Walking-Related Changes in Infants' Everyday Experiences of Postural Transitions: A Longitudinal Assessment

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Abstract

Postural transitions occur when infants switch from one posture to another, such as from prone to sitting. Postural transitions facilitate perceptual-motor exploration because different postures afford unique learning opportunities. However, extant studies on postural transitions are limited to laboratory play sessions, so it is unknown how frequently transitions occur in daily life. In the present study, we assessed infants' daily experiences with postural transitions. In particular, we tested whether the frequency of transitions and the type of transitions change with infants' increasing walking experience. We developed a novel video-based ecological momentary assessment (vEMA) to longitudinally collect videos of infants' activities throughout the day in their home environment at 11 and 13 months of age. We identified postural transitions in the resulting 3210 video observations collected from $N = 44$ infants across the United States, which revealed that the frequency and type of transitions differed according to walking experience. The frequency of postural transitions decreased with accumulated walking experience. Infants with greater walking experience more frequently engaged in transitions involving upright postures in their daily lives.

Walking-Related Changes in Infants' Daily Experiences of Postural Transitions: A Longitudinal Assessment

The acquisition of independent walking is linked to infants' later perceptual, cognitive, and linguistic development (Iverson, 2022; Oudgenoeg-Paz et al., 2016; Walle & Campos, 2014). Such far-reaching effects presumably occur because the ability to walk changes infants' daily experiences in ways that change opportunities for learning (Franchak, 2020; Oakes, 2017). One aspect of infants' daily experiences that change with the walking onset is how they spend time in various body postures. For example, Franchak (2019) and Franchak, Kadooka, et al. (2024) found that walking infants spent less time sitting and more time upright compared to non-walking infants throughout the day.

However, most studies on infants' postural experiences focused on posture rates in isolation (e.g., sitting and upright frequency) but not on the real-time connections between postures, that is, **postural transitions**. The few laboratory studies of infant postural transitions reveal that infants do not remain in one body posture for long (Soska et al., 2015; Thurman & Corbetta, 2020; Thurman & Rose, 2025). Yet, how infants switch between postures in a laboratory free play session might not generalize to how frequently postural transitions occur in naturalistic situations across the day. Non-play aspects of infants' everyday activities both inside (e.g., mealtimes, TV viewing) and outside the house (e.g., car rides, grocery shopping) might create situations in which infants stay in one posture for a prolonged period of time (Franchak et al., 2026; Franchak, Tang, et al., 2024). In the present study, we address this gap by focusing on walking-related changes in postural transitions measured in daily life.

The Significance of Postural Transitions

Postural transitions can take many forms: rolling over from lying supine to lying prone on the belly (Piper & Darrah, 2021), sitting down to reorient their bodies during locomotion (Soska et al., 2015), or pulling-to-stand to interact with objects or caregivers (Piper & Darrah, 2021; Thurman & Rose, 2025). Gross motor skill assessments, such as the Alberta Infant Motor Scale (AIMS), assess postural transitions (e.g., rolling over, sitting-to-prone, pulling-to-stand, etc.) as part of the normative trajectory of motor development in the first two years. For example, infants typically roll from supine to prone at 7 months, and sitting-to-prone and pulling-to-stand transitions emerge at 8 months (Piper & Darrah, 2021). Some prior literature looked beyond normative ages for transitions to see how postural transitions were actually employed in spontaneous behavior. For example, Soska et al. (2015) found that pre-walking infants displayed 3-6 crawl-to-sit transitions per minute during laboratory free play.

Understanding the frequency and type of postural transitions is important beyond motor development because postural transitions have functional value for infants' exploration and learning. For example, pulling-to-stand, a type of transition that typically begins prior to the onset of walking (Adolph et al., 2014; Piper & Darrah, 2021), provides unique vestibular information (Barela et al., 1999; Chen et al., 2008; Metcalfe & Clark, 2000) and frequently accompanies object exploration and social interactions (Thurman & Rose, 2025). Moreover, prior work suggested that postural transitions alter infants' visual field of view. Crawling-sitting transitions allow them to reorient their bodies to quickly gain wider visual access to their surroundings (Soska et al., 2015). In addition, transitioning to postures with higher vantage points such as standing upright may help infants access elevated and distant visual targets (e.g.,

caregivers' faces, toys on a shelf, far toys, etc.) that are difficult to see when remaining prone (Kretch et al., 2014; Luo & Franchak, 2020). Thus, postural transitions afford unique opportunities for infants' perceptual-motor exploration in everyday life.

However, infants' experiences with postural transitions in naturalistic settings across the day are under-studied. Extant studies on postural transitions (Soska et al., 2015; Thurman & Corbetta, 2020; Thurman & Rose, 2025) were conducted in brief laboratory free play sessions. The expression of infants' motor behavior is not uniformly distributed across the day: For instance, infants may switch frequently between postures while playing unrestrained, but are most likely sitting restrained during mealtime (Franchak, Tang, et al., 2024). Therefore, although laboratory free play studies suggested that postural transitions are frequent and afford unique learning opportunities, we do not know how often such behaviors are expressed in infants' daily lives at home, where they engage in a wide range of activities beyond play.

Independent Walking Might Alter Daily Experiences with Postural Transitions

Since infants' everyday experiences with postures differs between walkers and non-walkers of the same age (Franchak, 2019; Franchak, Kadooka, et al., 2024), it is reasonable to expect that the **frequency** and **type** of postural transitions may also change when infants become more proficient at walking. Across motor development, infants' expanding motor skills can change how postural transitions accomplish various functional goals in their daily activities, thereby changing the expression of postural transitions in infants' daily lives. For example, although crawling-sitting transitions help pre-walking infants to reorient their bodies during locomotor exploration (Soska et al., 2015), the functional significance of this transition might

decline after they learn to walk: As infants become increasingly proficient in maintaining upright balance after prolonged walking experience (Chen et al., 2008), they can reorient their bodies while remaining upright (e.g., stop walking and reorient themselves while standing) without switching to a completely different posture, thus decreasing the frequency of crawling-sitting transitions during free play. The present study focuses on two aspects of infants' daily experiences with postural transitions that might change with the onset of walking: the overall **frequency** of transitions—how frequently transitions of any type occur during the day—and the **type** of transitions, which was defined by the specific postures involved during transitions (e.g., supine-prone, sitting-upright).

Current literature implicates two plausible but mutually exclusive hypotheses regarding changes in the frequency of infants' daily postural transitions after learning to walk. One line of evidence suggests that transitions should decrease as walking experience increases: After learning to walk, infants persistently attempt to walk upright despite being more adept at crawling (Adolph et al., 1997; Adolph & Tamis-LeMonda, 2014). Through practicing, infants are able to maintain upright locomotion for longer, uninterrupted bouts without falling or stopping (Hospodar et al., 2021). Therefore, these changes may lead to increases in infants' prolonged upright experiences throughout the day, thus **decreasing** the frequency of postural transitions. However, the opposite effect is also possible. Infants' motor repertoires expand as they acquire new postures and actions (e.g., kneeling/squatting, cruising, independent walking, etc.) across motor development (Thurman & Corbetta, 2020). As infants actively exercise these new motor skills and combine them with previously acquired abilities (e.g., sitting), their experiences with postural transitions are likely to **increase** throughout the day as they explore and experiment with

their bodies' changing capacities. However, it is uncertain which account more accurately describes infants' daily postural experiences after the onset of walking.

The types of transitions that infants perform might also change as infants become more proficient at walking. By type, we refer to which postures categories are most often displayed in infants' postural transitions. Motor development has been proposed to reorganize infants' daily motor experiences (Franchak, 2020). Indeed, using network-based analysis on infants' postural experiences during laboratory free play, Thurman & Corbetta (2020) found that infants' postural systems went through a restructuring across motor development that changed which types of transitions infants were more likely to engage in. For example, upright standing had the highest connections with other postures among walking infants, whereas among pre-walking infants, the most central posture was kneeling/squatting. This suggests that the frequency of different postures involved during infants' daily postural transitions might change as infants adapt to changes to their bodies following the walking onset, such that infants with more walking experience are more likely to engage in transitions involving upright postures and less likely to engage in non-upright transitions (e.g., sitting-prone transitions) than those with less or no walking experience.

Methodological Limitations when Measuring Infants' Daily Experiences

Infants' motor behaviors can vary greatly within a single day, but extant methods differ in how well they can capture such variability. Laboratory free play (e.g., Franchak et al., 2018; Hoch et al., 2020; Lee et al., 2018; Soska et al., 2015; Thurman & Corbetta, 2020) is commonly used to study infants' motor behaviors. However, behaviors displayed in a novel, unfamiliar

laboratory environment might not generalize to those displayed in infants' naturalistic environments. A common alternative is to video record infants' behavior in the home, with observation sessions that typically span 1-2 hours (e.g., Herzberg et al., 2022; Karasik et al., 2011, 2012; Swirbul et al., 2022; West & Iverson, 2021). Although more ecologically valid than laboratory studies, such measurements cannot capture the full range of infants' activities across the day due to their limited duration.

To address these limitations, Franchak (2019) applied ecological momentary assessment (EMA) by repeatedly sending caregivers text-based surveys (e.g., 'Please indicate which of the following positions your child is in right now') inquiring about infants' body postures at multiple randomized time slots throughout the day over a week. By repeatedly sampling across infants' entire waking hours from morning to evening, EMA can capture the within-day variability of infants' motor experiences that is missed when behavior is only studied for 1-2 continuous hours. Remote EMA data collection also allows a broader sampling range across the United States and eliminates the potential effects of reactivity because experimenters do not need to visit the home (Franchak, Kadooka, et al., 2024). However, this method has one limitation with regard to our current aims: EMA surveys yield momentary rather than continuous data about infants' behavior. Infants' postural transitions, by definition, occur over time, thus, text-based surveys preclude researchers from observing postural transitions using existing EMA methods.

Current Study

The current study offers "video EMA" (vEMA) as a new alternative to assess infants' everyday experiences. Here, we apply the new vEMA method in longitudinal age windows at 11

and 13 months to track changes in postural transitions spanning the acquisition of independent walking. Instead of text-based surveys, we repeatedly requested caregivers to record short video clips (~10 seconds) of infants during natural activities throughout the day. Although the total duration of video data is shorter than a continuous home recording spanning 1-2 hours, collecting brief samples across the day captures contextually varied behavior, thus enhancing representativeness of infants' full-day experiences. As we will demonstrate, even short video clips were sufficiently long to capture multiple postural transitions. We defined postural transitions as motor actions involving coordinated body movements that result in a distinct change in infants' body posture between the following categories: supine, prone, sitting, squatting, kneeling, and upright.

The first aim of the current study was to investigate whether changes in the frequency of infants' postural transitions across the day were associated with their walking experience. We chose walking because prior work identified walking onset as a strong predictor of changes in daily postural experiences, correlating with changes in their prone, sitting, and upright frequency (Franchak, 2019; Franchak, Kadooka, et al., 2024). We employed a longitudinal design that assessed infants' postural experiences through 2 age windows at 11 and 13 months old, following past work that investigated the role of independent walking (Karasik et al., 2011). On average, independent walking emerges at 12 months (WHO Multicentre Growth Reference Study Group, 2006), thus, most infants will be non-walkers at 11 months and approximately half will be walkers by 13 months.

The second aim was to assess potential walking-related changes in the types of postural transitions that occur, focusing on the involvement of upright posture, a category which includes

standing, cruising, and walking. We tested whether age and walking experience were associated with increased upright-involved transitions (e.g., prone-upright transitions, sitting-upright transitions) and decreased non-upright transitions (e.g., prone-sitting transitions, prone-kneeling transitions).

Method

Participants and Design

Given the novel aim of measuring postural transitions in daily life, no prior effect sizes were available to guide sample size selection. So, we collected data based on study resources: We collected data from as many participants as possible during the Expiwell survey software subscription period. Seventy-two families were recruited from social media advertisements distributed across the United States. Our final sample consisted of $N = 44$ infants (20 male, 24 female). Each age window of the present study lasted 14 days. To be included in the study, caregivers must be able to stay with their infants at least 6 hours per day for at least 10 days across the 14 days. After their eligibility for inclusion was confirmed, caregivers selected a start date within 1 week of the focal ages (11 and 13 months). Infants' mean age at each age window was $M = 10.94$ months ($SD = 0.13$) at the 11-month window and $M = 12.95$ months ($SD = 0.19$) at the 13-month window. Twenty-six infants were walking by the end of the study (9 infants were already walking at 11 months old, and 17 infants started walking between the 11- and 13-month windows). Across all walking infants in the final sample, the age of walking onset ranged from 8.64 to 13.50 months.

Caregivers reported infants' ethnicity as Hispanic or Latinx ($n = 4$) or not ($n = 40$) and their race as White ($n = 29$), Black or African American ($n = 4$), Asian or Asian American ($n =$

1), Multiracial (n = 7), or not reported (n = 2). Caregivers also reported their residence types as Single-Family House (n = 31), Duplex Triplex or Row House (n = 3), Trailer or Mobile Home (n = 2), Apartment or Condo (n = 7), or not reported (n = 1). Among the primary caregivers who communicated with the research team throughout the study, 23 identified as being full-time or part-time employed, 20 identified as stay-at-home parents, and 1 did not report their employment status. All infants had normal visual, hearing, and motor development. Twenty-eight families were excluded from the study for not submitting at least 6 videos in both age windows (i.e., parental busyness (n = 3), technical problems (n = 13), or unexplained issues (n = 12)).

The procedure for the current study was approved by the BLINDED Institutional Review Board. Families that completed all the requirements for the study received $50 gift certificates as compensation.

Procedure

Introductory Phone Call

An introductory phone call was scheduled between the caregiver and the experimenter to explain study procedures. The current study used Expiwell (https://app.expiwell.com), a smartphone application previously used in research (e.g., Noël et al., 2021; Taylor et al., 2022). Caregivers received the application Android and iOS download links by email prior to the call. After providing informed consent, caregivers selected the start date for their 11-month window. During the remainder of the call, the experimenter collected infants' birth and health information, explained the survey questions and video-recording prompts, and provided instructions for recording videos.

Video Survey

Each day, caregivers received 10 notifications from Expiwell between 9 am to 7 pm local time. The notifications were scheduled randomly within each hour to avoid predictability (e.g., 9:20 am, 10:43 am, 11:18 am, 12:35 pm). Each notification contained two survey questions: The first asked whether caregivers were with the infant at the moment, and the second asked whether they could take a video of their infants. Caregivers were instructed not to take videos if the infant was being held by the caregiver or another person or if the infant was in a public place. Caregivers were prompted to record and upload a video only if they responded 'yes' to both questions. We requested that videos be filmed in landscape (horizontal) view with the infant in the center of the frame for around 10 seconds, with infants' faces and entire bodies visible throughout the video if possible. Each prompt remained active for 15 minutes before it expired, and caregivers were encouraged to respond to as many notifications as possible.

Follow-Up Phone Calls

After the 11-month window an experimenter verified whether caregivers could proceed to the 13-month window by checking if they submitted at least 6 video clips. If this criterion was met, a follow-up phone call was scheduled when infants were around 12.5 months old. During the call, the experimenter collected motor milestone onset dates for independent sitting, crawling, cruising, and walking following a previously used set of questions (Adolph et al., 2003), for example, 'Does your infant walk 10 feet across the floor without stopping or falling?' Caregivers reported the onset date if the infant had performed the skill. At the end of the call, caregivers selected the start date for the 13-month window. If caregivers completed both age windows, a final phone call was scheduled at around 13.5 months to collect the onset dates of motor skills not previously attained (e.g., if the infants had not learned to walk by 12.5 months

old) and demographic information including race/ethnicity, family size, caregivers' occupations, and residence type.

Data Processing

Survey Responsivity

Participants received 140 total notifications over 14 days for each age window, making the present study more demanding than previous survey-based EMA studies (Franchak, 2019; Franchak, Kadooka, et al., 2024) that sent only 35-40 notifications across 4-7 days. Therefore, we calculated the response rates to assess participant compliance. Participants responded to M = 57.8% (SD = 25.3%) of the total notifications. Although lower than the 95.6% in Franchak (2019), we collected more total responses due to the higher total number of requested surveys. Participants responded for M = 13 days (SD = 2), indicating that responses were made consistently over the two-week period rather than clustered into only a few days.

Out of the total responses, 52.7% included a video submission. Out of the responses without videos, 20.8% were due to the caregiver being away from the baby, 48.7% due to the baby sleeping, 15.4% due to the baby being held, 8.8% due to the baby in a public place, and 6.5% unexplained (i.e., responding 'yes' to both questions but did not upload a video). These responsivity statistics showed that participants adhered to study instructions and provided sufficient video data.

Processing and Coding Videos

We downloaded the video clips from Expiwell and used a custom *ffmpeg* (ffmpeg.org) script to concatenate all of the submitted clips from one age window into a single video file. The average length of video clips across both age windows was 13.3s (SD = 5.1). The videos were then imported into Datavyu (datavyu.org) for coding. To ensure the quality of the video data, we

excluded clips where infants' bodies were out of the camera frame for more than 1 second. The number of excluded clips did not significantly differ by infants' walking status (p = .212)

A primary coder scored *body posture* depending on whether infants were supine, prone, sitting, kneeling, squatting, or upright. Since a clip could contain various postures, the coder marked the first and last frames in which the detected body posture occurred. Supine was scored when infants were lying on their backs, on their sides, or reclined up to 45 degrees. Prone was scored when infants were on all fours or lying with their bellies on the floor. Sitting was scored when infants were supported with their buttocks contacting a surface, regardless of hand support, kneeling-sit posture, or usage of sitting devices (e.g., high chair, car seat). Kneeling was scored when infants supported themselves on one or two knees. Squatting was scored when infants supported themselves on two feet while displaying a knee flexion angle of at least 90°. Upright was scored when infants supported themselves on two feet with their torsos, thighs, and knees in line, which included standing, cruising, and walking. A secondary coder scored reliability among 25% of the data (i.e., 11 participants' videos at both age windows), which yielded an M = 95.74% agreement and an κ = 93.86% interrater reliability between the two coders.

Calculating Dependent Measures

We used the resulting body position time series to derive the dependent measures of our analyses: the frequency of postural transitions and transition types. For all analyses, responses without videos (e.g., "not with child", "baby is sleeping") were excluded from the total so that behaviors reflected the frequency out of awake behavior during which the respondent could observe the infant. A clip was categorized as a "transition" if at least 2 postures were observed with each lasting at least 0.5 seconds (Adolph, 1995).

We further examined all the video clips categorized as "transition" to derive the *transition type.* A *transition type* was defined by the temporal sequence of body postures in a given transition bout, therefore, one transition bout could contain multiple transitions depending on the order of displayed postures: For example, a 10-s clip featuring an infant crawling, sitting, and then crawling again would contain a "prone-sitting" transition and a "sitting-prone" transition. Our dataset yielded 30 unique types of transition—*supine-prone, supine-sitting, supine-kneeling, supine-squatting, supine-upright, prone-supine, prone-sitting, prone-kneeling, prone-squatting, prone-upright, sitting-supine, sitting-prone, sitting-kneeling, sitting-squatting, sitting-upright, kneeling-supine, kneeling-prone, kneeling-sitting, kneeling-squatting, kneeling-upright, squatting-supine, squatting-prone, squatting-sitting, squatting-kneeling, squatting-upright, upright-supine, upright-prone, upright-sitting, upright-kneeling, and upright-squatting* transitions.

Data Analysis

For data analyses and visualizations, we used R (Version 4.2.1; *The R Project for Statistical Computing*, n.d.) and the R-packages *lme4* (Version 1.1.31; Bates et al., 2015) and *tidyverse* (Version 1.3.2; Wickham et al., 2019). We determined infants' walking status by comparing their parent-reported walking onset dates (if applicable) against the start dates of the two age windows. To examine whether age and walking experience predicted changes in the overall frequency of daily postural transitions, we used a generalized linear models (GLM) that functioned as negative binomial regressions to estimate the raw count of postural transitions in a given video clip using age (i.e., 11-month-old, 13-month-old) and walking experience (i.e., the number of weeks elapsed between the walking onset date and the age window start date) as fixed effect predictors. Because the total number of submitted video clips differed across participants,

we also included the number of clips for each infant at each age window as a potential covariate, as commonly used in prior research (e.g., Kretch et al., 2025; Sano et al., 2011; Valluri et al., 2015). The number of clips included samples where a caregiver indicated that they could not upload a video due to the infant being held (these times could not involve a postural transition but were valid observations of infants' behavior). To examine whether age and walking experience predicted changes in the types of transitions infants engaged in throughout the day, we used generalized linear mixed-effects models (GLMMs) that functioned as logistic regressions to estimate the likelihood of observing various transition types in binary outcomes (e.g., 1 = the infant engaged in a prone-sitting transition in this clip, 0 = the infant engaged in a different type of transition)—using age and walking experience as predictors. All fixed effect predictors were mean-centered. We modeled random effect intercepts for each participant to account for individual differences (random slope models failed to converge). Interaction terms between fixed effects were not justified when testing preliminary models, so were omitted from the final modeling results. The dataset and analyses are openly shared through the Open Science Foundation (https://osf.io/skqgb/?view_only=306ca98e32f740118202cb0f8b9f50fe).

Results

We analyzed 3,210 video clips (~36 per infant per age window) capturing infants' daily postural experiences at home. Our results are divided into two sections. The first examines walking-related changes in the frequency of infants' postural transitions across the day. The second focuses on walking-related changes in the types of postural transitions displayed.

Changes in the Frequency of Postural Transitions by Age and Walking Experience

Figure 1 shows the overall distribution of postural transition counts per video clip, which revealed that the video EMA method captured variability in infants' real-time postural

experiences: Although 71.4% of the 10-s clips contained no transitions, others captured up to 9 transitions. The mean number of transitions (averaged across all clips) was $M = 0.5$ ($SD = 1.1$), but as Figure 1 shows, those transitions were distributed asymmetrically. When focusing only on 10-s clips that contained transitions, the average number of transitions was $M = 1.9$ ($SD = 1.2$). That the average was greater than 1 despite the brief, 10-s observation suggests that postural transitions were likely to be clustered closely in time.Overall, our findings suggested that the frequency of postural transitions was associated with their walking development: when controlling for age, infants who accrued more walking experiences engaged in fewer postural transitions across the day. Table 1 shows the results of a negative binomial generalized linear model which confirmed that the frequency of postural transitions were associated with their walking experience. The model yielded a significant effect of walking experience ($\beta = -0.04$, 95% CI [-0.07, -0.00]) while controlling for age and number of submitted video clips. Infants' age and the number of submitted video clips at each age window were not significant predictors in the model (ps > .426).

Changes in the Frequency of Transitions Types by Age and Walking Experience

Next, we focused only on video samples categorized as postural transitions ($n = 919$) to examine the types of transitions that occurred. Table 2 presents the frequency of each transition type, defined by the preceding and following postures. Transition types that accounted for less than 4% of infants' total transition bouts were excluded from further analyses because the data were insufficiently small to model. We divided the included transition types into common non-upright (e.g., *prone-sitting, sitting-prone, prone-kneeling, etc.*) and upright-involved transitions (e.g., *prone-upright, upright-prone, squatting-upright, etc.*) and tested their associations with age (in months) and walking experience (in weeks).

Our findings indicate that non-upright transitions became less frequent with walking experience. We calculated the percentages of prone-sitting (Figure 2A), sitting-prone (Figure 2B), prone-kneeling (Figure 2C), and sitting-kneeling (Figure 2D) transitions across the total transition bouts for each infant as a function of walking experience at each age window. Table 3 shows the results of a GLMM model predicting the likelihood of observing the four non-upright transitions with age and walking experience. Increases in walking experience were associated with significant decreases in all four transition types: prone-sitting (β = -0.11, 95% CI = [-0.17, -0.05]), sitting-prone (β = -0.05, 95% CI = [-0.08, -0.01]), prone-kneeling (β = -0.15, 95% CI = [-0.25, -0.05]), and sitting-kneeling (β = -0.12, 95% CI = [-2.20, -0.28]). We also found a significant age-related decrease in sitting-prone transitions (β = -0.34, 95% CI = [-0.59, -0.09]), however, age did not reach significance for other non-upright transition types (ps > .246).

Our findings supported the hypothesis that infants' postural transitions are more likely to involve upright postures as walking experience increases. We calculated the percentages of prone-upright (Figure 3A), upright-prone (Figure 3B), squatting-upright (Figure 3C), upright-squatting (Figure 3D), kneeling-upright (Figure 3E), and upright-sitting (Figure 3F) transitions across the total transition bouts for each infant as a function of walking experience at each age window. Table 4 shows the results of our GLMM model predicting the likelihood of observing the six upright-involved transitions with age and walking experience. Increases in walking experience was associated with increases in prone-upright (β = 0.11, 95% CI = [0.05, 0.17]), squatting-upright (β = 0.11, 95% CI = [0.05, 0.17]), and upright-squatting transitions. (β = 0.10, 95% CI = [0.05, 0.16]). Upright-prone and upright-sitting transitions displayed similar increasing trends with walking experience (β = 0.05), however, the effects of walking experience did not reach statistical significance (ps > .054). Kneeling-upright is the only upright-involved

transition type that significantly decreased by walking experience (β = -0.17, 95% CI = [-0.26, -0.09]).

Discussion

We assessed infants' daily experiences with postural transitions longitudinally at 11 months and 13 months across the onset of walking. The present study expanded upon prior work linking walking onset and infants' daily postural experiences (Franchak, 2019; Franchak, Kadooka, et al., 2024), showing that the frequency of their postural transitions also differed according to walking experience. The overall frequency of postural transitions decreased with increasing walking experience, suggesting that infants with more walking proficiency tend to stay in one posture for prolonged periods of time instead of more often switching to different postures. In addition, walking experience was also associated with changes in the type of postural transitions infants engage in, such that infants with greater walking experience engaged in non-upright transitions less frequently than non-walking infants. Instead, their transitions more frequently involved upright postures.

Changes in the Frequency of Postural Transitions

Our results on the overall frequency of postural transitions highlight the difference between competence (i.e., what infants *can do*) and performance (i.e., what infants *actually do*) in infants' motor activities. Current motor development research suggests that competence alone is insufficient to explain performance, for example, infants' sitting capacity measured by standardized gross motor assessments did not fully predict their spontaneous sitting behavior during free play (Kretch et al., 2024). In the present study, our results revealed that having a larger motor skill repertoire does not translate to an increase in the frequency of transitioning between body postures throughout the day.

What might explain the age-related decrease in postural transitions observed among the more experienced walking infants? One possible explanation is that improved postural stability while standing and walking decreases the necessity of postural transitions in many daily contexts because it is most efficient to stay on two feet. For example, body reorientation during locomotion was achieved through transitions between sitting and crawling among non-walking infants whose means of locomotion is limited to crawling (Soska et al., 2015). However, for infants who have accrued sufficient walking experience, this can be carried out while remaining upright (e.g., stop walking and reorient themselves while standing), thereby facilitating more efficient sequences of motor behavior during exploration with fewer motor costs compared to postural transitions. Therefore, as infants become more skilled in maintaining upright balance after accumulating more walking experience, they might increasingly adopt more efficient movements by staying upright rather than transitioning between postures.

This explanation is consistent with prior studies highlighting the importance of postural stability. Postural transitions require effortful and strategic control of the body (e.g., pulling-to-stand; Thurman & Rose, 2025), motor costs from transitions might disrupt infants' attentional and memory processes during learning. For example, Benitez (2013) found that infants who shifted postures during object naming events performed significantly worse at learning word-object mappings than those who remained in the same posture. Compared to transitions, sustained sitting and upright postures provide more stable postural contexts for infants to focus on exploratory behaviors without being distracted by the frequent need to coordinate their bodies during transitions (Atun-Einy et al., 2012).

These findings implicated a developmental shift that infants' exploratory experiences become increasingly continuous after the onset of walking, with fewer interruptions that occur by

switching position. Walking infants spend more time in upright postures (Franchak, 2019; Franchak, Kadooka, et al., 2024) which afford a broader visual sampling of the environment (Kretch et al., 2014) compared to non-walking infants. The current findings suggest that walking infants not only benefit from the overall frequency of upright experiences, but also an increase in the stability within upright positions. Walking infants can engage in longer, undisrupted bouts of exploration which may support the integration of perceptual information from their environment across time.

Changes in the Types of Postural Transitions

As predicted, infants' walking skill was associated with changes in the types of postures observed in postural transitions: as infants accrue more walking skill and become increasingly sufficient in maintaining upright balance, their transitions more frequently involved upright postures and transitions lacking upright postures were less frequent. Consistent with prior studies regarding infants' persistence in upright postures once they learn to walk (Adolph et al., 1997; Adolph & Tamis-LeMonda, 2014), our results showed that the walking-related increase in daily upright experiences (Franchak, 2019; Franchak, Kadooka, et al., 2024) was achieved not only through prolonged time upright with fewer falling/stopping (Hospodar et al., 2021) but also through an increase in transitions involving upright postures. This aligns with findings from previous network-based analyses on infants' postural behavior (Thurman & Corbetta, 2020), such that changes across motor development reorganizes infants' postural repertoire, thereby changing the types of transitions they engage in.

Interestingly, not all upright-involved transitions increased as a function of walking experience: Transitioning from kneeling to upright postures decreased as infants gained more walking experience. One potential explanation is that this reflects a refinement in which more

efficient and/or mature postural transitions supplant earlier forms. For example, when investigating the infants' experiences with pulling-to-stand, the earliest type of upright-involved transition (Piper & Darrah, 2021) theorized to mark the beginning of infants' improving upright expertise (Alexander et al., 1993; Capute et al., 1985; Frankenburg et al., 1992; Frankenburg & Dodds, 1967; Trettien, 1900), Thurman & Rose (2025) noted that the efficiency of this action varied according to which posture the infant arises from: pulling-to-stand is the slowest when starting with both knees on the ground and faster when at least one foot was contacting the ground. This also corresponds to our finding of increased squatting-upright transitions. Therefore, it is likely that with more walking experience, infants' postural transitions favor more efficient transitions, such as squatting-upright, over less efficient ones, such as kneeling-upright.

Upright-prone and upright-sitting transitions did not significantly differ by walking experience. This might reflect a general reduction in the baseline frequency of the two end-point postures, prone and sitting, after learning to walk. Prior studies have shown that the onset of walking was associated with decreases in both prone and sitting experiences across the day (Franchak, Kadooka, et al., 2024). Therefore, it is likely that the overall decrease in prone and sitting postures limit the room for further increase as a function of walking experience.

These changes in the postures involved in postural transitions further suggest that after walking, transitions increasingly reflect strategic, goal-oriented adjustments of body postures that facilitate exploration. Freed from making transitions to keep balance, infants may increasingly use transitions in functional ways that more closely support infants' ongoing exploratory goals. This aligns with evidence from Thurman & Rose (2025) that infants' pulling-to-stand transition keeps getting refined towards more efficient solutions, often followed by object interactions, social interactions, and locomotor exploration. Therefore, with increasing walking experience,

postural transitions might become more selectively deployed by infants to support their immediate demands of exploration.

Conclusions and Future Directions

The present study expanded upon prior work about infants' postural experiences by assessing postural transitions throughout the day via video EMA. We believe vEMA is an effective alternative for assessing infant daily experiences because it combines the continuous data format of home recordings with the ecological advantages of survey-based EMA, thereby allowing researchers to observe a wider temporal range of behaviors while accounting for the variability across the day. Future research examining other aspects of infant behavior may benefit from the vEMA approach. For example, research may employ vEMA to assess infants' full-day visual and manual experiences with objects, to gain a refined understanding regarding how learning opportunities for object labels and object knowledge (Clerkin et al., 2017; Suarez-Rivera et al., 2022) are distributed across various contexts (i.e., beyond free play) throughout the day. Similarly, research may also employ vEMA to study infants' emotional expressions along with their contextual triggers across the day, thus providing a more nuanced understanding for how infants' emotional experiences unfold in naturalistic environments.

The present study captured the sequence of infants' various body postures, which is an important temporal parameter for assessing behaviors/events in real-time (Abney et al., 2025). This yields important implications regarding the temporal structure of infant behavior, which is often marked by its burstiness/clustering in time (e.g., Warlaumont et al., 2022; Mendoza & Fausey, 2022). Indeed, the asymmetric distribution of postural transitions suggests that they are clustered in certain parts of the day, since many samples lacked transitions while others contained multiple. Future studies may further explore these temporal parameters of infant

postural behavior–such as the durations of uninterrupted postures or the temporal spacing of transitions during continuous exploratory activities–and how they change across motor development to refine current understanding regarding how various postures are organized in real-time and offer insights regarding the process of infants' burgeoning control over how they can explore and move in their natural environments.

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Table 1

Results of Negative Binomial GLM Predicting the Number of Postural Transitions Per Video Clip from Age and Walking Experiences (in Weeks).

	Fixed Effects				Random Effects (SD)
Predictor	*β*	*SE*	*z*	*p*	Participant
Intercept	**-0.88**	**0.186**	**-4.73**	**<.001**	0.5263
Age	0.03	0.047	0.66	.507	
Walking Experience	**-0.04**	**0.016**	**-2.25**	**.025**	
Number of Clips	0.00	0.004	0.80	.426	

Note. Significant fixed effects (< .05) are shown in bolded font.

Table 2

Frequencies of Each Postural Transition Type Based on the Sequence of Two Postures.

	Following Posture					
Preceding Posture	Supine	Prone	Sitting	Kneeling	Squatting	Upright
Supine	-	16	5	0	0	1
Prone	8	-	245	124	32	81
Sitting	3	423	-	85	11	36
Kneeling	0	49	48	-	4	128
Squatting	0	18	31	7	-	81
Upright	0	79	79	29	97	-

Note. Shaded cells represent upright-involved transitions. The shaded row represents transitions from upright to other postures (i.e., upright-supine, upright-prone, upright-sitting, upright-kneeling, and upright-squatting transitions). The shaded column represents transitions from other postures to upright (i.e., supine-upright, prone-upright, sitting-upright, kneeling-upright, and squatting-upright transitions).

Table 3

Results of GLMMs Predicting the Likelihood of the Four Non-Upright Transitions from Age and Walking Experiences.

	Fixed Effects				Random Effects (SD)
Predictor	*β*	*SE*	*z*	*p*	Participant
Prone-Sitting					
Intercept	**-1.90**	**0.116**	**-16.36**	**<.001**	0.516
Age	-0.04	0.163	-0.25	.803	
Walking Experience	**-0.11**	**0.030**	**-3.70**	**<.001**	
Sitting-Prone					
Intercept	**-1.12**	**0.070**	**-15.97**	**<.001**	0.2295
Age	**-0.34**	**0.128**	**-2.65**	**.008**	
Walking Experience	**-0.05**	**0.018**	**-2.72**	**.006**	
Prone-Kneeling					
Intercept	**-2.92**	**0.176**	**-16.55**	**<.001**	0.7093
Age	-0.26	0.228	-1.16	.246	
Walking Experience	**-0.15**	**0.053**	**-2.84**	**.005**	
Sitting-Kneeling					
Intercept	**-3.17**	**0.185**	**-17.14**	**<.001**	0.7628
Age	0.24	0.267	0.89	.373	
Walking Experience	**-0.12**	**0.050**	**-2.51**	**.012**	

Note. Significant fixed effects (< .05) are shown in bolded font.

Table 4

Results of GLMMs Predicting the Likelihood of the Six Types of Upright-Involved Transitions from Age and Walking Experiences.

	Fixed Effects				Random Effects (SD)
Predictor	*β*	*SE*	*z*	*p*	Participant
Prone-Upright					
Intercept	**-3.24**	**0.176**	**-18.37**	**<.001**	0.6678
Age	0.08	0.283	0.29	.775	
Walking Experience	**0.11**	**0.031**	**3.42**	**<.001**	
Upright-Prone					
Intercept	**-3.14**	**0.161**	**-19.49**	**<.001**	0.5813
Age	0.49	0.267	1.83	.068	
Walking Experience	0.05	0.030	1.66	.097	
Squatting-Upright					
Intercept	**-3.40**	**0.176**	**-19.28**	**<.001**	0.5782
Age	0.55	0.293	1.87	.061	
Walking Experience	**0.11**	**0.029**	**3.85**	**<.001**	
Upright-Squatting					
Intercept	**-3.12**	**0.152**	**-20.55**	**<.001**	0.4919
Age	0.39	0.260	1.50	.134	
Walking Experience	**0.10**	**0.026**	**3.96**	**<.001**	
Kneeling-Upright					
Intercept	**-2.70**	**0.124**	**-21.89**	**<.001**	0.2435
Age	0.18	0.201	0.89	.376	
Walking Experience	**-0.17**	**0.044**	**-3.96**	**<.001**	
Upright-Sitting					
Intercept	**-3.06**	**0.126**	**-24.22**	**<.001**	0.2539
Age	-0.06	0.255	-0.25	.804	
Walking Experience	0.05	0.025	1.92	.054	

Note. Significant fixed effects (< .05) are shown in bolded font.

Figure 1

The Distribution of the Number of Postural Transitions Per Video Clip.

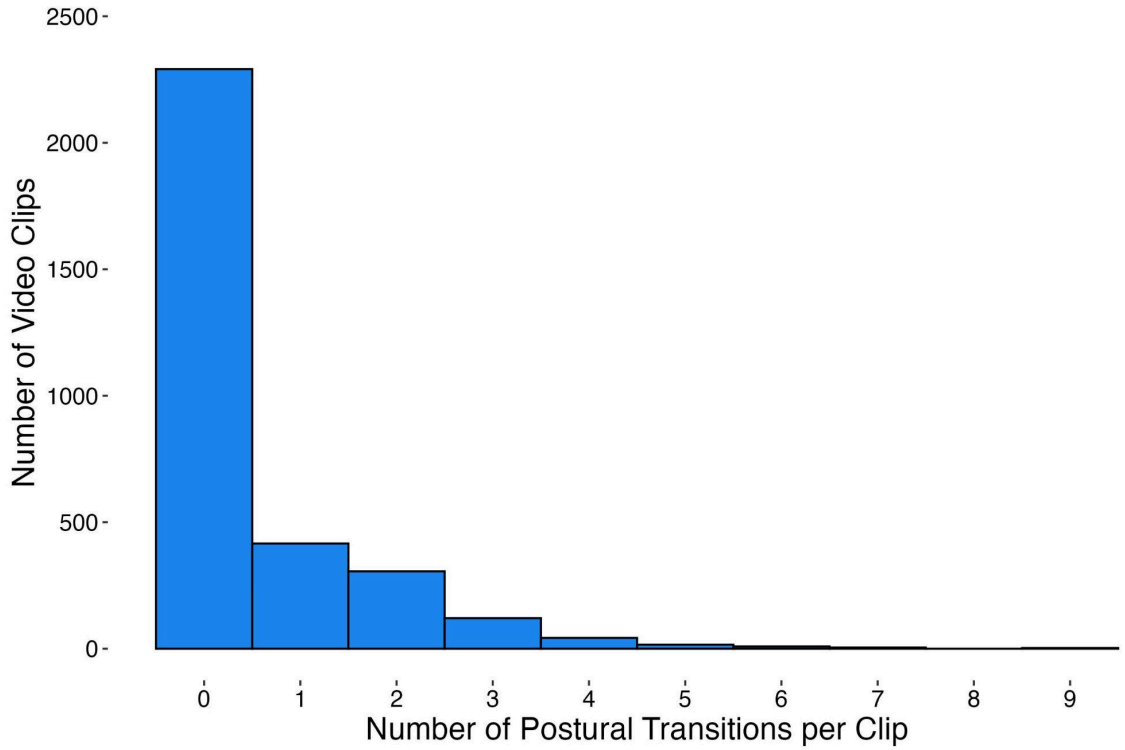
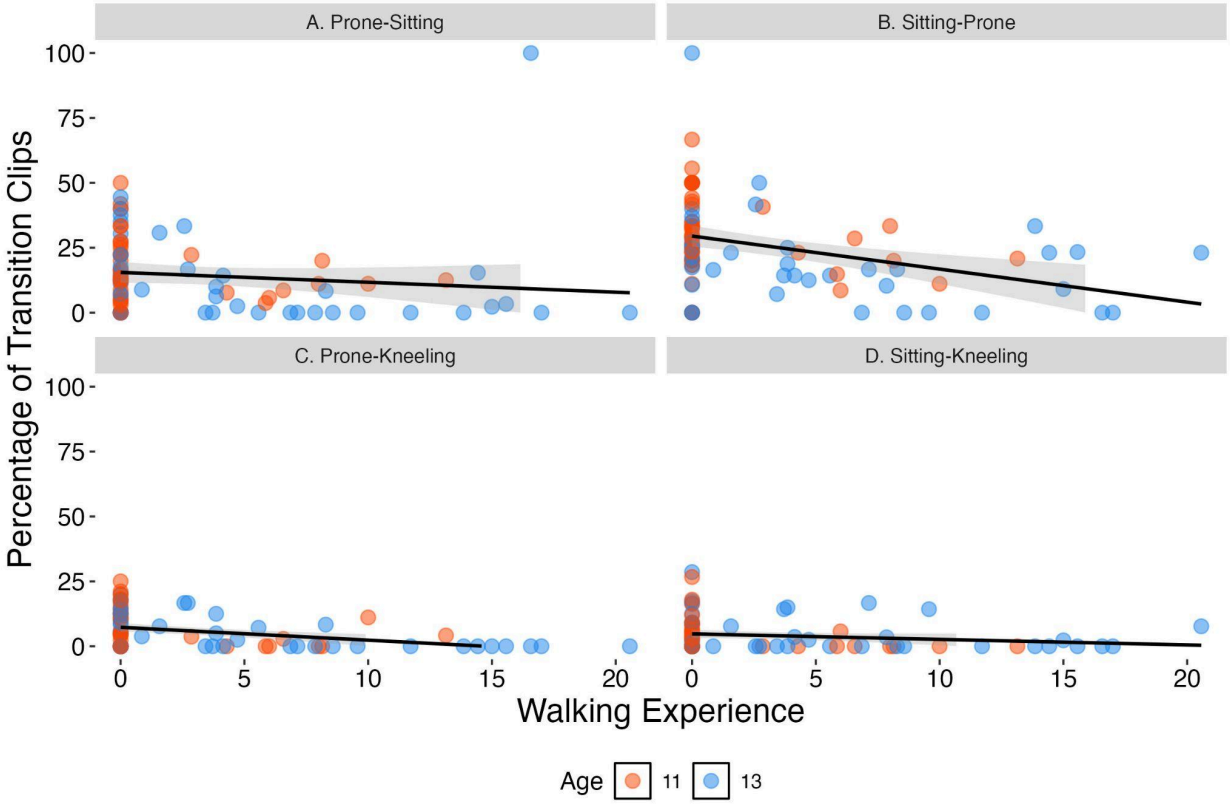


Figure 2

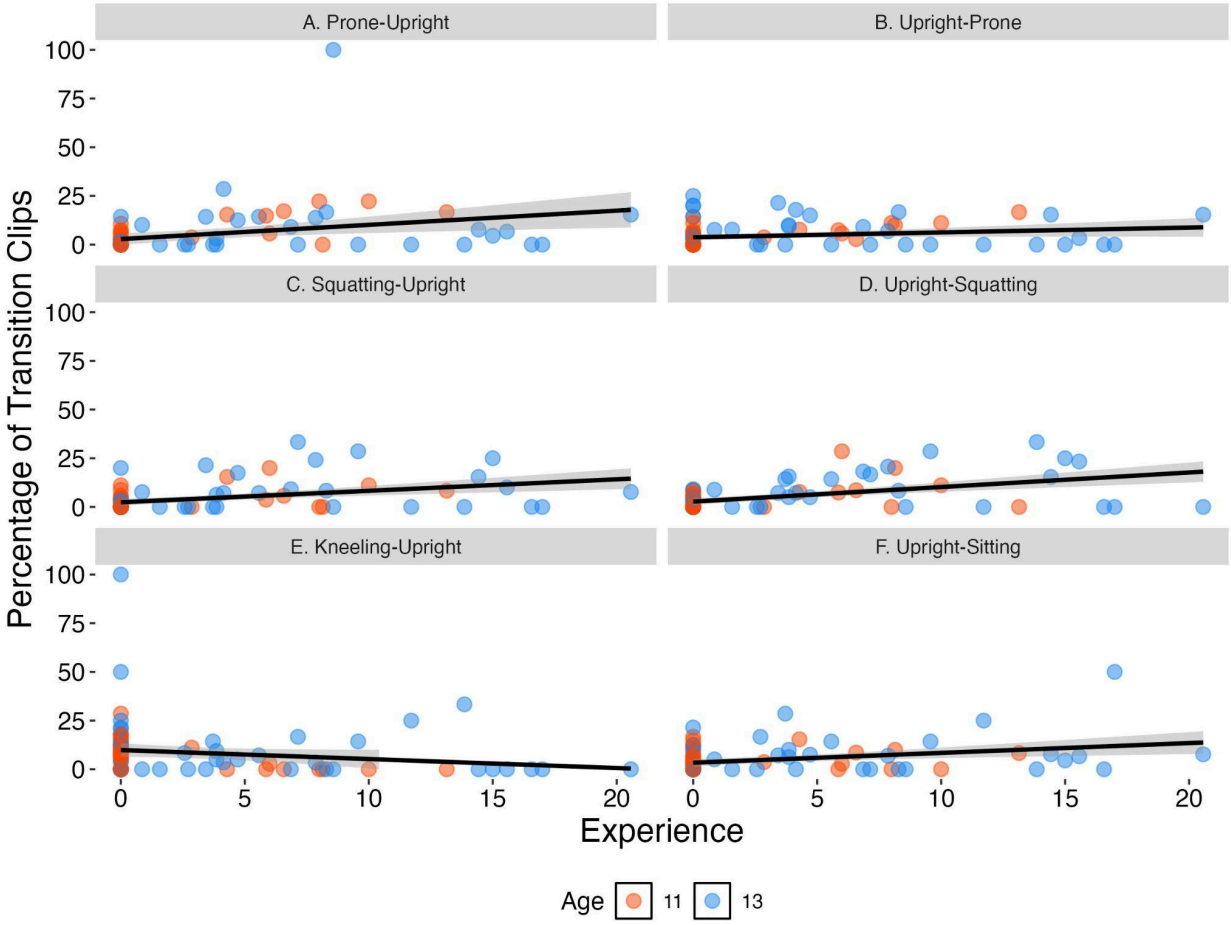
Percentages of Non-Upright Transitions Among the Total Transition Clips Across Walking Experience in Weeks (x-axis) and Age Group.



Note. The points represent individual infants assessed at a particular age. The black lines represent linear regressions predicting the percentages of various transition types with walking experiences.

Figure 3

Percentages of Upright-Involved Transitions Among the Total Transition Clips Across Walking Experience in Weeks (x-axis) and Age Group.



Note. The points represent individual infants assessed at a particular age. The black lines represent linear regressions predicting the percentages of various transition types with walking experiences.