitzmann, 2011)	High	High	High	High	High	High

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