Tummy Time and Infant Health Outcomes: A Systematic Review

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abstract

CONTEXT: The World Health Organization recommends tummy time for infants because of the benefits of improved motor development and reduced likelihood of plagiocephaly. Because of poor uptake of these recommendations, the association of tummy time with other health outcomes requires further investigation.

OBJECTIVE: To review existing evidence regarding the association of tummy time with a broad and specific range of infant health outcomes.

DATA SOURCES: Electronic databases were searched between June 2018 and April 2019.

STUDY SELECTION: Peer-reviewed English-language articles were included if they investigated a population of healthy infants (0 to 12 months), using an observational or experimental study design containing an objective or subjective measure of tummy time which examined the association with a health outcome (adiposity, motor development, psychosocial health, cognitive development, fitness, cardiometabolic health, or risks/harms).

DATA EXTRACTION: Two reviewers independently extracted data and assessed their quality.

RESULTS: Sixteen articles representing 4237 participants from 8 countries were included. Tummy time was positively associated with gross motor and total development, a reduction in the BMI-*z* score, prevention of brachycephaly, and the ability to move while prone, supine, crawling, and rolling. An indeterminate association was found for social and cognitive domains, plagiocephaly, walking, standing, and sitting. No association was found for fine motor development and communication.

LIMITATIONS: Most studies were observational in design and lacked the robustness of a randomized controlled trial. High selection and performance bias were also present.

CONCLUSIONS: These findings guide the prioritization of interventions aimed at assisting parents meet the global and national physical activity guidelines.

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Dr Hewitt conceptualized and designed the study, conducted the screening of records, appraised the quality of evidence, extracted, analyzed, and interpreted the data, drafted the initial manuscript, and reviewed and revised the manuscript; Ms Kerr conducted the screening of the records, appraised the quality of evidence, extracted, analyzed, and interpreted the data, and critically reviewed the manuscript for important intellectual content; Drs Stanley and Okely supervised data collection and critically reviewed the manuscript for important intellectual content; and all authors approved the final manuscript as submitted.

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In 1992, the American Academy of Pediatrics recommended that infants be placed supine to sleep.[1] This was due to the high incidence of sudden infant death syndrome (SIDS) caused from prone sleeping.[1] This became known as the Back to Sleep campaign, which contributed to a 40% decrease in SIDS incidence in the United States.[2] However, although the incidence of SIDS was reduced, infants placed supine to sleep had slower achievement of their motor milestones[3,4] and an increased occurrence of head-shape abnormalities.[5] To counteract these effects, parents were encouraged to provide their infants with tummy time.[6] Tummy time is a form of physical activity recommended for infants <6 months of age. It is defined as awake prone positioning on the floor that is encouraged and supervised by an adult.[7] Because studies have demonstrated a positive association between tummy time and gross motor development,[8–12] tummy time is a component of the national movement guidelines in Australia, the United Kingdom, Canada, and South Africa.[13–16] It is also a component of the guidelines from the National Academy of Medicine[17] and the American Academy of Pediatrics[18]; and is included in the World Health Organization global guidelines for physical activity, sedentary behavior, and sleep for children <5 years of age.[19] Thirty minutes of tummy time spread over a 24-hour period is recommended to optimize healthy growth and development.

Evidence shows that only ~30% of parents and 75% of child care educators adhere to these recommendations.[20,21] The potential benefits of tummy time outlined in the current physical activity guidelines include the effect of tummy time on an infant's gross motor development. Whereas, the effects of tummy time on individual aspects of motor development are not currently highlighted. Research in which the association of tummy time with specific aspects of motor development (such as the ability to move while prone, including the ability to roll, sit, or walk) is investigated has not yet been systematically reviewed. Additionally, the association of tummy time with other infant health outcomes, such as adiposity, psychosocial health, cognitive development, fitness, and cardiometabolic health, is currently unknown because current evidence regarding tummy time interventions is focused primarily on motor development and head shape.[21–23] A previous review investigating the effect of tummy time on other infant health outcomes has been conducted.[24] However, to be included in this systematic review, the minimum sample size was 100 participants for observational studies. As such, only 2 studies were found relating to tummy time. One study revealed a positive effect on motor development,[23] and the other study revealed a protective effect against deformational plagiocephaly.[25] Some of the health benefits that may be present in other smaller studies may be a decrease in BMI in older children, fine motor skill development, cardiovascular fitness, bone mineral density, and a reduction in other head-shape abnormalities such as brachycephaly.

The early years are a crucial period of physical, cognitive, social, and emotional development.[24,26] Identifying the association of tummy time with specific aspects of motor development as well as other health outcomes is important for the development of evidence-based interventions and may assist parents and educators in meeting the recommended guidelines of 30 minutes per day. Our purpose for this systematic review was to determine the association of tummy time with infant health outcomes across experimental and observational study designs.

METHODS

Registration

A systematic review of the literature was undertaken on the association of tummy time with infant health outcomes. It was prospectively registered with PROSPERO, the International Prospective Register of Systematic Reviews (http://www.crd.york.ac.uk/prospero; identifier CRD42017075156) and was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[27]

Search Strategy

Computerized searches of databases were completed in May 2018 and May 2019 by using Medline, Cumulative Index to Nursing and Allied Health Literature, Scopus, and PsycINFO. The search was limited to titles and abstracts containing "all infant (birth to 23 months)" and English and humans. The Scopus search strategy was as follows: (TITLE-ABSKEY(("tummy time" OR tummy OR prone OR position* OR abdomen OR stomach OR belly OR front)) AND TITLEABS-KEY(effect* OR result* OR influence* OR impression* OR appear* OR achieve* OR consequence* OR outcome* OR conclusion* OR correlat* OR determin* OR predictor* OR relationship* OR associate* OR difference*) AND TITLE- ABS-KEY((infant* OR baby OR babies OR newborn))) AND (LIMIT-TO(DOCTYPE,"ar") OR LIMIT-TO(DOCTYPE,"re") OR LIMIT-TO(DOCTYPE,"ip")) AND (LIMIT TO(EXACTKEYWORD,"Human") OR LIMIT TO(EXACTKEYWORD,"Humans")) AND (LIMIT- TO(LANGUAGE,"English")). The following search terms (keywords) were used: "tummy time" OR "tummy" OR "prone" OR "position*" OR "abdomen" OR "stomach" OR "belly" OR "front" AND "effect*" OR "result*" OR "influence*" OR "impression*" OR "appear*" OR "achieve*" OR

"consequence*" OR "outcome*" OR "conclusion*" OR correlat* OR determin* OR predictor* OR relationship* OR associat* OR difference* OR investig*. Duplicates were removed by using EndNote software, and the search output was screened manually also by using EndNote. After duplicates were removed, two researchers independently reviewed the titles of the articles to determine if they met the criteria for inclusion. Abstracts and full-text articles were then studied to clarify and confirm eligibility. Any differences between reviewers were discussed to reach consensus regarding inclusion. 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 2018 and May 2019 by using the search term "tummy time" and the infant age group.

Inclusion and Exclusion Criteria

To be included in this review, the article was required to be peer-reviewed, be published or in press, be written in English, and meet the predetermined study criteria (see Supplemental Information). The review was based on the population, intervention or exposure, comparator or control, and outcome study criteria[28] from the Grading of Recommendations Assessment, Development, and Evaluation framework.[29,30] Conference abstracts, book chapters, and dissertations were excluded.

Population, Intervention, Comparator, and Outcome

The population chosen to review was apparently healthy (ie, general population) infants aged from 0 to 12 months old. Studies that only included children with a diagnosed medical condition (eg, Down syndrome), with the exception of studies relating to prematurity, SIDS, or low birth weight, were excluded. If an age range was described rather than the mean age, infants up to 12 months of age were included. If a mean age or age range was not reported, participants who were described as infants and newborns were included. For longitudinal or experimental studies, the age criterion is unlimited for the outcome measures; however, the intervention must have taken place while the infant was between the ages of 0 and 12 months old. Experimental and observational studies were required to have a minimum sample size of 15 (in 1 intervention group) and 30 participants, respectively.

The interventions comprised different durations, frequencies, patterns, types, and intensities of tummy time and/or prone positioning when awake. Tummy time was defined as awake and supervised prone positioning. Prone positioning ability was defined as an infant's ability to move their body when placed on their stomach. This could include the ability to roll from front to back, the ability to lift their head, the ability to push up with their arms, and the ability to move their arms and/or legs.[31] Studies in which only prone positioning during prone sleeping was investigated were excluded. Tummy time and/or prone positioning ability could be measured objectively (eg, accelerometer, direct observation) or subjectively (eg, proxy report). For experimental studies, interventions targeting tummy time and/or prone positioning exclusively were included. Interventions targeting multiple health behaviors (eg, tummy time and breastfeeding) were not included to avoid over- or underreporting the effect of tummy time on an infant health outcome from a combined intervention.

The comparators were objective (eg, accelerometer) or subjective (eg, proxy report, questionnaire) measures of tummy time and/or prone positioning ability from an observational or experimental study.

The outcomes were various health outcomes; for example, adiposity (eg, overweight, obesity, BMI), motor development (eg, gross motor skills, fine motor skills, specific components of a motor skill, locomotor and object control skills), psychosocial health (eg, self-efficacy, self-esteem, prosocial behavior, social functioning, depressive symptoms, anxiety symptoms), cognitive development (eg, language development, attention, executive functioning), fitness (eg, cardiovascular fitness, musculoskeletal fitness), bone and skeletal health (eg, bone mineral density, bone mineral content, skeletal area, vitamin D), cardiometabolic health (eg, blood pressure, insulin resistance, blood lipid levels), and risks and/or harms (eg, injury, plagiocephaly).

Data Extraction

Data extracted included authors' names, publication year, country, study design, sample size, characteristics of participants, tummy time measure, health outcome measure, type of health outcome, association of tummy time with an infant health outcome, and the risk of bias. A finding was deemed to be statistically significant if $P < .05$. Two reviewers completed data extraction for each included article and cross-checked the findings.

Quality Assessment

Risk of bias was assessed at the individual study level by using the Cochrane risk of bias assessment for observational and intervention studies.[32] Selection bias, performance bias, selective reporting bias, detection bias, attrition bias, and other biases (eg, inadequate control for key confounders) were assessed.[33] For all studies, risk of bias was assessed independently by both reviewers and then confirmed to ensure consistency. Overall quality of

TABLE 1 Descriptive Information of Included Studies (Ordered Alphabetically)

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-*z*; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
Aarnivala et al, 2016[35]	Finland	Longitudinal	52, 47	3, 6, 12 mo	Questionnaire	Daily time spent prone on the floor when awake (h)	2	Three-dimensional stereophotogrammetry (CI for brachycephaly and OCLR for plagiocephaly)	Hours per day prone on the floor when awake (effect of tummy time on skull deformation after 3 mo of age): a significant decrease in CI scores ($P < .01$); no association with OCLR ($P > .05$)	Positive (beneficial) for brachycephaly; neutral for plagiocephaly
Carmeli et al, 2009[39]	Israel	Longitudinal	80, 0	1, 3, 6 mo	Position log	Preferred position to be awake and to play in; whether infant spent <15 or >15 min in the prone position each day	1	AIMS	No significant association of preferred play position or time in play position with motor development	Neutral for AIMS percentile distribution; AIMS prone and supine categories analyzed separately
Davis et al, 1998[3]	United States	Longitudinal	172, 179	1 wk, 1–6 mo	Position log	Percentage of time the infant spent in the prone position while awake (measured as h/d)	1	Attainment of infant motor milestones (rolls prone to supine, rolls supine to prone, sits supported [tripod], sits unsupported, transfers objects, creeping [pulling self along on abdomen], crawling [moving on hands and knees or hands and feet with trunk off the ground], pulls to stand, walks 10–15 steps independently)	Increased prone playtime (supine-sleeping infants only) was significantly associated with earlier attainment of supported sitting (tripod), sitting unsupported, crawling, and pulling to stand ($P < .05$). However, when maternal education, race, sex, birth wt, and No. older siblings were controlled for, the difference was significant only for pulling to stand ($P < .01$).	Positive for supported sitting (tripod), sitting unsupported, crawling, and pulling to stand; neutral for rolling prone to supine, rolling supine to prone, transferring small objects between hands, creeping, and walking

TABLE 1 Continued

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-*z*; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
Dudek-Shriber and Zelazny, 2007[9]	United States	Observational	48, 52	Mean (SD): 134.8 (9.2) d	Questionnaire	Amount of time in a typical 24-h period that the infant spent on their tummy while awake	1	AIMS	Time spent in prone position while awake when 4 mo old was significant to predict the achievement of forearm support 1 (elbows in line with shoulders) (P =.001), forearm support 2 (elbows in front of shoulders) ($P < .001$), extended arm support ($P < .001$), rolling prone to supine ($P < .001$), swimming ($P < .001$), reaching (P = .004), pivoting (P = .001), supine hands to knees (P = .016), supine active extension (P = .001), rolling supine to prone without rotation (P = .003), sitting propped with arms ($P < .001$), unsustained sitting ($P < .001$), and sitting with arm support (P = .001). Infants who spent more time awake in a prone position at 4 mo old achieved their expected milestones significantly more compared with infants who spent less time awake in	Positive for forearm support 1, forearm support 2, extended arm support, rolling prone to supine, swimming, reaching, pivoting, supine hands to knees, supine active extension, rolling supine to prone, sitting propped with arms, unsustained sitting, and sitting with arm support

TABLE 1 Continued

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-*z*; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
									a prone position ($P <$ .001).	
Jennings et al, 2005[34]	United States	Nonrandomized intervention	41, 37	6, 18 mo	Questionnaire	Regularity of placing infant in prone for play (seldom; sometimes: <1 time a d; frequently: 1 time a d; routinely: >1 time a d); age of infant when started placing them prone for playtime	1	PDMS	Infants placed in prone to play before the age of 6 mo achieved a significantly higher locomotion score when 18 mo old ($P =$ .015). Infants <174 d old who had tummy time routinely (more than once per day) had significantly higher locomotion scores than other infants in the youngest group who were seldom placed prone to play ($P =$ .0012) or who were placed prone less than once per day ($P =$ .0367). There was no significant difference in locomotion scores for infants older than 174 d who were placed seldom, sometimes, frequently, or routinely in a prone position to play.	Positive for locomotion (had tummy time before 6 mo of age) and locomotion (infants < 174 d old when they received tummy time more than once per day)

TABLE 1 Continued

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-*z*; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
Koren et al, 2019[36]	United States	Longitudinal	70, 49	2, 4 mo	Telephone survey	Minutes of tummy time per day	1, 3	PDMS 2 (attainment of gross and fine motor development) and BMI-*z*	There was a significant association between development, level of BMI-*z*, and time spent in tummy time at 2 mo of age ($P <$ .0001). There was a higher percentage of 2-mo-old infants reaching developmental milestones if they had more tummy time and if controlling for BMI-*z*. More time in tummy time resulted in a higher percentage of infants achieving prone developmental milestones, such as lifting head ($P =$ .0001), turning head ($P =$ .0033), looking when talked to ($P \leq$ 0.0001), bringing hand to mouth ($P =$ .0284), and kicking on tummy ($P =$ .0006). But the outcome was neutral for moves arms when on tummy ($P =$ .1072). There was a decline in the BMI-*z* at 4 mo as daily tummy time at 2 mo increased past the threshold of 12 min/d. Tummy time duration at 2 mo of age was a significant predictor of BMI-*z* at 4 mo ($P =$ .0412).	Positive for attainment of prone motor milestones (lifting head, turning head, looking when talked to, bringing hand to mouth, and kicking on tummy), decrease in BMI-*z* at 4 mo (tummy time >12 min at 2 mo), and prediction of BMI-*z* at 4 mo (tummy time at 2 mo); neutral for moving arms when on tummy

TABLE 1 Continued

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-*z*; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
Kuo et al, 2008[23]	Taiwan	Longitudinal	152, 136	4, 6, 12, 24 mo	Questionnaire	Experience in prone position (awake), duration in prone play (min), and preference of wakeful prone position	1	Attainment of motor milestones (rolling, crawling on abdomen, crawling on all fours, transferring objects, sitting, and walking), GMDQ, FMDQ, and the Comprehensive Developmental Inventory for Infants and Toddlers	Prone experience: Infants with prone experience attained crawling on abdomen significantly earlier than infants without prone experience (P = .012). There was so effect on attainment of the other milestones. There was no effect on GMDQ and FMDQ. Prone duration: Infants with longer prone duration significantly achieved rolling, crawling on abdomen, crawling on all fours, and sitting earlier ($P < .0167$). There was no effect on transferring objects or walking. There was a higher 6-mo GMDQ by using the Krukal-Wallis test (P = .018). There was no effect on FMDQ. Prone preference: The prone preference group attained rolling, crawling on abdomen and crawling on all fours significantly earlier than the nonprone preference group ($P < .0167$). There was no effect on transferring objects, sitting, and	Positive for attainment of the following motor milestones: crawling on abdomen, rolling, crawling on all fours, sitting, GMDQ,; neutral for rolling, crawling on all fours, transferring objects, sitting, walking, GMDQ, and FMDQ

TABLE 1 Continued

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-*z*; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
									walking. There was a higher 6-mo GMDQ by using the Mann–Whitney *U* test ($P = .037$). There were no significant differences in FMDQ.	
Majnemer and Barr, 2005[10]	Canada	Observational	38, 33 (4 mo); 21, 29 (6 mo)	4, 6 mo	Parent diary	Duration (min/d) spent awake in prone position	1	PDMS (FMQ and GMQ), AIMS	Exposure to prone positioning while awake was significantly positively associated with the AIMS percentile at both 4 ($P < .01$) and 6 mo ($P < .0001$) of age. Exposure to prone positioning was significantly negatively associated with the FMQ at 4 mo of age ($P < .05$). Exposure to prone positioning while awake was significantly positively associated with the GMQ ($P < .001$) and FMQ ($P < .05$) at 6 mo of age.	Positive for the AIMS percentile (4 and 6 mo old), FMQ (6 mo), and GMQ (6 mo); negative for the FMQ (4 mo old)
Majnemer and Barr, 2006[40]	Canada	Observational	42, 41 (4 mo); 32, 40 (6 mo)	4, 6 mo	Parent diary	Duration (min/d) spent awake in prone position	1	PDMS (GMQ), AIMS	The mean daily exposure to prone positioning while awake (min/d) was significantly correlated with the AIMS prone raw score, total score, and percentile score at 4 mo of age ($P < .05$). The mean daily exposure to prone	Positive for the AIMS prone score (4 mo), AIMS total score (4 mo), AIMS percentile (4 mo), AIMS prone score (6 mo), AIMS percentile (6 mo), and GMQ (6 mo)

TABLE 1 Continued

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-*z*; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
									positioning while awake (min/d) was significantly correlated with the AIMS prone raw score and percentile score at 6 mo of age ($P <$ .01) as well as with the PDMS GMQ at 6 mo of age (P = .001).	
Mawji et al, 2014[37]	Canada	Prospective cohort	261, 179	9 wk (mean) 7–12 wk (range) (R R)	Questionnaire	Times per day, length of tummy time received; unclear if length of tummy time is measured in min/h or time since started tummy time	2	Argenta scale	Times per day: no result specified; length of tummy time received: no association with plagiocephaly (P = .83).	Neutral for plagiocephaly
Monson et al, 2003[11]	United States	Observational	7, 23	6 mo	Parent interview	How often infant is placed on their stomach to play (rarely: 0–1 times a day; sometimes: 2–3 times a day; frequently: ≥4 times a day)	1	AIMS	Infants who received more tummy time in a day were associated with a significantly higher AIMS raw score (P = .004), percentile score (P = .003), prone raw score ($P <$ .001), and supine raw score (P = .019). There was no significant association with the No. experiences of tummy time per day with the AIMS subscale sitting raw score (P = .24) and standing raw score (P = .79).	Positive for the AIMS total score, AIMS percentile score, AIMS prone score, and AIMS supine score; neutral for the AIMS sitting score and AIMS standing score

TABLE 1 Continued

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-*z*; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
Russell et al, 2009[8]	South Africa	Observational	59, 61	6 wk	Questionnaire	Length of time (min) spent in prone position when awake (infants were classified as prone if they spent >30 min/d in tummy time and nonprone if they spent <30 min/d in tummy time)	1	Blys development guidelines: when prone, their ability to turn head, lift head 45°, displace wt on upper trunk or thorax, actively move arms, push up on arms, have elbow behind shoulder, bear wt on hands with forearms in mid position, have hands open or not open, move anterior thigh, and extend knee <180°; when being pulled to sit: head control, presence of shoulder girdle elevation, any activity of the legs, and presence of hip flexion resistance	Spending >30 min/d in tummy time was associated with a significantly greater ability in prone head control ($P < .0001$), active movement of the arms, ($P < .0001$) and pushing up on the arms ($P < .0001$), elbow positioning in relation to the shoulder ($P = .0039$), wt bearing on hands in the mid position ($P = .0002$), anterior thigh positioning in relation to the floor ($P = .0008$), and knee extension ($P = .0334$). There was no significant association with keeping hands open or not and pull-to-sit action ($P > .05$).	Positive for head control in prone position (turn head, lift head, wt displacement of trunk), active movement of arms when prone, pushing up on arms when prone, elbow positioning in relation to the shoulder when prone, wt bearing on hands when prone, anterior thigh positioning when prone, and knee extension when prone; neutral for hands open or not open when prone, pull-to-sit action
Salls et al, 2002[12]	United States	Observational	66 in total[a]	2 mo	Questionnaire	Awake time spent in prone per day (0, 1–15, 16–30, 31–60, 61–90, 91–120, and >120 min)	1	Denver II gross motor sector: head up 45°, head up 90°, sitting with head steady, chest up with arm support, rolling over, pulling to sit (no head lag), sitting (no support)	Two-month-old infants spending ≤15 min of awake time in prone position passed the gross motor milestones at significantly lower percentages. Infants who spent >15 min/d of awake time in prone position at 2 mo of age were associated with a significantly earlier	Positive for gross motor milestones (2 mo), head up 45° (2 mo), head up 90° (2 mo), and sitting with head steady (2 mo); neutral for chest up with arm support, rolling over, pulling to sit (no head lag), and sitting with no support

TABLE 1 Continued

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-*z*; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
									achievement of head up 45°, head up 90°, and sitting with head steady. No significant association with time spent awake in prone position was noted at 4 and 6 mo of age.	
Senju et al, 2018[41]	Japan	Longitudinal	898, 906	6 mo, 1, 1.5, 2, 2.5, 3 y	Questionnaire	Ability in prone position at 6 mo old (can the infant straighten both arms and push their whole chest off the floor when on their tummy?)	1	ASQ-3	Significant difference between prone and nonprone infants in the gross motor development domain ($P < .001$), which persisted until 3 y of age ($P = .001$); in the personal-social domain ($P < .001$), which persisted until 1.5 y of age ($P = .035$); in the fine motor domain ($P < .001$), which persisted until 2 y of age ($P = .009$); in the problem-solving domain ($P < .001$), which persisted until 2 y of age ($P = .009$); in the communication domain ($P = .027$), which persisted until 1 y of age ($P = .003$); and in the ASQ-3 total score ($P < .001$), which persisted until 2 y of age	Positive for gross motor development, personal-social development, fine motor development, problem-solving, communication, and the ASQ-3 total score
Soska and Adolph, 2014[38]	United States	Observational	14, 15	6.02 mo (mean)	Parent interview	Frequency of playing with toys while prone (never,	4	Scoring of manual, visual, and oral exploration of objects by using Datavyu (a	No association between frequency of play in prone position and amount of manual,	Neutral for manual, oral, and visual exploration

TABLE 1 Continued

Author, Year	Country	Study Design	Sex (Boys, Girls), *n*	Age at Measurement	Tummy Time Outcome Measure Used	Tummy Time Outcome Measure Result	Health Outcome Measure Type (1 = Motor Development; 2 = Head Shape; 3 = BMI-z; 4 = Cognition)	Health Outcome Measure Used	Association of Tummy Time With an Infant Health Outcome	Overall Association of Tummy Time With Health Outcome (Positive, Negative, or Neutral)
						seldom, sometimes, or often)		computerized video coding software)	oral, or visual exploration overall	
van Vlimmeren et al 2007[25]	Netherlands	Longitudinal	160, 197	Birth, 7 wk	Parent interview	Positioning of infant while awake in prone position; age (wk) of infant when put in prone position to play for the first time; frequency (per d) and duration (min) of prone play when awake	2	Plagiocephalometry: plagiocephaly (oblique diameter difference index)	Infants receiving tummy time <3 times per d were at a significant risk for developing plagiocephaly at 7 wk of age (P = .02). There was no significant association between age of first tummy time (≥3 wk of age) (P = .7) and tummy time ≤5 min/d (P = .6).	Positive (beneficial) for plagiocephaly

ASQ-3, Ages and Stages Questionnaires, Third Edition; CI, Cephalic index; FMDQ, fine motor developmental quotient; FMQ, fine motor quotient; GMDQ, gross motor development quotient; GMQ, gross motor quotient; OCLR, oblique cranial length ratio; PDMS, Peabody Developmental Motor Scale.

[a] No. boys and girls not reported.

evidence was evaluated by 1 reviewer and verified by the larger review team.

RESULTS

Description of Studies

After duplicates were removed, 4233 titles, 790 abstracts, and 130 full-text articles were screened (see Fig 1). A total of 16 articles met the inclusion criteria. Reasons for excluding articles are summarized in Fig 1. The 16 articles involved 4237 participants from 8 different countries. The year of publication ranged from 1998 to 2018. An experimental study design was used in 1 article[34]; this was a nonrandomized intervention (n = 1). Observational study designs were used in the remaining 15 articles, [3,8,9,23,25,35–41]which included longitudinal (n = 8) and cross-sectional (n = 7) studies.

Tummy time was measured subjectively in all 16 included articles by using a questionnaire or parent interview (n = 12) or a position log or diary (n = 4). Parents were asked to record or describe the amount of time their infant spent in tummy time (hours or minutes per day) in 8 studies, to report the number of times per day spent in tummy time in 7 studies, to report the number of experiences spent in a prone position when awake in 3 studies, to outline their infant's preferred position in which to be awake and play in 2 studies, to identify the age at which the infant started tummy time in 2 studies, and to report their infant's ability to move while prone in 1 study. Motor development was assessed as the health outcome of interest in 12 studies,[3,8,9,23,34,36,39–41] head shape in 3 studies,[25,35,37] BMI in 1 study,[36] and cognition in 1 study.[38] The most common assessments for motor development were the Alberta Infant Motor Scale (AIMS) and the Peabody Developmental Motor Scale, which were each used in 5 studies. Further information on the study

TABLE 2 Risk of Bias (Observational Studies)

Observational Studies	Selection Bias[a]	Performance Bias[b]	Detection Bias[c]	Attrition Bias[d]	Selective Reporting Bias[e]	Other Bias[f]
Author						
Aarnivala et al[35]	High	High	Low	Low	Low	Low
Carmeli et al[39]	High	High	Low	Low	High	High
Davis et al[3]	High	High	Low	Low	Low	Low
Dudek-Shriber et al[9]	High	High	Low	Low	Low	Low
Koren et al[36]	High	High	Low	Low	Low	Low
Kuo et al[23]	High	High	Low	Low	Low	Low
Majnemer and Barr[10]	High	Low	Low	Low	Low	Low
Majnemer and Barr[40]	High	Low	Low	High	High	Low
Mawji et al[37]	High	High	Low	Low	Low	High
Monson et al[11]	High	High	Low	Low	Low	High
Russell et al[8]	High	High	Low	Low	Low	Low
Salls et al[12]	High	High	Low	Low	High	Low
Senju et al[41]	High	High	Low	Low	Low	Low
Soska and Adolph,[38]	High	High	Low	Low	Low	Low
van Vlimmeren et al[25]	High	High	Low	Low	Low	Low

[a] How participants were selected to be in the study.
[b] How was tummy time measured? Was it a valid and reliable tool?
[c] How was the health outcome measured? Was it a valid and reliable tool?
[d] Did an adequate proportion of those consenting to participate in the study have complete data (ie, no more than 20% of data missing from a cross-sectional study and no more than 30% for a longitudinal study)?
[e] Incomplete or absent reporting of some outcomes and not others on the basis of the results.
[f] Other factors that may lead to an increased risk of bias.

design, sample size, tummy time outcome measure, and association of tummy time with the health outcome is summarized in Table 1.

The quality of included studies ranged from low to high. All studies had high selection bias due to homogenous participants in each of the studies. Most studies relied on unvalidated questionnaires or position logs to measure the amount of tummy time the infant received. However, the majority of studies used a validated tool to measure the health outcome and had <20% of participants drop out from the studies. Further information regarding risk of bias of the included studies is reported in Tables 2 and 3. Rules for classifying the strength of tummy time and a summary of the association of tummy time[31] with health outcomes are reported in Tables 4 and 5 respectively.

Association With Infant Health Outcomes

All outcomes that had a positive, neutral, or negative association with tummy time are reported in Tables 1 and 5. In general, there were 5 health and development outcomes examined, including head shape, motor development, BMI, social communication, and cognition. When separating these outcomes into more specific components, there were 16 health and development outcomes found, including brachycephaly; plagiocephaly; gross motor development; fine motor development; total development; ability to move while prone or supine, including sitting, standing, rolling, crawling, and walking; personal and/or social communication; BMI; and cognition (Table 5).

Experience in tummy time was found to have a significant positive association with an infant's total development (communication, gross

TABLE 3 Risk of Bias (Intervention Study)

Intervention Study, Author	Selection Bias		Performance Bias	Detection Bias	Attrition Bias	Reporting Bias	Other Bias
	Was the Allocation Sequence Adequately Generated?	Was Allocation Adequately Concealed?	Blinding of Participants, Personnel, and Outcome Assessors	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	
Jennings et al[34]	High	High	High	High	High	High	High

TABLE 4 Rules for Classifying Variables Regarding Strength of Association of Tummy Time With a Health Outcome

Studies Included in Review Supporting Association, %	Summary Code	Explanation of Code
0–33	0	No association
34–59	?	Indeterminate or inconclusive association
60–100	+	Positive association
60–100	−	Negative association

When an outcome was found ≥4 times, it was coded as 00 (no association), ?? (indeterminate), ++ (positive association), or −− (negative association).

motor and fine motor development, problem-solving, and social skills), gross motor development, the ability to move while prone, supine, rolling, and crawling; a decrease in the BMI *z* score (BMI-*z*); and the prevention of brachycephaly. Seventeen positive associations of tummy time with an infant's gross motor development were found in 7 different studies, 26 positive associations of tummy time with an infant's ability to move while prone were found in 6 different studies, 6 positive associations of tummy time with an infant's ability to crawl were found in 2 different studies, and 4 positive associations of tummy time with an infant's ability to move while supine were found in 2 different studies. Indeterminate associations were found between tummy time and plagiocephaly; the ability to sit, stand, and walk; cognition; and personal and/or social domains. No association was found between tummy time and fine motor development and communication.

Head Shape

The authors of 3 studies examined the association between tummy time and head shape. Plagiocephaly and brachycephaly are defined as flattening of the side and back of the skull by external forces, respectively.[42,43] There was a significant decrease in brachycephaly scores ($P < .01$) associated with more hours per day prone on the floor when awake, but there was no association with plagiocephaly scores ($P > .05$).[35] Another study did not reveal an association between length of tummy time and plagiocephaly ($P = .83$).[37] However, it was found that infants who received tummy time <3 times per day were at greater risk to develop plagiocephaly at 7 weeks of age ($P = .02$).[25]

Motor Development

The association between physical activity and motor development was examined in 12 studies. Eleven studies revealed a positive effect, and 1 study revealed a neutral effect. One nonrandomized controlled trial revealed that infants <6 months old who had tummy time routinely (more than once per day) had significantly higher locomotion scores than other infants in the youngest group who were seldom placed prone to play ($P = .0012$) or who were placed prone less than once per day ($P = .0367$).[34] Authors of the 4 longitudinal studies reported a significant difference between prone and nonprone infants in gross motor development ($P < .001$)[41]; achievement of rolling, crawling on abdomen, crawling on fours, and sitting earlier ($P < .0167$)[23]; achievement of prone developmental milestones ($P < .01$)[36]; and earlier attainment of supported sitting, sitting unsupported, crawling, and pulling to stand ($P < .05$).[3] Interestingly, in one of these studies, the gain in motor development persisted until the child was 3 years of age ($P = .001$).[41] The 6 observational studies also revealed that infants who spent more time awake in a prone position achieved their expected milestones earlier ($P < .001$)[9] and had higher AIMS percentile and prone scores ($P < .01$)[10,11,40] compared with infants who spent less time awake in a prone position. Spending >30 minutes per day in tummy time was associated with a significantly greater ability in prone head control ($P < .0001$), active movement of the arms ($P < .0001$), pushing up on the arms ($P < .0001$), elbow positioning in relation to the shoulder ($P = .0039$), weight bearing on hands in the mid position ($P = .0002$), anterior thigh positioning in relation to the floor ($P = .0008$), and knee extension ($P = .0334$).[8] Likewise, infants who spent >15 minutes per day of awake time in a prone position at 2 months of age were more likely to achieve earlier 45° and 90° head up and were more likely to sit head steady.[12]

BMI

One study revealed a significant association between developmental milestones, level of BMI-*z*, and time spent in tummy time at 2 months of age ($P < .0001$). More time in tummy time resulted in a higher percentage of infants achieving prone developmental milestones ($P < .01$). In addition, there was an association between an increase in daily tummy time past the threshold of 12 minutes per day at age 2 months and a decline in BMI-*z* at 4 months.

Social Communication and Cognition

The authors of one study investigated the association between tummy time and communication. They found a significant difference between prone and nonprone infants in the communication domain ($P = .027$) that persisted until 1 year ($P = .003$) but no association after this age. In 2 studies, authors investigated the effect of tummy time on cognition. In one study, authors found a significant association between the infant's ability to move while prone at 6 months of age and cognition (problem-solving), which persisted until the infant was 2 years old. However, combining this result with

TABLE 5 Summary of Reported Association of Tummy Time With a Health Outcome

Health Outcome Measure	Investigated an Association of Tummy Time With the Health Outcome (Reference)	Association (0, ?, –, or +)	Association Was Found	Effect Sizes	Summary Coding for Studies With an Association, *n*/*N* (%)	Summary Code for Association (0, –, +, or ?)
Brachycephaly	Aarnivala et al, 2016[35]	+, $P < .01$	Daily time spent in tummy time (h)	Coefficient estimate −0.14; 95% CI −0.24 to 0.03	1/1 (100)	+
Plagiocephaly	Aarnivala et al, 2016[35]	0, $P > .05$	Daily time spent in tummy time (h)	No effect size given	1/3 (33)	?
	Mawji et al, 2014[37]	0, $P = .83$	Length of tummy time received (time measure not reported)	OR 0.93; 95% CI 0.61 to 1.41	—	—
	van Vlimmeren et al, 2007[25]	+, $P = .02$	Tummy time <3 times per d	OR 2.7; 95% CI 1.12 to 6.55	—	—
AIMS percentile, total score, or gross motor development	Carmeli et al, 2009[39]	0, $P > .05$	Preferred position to be awake and play in	No effect size given	17/19 (89)	++
	Dudek-Shriber and Zelazny, 2007[9]	+, $P < .001$	Daily time spent in tummy time	No effect size given	—	—
	Kuo et al, 2008[23]	+, $P = .018$	Duration in prone play (min)	$\chi^2_3 = 10.1$	—	—
	Kuo et al, 2008[23]	+, $P = .037$	Preference in wakeful prone position	Mann–Whitney *U* test = 363.5	—	—
	Kuo et al, 2008[23]	0, $P > .05$	Experience in prone position when awake	No effect size given	—	—
	Majnemer and Barr, 2005[10]	+, $P < .01$	Exposure to prone positioning when awake (AIMS percentile, 4 mo old)	Correlation matrix = 0.38	—	—
	Majnemer and Barr, 2005[10]	+, $P < .0001$	Exposure to prone positioning when awake (AIMS percentile, 6 mo old)	Correlation matrix = 0.64	—	—
	Majnemer and Barr, 2005[10]	+, $P < .001$	Exposure to prone positioning when awake (GMQ, 6 mo old)	Correlation matrix = 0.55	—	—
	Majnemer and Barr, 2006[40]	+, $P < .05$	Duration of tummy time per day (min) (AIMS total score, 4 mo old)	$r = 0.27$ to 0.33	—	—
	Majnemer and Barr, 2006[40]	+, $P < .05$	Duration of tummy time per day (min) (AIMS percentile score, 4 mo old)	$r = 0.27$ to 0.33	—	—
	Majnemer and Barr, 2006[40]	+, $P < .01$	Duration of tummy time per day (min) (AIMS percentile score, 6 mo old)	$r = 0.39$	—	—
	Majnemer and Barr, 2006[40]	+, $P = .001$	Duration of tummy time per day (min) (PDMS GMQ, 6 mo old)	$r = 0.49$	—	—
	Monson et al, 2003[11]	+, $P = .004$	Times per day given tummy time (AIMS raw score)	No effect size given	—	—
	Monson et al, 2003[11]	+, $P = .003$	Times per day given tummy time (AIMS percentile score)	No effect size given	—	—

TABLE 5 Continued

Health Outcome Measure	Investigated an Association of Tummy Time With the Health Outcome (Reference)	Association (0, ?, –, or +)	Association Was Found	Effect Sizes	Summary Coding for Studies With an Association, *n*/*N* (%)	Summary Code for Association (0, –, +, or ?)
	Salls et al, 2002[12]	+, $P < .05$	Awake time spent in prone position at 2 mo old (min)	$\chi^2_1 \geq 3.84$	—	—
	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo old (infant)	g = 1.83; 95% CI 1.67 to 2.00	—	—
	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo old (1 y of age)	g = 0.54; 95% CI 0.38 to 0.70	—	—
	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo old (1.5 y of age)	g = 0.45; 95% CI 0.29 to 0.61	—	—
	Senju et al, 2018[41]	+, $P = .001$	Ability in prone position at 6 mo old (2 y of age)	g = 0.31; 95% CI 0.15 to 0.47	—	—
	Senju et al, 2018[41]	+, $P = .001$	Ability in prone position at 6 mo old (2.5 y of age)	g = 0.36; 95% CI 0.19 to 0.52	—	—
	Senju et al, 2018[41]	+, $P = .001$	Ability in prone position at 6 mo old (3 y of age)	g = 0.33; 95% CI 0.16 to 0.49	—	—
Ability to move while prone (AIMS prone subscale, rolling prone to supine, forearm support, extended arm support, swimming, reaching, pivoting, head control in prone position, active movement of arms when prone, pushing up on arms when prone, elbow position in relation to the shoulder when prone, wt bearing on hands when prone, anterior thigh positioning in relation to the floor, knee extension when prone, keeping hands open when prone, head up 45°, head up 90°, chest up with arm support, lifting head, turning head, looking when talked to, bringing hands to mouth, kicking on tummy)	Carmeli et al, 2009[39]	0, $P > .05$	Preferred position to be awake and play in	No effect size given	26/31 (84)	++
	Majnemer and Barr, 2006[40]	+, $P < .05$	Duration of tummy time per day (min) (AIMS prone score, 4 mo old)	r = 0.27 to 0.33	—	—
	Majnemer and Barr, 2006[40]	+, $P < .01$	Duration of tummy time per day (min) (AIMS prone score, 6 mo old)	r = 0.39	—	—
	Monson et al, 2003[11]	+, $P < .001$	Times per day given tummy time (AIMS prone raw score)	No effect size given	—	—
	Davis et al, 1998[3]	0, $P > .05$	Hours per day spent in tummy time	No effect size given	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P = .001$	Daily time spent in tummy time (forearm support 1)	OR = 19.33	—	—
		+, $P < .001$		OR = 5.41	—	—

TABLE 5 Continued

Health Outcome Measure	Investigated an Association of Tummy Time With the Health Outcome (Reference)	Association (0, ?, –, or +)	Association Was Found	Effect Sizes	Summary Coding for Studies With an Association, *n*/*N* (%)	Summary Code for Association (0, –, +, or ?)
	Dudek-Shriber and Zelazny, 2007[9]		Daily time spent in tummy time (forearm support 2)			
	Dudek-Shriber and Zelazny, 2007[9]	+, $P < .001$	Daily time spent in tummy time (extended arm support)	OR = 3.60	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P < .001$	Daily time spent in tummy time (rolling prone to supine)	OR = 3.69	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P < .001$	Daily time spent in tummy time (swimming)	OR = 4.14	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P = .004$	Daily time spent in tummy time (reaching)	OR = 3.42	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P = .001$	Daily time spent in tummy time (pivoting)	OR = 4.02	—	—
	Russell et al, 2009[8]	+, $P < .0001$	Tummy time >30 min/d (turning head while prone)	No effect size given	—	—
	Russell et al, 2009[8]	+, $P < .0001$	Tummy time >30 min/d (lifting head while prone)	No effect size given	—	—
	Russell et al, 2009[8]	+, $P < .0001$	Tummy time >30 min/d (wt displacement of trunk)	No effect size given	—	—
	Russell et al, 2009[8]	+, $P < .0001$	Tummy time >30 min/d (active movement of arms)	No effect size given	—	—
	Russell et al, 2009[8]	+, $P < .0001$	Tummy time >30 min/d (pushing up on arms)	No effect size given	—	—
	Russell et al, 2009[8]	+, $P = .0039$	Tummy time >30 min/d (elbow positioning)	No effect size given	—	—
	Russell et al, 2009[8]	+, $P = .0002$	Tummy time >30 min/d (wt bearing on hands)	No effect size given	—	—
	Russell et al, 2009[8]	+, $P = .0008$	Tummy time >30 min/d (anterior thigh positioning)	No effect size given	—	—
	Russell et al, 2009[8]	+, $P = .0334$	Tummy time >30 min/d (knee extension)	No effect size given	—	—
	Russell et al, 2009[8]	0, $P > .05$	Tummy time >30 min/d (keeping hands open)	No effect size given	—	—
	Salls et al, 2002[12]	+, $P < .05$	Tummy time >15 min/d (head up 45°; 2 mo old)	$\chi_1^2 \geq 4.91$	—	—
	Salls et al, 2002[12]	+, $P < .05$	Tummy time >15 min/d (head up 90°; 2 mo old)	$\chi_1^2 \geq 8.90$	—	—
	Salls et al, 2002[12]	0, $P > .05$	Tummy time >15 min/d (chest up with arm support; 2 mo old)	$\chi_1^2 \geq 0.01$	—	—

TABLE 5 Continued

Health Outcome Measure	Investigated an Association of Tummy Time With the Health Outcome (Reference)	Association (0, ?, –, or +)	Association Was Found	Effect Sizes	Summary Coding for Studies With an Association, *n*/*N* (%)	Summary Code for Association (0, –, +, or ?)
	Koren et al, 2019[36]	+, $P = .0001$	Minutes of tummy time (lifting head)	No effect size given	—	—
	Koren et al, 2019[36]	+, $P = .0033$	Minutes of tummy time (turning head)	OR = 4.73; 95% CI 0.57 to 39.11	—	—
	Koren et al, 2019[36]	+, $P < .0001$	Minutes of tummy time (looking when talked to)	OR = 10.06; 95% CI 1.25 to 81.23	—	—
	Koren et al, 2019[36]	+, $P = .0284$	Minutes of tummy time (bringing hand to mouth)	OR = 2.7; 95% CI 0.88 to 8.36	—	—
	Koren et al, 2019[36]	+, $P = .0006$	Minutes of tummy time (kicking on tummy)	OR = 2.93; 95% CI 0.6 to 14.27	—	—
	Koren et al, 2019[36]	0, $P = .1072$	Minutes of tummy time (moving arms)	OR = 1.62; 95% CI 0.56 to 5.23	—	—
Ability in supine (AIMS supine subscale, rolling supine to prone, supine hands to knees, supine active extension)	Carmeli et al, 2009[39]	0, $P > .05$	Preferred position to be awake and play in	No effect size given	4/6 (67)	++
	Monson et al, 2003[11]	+, $P = .019$	Times per day given tummy time (AIMS supine raw score)	No effect size given	—	—
	Davis et al, 1998[3]	0, $P > .05$	Hours per day spent in tummy time	No effect size given	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P = .003$	Daily time spent in tummy time (rolling supine to prone)	OR = 2.01	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P = .016$	Daily time spent in tummy time (supine hands to knees)	OR = 1.84	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P = .001$	Daily time spent in tummy time (supine active extension)	OR = 2.21	—	—
Ability to sit (AIMS sitting subscale, supported sitting [tripod], sitting unsupported, unsustained sitting, siting with arm support, pulling to sit, sitting with head steady)	Monson et al, 2003[11]	0, $P = .24$	Times per day given tummy time (AIMS sit score)	No effect size given	7/12 (58)	??
	Davis et al, 1998[3]	+, $P < .05$	Hours per day spent in tummy time (supported sitting)	No effect size given	—	—
	Davis et al, 1998[3]	+, $P < .05$	Hours per day spent in tummy time (unsupported sitting)	No effect size given	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P < .001$	Daily time spent in tummy time (sitting propped with arms)	OR = 4.12	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P < .001$	Daily time spent in tummy time (unsustained sitting)	OR = 2.82	—	—
	Dudek-Shriber and Zelazny, 2007[9]	+, $P = .001$	Daily time spent in tummy time (sitting with arm support)	OR = 3.46	—	—
	Kuo et al, 2008[23]	+, $P < .0167$	Duration in prone play (min) (sitting earlier)	No effect size given	—	—

TABLE 5 Continued

Health Outcome Measure	Investigated an Association of Tummy Time With the Health Outcome (Reference)	Association (0, ?, –, or +)	Association Was Found	Effect Sizes	Summary Coding for Studies With an Association, *n*/*N* (%)	Summary Code for Association (0, –, +, or ?)
	Kuo et al, 2008[23]	0, $P > .05$	Preference in wakeful prone position (sitting)	No effect size given	—	—
	Salls et al, 2002[12]	+, $P < .05$	Tummy time >15 min/d (sitting with head steady; 2 mo old)	$\chi^2_1 = 5.76$	—	—
	Salls et al, 2002[12]	0, $P > .05$	Tummy time > 15 min/d (pulling to sit, no head lag; 2 mo old)	$\chi^2_1 = 1.85$	—	—
	Salls et al, 2002[12]	0, $P > .05$	Tummy time >15 min/d (sitting with no support; 2 mo old)	$\chi^2_1 = 3.00$	—	—
	Russell et al, 2009[8]	0, $P > .05$	Tummy time in min/d (pulling to sit)	No effect size given	—	—
Ability to stand (AIMS standing subscale, pulling to stand)	Monson et al, 2003[11]	0, $P = .79$	No. experiences of tummy time per day	No effect size given	1/2 (50)	?
	Davis et al, 1998[3]	+, $P < .05$	Hours per day spent in tummy time (pulling to stand)	No effect size given	—	—
Ability in or to crawl (creeping, all fours, crawling on abdomen)	Davis et al, 1998[3]	+, $P < .05$	Hours per day spent in tummy time (crawling)	No effect size given	6/7 (86%)	++
	Davis et al, 1998[3]	0, $P > .05$	Hours per day spent in tummy time (creeping)	No effect size given	—	—
	Kuo et al, 2008[23]	+, $P < .0167$	Duration in prone play (crawling on abdomen)	No effect size given	—	—
	Kuo et al, 2008[23]	+, $P < .0167$	Duration in prone play (crawling on all fours)	No effect size given	—	—
	Kuo et al, 2008[23]	+, $P = .012$	Experience in prone (crawling on abdomen)	Log rank = 6.3	—	—
	Kuo et al, 2008[23]	+, $P < .0167$	Preference in wakeful prone position (crawling on abdomen)	No effect size given	—	—
	Kuo et al, 2008[23]	+, $P < .0167$	Preference in wakeful prone position (crawling on all fours)	No effect size given	—	—
Walking	Davis et al, 1998[3]	0, $P > .05$	Tummy time, h/d	No effect size given	3/6 (50)	??
	Jennings et al, 2005[34]	+, $P = .015$	Tummy time given before 6 mo of age	No effect size given	—	—
	Jennings et al, 2005[34]	+, $P = .0012$	Tummy time given more than once per day	No effect size given	—	—
	Jennings et al, 2005[34]	+, $P = .0367$	Tummy time given less than once per day but more than seldom placed in prone	No effect size given	—	—
	Kuo et al, 2008[23]	0, $P > .05$	Duration in prone play	No effect size given	—	—
	Kuo et al, 2008[23]	0, $P > .05$	Preference of wakeful prone position	No effect size given	—	—
FMDQ, transferring small objects between hands	Davis et al, 1998[3]	0, $P > .05$	Hours per day spent in tummy time (FMDQ)	No effect size given	5/15 (33)	0

TABLE 5 Continued

Health Outcome Measure	Investigated an Association of Tummy Time With the Health Outcome (Reference)	Association (0, ?, –, or +)	Association Was Found	Effect Sizes	Summary Coding for Studies With an Association, *n*/*N* (%)	Summary Code for Association (0, –, +, or ?)
	Kuo et al, 2008[23]	0, $P > .05$	Experience in prone position when awake (FMDQ)	No effect size given	—	—
	Kuo et al, 2008[23]	0, $P > .05$	Experience in prone position when awake (transferring objects)	No effect size given	—	—
	Kuo et al, 2008[23]	0, $P > .05$	Duration in prone position when awake (FMDQ)	No effect size given	—	—
	Kuo et al, 2008[23]	0, $P > .05$	Duration in prone position when awake (transferring objects)	No effect size given	—	—
	Kuo et al, 2008[23]	0, $P > .05$	Preference of wakeful prone position (FMDQ)	No effect size given	—	—
	Kuo et al, 2008[23]	0, $P > .05$	Preference of wakeful prone position (transferring objects)	No effect size given	—	—
	Majnemer and Barr, 2005[10]	–, $P < .05$	Tummy time in min/d (4 mo old)	Correlation matrix = −0.29	—	—
	Majnemer and Barr, 2005[10]	+, $P < .05$	Tummy time in min/d (6 mo old)	Correlation matrix = 0.33	—	—
	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo of age (infant)	g = 0.48; 95% CI 0.32 to 0.63	—	—
	Senju et al, 2018[41]	+, $P = .001$	Ability in prone position at 6 mo of age (1 y of age)	g = 0.31; 95% CI 0.15 to 0.47	—	—
	Senju et al, 2018[41]	+, $P = .014$	Ability in prone position at 6 mo of age (1.5 y of age)	g = 0.21; 95% CI 0.05 to 0.37	—	—
	Senju et al, 2018[41]	+, $P = .009$	Ability in prone position at 6 mo of age (2 y of age)	g = 0.26; 95% CI 0.10 to 0.42	—	—
	Senju et al, 2018[41]	0, $P = .264$	Ability in prone position at 6 mo of age (2.5 y of age)	g = −0.07; 95% CI −0.23 to 0.09	—	—
	Senju et al, 2018[41]	0, $P = .806$	Ability in prone position at 6 mo of age (3 y of age)	g = 0.37; 95% CI −0.13 to 0.20	—	—
Rolling (unspecified direction)	Kuo et al, 2008[23]	+, $P < .0167$	Duration in prone play (min)	No effect size given	2/3 (67)	+
	Kuo et al, 2008[23]	+, $P < .0167$	Preference of wakeful prone position	No effect size given	—	—
	Salls et al, 2002[12]	0, $P > .05$	Awake time spent in prone position in min/d	$\chi^2_1 = 2.96$	—	—
Cognition (manual, oral, and visual exploration, problem-solving)	Soska and Adolph, 2014[38]	0, $P > .05$	Frequency of playing in prone position	No effect size given	4/7 (57)	?
	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo of age (infant)	g = 0.40; 95% CI 0.24 to 0.55	—	—
	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo of age (1 y of age)	g = 0.28; 95% CI 0.12 to 0.44	—	—

TABLE 5 Continued

Health Outcome Measure	Investigated an Association of Tummy Time With the Health Outcome (Reference)	Association (0, ?, –, or +)	Association Was Found	Effect Sizes	Summary Coding for Studies With an Association, *n*/*N* (%)	Summary Code for Association (0, –, +, or ?)
	Senju et al, 2018[41]	+, $P = .004$	Ability in prone position at 6 mo of age (1.5 y of age)	$g = 0.24$; 95% CI 0.08 to 0.40	—	—
	Senju et al, 2018[41]	+, $P = .009$	Ability in prone position at 6 mo of age (2 y of age)	$g = 0.22$; 95% CI 0.06 to 0.38	—	—
	Senju et al, 2018[41]	0, $P = .420$	Ability in prone position at 6 mo of age (2.5 y of age)	$g = -0.08$; 95% CI −0.25 to 0.08	—	—
	Senju et al, 2018[41]	0, $P = .878$	Ability in prone position at 6 mo of age (3 y of age)	$g = 0.01$; 95% CI −0.15 to 0.18	—	—
BMI-*z*	Koren et al, 2019[36]	+, $P = .0412$	Tummy time duration at 2 mo of age	Slope −0.0384; 95% CI −0.0752 to −0.0015	1/1 (100)	+
Communication	Senju et al, 2018[41]	+, $P = .027$	Ability in prone position at 6 mo of age (infant)	$g = 0.20$; 95% CI 0.45 to 0.35	2/6 (33)	0
	Senju et al, 2018[41]	+, $P = .003$	Ability in prone position at 6 mo of age (1 y of age)	$g = 0.25$; 95% CI 0.09 to 0.41	—	—
	Senju et al, 2018[41]	0, $P = .226$	Ability in prone position at 6 mo of age (1.5 y of age)	$g = 0.08$; 95% CI −0.08 to 0.24	—	—
	Senju et al, 2018[41]	0, $P = .888$	Ability in prone position at 6 mo of age (2 y of age)	$g = -0.02$; 95% CI −0.18 to 0.14	—	—
	Senju et al, 2018[41]	0, $P = .839$	Ability in prone position at 6 mo of age (2.5 y of age)	$g = -0.01$; 95% CI −0.17 to 0.15	—	—
	Senju et al, 2018[41]	0, $P = .142$	Ability in prone position at 6 mo of age (3 y of age)	$g = 0.11$; 95% CI −0.05 to 0.28	—	—
Personal-social	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo of age (infant)	$g = 0.58$; 95% CI 0.42 to 0.73	3/6 (50)	?
	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo of age (1 y of age)	$g = 0.30$; 95% CI 0.14 to 0.46	—	—
	Senju et al, 2018[41]	+, $P = .035$	Ability in prone position at 6 mo of age (1.5 y of age)	$g = 0.21$; 95% CI 0.05 to 0.37	—	—
	Senju et al, 2018[41]	0, $P = .104$	Ability in prone position at 6 mo of age (2 y of age)	$g = 0.16$; 95% CI 0.00 to 0.32	—	—
	Senju et al, 2018[41]	0, $P = .130$	Ability in prone position at 6 mo of age (2.5 y of age)	$g = 0.13$; 95% CI −0.03 to 0.30	—	—
	Senju et al, 2018[41]	0, $P = .507$	Ability in prone position at 6 mo of age (3 y of age)	$g = 0.06$; 95% CI −0.11 to 0.22	—	—
Total development (communication, gross motor, fine motor, problem-solving, personal-social)	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo of age (infant)	$g = 0.96$; 95% CI 0.80 to 1.11	4/6 (67)	++
	Senju et al, 2018[41]	+, $P < .001$	Ability in prone position at 6 mo of age (1 y of age)	$g = 0.46$; 95% CI 0.30 to 0.62	—	—
	Senju et al, 2018[41]	+, $P = .001$			—	—

TABLE 5 Continued

Health Outcome Measure	Investigated an Association of Tummy Time With the Health Outcome (Reference)	Association (0, ?, –, or +)	Association Was Found	Effect Sizes	Summary Coding for Studies With an Association, *n*/*N* (%)	Summary Code for Association (0, –, +, or ?)
			Ability in prone position at 6 mo of age (1.5 y of age)	*g* = 031; 95% CI 0.15 to 0.47		
	Senju et al, 2018[41]	+, *P* = .016	Ability in prone position at 6 mo of age (2 y of age)	*g* = 0.21; 95% CI 0.49 to 0.37	—	—
	Senju et al, 2018[41]	0, *P* = .526	Ability in prone position at 6 mo of age (2.5 y of age)	*g* = 0.05; 95% CI −0.11 to 0.22	—	—
	Senju et al, 2018[41]	0, *P* = .119	Ability in prone position at 6 mo of age (3 y of age)	*g* = 0.12; 95% CI −0.44 to 0.29	—	—

OR, odds ratio; CI, confidence interval; FMDQ, fine motor development quotient; GMQ, gross motor quotient; PDMS, Peabody Developmental Motor Scale; *g*, Hedge's *g*; *r*, regression; 0, no association; ?, indeterminate or inconclusive association; +, positive association; −, negative association; —, not applicable.

that of the other study investigating cognition resulted in an indeterminate association overall (Table 5).

Fine Motor Development

In 4 studies, authors investigated the association of tummy time with fine motor development. No association was found in 10 of 15 outcomes measured.

DISCUSSION

In this systematic review, we identified the association of tummy time with a range of infant health and development outcomes. Combining the current available evidence further confirms the importance of tummy time to enhance infant development. In addition, it highlights the association of tummy time with specific aspects of motor development (ability to move while prone or supine, including rolling and crawling), the reduction in BMI-*z*, and the prevention of brachycephaly. This review also further reveals the need for objective tummy time measurement techniques because subjective questionnaires or parent position logs were used in all included studies.

Investigating specific benefits of tummy time can be beneficial for parents, health care professionals, and early-care educators. Attainment of specific "small skills," such as the ability of the infant to lift their head off the ground, the ability to move their arms and legs while prone, the ability to reach while prone, and the ability to sit with their arms supporting them, are small yet tangible goals parents can strive to meet. This was shown in a previous study[44] in which tummy time was achieved by the infants' first learning to lift their heads, then lift their legs, then lift their arms. This order of achievement of tummy time was shown to be positively correlated with their ability to move when on their stomachs.[31] Breaking down the achievement of "big skills," such as rolling, sitting up unsupported, and walking, into smaller, achievable stages of motor development could be a motivating factor, especially for those struggling with meeting the guidelines for tummy time; however, this is currently unknown.

The findings in this study are similar to those in the systematic review by Carson et al,[24] who found that tummy time participation of <3 times per day was significantly associated with plagiocephaly in unadjusted models[25] and that at least 30 minutes of tummy time per day appeared beneficial to motor development.[23] Fourteen additional studies were found in the current review because of new studies published and the reduced number of participants required in our inclusion criteria. It is also interesting to note that the incidence of positional plagiocephaly in the population measured by Mawji et al[37] in 2014 (n = 440) was 46.6% at 9 weeks of age. In the study by van Vlimmeren et al[25] in 2007 (n = 357), the incidence was 22.1% at 7 weeks of age. Because a low level of motor development is a risk factor for plagiocephaly,[35] this rise in plagiocephaly from 2007 to 2018 may be a potential indicator of a generation of infants not achieving the motor development skills they require. Previous studies also revealed an increased incidence in head-shape abnormalities after the introduction of the Back to Sleep campaign.[3] Despite this, parents are encouraged to continue to place their infants supine to sleep and to counteract these negative effects by ensuring participation in recommended levels of tummy time when their infants are awake and supervised.[45]

To our knowledge, this is the first systematic review that includes a positive association of tummy time with BMI.[36] This information is vital

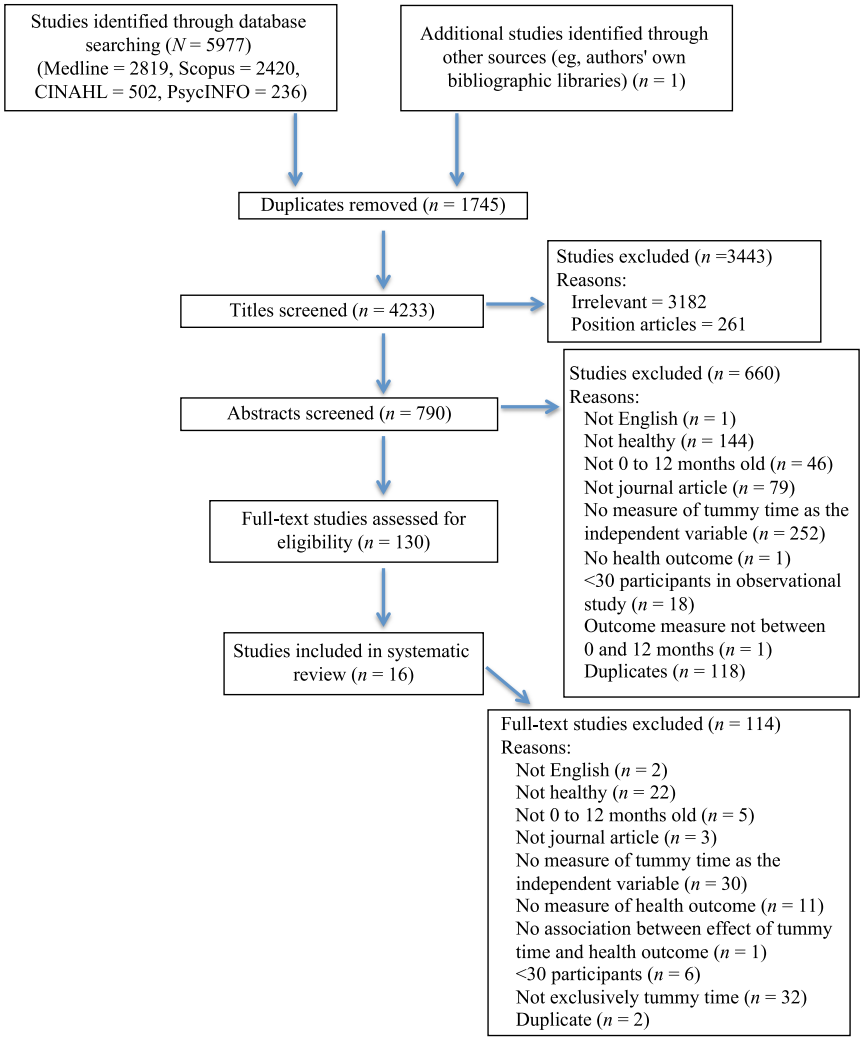

FIGURE 1
Flowchart of included and excluded studies. CINAHL, Cumulative Index to Nursing and Allied Health Literature.

to include in the list of health benefits of tummy time for infants. Because there is currently only one study in which the association of tummy time with BMI is being investigated, further research into the effect of tummy time on unhealthy weight gain among young children is recommended. At this time, the guidelines are focused on the prevention of plagiocephaly and the enhancement of motor development. The inclusion of the benefit of a reduction in infant BMI-*z* will be an important finding to translate to assist parents and educators with adherence to the global physical activity guidelines. These findings may also guide the prioritization of interventions aimed at increasing tummy time practices for both healthy infants as well as infants with developmental disorders.

Current adherence to the infant physical activity guidelines is 30% in Australia.[21,46] Correlates that are negatively associated with tummy time are older parents, low education level, and the amount of time spent awake in the supine position.[31] It has also been shown that knowledge of tummy time, having a fearful attitude about tummy time,[47] and receiving information about tummy time from a pediatrician has minimal effect on tummy time.[34] Further investigation into the causes of this low adherence rate and strategies to improve adherence is required.

Limitations of this study are the small number of studies available to review. A publication bias may also be present because it is unknown if other studies were conducted but not published because of null results. In addition, most studies were observational in design and lacked the robustness of a randomized controlled trial design. High selection and performance bias were present for the majority of studies, which reduces their ability to be accurately representative of other socioeconomic and cultural groups. As such, race, ethnicity, country, socioeconomic status, and cultural effects on tummy time remain to be investigated. Limits were placed on the selection criteria to only include studies written in English and studies that included tummy time as awake prone positioning on the floor. In addition, in some studies, authors combined various interventions (supine positioning, prone positioning, prone sleeping, counseling, nutrition, etc) and investigated the combined effect of these interventions on infant health outcomes. To include these in the review would have confounded the effect tummy time alone had on infant health outcomes because it would be impossible to determine the effect tummy time alone had on the measured infant outcomes. To ensure that the true (not confounded) effect of tummy time on infant health outcomes could be examined, studies were only included if the authors conducted an exclusive tummy time intervention. As such, this may have excluded some studies written in other languages, studies in which

authors investigated a combination of interventions, or studies that had tummy time on a location other than the floor, which may have revealed associations different from those in this review. In addition, studies that had infants with and without plagiocephaly grouped together were also excluded because of the potential differences in motor development that could not be distinguished.

Although authors of a number of systematic reviews have examined the effect of physical activity interventions on older children's health outcomes,[16,24] research to examine the relationships between physical activity and health among infants is limited. It is recommended that more research be conducted to examine the relationships between physical activity and health indicators in infants. This can ensure the identification of developmentally appropriate types and doses of physical activity that have a positive impact on the health and well-being of the infant.

CONCLUSIONS

In this study, we systematically reviewed evidence from 16 studies regarding the association of tummy time with infant health outcomes. Total development, gross motor development, and the ability to move while prone or supine (including crawling) were the health outcomes that had a significantly strong positive association. Studies, by using tummy time objective measurement techniques and assessing a broader range of health outcomes, are warranted to further inform future physical activity guidelines for infants.

Clinical implications and public health significance are as follows:

- Results from this review (tummy time being positively associated with gross motor and total development, reduction in BMI-*z*, prevention of brachycephaly, and ability to move while prone or supine, including crawling and rolling) can be used to educate parents about the benefits of tummy time.
- Further understanding of the effects of tummy time on infant health and development may assist to improve compliance with the World Health Organization tummy time recommendations of 30 minutes per day.
- This review reveals that further work is required regarding the objective measurement of tummy time rather than reliance on parent-proxy questionnaires.

ABBREVIATIONS

AIMS: Alberta Infant Motor Scale
BMI-*z*: BMI *z* score
SIDS: sudden infant death syndrome

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