EMPIRICAL ARTICLE

Gahvora cradling in Tajikistan: Cultural practices and associations with motor development

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Abstract

In Tajikistan, infants are bound supine in a "gahvora" cradle that severely restricts movement. Does cradling affect motor development and body growth? In three studies (2013–2018), we investigated associations between time in the gahvora (within days and across age) and motor skills and flattened head dimensions in 8–24-month-old Tajik infants ($N = 269$, 133 girls, 136 boys)) and 4.3–5.1-year-old children ($N = 91$, 53 girls, 38 boys). Infants had later motor onset ages relative to World Health Organization standards and pronounced brachycephaly; cradling predicted walk onset age and the proficiency of sitting, crawling, and walking. By 4–5 years, children's motor skills were comparable with US norms. Cultural differences in early experiences offer a unique lens onto developmental processes and equifinality in development.

A central issue in developmental science is the role of experience in child learning and development (Greenough et al., 1987; Piaget, 1954). To what extent do particular experiences at particular developmental time points facilitate acquisition of particular skills? Experimental evidence, of course, is the gold standard to demonstrate causality. Classic work in behavioral embryology (Haverkamp & Oppenheim, 1986), ethology (Lorenz, 1965), and comparative psychology (Harlow & Harlow, 1961) tested the role of experience by experimentally depriving non-human infants of putative, critical experiences. Although deprivation experiments are not possible with human infants, natural experiments and cultural comparisons can shed light on the importance of particular experiences. For example, lack of patterned visual input in infancy prior to cataract removal compromises later visual acuity, global motion, and face processing (Maurer, 2017). Likewise, lack of exposure to speech in infancy prior to cochlear implants attenuates sensitivity to the sounds of language (e.g., Pisoni, 2000).

In cultures that do not have words for numbers (e.g., the Piraha in Amazonia), children and adults lack specific aspects of numerical cognition (Gordon, 2004).

For decades, research on motor development and physical growth was dominated by a maturational perspective that de-emphasized the role of experience (e.g., Gesell, 1928). Here, we examined the effects of early restricted movement on infant and child motor and physical development due to a traditional cradling practice in Central Asia in which babies are bound supine for extended periods. We focused on foundational motor skills (sitting, crawling, standing, walking) that are critical for functional behavior with downstream consequences on other psychological domains (Adolph & Hoch, 2019; Campos et al., 2000). And we used head dimensions as corroborating evidence for prolonged time in a supine position. Moreover, motor behavior and physical growth are directly observable and measurable, providing a useful window into general developmental processes.

Abbreviations: BMI, body mass index; TGMD-2, Test of Gross Motor Development, 2nd edition; WHO, World Health Organization.

Freedom to move

Prominent theories of infant development rest on the premise that freedom to move is essential for perceptual, motor, social, and cognitive development (e.g., Gibson, 1988; Piaget, 1954). Indeed, in the cultures that spawned such theories, caregivers encourage infant movement and rarely restrict babies' limbs and torso. Premobile infants can roll, sit, pivot, and so on while on the floor or in the crib. Crawling and walking infants move freely from object to object and place to place (Herzberg et al., 2022; Karasik et al., 2012). Toddlers average 2400 steps per hour (Adolph et al., 2012). Even when strapped into car seats, highchairs, or strollers, infants can manipulate objects, move their bodies, and kick their legs.

Moreover, researchers agree that practice moving is critical to motor skill acquisition (for reviews, see Adolph & Hoch, 2019; Adolph & Robinson, 2015). Months of sitting, crawling, and walking better predict proficiency for the target skill than do infants' test age or body dimensions (Adolph et al., 1998, 2003; Harbourne et al., 2013; Hospodar et al., 2021). Infants given extra practice in experimental studies show greater gains in motor skills relative to controls (Lobo & Galloway, 2012; Zelazo et al., 1972). However, short of unethical experimental manipulations or situations of extreme deprivation, testing associations between restricted movement and motor skills in humans requires observing infants in settings where motor constraint is normative. Cultural research offers such an opportunity: Restricted movement due to strapping infants to cradleboards, enclosing them in pouches or sandbags, or putting them to sleep on their back delays onset ages for the constrained skill relative to Western norms and standards developed by the World Health Organization (WHO; for reviews, see Adolph & Hoch, 2019; Adolph et al., 2010; Adolph & Robinson, 2015). Note, however, that WHO standards exclude parts of the globe with childrearing practices that constrain (or enhance) infant movements.

We investigated motor development in Central Asia (Tajikistan), a large, unrepresented region of the world in international norms and WHO standards of infant motor and physical development. Tajik caregivers traditionally bind infants head to toe in a "gahvora" cradle for hours at a time. We leveraged this distinctive cultural practice to test the implications of restricted movement for motor development in infancy and early childhood, without concomitant social restrictions. We tested concurrent (Study 1) and prospective (Study 2) associations between cradling and infant motor skill status, onset age, and proficiency; sought to replicate associations between months walking and proficiency (Study 2); and examined associations between cradling in infancy and motor skills in early childhood (Study 3). Across studies, we also asked whether extensive cradling, which involves lying supine for prolonged periods, is associated with brachycephaly (flattened back of the head).

Gahvora cradling in Tajikistan

We ventured into Tajikistan to investigate cradling practices that severely restrict infant movement. In the gahvora (Figure 1), infants lie swaddled in a supine position on a soft mattress, with arms and legs secured by wide bands and strings knotted to the cradle's overhead handle to prevent infants from falling out (Karasik et al., 2018). Infants remain immobilized in the gahvora during breast or bottle feeding and toileting. A hole in the cradle bottom and an external catheter drain waste into a container beneath the cradle. Caregivers report they use the gahvora to enhance infant sleep, keep infants clean and dry, calm infants when awake, and protect infants from harsh environmental conditions. Moreover, gahvora cradling occurs in the context of a loving home. Infants are immersed in family life and surrounded by children, caregivers, and other adults who affectionately respond to their needs (Karasik et al., 2018). Thus, the physical restriction of gahvora cradling is not confounded with social deprivation, in contrast to research with children reared in orphanages (Roeber et al., 2012, 2013), left unattended in sandbags for prolonged periods (Mei, 1994), or raised under extreme deprivation (Dennis, 1935). Moreover, gahvora use extends into the second and third postnatal years (Karasik et al., 2018), distinguishing it

FIGURE 1 Infant bound in the gahvora cradle. (a) First infants are placed in the gahvora, positioned with their bottoms over a hole in the mattress and cradle bottom; an external catheter is placed over the genitals; waste drains through the hole into a bowl beneath the cradle. (b) Then infants' arms and legs are straightened and wrapped in swaddling cloth and tightly bound with wide straps, which are tied to the gahvora handle. (c) In cold weather, heavy blankets are draped over the entire gahvora (shown open) covering infants' faces and bodies to keep them warm and shield them from light; in warm weather, translucent covers are draped over the gahvora to protect infants from insects.

from other cultural practices like cradleboards and pouches, which are used only in the first postnatal year (Dennis, 1940; Tronick et al., 1994).

In the context of widespread gahvora use, the amount of time infants spend in the cradle varies among families and declines with infant age (Karasik et al., 2018). Some infants spend nearly 24 h per day in the gahvora, whereas others spend only an hour or two. Do differences in infants' cradling experiences relate to their motor development and physical growth? If so, do associations persist into early childhood? Furthermore, prolonged time in a supine position in the gahvora may relate to head shape. Back-sleeping in US infants leads to increased likelihood of brachycephaly (Graham et al., 2005). Thus, brachycephaly in Tajik infants and children would provide corroborating evidence of extensive time in the gahvora.

Current studies

In three studies, we examined cradling experiences, postural and locomotor skills, and head shape of infants and young children from rural regions in Tajikistan. In Study 1, we assessed infants' motor skills cross-sectionally and obtained information on prior-day cradling from time-diary interviews (Karasik et al., 2018) to test links between cradling hours and motor skill status and proficiency. In Study 2, we tracked walk onset and proficiency longitudinally and obtained diary data on cradling hours at three ages. In both studies, we incidentally observed older children running around and competently navigating their environments, and thus wondered about effects beyond infancy. In Study 3, we tested children 4–5 years of age on locomotor tasks to test whether their cradling histories predicted performance. Across studies, we measured children's body size as an index of healthy physical growth and head shape to corroborate extensive time spent supine in the cradle. Figure 2 shows the number of children who contributed each type of data in the three studies.

Studies 1 and 2 were confirmatory. We hypothesized that extensive time in the gahvora hinders infants' developing motor skills and leads to brachycephaly. Thus, we predicted that fewer Tajik infants would display target motor skills relative to WHO standards (Wijnhoven et al., 2004; that do not include children from Central Asia), and we expected increased brachycephaly relative to published reports given the association between brachycephaly and supine positioning (Graham et al., 2005). Furthermore, we expected to replicate associations between months walking (elapsed time since walk onset) and walking proficiency, confirming associations seen in US infants (Adolph et al., 2003). That is, months walking should predict variation among infants in walking proficiency, even if the onset of walking in Tajik infants occurs later than averages reported for WHO standards and Western samples.

Study 3 was exploratory. By 4–5 years of age, children have had several years to freely move about, and their motor skills may be indistinguishable from those of US children. Alternatively, extensive time in the gahvora in infancy may have prolonged effects on motor development. Similarly, we were uncertain whether brachycephaly would self-correct by early childhood.

Every session was video recorded (including consent, time diaries, motor skill assessments, and body measures) and shared on Databrary. Raw video data and spreadsheets of coded behaviors are shared with authorized investigators—Study 1 at https://nyu.databrary.org/volume/11; Study 2 at https://nyu.databrary.org/volume/296; and Study 3 at https://nyu.databrary.org/volume/226. Exemplar video clips, coding manuals, processed data, and analysis syntax files are shared publicly at https://nyu.databrary.org/volume/1505.
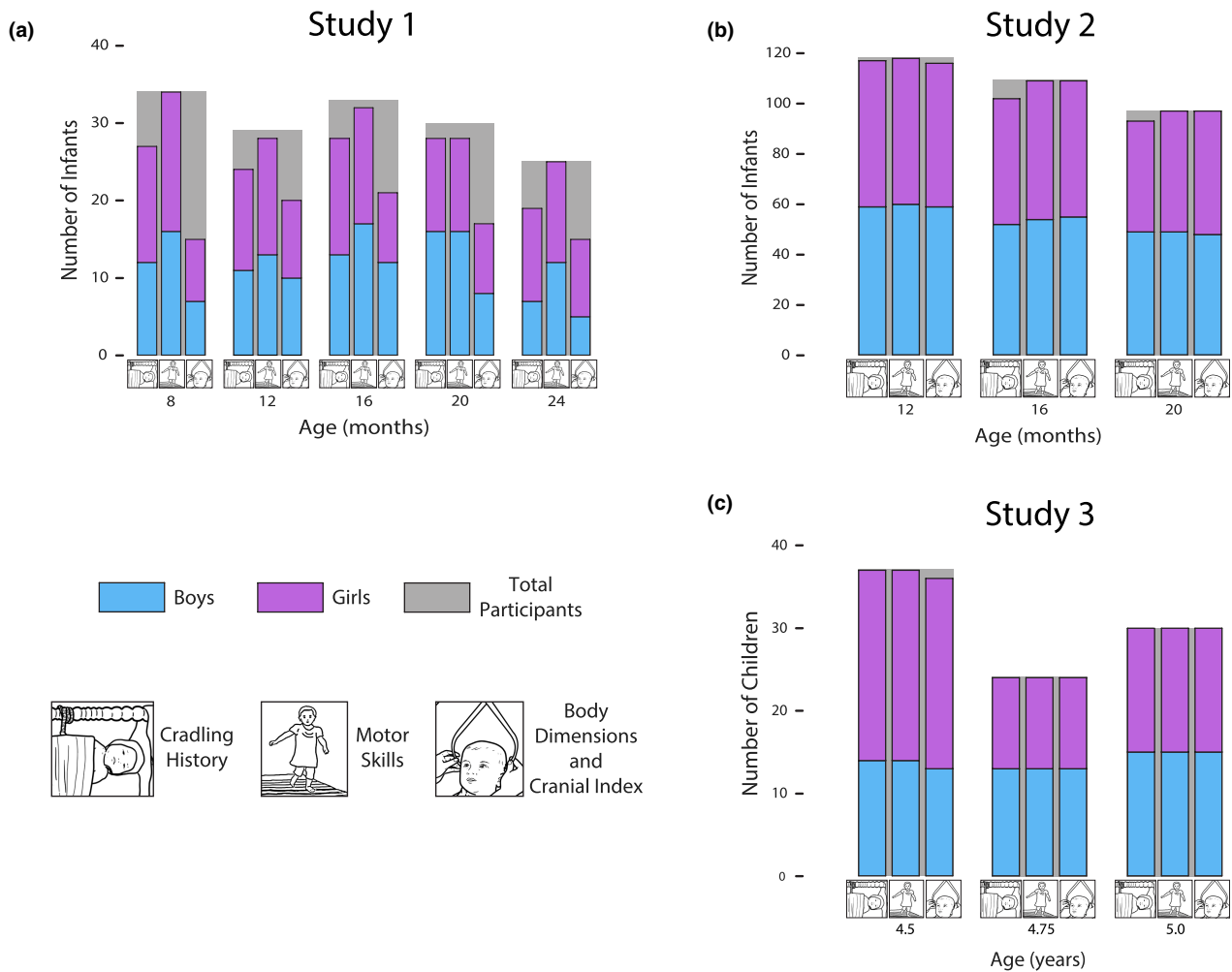
STUDY 1: CROSS-SECTIONAL INVESTIGATION OF MOTOR SKILLS IN INFANCY

We tested hypothesized concurrent associations between infants' cradling experience and age-relevant motor skills—sitting, crawling, standing, and walking—in infants aged 8–24 months who had been cradled since birth. We interviewed mothers about their infants' *prior-day cradling* using a 24-h time diary; assessed infants' sitting, crawling, standing, and walking *status* (i.e., whether infants displayed the target behavior) and *proficiency* (e.g., skill at sitting at 8 months; crawling, standing, and walking at older ages); and measured infants' *head dimensions*. We expected infants to lag in motor skills relative to WHO standards, which are based on longitudinal observations of infants from 4 to 24 months of age in Brazil, Ghana, India, Norway, Oman and the United States, locations where infants' movements are not constrained (de Onis et al., 2006; Martorell et al., 2006). Furthermore, we hypothesized a dose–response effect: More cradling hours would be associated with lower motor status and less proficient motor skills. Finally, we expected time supine in the cradle to predict the extent of brachycephaly.

Method

Participants

In 2013–2014, a trained Tajik researcher visited 151 families (76 boys, 75 girls) in their homes for 1.5–2 h. Infants were ±1 week of 8, 12, 16, 20, or 24 months (Figure 2a). Partners from UNICEF and Save the Children in Tajikistan recruited families from medical clinics serving the villages in the Khatlon ($n = 110$) and Rasht ($n = 37$) regions. Inclusionary criteria were infants' age and term birth with no complications.

FIGURE 2 Study design, child age and sex, and available data. (a) Study 1: Cross-sectional examination of effects of cradling on infant motor skills and cranial index. (b) Study 2: Longitudinal examination of effects of cradling on infant walking and cranial index. (c) Study 3: Cross-sectional examination of effects of cradling on young children's motor skills and cranial index. Bar heights show the number of children with available data for parents' report of cradling; observed motor skills; and measures of body dimensions and cranial index. Colors represent boys and girls. Illustrations denote the measures. Background gray panels show the total number of participants per age group.

Families were told that the purpose of the study was to learn about infant development. Researchers did not mention cradling to prevent influencing caregiver reports. Families received infant clothing as gifts for participation.

Mothers ranged from 19 to 42 years of age (M = 26.6 years). A few mothers (5%) completed more than 11 years of schooling; 56% completed secondary school (11 years); 31% primary school (4 years); and 8% had no education. Most mothers did not work for pay (82%); 14% worked on collective farms; and 4% did odd jobs. Most mothers (98%) were married; 2 were divorced, 1 was widowed, and 1 was unmarried. Many fathers were migrant workers in Russia (45%) and did not live at home; 27% did various types of work for pay; 10% worked in construction; 7% were drivers; and 11% did not work. Mothers reported breastfeeding since birth and 64% were still breastfeeding at the time of the study.

Postural and locomotor skills: Skill status and proficiency

Using the same criteria as the WHO standards (Martorell et al., 2006), the researcher tested *skill status* (Figure 3a) to determine whether infants could independently sit (unsupported for 10 s with head and back straight), crawl on hands and knees (3 consecutive cycles with hand-knee alternation), stand (unsupported without holding onto anything for 10 s), and walk (without external support, 5 consecutive steps with one leg moving forward while the other supports body weight, and back held straight). Skill status was coded as "success" or "failure." We indexed *skill proficiency* based on quantitative measures of each skill.

When eliciting sitting skills and proficiency, the researcher placed infants on the ground with legs outstretched in a "V" position. If infants did not maintain an upright posture and collapsed onto their hands or into the researchers' arms before 10 s, sitting was coded as a failure.
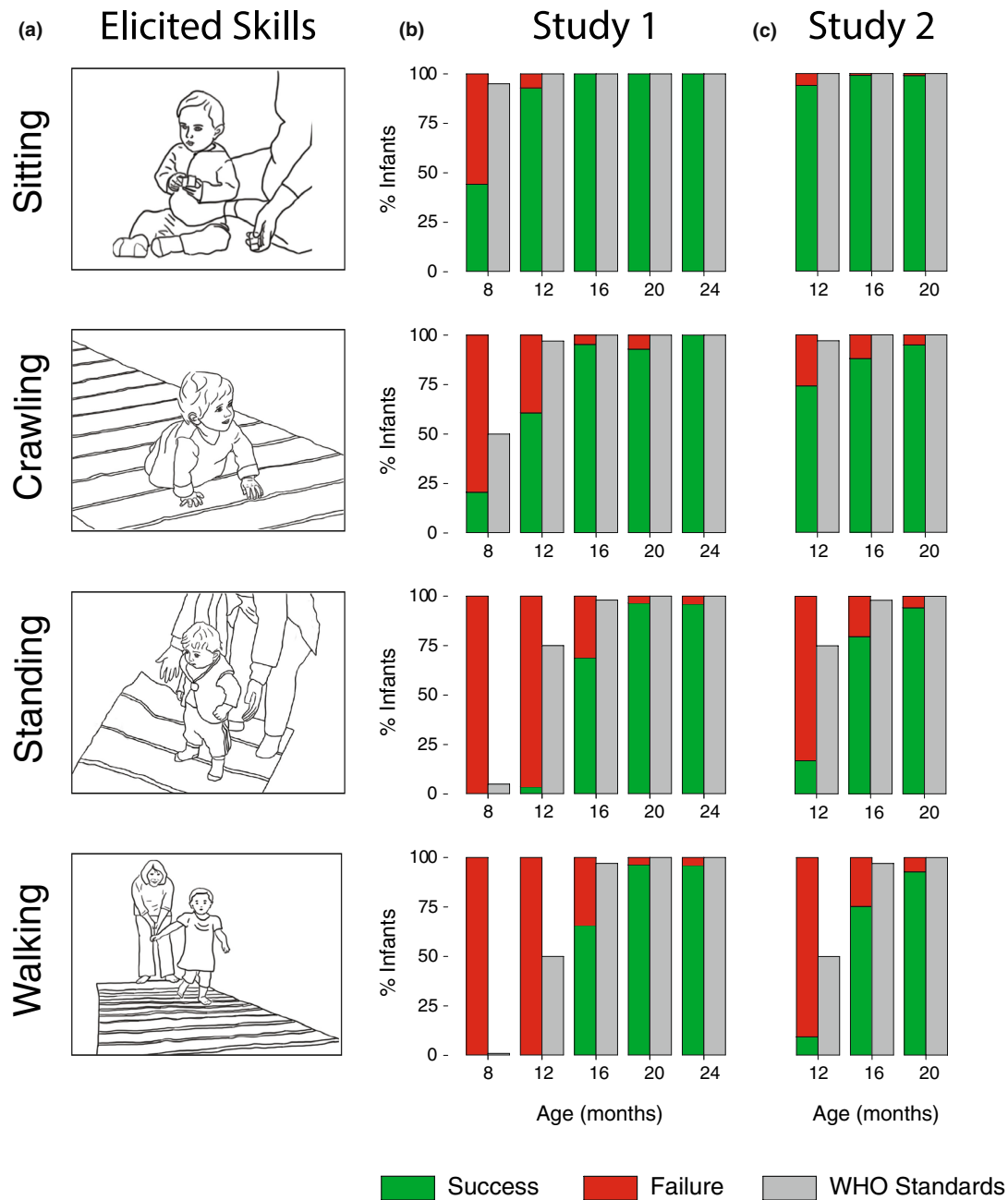
FIGURE 3 Motor skill status for sitting, crawling, standing, and walking. Percentage of Tajik infants (colored bars) who successfully demonstrated the target skill or failed to demonstrate the target skill relative to World Health Organization standards (gray bars). (a) Line drawings show testing procedures for sitting, crawling, standing, and walking. (b) Cross-sectional Study 1 with infants. (c) Longitudinal Study 2 with infants.

If infants transitioned out of a sit into a hands-knees or standing posture immediately after being placed in a sitting position, sitting was coded as a success. Sitting proficiency was based on the duration of the longest trial from the onset of the infant being placed on the floor until the offset when the infant lost balance. Infants who shifted to crawling or upright were excluded from analyses of sitting proficiency.

When eliciting crawling skill and proficiency, the researcher placed infants on hands and knees at one end of a 3-m, gridded mat (unrolled inside the house if possible,

outside if not) marked every 25 cm, and caregivers called infants from the far side of the mat. If infants collapsed onto their bellies before traveling 3 cycles or rocked back and forth without locomoting forward, crawling was coded as a "failure." If infants immediately stood up and walked after being placed on hands and knees, crawling was coded as a "success." Failed crawling attempts were further checked against videos of infants' natural activity outside the cradle, which confirmed that all infants who failed to crawl did not exhibit successful crawling during spontaneous

activity. Infants who stood up when placed prone were excluded from measures of crawling proficiency.

When eliciting standing and walking status, the researcher placed infants upright; for walking, caregivers encouraged infants to walk toward them from the far side of the 3-m mat. If infants lost balance and fell before 10 s while standing, standing was coded as a "failure." If infants began walking before 10 s, standing was coded as a "success." Failed standing and walking attempts were further checked against natural play videos, which confirmed that all infants who failed to stand or walk did not exhibit success during spontaneous activity.

Crawling and walking gait proficiency (speed and step length) were calculated by measuring the distance (number of grid lines multiplied by 25 cm) between the first to last step divided by time (seconds). Step length for crawling (based on knee movements) and walking was computed by dividing the number of grid lines by the number of steps. Of the 105 infants who could crawl or walk, gait data were available for 59 (15 crawlers and 44 walkers). Gait data from 46 infants were unavailable due to lack of indoor space and poor weather conditions that prevented the researcher from rolling out the gridded mat outside. For analyses, we averaged the two fastest crawling and walking trials for measures of speed and step length, rs > .89, ps < .001. As expected based on lab studies of infant gait (e.g., Lee et al., 2018), speed and step length were correlated at every time point for both crawling and walking, rs > .83–.98, ps < .001. For full transparency, we report both measures in analyses. As expected, crawling and walking speed and step length improved with age (Fs(2, 41) = 6.56, 8.08, ps < .01). We could not measure standing proficiency because infants who could not stand fell immediately, and infants who could stand refused to remain stationary and walked away.

A primary coder scored infant motor status and proficiency in Datavyu (datavyu.org), a computerized video coding tool that allows for frame-by-frame analysis of behaviors. A second coder (LBK) scored 100% of each child's data to verify interobserver reliability. Coders agreed on 92%–99% of motor skills; κs > .85, ps < .001. Correlations for time, steps, and grid lines were high, rs(331) > .97, ps < .001.

Cranial index and body dimensions

At the end of the visit, the researcher used anthropometric calipers (Figure 4a) to measure the infant's head from side-to-side (at tip of each ear) and front-to-back (between the eyes at the brow line to back of head); we used head dimensions to calculate the cranial index (side-to-side ÷ front-to-back × 100), a standard measure of brachycephaly. A cranial index above 80% is considered brachycephalic (Graham et al., 2005). A cranial index above 100% is considered severe brachycephaly. The researcher measured weight with a pediatric scale, and recumbent height (head to heel) with a pediatric

measuring board. Only 89 infants (60% of sample) contributed body dimensions; the others were too fussy.

Gahvora use

After confirming that the prior day was typical for the infant, the researcher interviewed mothers (grandmothers were often present and contributed information) in their native language about gahvora use the prior day (17% of mothers reported that the prior day was atypical, so their data were not analyzed). We used a 24-h time-diary method (Hofferth et al., 1997; Karasik et al., 2018), asking caregivers to report on infants' location throughout the day to create an hour-by-hour timeline of when infants were in the gahvora from 6 AM the prior day until 6 AM the current day.. From diaries, we calculated the total number of cradling hours across the prior 24-h period.

Results

Body dimensions

Infants' body dimensions (weight, height, body mass index [BMI], and head circumference) were generally within range of WHO growth parameters and regional norms in Dushanbe, the capital city (Abdullaeva & Olimova, 2018; de Onis et al., 2006). Figure 5a shows age differences in height, weight, and head circumference, Fs(4, 84) = 56.07, 19.41, 24.71, ps < .001. As expected based on the WHO standards, compared with girls, boys were taller and weighed more at 8 and 24 months and had larger heads at 8 and 20 months, ts(13 and 14) > 2.14, ps < .05. BMI did not differ by age or sex.

Motor skill status relative to WHO standards

Fewer Tajik infants could sit, crawl, stand, and walk relative to infants on the WHO standards (Figure 3b). At 8 months, 44% of Tajik infants sat compared with 95% of WHO infants, χ^2(1, 34) = 185.32, p < .001, although an additional 22% of Tajik infants (n = 4) demonstrated tripod sitting. At 8 and 12 months, 20% and 61% of Tajik infants crawled compared with 50% and 97% of WHO infants, χ^2(1, 34, 28) = 11.77, 126.69, ps < .01. At 12 and 16 months, only 4% and 69% of Tajik infants stood independently compared with 75% and 98% of WHO infants, χ^2(1, 28, 32) = 76.19, 139.68, ps < .001. At 12 and 16 months, 0% and 65% of Tajik infants walked compared with 50% and 97% of WHO infants; χ^2(1, 28) = 28.00, p < .001 at 12 months and χ^2(1, 32) = 108.25, p < .001 at 16 months. All but one Tajik infant walked at 20 and 24 months, χ^2(1, 27, 25) = 2.00, 2.27, ps > .05.

Notably, although Tajik infants lagged in crawling and walking relative to WHO standards, they found
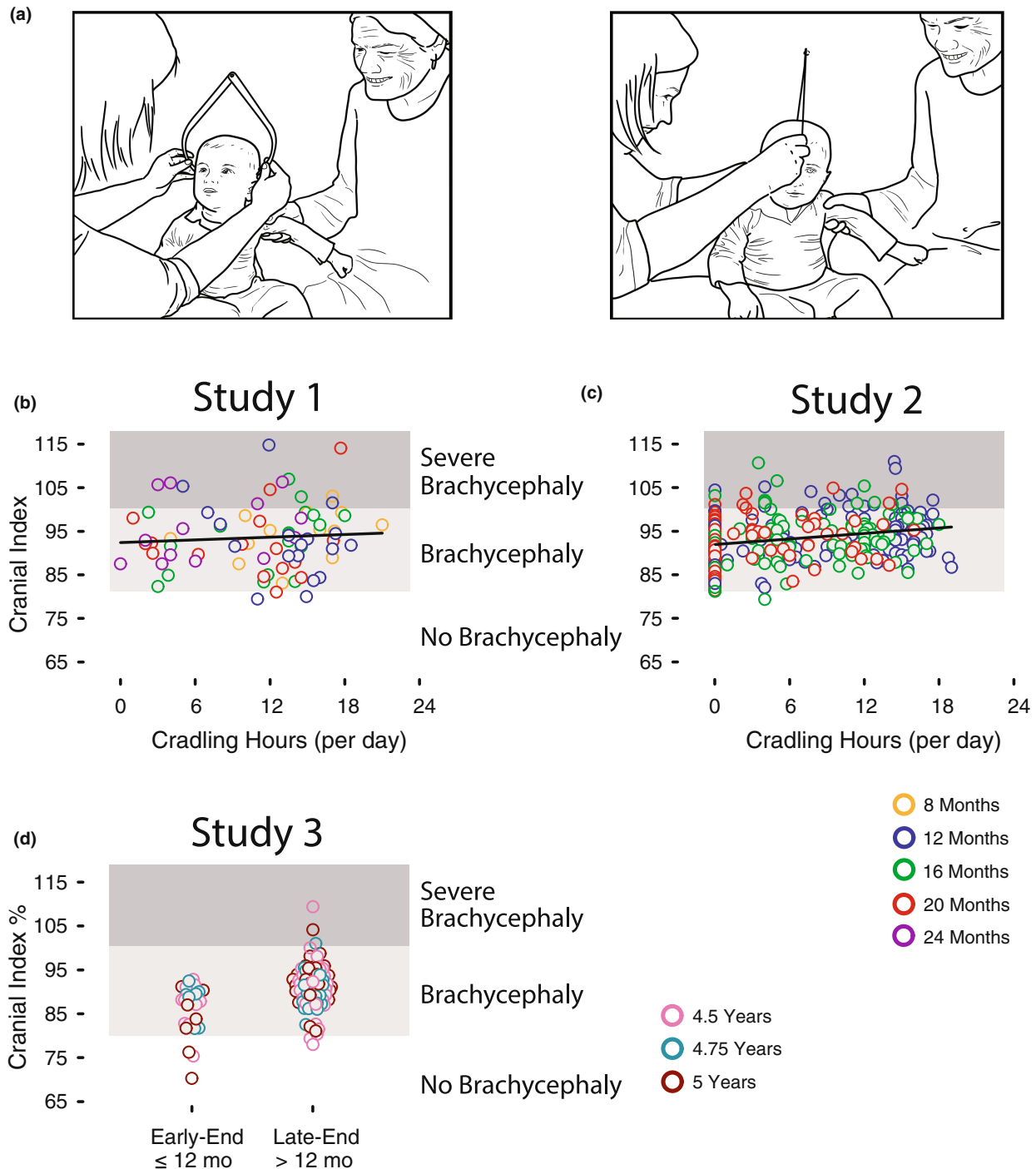
FIGURE 4 Cranial index. (a) Caliper measures of head dimensions. Cranial index % = (side-to-side ÷ front-to-back) × 100. (b) Cross-sectional Study 1 with infants. (c) Longitudinal Study 2 with infants. Scatterplot shows infants' last cranial index measure. (d) Cross-sectional Study 3 with children. Light gray regions denote brachycephaly (cranial index above 80%) as reported in the literature; dark gray regions denote severe brachycephaly (cranial index >100%, i.e., head wider than long); most children had brachycephaly. Cradling hours (*x*-axis in plots for Study 1 and Study 2) were unrelated to cranial index %, but longer duration of cradling (*x*-axis in plot for Study 3) was associated with larger cranial index % in older children.

other ways to locomote. At 8 months, 29% of infants (*n* = 10) belly crawled or log-rolled; at 12 months, 21% of infants (*n* = 6) belly crawled or log-rolled. In 4% of cases (*n* = 6) 8- and 12-month-olds who did not yet sit locomoted on hands-knees (*n* = 1) or log-rolled or belly crawled (*n* = 5). The pre-walking 20-month-old scooted and the pre-walking 24-month-old crawled on hands-knees.
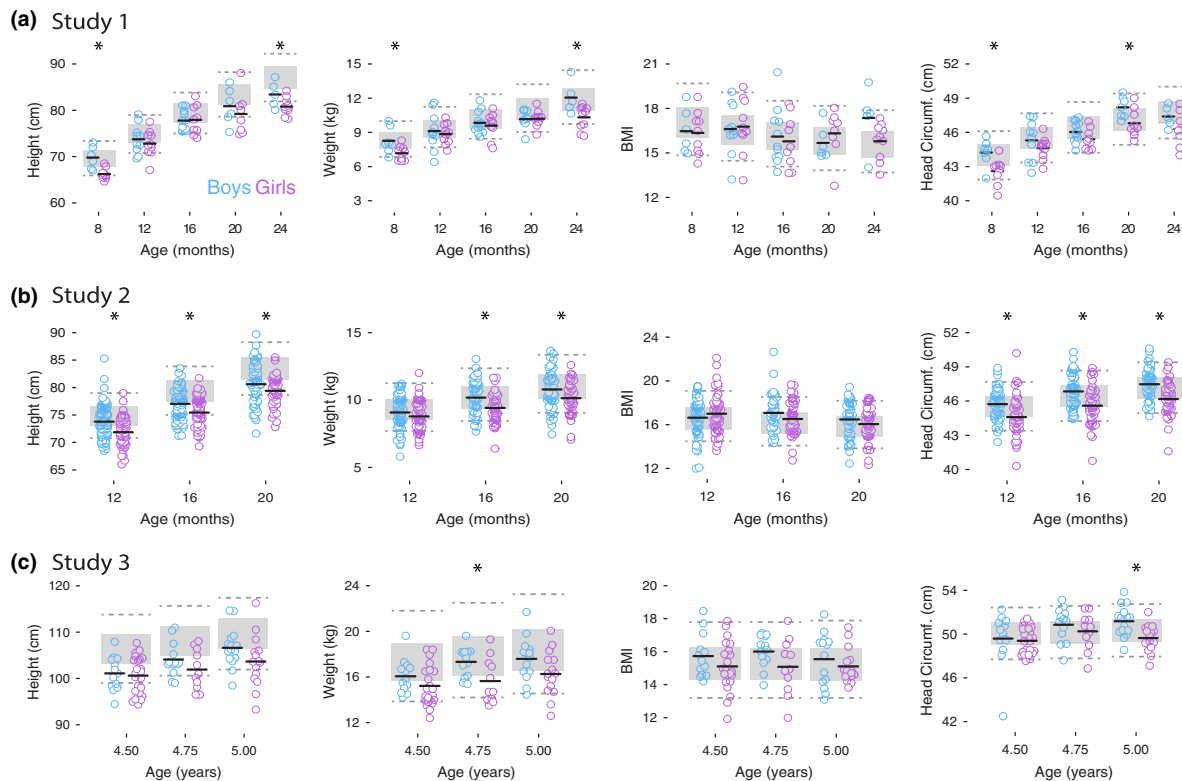
FIGURE 5 Height, weight, body mass index, and head circumference of Tajik samples compared with World Health Organization (WHO) standards. (a) Cross-sectional Study 1 with infants. (b) Longitudinal Study 2 with infants. (c) Cross-sectional Study 3 with young children. Each symbol represents one child in Study 1 and Study 3; each infant's data are shown for each session in Study 2. Boys are shown in blue and girls in purple. Gray regions denote the 25th to 75th percentiles based on the WHO standards; dashed horizontal lines show 5th and 95th percentiles. Tajik data compared with the WHO data indicate generally healthy physical growth.

Gahvora cradling in relation to motor skill status and proficiency

Every infant had been cradled from early infancy, but 7 were no longer cradled at the time of testing so we did not collect their time diaries. The time diaries revealed large individual differences in cradling hours (e.g., 1 to 18 h for 16-month-olds). Across age groups, 57% of infants were constrained in the gahvora for at least 12 h per day. Younger infants accumulated more cradling hours than did older infants, $F(4, 114) = 4.67$, $p < .01$, with 8- and 12-month-olds (Ms = 13.90 and 12.18 h, SDs = 4.29 and 4.42, respectively) spending more hours in the gahvora than 24-month-olds (M = 7.94 h, SD = 4.47).

Prior-day cradling hours did not relate to infant motor skill status (i.e., sitting at 8 months; crawling at 12 months; walking at 16 months). Cradling hours at 8 months did not predict sitting status, logistic regression, $\chi^2(1) = 0.40$, $p = .53$ (Ms = 12.5 and 13.8 h, SDs = 5.7 and 4.7 in presitters and sitters, respectively). Similarly, cradling hours at 12 months did not predict crawling status, $\chi^2(1) = 0.14$, $p = .71$ (Ms = 11.9 and 12.6, SDs = 4.2 and 4.9 in precrawlers and crawlers, respectively). Finally, cradling hours at 16 months did not predict walking status, $\chi^2(1) = <.001$, $p = .98$ (Ms = 10.1 and 10.0 h, SDs = 5.6 and 6.3 in prewalkers and walkers, respectively).

However, cradling hours were associated with walking proficiency. When pooling walkers across age groups (16, 20, and 24 months), partial correlations (controlling for age) revealed that fewer cradling hours were associated with faster walking speed, $pr(40) = -.35$, $p < .05$, and longer step length $pr(40) = -.33$, $p < .05$ (Figure 6a). Although nonsignificant due to small sample sizes, fewer cradling hours were related to better sitting proficiency in 8-month-olds, $r(9) = -.63$, $p = .07$, and to faster crawling speed and longer step lengths in 12-month-olds, $r(14) = -.47$ and $-.49$, ps = .08 and .07.

Cranial index

At all ages, infants' average cranial index exceeded 90% (range = 91.93%–116.5%, see Figure 4b). Because the WHO does not report cranial indices for infants, we compared indices for Tajik infants with published reports. Compared with US infants, whose cranial indices range from 76% to 81% (Graham et al., 2005), the cranial index for most Tajik infants (80%) indicated moderate to severe brachycephaly (range = 90%–100%), and 20% had a cranial index ≥100%. Cranial index did not relate to cradling hours when pooling data across the sample, controlling for age.
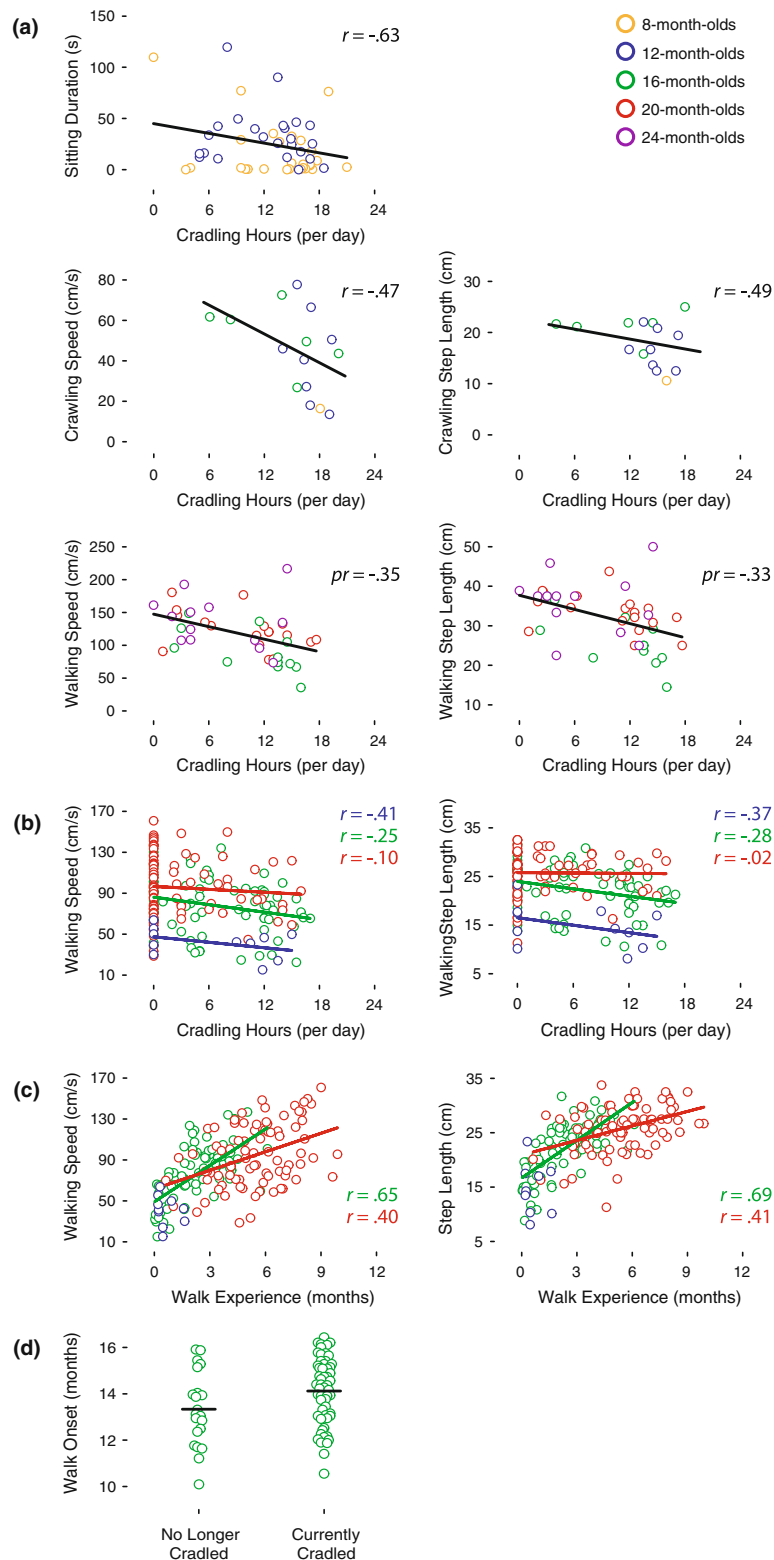
FIGURE 6 Relations between motor skill proficiency and cradling hours. Motor proficiency for sitting (duration), crawling (speed and step length), and walking (speed and step length) by cradle hours accumulated over the prior 24-h day. Each symbol represents one infant. (a) Cross-sectional Study 1 with infants. (b) Longitudinal Study 2 with infants. (c) Walking experience (in months) by walking speed and step length for infants in Study 2. (d) Walk onset age for 16-month-olds in Study 2 who stopped cradling and who continued cradling.

Summary

As hypothesized, Tajik infants lagged behind WHO standards on postural and locomotor skills. However, prior day cradling hours did not predict sitting, crawling, standing, or walking status and did not relate to cranial index. Nonetheless, cradling hours predicted low walking proficiency. In Study 2, we tested whether associations between cradling hours and walking proficiency were replicable; assessed brachycephaly; and longitudinally tested associations between cradling hours and age at walk onset.

STUDY 2: PROSPECTIVE INVESTIGATION OF INFANT WALKING

We observed infants longitudinally at 12, 16, and 20 months to track walk onset, assess walking proficiency, and measure cranial index (Figure 2b). We focused on walking because it is a skill of universal, functional significance that cascades to social interaction, language, and engagements with objects (Adolph & Tamis-LeMonda, 2014; Karasik et al., 2014; Walle & Campos, 2014; West et al., 2019). As in Study 1, at each visit, mothers reported infants' prior-day cradling hours and the date they first saw their infants walk independently (if the infant had not yet walked by the prior visit). A researcher video-recorded infants walking on a gridded mat to confirm walking status and assess walking proficiency, and measured their head circumference. And we collected body dimensions to verify healthy physical growth.

We expected to replicate the finding of later walk onset ages relative to WHO standards and expected cradling hours and duration of cradling to relate to walk onset age and walking proficiency. Additionally, we expected walking experience (i.e., days since walk onset) to predict walking proficiency (speed and step length), mirroring the experience-proficiency associations documented in US samples (Adolph et al., 2003, 2012; Lee et al., 2018).

Method

Participants

In 2016–2018, two Tajik researchers recruited a new sample of infants and visited families when infants were 12, 16, and 20 months (±1 week; *n* = 118; 60 boys, 58 girls; Figure 2b). A clinical research center in Dushanbe assisted with recruitment. Families were recruited from medical clinics in villages in the Khatlon district (*n* = 62, 52.5% of sample) and Districts of Republican Subordination (*n* = 56, 47.5%), two regions in Tajikistan outside of Dushanbe. Inclusionary criteria were infants' age and term birth without complications. Families were told that the purpose of the study was to learn about infant development. They received infant clothing and toys at each session. Sessions were video recorded, including consent.

Mothers ranged from 20 to 37 years of age (*M* = 25.58 years); fathers ranged from 22 to 45 years (*M* = 30 years). Some mothers (11%) completed more than 11 years of schooling; 52% completed secondary school (11 years); 32% primary school (4 years); 5% had no education. Most mothers did not work for pay (92%); 3 mothers (2%) were professionals (nurses, teachers); and 7 mothers (6%) engaged in odd jobs. Most mothers (98%) were married; 1 was divorced, and 1 was widowed. Fathers worked in mining, construction, or service work (46%); only a few (5%) held professional positions (e.g., teacher, medical worker); 2.3% did other odd jobs; 17% did not work; and 30% of fathers were migrant workers in Russia and did not live at home.

Postural and locomotor skills, cranial index, and body dimensions

Assessments of body dimensions, cranial index, motor status, and walking proficiency (speed and step length) followed the same procedures as in Study 1. A primary coder scored all walk trials using Datavyu (datavyu.org); a second coder scored 30% of each child's walk trials to verify inter-observer reliability. Correlations for time, steps, and grid lines (used to calculate walking speed and step length) were strong, *r*s(187) = .99, .99, .98 *p*s < .001. For analyses, the fastest two gait trials were averaged; the two fastest trials correlated at all three sessions (*r*s = .95, .98, .95, *p*s < .001). As expected, walking speed correlated with step length (*r*s = .93, .94, .85, *p*s < .001, at each session).

We tracked walk onset prospectively based on when caregivers first saw their infant walk independently the length of a room (~3 m) without falling, stopping, or holding onto a support, rather than retrospectively as in Study 1. To remind caregivers of our criteria for independent walking, we left a paper illustration for reference. We used the 3-m criterion to ensure that walking was salient to mothers, that infants could produce sufficient gait data on the gridded mat, and to allow comparisons with prior lab-based studies (e.g., Lee et al., 2018).

Gahvora use

At each session, the researcher collected time diaries of infants' gahvora use the prior day following procedures in Study 1.

Results

Body dimensions

Infants' body dimensions were largely comparable with infants on the WHO standards and regional standards in Dushanbe (Abdullaeva & Olimova, 2018; de Onis et al., 2006). Height, weight, and head circumference increased with age, $Fs(2, 182) = 579.69, 124.00, 219.67, ps < .001$ (Figure 5b). As expected based on WHO standards, boys were taller, $F(1, 91) = 6.99, p < .05$ and had larger head circumferences, $F(1, 91) = 21.52, p < .001$ at all ages. Boys weighed more than girls at 16 and 20 months, $F(1, 91) = 7.25, p < .05$. BMI did not differ by age or sex.

Walking status, onset, and proficiency by age and experience

Chi-square goodness of fit tests confirmed differences between the percentages of Tajik infants and infants on the WHO standards for motor skill status (Figure 3), replicating findings from Study 1. At 12 months, fewer Tajik infants could crawl, 74%, $\chi^2(1, 104) = 105.65, p < .001$, stand, 16%, $\chi^2(1, 114) = 213.16, p < .001$, and walk, 9%, $\chi^2(1, 118) = 78.10, p < .001$. At 16 months, fewer Tajik infants could stand, 80%, $\chi^2(1, 104) = 157.34, p < .001$, and walk, 75%, $\chi^2(1, 109) = 177.53, p < .01$. At 20 months, almost all Tajik infants walked, 93%, $\chi^2(1, 97) = 37.86, p < .001$.

Walking speed and step length increased with infant age. Between 16 and 20 months, walking speed increased from $M = 77.84$ cm/s (SD = 27.67) to $M = 98.90$ cm/s (SD = 29.85), paired $t(70) = 5.19, p < .001$; and step length increased from $M = 22.28$ cm (SD = 5.07) to $M = 26.37$ cm (SD = 4.00), paired $t(70) = 6.78, p < .001$. However, speed and step length unexpectedly decreased between 16 and 20 months for 20% of infants ($n = 15$). Review of gait trials indicated that 6 infants were fussy, but the 9 others were content and simply did not walk fast on the gridded mat.

Walking experience related to speed and step length at 16 months, $rs(76) = .65, .69, ps < .001$, for speed and step length, respectively and at 20 months, $rs(83) = .40, .41, ps < .001$, for speed and step length respectively (Figure 6c). When focusing on the 80% of infants who increased in walking speed between the two ages, the correlations at 20 months strengthened, $rs(47) = .60, .50, ps < .001$. Walking speed and step length were modestly stable between 16 and 20 months, $rs(71) = .30, .39, ps < .05$, especially for the subset of infants who increased in speed and step length between the two ages, $rs(50) = .65, .60, ps < .001$.

Cranial index and walk onset

Infants' cranial index (Figure 4c) indicated moderate brachycephaly ($Ms = 94.01\%, 93.13\%,$ and 93.04% at each session), replicating findings from Study 1. Nineteen infants (14% of the sample) met the criterion for severe brachycephaly with a cranial index ≥100% at 12 months; 12 met the criterion at 16 months (11%) and 8 at 20 months (8%). Higher cranial index was related to later walk onset age, $r(84) = .34, p < .01$.

Gahvora use and cranial index

Prior day cradling hours related to cranial index. A GEE with session and cradling hours confirmed a main effect of cradling, Wald $\chi^2(1) = 11.46, p < .001$.

Time in gahvora and walk onset age

Duration of cradling and patterns of cradle use across age related to walk onset age. We first compared walk onset age in "still-cradled" with "no-longer-cradled" infants. At 12 months, 90% of infants ($n = 84$) were still cradled and 10% ($n = 9$) were no longer cradled; 11 walked. Infants who were no longer cradled at 12 months had an earlier walk onset age ($M = 12.91$ months, SD = 1.90) than infants who were still cradled ($M = 14.66$ months, SD = 1.94), $t(91) = 2.58, p < .01$. At 16 months, 71% of infants ($n = 72$) were still cradled and 29% ($n = 29$) were no longer cradled; most infants 75% ($n = 82$) walked. Infants who were no longer cradled at 16 months had an earlier walk onset age ($M = 13.66$ months, SD = 1.89) than infants who were still cradled ($M = 14.78$ months, SD = 1.94), $t(90) = 2.40, p < .05$ (Figure 6d). By 20 months, the 45% ($n = 37$) of infants who were still cradled did not differ on walk onset age ($M = 14.91$, SD = 1.97) from the 55% ($n = 46$) who were no longer cradled ($M = 14.26$, SD = 2.05), $t(81) = 1.46, p > .05$.

Of course, the association between cradling experience and walk onset does not inform on causality. Being cradled might hinder walking and reciprocally, mothers may continue to cradle infants who do not yet walk. Thus, we explored bidirectional influences on motor development, by comparing infants who walked with those who did not walk at 16 months on their cradling hours at 20 months. Infants who walked at 16 months were cradled fewer hours at 20 months ($M = 2.40$ h, SD = 4.11) than infants who did not walk ($M = 5.08$ h, SD = 5.69), $t(91) = 2.48, p < 01$. And, although only 11 infants walked at 12 months, they were also cradled fewer hours at 16 months ($M = 3.60$ h, SD = 4.88) compared with infants who did not walk at 12 months ($M = 7.54$ h, SD = 5.61), $t(101) = 2.13, p < .05$.

Next, we tested whether patterns of cradling hours across the three ages related to infants' walk onset age and proficiency using exploratory K-means cluster analyses. Constraints set for a 4-cluster solution appeared to be optimal when contrasted with 2-, 3-, and 5-cluster solutions, producing cluster centers that were interpretable as different patterns of decrease in cradle hours over

the sessions, with relatively even membership distributions; the solution converged within a maximum of 10 iterations. Four groups were identified: (1) *consistently low* infants ($n = 23$) were cradled for few hours at all ages; (2) *early decline* infants ($n = 23$) showed high early cradling followed by a sharp decrease in cradling hours by 16 months and remained low at 20 months; (3) *late decline* infants ($n = 25$) showed high cradling hours at 12 and 16 months, but substantially decreased in cradling by 20 months; and (4) *consistently high* infants ($n = 18$) were high in cradling hours across the three ages, Figure 7a,b.

The four patterns of gahvora use related to walk onset age (Figure 7c). Infants in the *consistently low* group ($M = 14.07$ months, SD = 2.32) and *early decline* group ($M = 13.63$ months, SD = 1.79) showed earlier walk onset than infants in the *consistently high* group ($M = 15.93$ months, SD = 1.85). The age at walk onset for the *late decline* group ($M = 14.84$ months, SD = 1.95) did not differ from the *consistently high* group. An ANOVA, $F(3, 73) = 4.26$, $p < .01$, and Sidak post-hoc comparisons ($ps < .05$) confirmed these differences.

About 1/3 of infants in the *consistently low* (29%) and *early decline* groups (37%) fell 1 SD below the mean for walk onset age—meaning they started walking at earlier ages than the average walk onset age—compared with infants in the *late decline* (18%) and *consistency high* (only 1 infant) groups.

Gahvora use and walking proficiency

For the 11 infants who walked at 12 months, prior-day cradling hours did not predict walking speed or step length, $rs(11) = .41$ and .37, $ps > .05$. At the 16-month session, prior-day cradling hours related to slower walking speed, $r(74) = −.32$, $p < .01$, and shorter step length, $r(74) = −.36$, $p < .01$. Prior-day cradling hours did not relate to walking proficiency at 20 months, $rs(88) = .10$ and .06, $ps > .05$.

Cradling patterns across age related to walking proficiency at 16 months (Figure 7d,e). Infants in the *consistently low* ($M = 85.65$, SD = 29.27) and *early decline* groups ($M = 89.61$, SD = 29.49) had faster walking speeds than did infants in the *late decline* ($M = 70.81$, SD = 23.27) and *consistently high* groups ($M = 60.69$, SD = 26.99), $F(3, 60) = 3.17$, $p < .05$, Sidak post-hoc
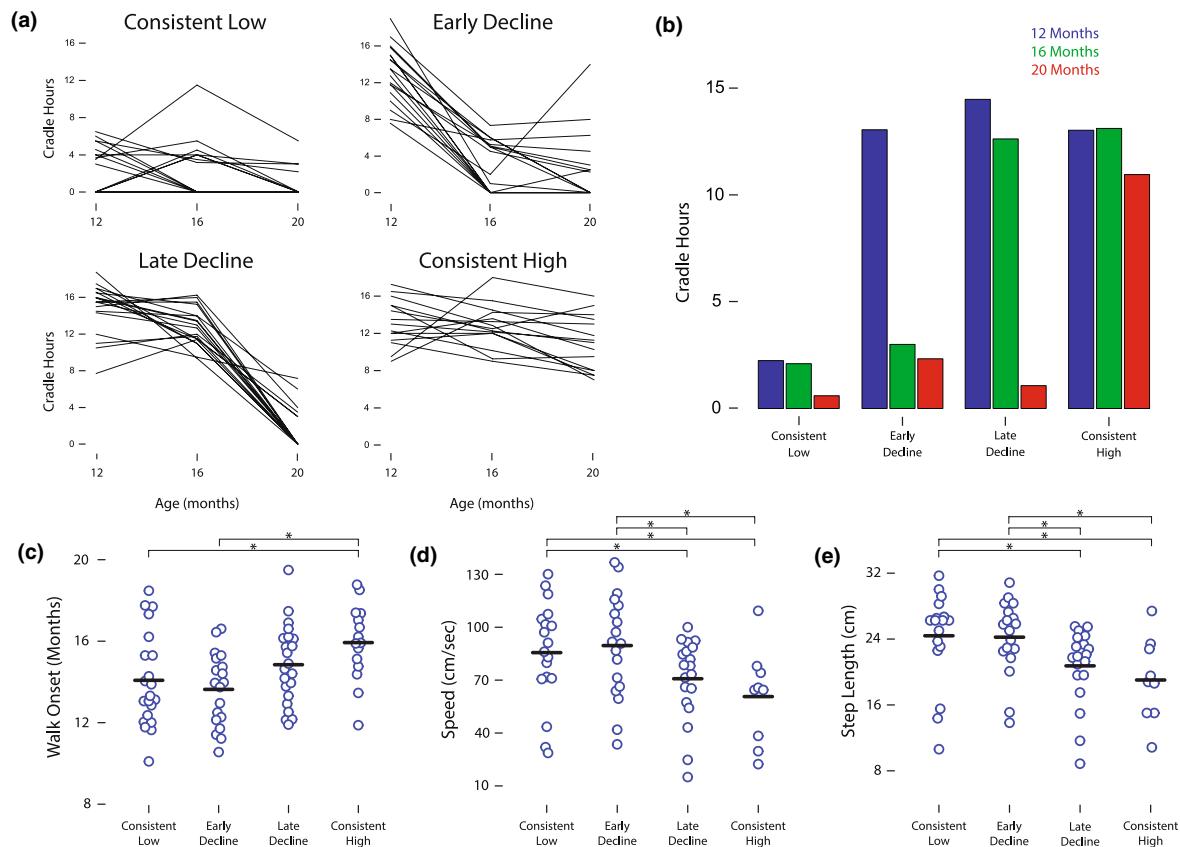
FIGURE 7 Relations between cradling patterns over age and walk onset and walking proficiency for Study 2. (a) Four patterns of cradling based on results of *K*-means cluster analyses. Each curve shows one infant's prior-day cradling hours across the 12-, 16-, and 20-month test sessions. (b) Bars represent averages for the four cluster groups at the 12-, 16-, and 20-month sessions. Differences in the four cluster groups for (c) walk onset age, (d) walking speed, and (e) step length. Each symbol represents one infant and solid horizontal lines denote group means.

comparisons, $ps < .05$. Infants in the *consistently low* (M = 24.38, SD = 5.56) and *early decline* groups (M = 24.22, SD = 4.52) also had longer step lengths than infants in the *late decline* (M = 20.72, SD = 4.60) and *consistently high* groups (M = 19.03, SD = 5.04), $F(3, 60)$ = 3.91, $p < .05$, Sidak post-hoc comparisons, $ps < .05$. Although patterns were similar at 20 months, differences among cluster groups were no longer significant, $ps > .05$.

Summary

Results replicated later walk onset age in Tajik infants relative to WHO standards, based on measures of walking status (walk vs. not) and walk onset ages. Moreover, infants who were still cradled at 16 and 20 months had later walk onset ages than infants who were no longer cradled. Reciprocally, exploratory analyses revealed that infants' walk status at younger ages predicted their cradling hours at older ages, pointing to bidirectional associations in infants' locomotor opportunities and skills. Patterns of cradle use across the three ages related to walk onset and proficiency. And prior-day cradling related to cranial index. In Study 3, we tested whether cradling in infancy has lasting effects on motor development in early childhood.

STUDY 3: MOTOR SKILLS IN EARLY CHILDHOOD

Infants in Tajikistan, all cradled since birth, lagged in postural and locomotor skills relative to WHO standards, based on cross-sectional (Study 1) and longitudinal data (Study 2). Moreover, current cradling status, prior-day cradling, and patterns of cradle use across age predicted motor skill. Do motor skill differences persist into early childhood? We assessed Tajik 4.5–5-year-olds on a standardized test of gross motor skills, compared their performance with established US norms, and tested whether prior cradling experience predicted individual differences in children's motor skills.

If freedom to move is constrained during the early period of intensive gahvora use, then children with prolonged cradling histories might show lower motor performance relative to published norms (based on US children). Alternatively, Tajik children might be comparable with US children because opportunities to freely explore the environment when no longer cradled might mitigate early differences, in line with findings that initial delays from restrictive practices attenuate by childhood in other cultural groups, such as the Aché of Paraguay (Hill & Hurtado, 1996; Kaplan & Dove, 1987). Thus, our analyses were exploratory.

Method

Participants

In 2015–2017, two Tajik researchers visited children aged 4.32–5.09 years (N = 91) in the Districts of Republican Subordination and Sughd and Khatlon regions of Tajikistan (Figure 2c). Children were healthy with no known birth complications. We expanded the catchment area in an attempt to recruit children who had never been cradled, with assistance from the Ministry of Health Scientific-Clinical Center. However, we were unable to identify a region without extensive cradling. Thus, we compared two unbalanced groups of children—those who stopped cradling before 12 months (*early-end group*) and those cradled beyond 12 months (*late-end group*). Children in the *early-end* cradle group (n = 24, 10 boys, 14 girls; M = 4.73 years old, SD = 0.14) were cradled during their first year only (M = 4.78 months). Children in the *late-end* cradle group (n = 67, 28 boys, 39 girls, M = 4.73 years old, SD = 0.19) were cradled for more than 12 months (M = 24.49 months), with 8 cradled until 36 months and 3 past 36 months.

Test of gross motor development

We assessed children on a subset of items from the standardized Test of Gross Motor Development (2nd edition, TGMD-2; Ulrich, 2000)—on the quality of gross motor skills that involve large, force-producing muscles of the trunk, arms, and legs. The TGMD-2 was standardized on a diverse, large sample of 3–10-year-old children in the United States and is the only assessment that provides norm- and criterion-based interpretations. For this study, the TGMD provided a set of tasks we could apply in Tajik households to observe movement patterns in children; we did not use it as a diagnostic tool or to generate normed scores. To accommodate the setting, we modified some tasks (e.g., shortened distances; allowed footwear to vary) and eliminated others that may require familiarity with certain materials (e.g., dribbling a ball). Researchers who used the TGMD-2 with samples outside the United States also made adjustments that did not compromise the validity of data (Kim et al., 2014; Simons et al., 2008; Valentini, 2012; Wong & Cheung, 2010).

Two researchers video-recorded children completing locomotor tasks of *running, galloping, jumping, and hopping* (see illustrations in the left column of Figure 8). To minimize verbal instructions and standardize presentations of tasks, the researcher showed children a video of an adult performing each task. Children *ran* between two beanbags (placed 6–8 m apart, depending on space) as quickly as possible. Children *galloped* with a three-beat gait between beanbags placed 6–8 m apart, leading with
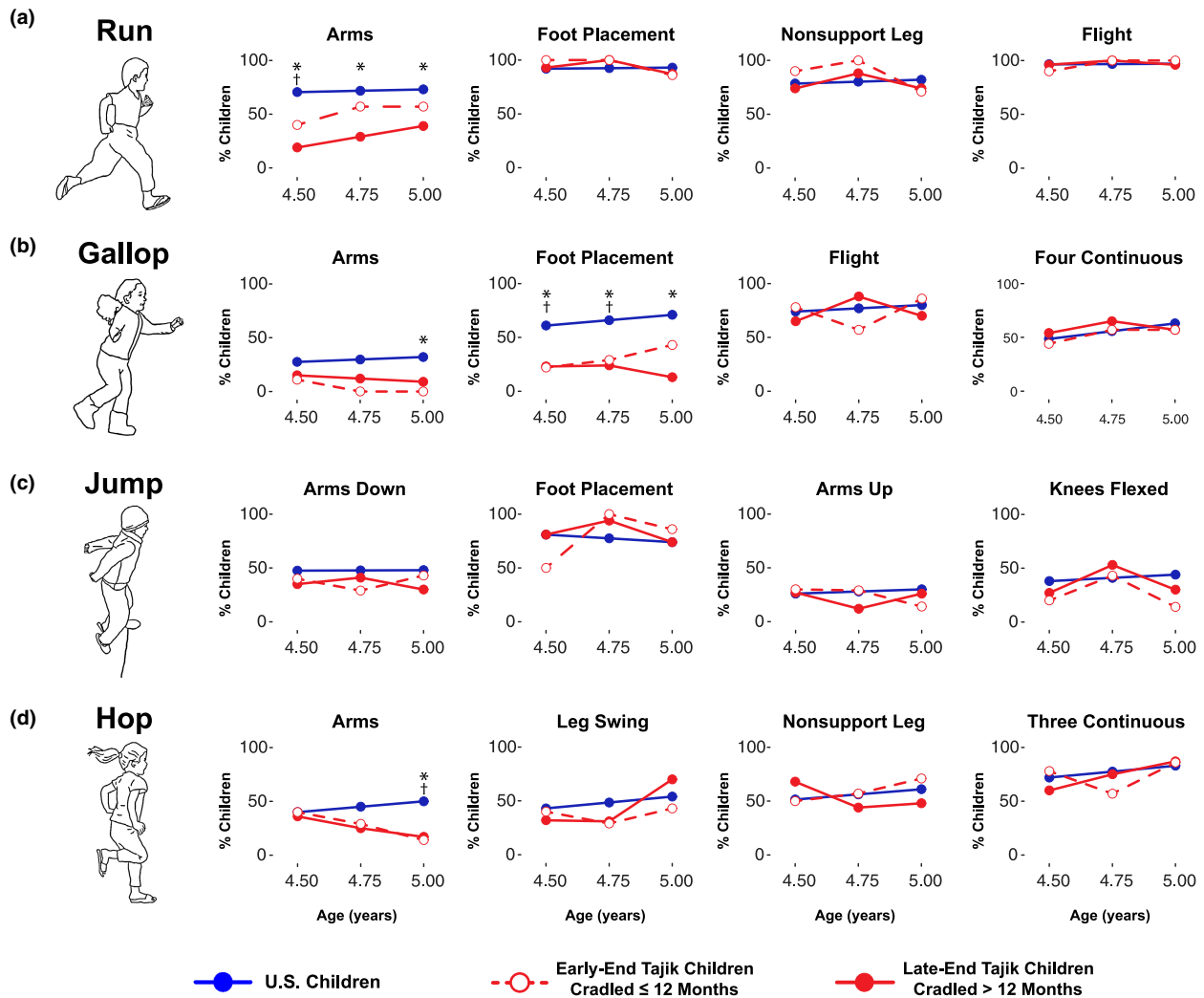
FIGURE 8 Effects of early (red dashed lines) and late (red solid lines) cradling on motor skills in young Tajik children relative to US norms (blue lines) on the Test of Gross Motor Development-2. (a) Running, (b) galloping, (c) jumping from two legs, and (d) one-legged hopping. Asterisks denote significant differences between US and Tajik children in the *late-end* cradle group ($p < .05$); swords indicate significant differences between US children and Tajik children in the *early-end* cradle groups.

one foot. They *jumped* from a standing position with arms swinging up and both feet simultaneously lifting. They *hopped* on one foot to get from one beanbag to another. An initial practice trial ensured that children understood the task. Two subsequent test trials comprised the data.

Cranial index

We measured children's heads as in the previous studies. Because the WHO does not report cranial indices for young children, measures were compared with published reports of children (Awwal Musa et al., 2014; Likus et al., 2014; van Vlimmeren et al., 2017).

Data coding and measures

A primary coder scored each trial for each task using Datavyu based on TGMD-2 criteria (4 criteria per skill).

Running criteria were moving arms in opposition to legs with elbows bent; displaying a period with both feet off the ground; landing on heel or toe rather than flat-footed; and bending the non-supporting leg about 90°. *Galloping* criteria were lifting bent arms to waist level at takeoff; leading with one foot while the trailing foot remains adjacent or behind the lead; displaying a period with both feet off the ground; and completing four consecutive gallops. *Jumping* criteria were starting with knees bent and arms extended behind; extending arms upward above the head while jumping; taking off and landing with feet together; and thrusting arms downward when landing. *Hopping* criteria were swinging the non-support leg forward like a pendulum; keeping the foot of the non-supporting leg behind the body; swinging bent arms forward to produce force; and hopping three times consecutively on the preferred foot. Coders scored each criterion as "1" if the child successfully met the criterion and as "0" if the child did not. The two test trials were summed for an average score from 0 to 2 per criterion,

per task. Thus, across tasks and test trials, each child contributed 32 data points averaged to 16 scores in total.

A second coder independently scored 100% of each child's data to calculate inter-observer reliability. Coders agreed on >90%, κs > .80 of categorical codes representing pass/fail for each criterion.

Results

Body dimensions

As shown in Figure 5c, children's BMI and head circumference fell within the 25th to 75th percentile based on the WHO standards; height fell below the 25th percentile, and weight fell below the 25th percentile (for girls only). Height, weight, and head circumference increased with age, Fs(2, 87) = 8.29, 4.69, 4.41, ps < .05. Boys were larger than girls on measures of weight at 4.75 years, $t(22) = 2.52$, $p < .05$, and head circumference at 5 years, $t(28) = 3.19$, $p < .05$. BMI did not differ by age or sex.

Skills relative to TGMD norms

We compared the percentages of Tajik children who demonstrated each motor task criterion to percentages of US children who passed based on TGMD-2 age norms using Chi-square goodness of fit tests. Because Tajik children ranged from 4.32 to 5.09 years, and TGMD-2 presents percentages of children passing criteria for each task at 4 and 5 years (Ulrich, 2000, p. 18), we bucketed children into 3 age groups (4.5 years for children spanning 4.32–4.64; 4.75 years for children spanning 4.65–4.84; and 5.0 years for children spanning 4.85–5.09), with comparable ns across age groups (ns = 36, 24, and 30). Then, we interpolated US percentages for norms at those ages for comparisons. Figure 8 presents percentages from US norms (blue curves) and percentages of Tajik children passing each criterion at each age group (red curves) for early-end and for late-end cradled children (solid and dashed lines).

Overall, the percentages of Tajik children who passed each task approximated US percentages. Twelve of the 16 criteria across the 4 locomotor tasks (running, jumping, hopping, and galloping) showed no group differences. However, for galloping, lower percentages of Tajik children of all ages passed foot placement compared with US children. Tajik children in the *early-end* and *late-end* cradle group differed significantly from US children at the earlier ages, $\chi^2(1, 9, 26) = 5.69$ and 15.72, $p < .05$ for *early-* and *late-end* at 4.5 years, respectively; and $\chi^2(1, 7, 17) = 4.37$ and 13.67 $p < .01$ for *early-* and *late-end* at 4.75 years, respectively. But only children in the *late-end* cradle group differed from US children at 5 years, $\chi^2(1, 23) = 37.52$, $p < .001$.

Tajik children also lagged on 3 criteria that involved arm placement and coordination of arms with the rest of the body—running with arms bent and swinging in opposition to legs; galloping with arms bent and lifted at takeoff; and hopping with arms bent and swinging at waist level. Notably, differences in arm placement were most pronounced for the Tajik *late-end* cradle group. Some children showed no signs of meeting arm-based criteria, although most partially met the criteria by moving one arm appropriately or by performing inconsistently across the two trials. For running, Tajik children in the *late-end* cradle group lagged behind US children at all ages, $\chi^2(1, 27, 17, 17) = 35.08$ and 15.03, 13.38, ps < .001, and Tajik children in the *early-end* cradle group lagged behind US children at 4.5 years, $\chi^2(1, 10) = 4.47$, $p < .05$. The *late-end* Tajik children also lagged behind the *early-end* Tajik children for arm placement when running, $\chi^2(1) = 3.69$, $p = .05$. We observed similar patterns for arm positions at 5 years in the gallop and hop tasks. For galloping, Tajik children in the *late-end* cradle group lagged behind US children, $\chi^2(1, 23) = 5.74$, $p < .05$. For hopping, Tajik children in both the *late-end* cradle group, $\chi^2(1, 23) = 9.78$, $p < .01$, and *early-end* cradle group, ($\chi^2(1, 7) = 3.57$, $p = .05$) lagged behind US children.

Gahvora use and cranial index

Tajik children's cranial index (Ms = 88.01 and 91.15, SDs = 6.80 and 5.28, for boys and girls respectively) was 10 points higher relative to published averages (range in Ms = .78–80; Graham et al., 2005), Figure 4d. Tajik girls had an elevated cranial index relative to Tajik boys, $t(88) = -2.46$, $p < .05$. Although both late-end and early-end cradle groups showed larger cranial indices relative to published norms, $t(66) = 17.40$, $p < .001$; $t(23) = 5.94$, $p < .001$, the difference was more pronounced for children in the *late-end* cradle group ($M = 91.11$, SD = 5.86) than for children in the *early-end* cradle group, ($M = 85.90$, SD = 5.86), $t(88) = 3.78$, $p < .001$.

Summary

Despite extensive cradling in infancy and lags in motor skill onsets and walking proficiency seen in Studies 1 and 2, differences between Tajik and US young children were negligible, suggesting that the effects of cradling may be mitigated by interim experiences. On most skills, Tajik children showed comparable performance with US children. Nonetheless, Tajik children showed lower performance for tasks requiring bilateral coordination of arms and legs; and differences were especially pronounced for children who had been cradled beyond 2 years of age. Differences in brachycephaly persisted beyond infancy and were more pronounced for the late-end cradling group.

GENERAL DISCUSSION

Movement is fundamental to motor development (for review, see Adolph & Hoch, 2019). Restricted

movement leads to delayed motor skills in non-human infants (Harlow & Harlow, 1961; Haverkamp & Oppenheim, 1986) and in human infants who experience tight swaddling, confined toileting, and cradleboards (Chisholm, 1978; Davis et al., 1998; Mei, 1994; Xie & Young, 1999). In three studies, we leveraged naturally occurring variation in the cradling experiences of 360 infants and children in Tajikistan to investigate associations between time in the gahvora (current cradling status, prior-day cradling hours, and months of cradling) and motor skill status, skill proficiency, and cranial index. Notably, although infants' arms, legs, and torso are immobilized in the gahvora cradle—sometimes for many hours a day—infants are otherwise surrounded by siblings, peers, and adult caregivers who lovingly tend to their needs. Thus, our focus on a widespread, culturally accepted practice in Tajikistan avoided confounds due to social deprivation.

Gahvora cradling and infant motor development

Fewer Tajik infants demonstrated sitting, crawling, standing, and walking (Studies 1 and 2) compared with same-age infants represented on WHO standards (Martorell et al., 2006), and cradling hours related to walking proficiency (Study 1 and Study 2). Associations between cradling hours and walking proficiency were especially pronounced for infants who had been cradled into their second postnatal year or beyond (Study 2). And across all three studies, infants and children had moderate to severe brachycephaly, and cradling related to measures of cranial index (Studies 2 and 3), corroborating caregiver reports of infants' extended time in the gahvora (Graham et al., 2005). Associations between cradling and motor development, and the prevalence of brachycephaly in infants and children, provide a clear demonstration of the hypothesis that movement restriction affects motor development and physical growth.

However, effect sizes linking cradling and motor development were mostly small to moderate, perhaps because time in the gahvora does not inform on infants' opportunities to move when unconstrained. When outside the cradle, infants likely took advantage of time to move and spent much of their time on the ground. Other than the gahvora, containment devices (e.g., carriers, strollers, playpens) were virtually absent in Tajik homes (Karasik et al., 2022). Although the constraints on movement imposed by gahvora cradling (Karasik et al., 2018) may seem extreme to Western eyes, other means of containment (e.g., car seats, highchairs, strollers, bouncers) are ubiquitous in Western cultures. And, like the gahvora, such constraint also delays infant motor development (Pin et al., 2007; Siegel & Burton, 1999; Talebian et al., 2009).

Notably, exploratory analyses revealed that associations between cradling and motor development were

bidirectional: Gahvora use related to later emergence of motor skills and reciprocally, caregivers' perception of low motor skills may have prolonged gahvora use. Indeed, infants who walked at 16 months were cradled for fewer hours at 20 months than infants who did not walk at 16 months; similar lagged correlations were found for walking status at 12 months. However, caregivers anecdotally reported that they stopped cradling their infants due to hot weather or the arrival of a new baby that needed the family gahvora, not because their infants had begun walking.

Cultural experiences may attenuate early effects

Associations between cradling and motor skills in infancy provide limited insight into the duration of effects across development. So we explored whether cradling effects persist into early childhood (Study 3).

Tajik children performed comparably to norms of US children on most motor skill criteria, suggesting that interim opportunities to practice motor skills may diminish the effects of early restricted movement on later motor development. During home visits, researchers observed children playing with siblings and peers, navigating a variety of terrains, and displaying motor skills not represented on standard developmental assessments—climbing tall ladders, carrying heavy loads, and maneuvering narrow passageways along cliffs. Freedom to navigate the environment echoes the experiences of Aché children in Paraguay. Aché caregivers limit their infants' locomotor exploration, discourage exploration to guard against environmental hazards, and rarely set infants on the ground to be left alone (Hill & Hurtado, 1996). As a result, Aché infants lag months behind US children on motor skills (Kaplan & Dove, 1987), but they surpass children from other cultures by around 5 years of age: They walk for miles through dense forest terrain when camps move, climb tall trees, and chop branches and vines with machetes (Hill & Hurtado, 1996; Kaplan & Dove, 1987). Nonetheless, Tajik children lagged on 3 of 4 criteria pertaining to arm positioning, and disparities were magnified for children who were cradled beyond 2 years of age. However, we are cautious in attributing these minor differences to cradling.

Gahvora cradling benefits may outweigh costs

Gahvora cradling highlights how communities adapt their practices to environmental and cultural demands. Presumably, gahvora use endured over centuries (Zawlacki & Derrick, 2020) because of immediate benefits that outweigh short-term costs. The gahvora cradle safely contains infants while caregivers complete chores or leave the room. It serves as a toileting method to keep infants clean and dry in a setting where water and

disposable diapers are scarce. And, during interviews, caregivers noted that cradling lulls infants to sleep, prolongs sleep, and reduces infant crying and fussiness—perhaps because cradling mirrors the motion, tactile containment, and reduced light of the prenatal environment, much like cradles designed to provide multisensory experiences (Gatts et al., 1995).

Limitations

Study limitations include small samples within age groups and reliance on caregiver report to quantify cradling hours (Study 1 and 2) and infant walk onset age (Study 2). Although we observed and tested over 300 children across three studies, the number of infants at each age reduced power to detect concurrent associations. Moreover, we interviewed mothers about cradling during the prior day, rather than tracking cradling over extended time frames. Although we tracked infant walk onset prospectively in Study 2 and observed babies longitudinally, caregivers may not be particularly sensitive to traditional milestones widely recognized by parents in other cultures. Nonetheless, despite the low power for certain analyses and the potential limitations of caregiver report, consistency of findings across studies lend credence to the role of motor movement in motor development, at least during infancy.

Implications for developmental science

Findings from this study have implications for key issues in developmental science—particularly the role of experience in early development. Notably, Tajik 4–5-year-olds—all of whom had been cradled—showed comparable performance on motor skills compared with US norms. The transient association between gahvora cradling and motor skills does not refute the importance of "freedom to move." Indeed, in infancy, cradling hours are related to motor status and proficiency to varying degrees.

Rather than eliminating movement, gahvora cradling may canalize experiences (Gottlieb, 1991; Waddington, 1942), with infants and children taking advantage of the opportunities available to them at different ages during different cultural activities. Development may allow for a range of experiences to eventually converge on similar outcomes. Children everywhere learn to walk, despite vastly different childrearing practices, even if onset ages and proficiency of skills differ (Adolph et al., 2010; Hospodar et al., 2021).

Findings suggest that the effects of gahvora cradling may be both bidirectional and non-linear. We have not yet explored the full range of infant and child experiences in and out of the gahvora. For example, while strapped supine in the gahvora with drapes open, infants are exposed to a rich visual and social environment; siblings, peers, and adults are often nearby interacting or otherwise occupied with other tasks. Caregivers breastfeed and tend to their cradled infants and often vigorously rock the gahvora with babies tightly fastened in. Gahvora cradling offers a natural experiment that allows researchers to examine cascading effects from cultural experiences to motor development to skills in language, social, and cognitive domains.

CONCLUSIONS

Cultural research offers a unique opportunity to broaden the lens of developmental science to illuminate childrearing practices that shape children's learning and development. The changing associations between gahvora cradling and motor development (namely, lags in infancy followed by comparable motor skills in early childhood), adhere to a principle of equifinality—different cultural pathways can result in similar outcomes. Equifinality of outcome raises questions about how caregivers both restrict and encourage children's skills across different communities and how much experience is sufficient for children to adapt to their cultural contexts.

DATA AVAILABILITY STATEMENT
The analyses presented here were not preregistered. All raw data and materials (i.e., coding manuals, video excerpt examples, coding spreadsheets, SPSS) are available on Databrary, https://nyu.databrary.org/volume/1505: Study 1 at https://nyu.databrary.org/volume/11; Study 2 at https://nyu.databrary.org/volume/296; and Study 3 at https://nyu.databrary.org/volume/226.

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