ABSTRACT. Background. As a result of the American Academy of Pediatrics’ recommendation that healthy infants be placed on their side or back for sleep, the percentage of infants sleeping prone has decreased dramatically. With the increase in supine sleeping, pediatricians have questioned if there are differences in the rate of acquisition of early motor milestones between prone and supine sleeping infants.

Methods. To examine this question, we performed a prospective, practice-based study of healthy term infants. Infants were recruited before the age of 2 months. Parents were asked to record infant sleep position and awake time spent prone until 6 months of age. A developmental log was used to track milestones from birth until the infant was walking. Age of acquisition of eight motor milestones was determined, and the mean ages of milestone attainment of prone and supine sleepers were compared.

Results. Three hundred fifty-one infants completed the study. Prone sleepers acquired motor milestones at an earlier age than supine sleepers. There was a significant difference in the age of attainment of rolling prone to supine, tripod sitting, creeping, crawling, and pulling to stand. There was no significant difference in age when infants walked.

Conclusions. The pattern of early motor development is affected by sleep position. Prone sleepers attain several motor milestones earlier than supine sleepers. However, all infants achieved all milestones within the accepted normal age range. Pediatricians can use this information to reassure parents. This difference in milestone attainment is not a reason to abandon the American Academy of Pediatrics’ sleep position recommendations. Pediatrics 1998;102:1135–1140; sleep position, sudden infant death syndrome, infant development, motor development.

ABBREVIATIONS. AAP, American Academy of Pediatrics; SIDS, sudden infant death syndrome.

In 1992, the American Academy of Pediatrics (AAP) published a recommendation that “healthy infants, when being put down for sleep, be positioned on their side or back” in an attempt to decrease the incidence of sudden infant death syndrome (SIDS). Since these recommendations and a subsequent national public education campaign, “Back to Sleep,” the percentage of infants sleeping prone has decreased dramatically from 70% in 1992 to 27% in 1995. With the increase in supine sleeping, several pediatricians in our community have observed differences in the rate of acquisition of early motor milestones between prone and supine sleeping infants. This observation is consistent with data reported from other cultures where supine is the predominant sleep position for infants. Since the sleep position recommendations, there have been no published prospective, longitudinal studies that have quantitated the association between sleep position and early motor development. Some recent studies support the observation that supine and prone sleepers may acquire milestones differently. A recent retrospective chart review demonstrated that sleep position influences the age when infants roll over. In addition, Dewey et al distributed questionnaires regarding development to participants in the Avon Longitudinal Study of Pregnancy and Childhood when the infants were 6 and 18 months of age. They found that prone sleepers had higher scores in gross motor, social skills, and overall development at 6 months but not at 18 months.

We conducted a prospective, longitudinal, practice-based study of healthy infants to determine the relationship between sleep position and the age of attainment of motor milestones in the first year of life. Based on our clinical observations, we hypothesized that supine sleeping would be associated with later age of attainment of certain motor milestones. Because prone positioning encourages use of upper body strength used in acquisition of many infant motor milestones, it may be that supine sleepers lag in milestone development in the first year because the upper body contributes less to daily movement than for predominantly prone positioned infants.

METHODS

This study was approved by the institutional review boards of Children’s National Medical Center, Holy Cross Hospital, Walter Reed Army Medical Center, and the Uniformed Services University of the Health Sciences. A prospective cohort of healthy infants was recruited at a community hospital nursery and in participating pediatricians’ offices before the age of 1 month. Infants were eligible for partic-
amilies if they were full term, healthy, and regularly seen by a pediatrician participating in the Children’s Pediatric Research Network. The Children’s Pediatric Research Network consists of 10 suburban private practices, 3 urban pediatric centers, and the Walter Reed Army Medical Center in the Washington, DC, area. The target population was healthy, full-term infants in the United States that represent the recent trends in changing sleep positions, well as both predictor and outcome variables remained the same for weeks at a time. Periodic chart review was performed by one of the investigators to verify physician documentation of developmental milestones. The validity of parental report was supported by physician observation of developmental milestones. Approximately 5% of parent reports differed from physician assessment as documented in the medical record. In those rare instances, the latter was used for analysis. Infants were followed until they could walk independently for 10 or more steps. To better compare the effects of prone and supine sleeping on development and to minimize the effect of changing sleep position with age, we identified consistently prone and supine subgroups within the cohort. These sleep positions have been reported to be the most stable (ie, infants placed prone tend to remain prone).

Infants were categorized as prone sleepers if they were placed in the prone sleep position >70% of sleep time from age 1 month to 5 months. Supine sleepers were defined as those placed in the supine sleep position >70% of sleep time from age 1 month to 5 months. Five months was chosen as the cutoff because we anticipated that some infants would begin to change sleep position spontaneously thereafter, diminishing reliability of sleep position based on parental placement. All other infants were reported to be mixed/side sleepers.

Of the 18 developmental tasks on the log, we included the 8 major motor milestones. Based on previous work by Capute et al,16 these major motor milestones are identified as such by a high reported frequency of parental recall and traditionally occurring within a narrow range of variation. For this reason, we selected the 8 major motor milestones for analysis purposes: rolling prone to supine, rolling supine to prone, sitting supported (tripod), sitting unsupported, creeping, crawling, pulling to stand, and walking independently. Additionally, the fine motor milestone of transferring small objects between hands was chosen.

The selection of sociodemographic variables were calculated for all participants. We determined the age of acquisition of the 8 major motor milestones for all participants, and we compared the age of acquisition of motor milestones among the subgroups by univariate analysis with the Kruskal-Wallis test. Linear regression analysis was then performed to compare the mean ages of milestone attainment between predominantly prone and supine sleepers, while controlling for possible confounders, such as infant size, gender, ethnicity, presence of siblings, and maternal education.

RESULTS

Demographic Data

Of the original 400 enrollees, 351 (87%) completed the study. Thirty-seven enrollees were lost to follow-up because of disconnected telephones, families not answering multiple telephone calls, family moves, or change to a nonparticipating pediatric practice. The remaining 12 patients developed medical conditions after enrollment which precluded further involvement in the study: congenital adrenal hyperplasia (n = 1), hypothyroidism (n = 1), conditions necessitating physical therapy referrals (n = 3), developmental hip dysplasia requiring use of Pavlik harness (n = 2), metatarsus adductus requiring casting (n = 2), and nonspecific asymmetric examinations requiring neurologic evaluation (n = 3). No cases of SIDS occurred in this cohort.

The mean birth weight of the infants was 3490 ± 41 g. Forty-nine percent of the infants were male. Sixty-eight percent were white, 20% African-American, 3% Asian-American, and 9% Hispanic, Native
American, or other. Forty-two percent (n = 146) were first born, 37% (n = 130) had one sibling, and 21% had two or more siblings. The mean maternal age was 31.3 ± 5 years, with only 2% of mothers younger than 20 years old. Ninety-three percent (n = 295) of the mothers were married. The mean maternal educational level was 15.3 ± 2.6 years. Six percent (n = 20) of the mothers had <12 years of schooling, 71% (n = 248) had received 2 to 4 years of college education, and 23% had >16 years of education. At enrollment, 90% of parents anticipated being the primary child care provider for the first year of life.

When the infants were subcategorized according to sleep position, they were similar for maternal age, gender, race/ethnicity, and birth weight. Prone sleepers were more likely to have older siblings (mean, 1.3 vs 0.81 for supine sleepers; P = .007), and their mothers were less likely to be married (P = .007). The mothers of prone sleepers had fewer years of education (mean, 14.08 years) than mothers of supine sleepers (mean, 15.39 years; P < .0001).

Sleep Characteristics

Twelve percent (n = 42) of 1-week-old infants were placed prone for sleep, and 28% (n = 98) were placed in the supine position. The remaining 60% (n = 210) of 1-week-old infants were placed in the side-lying position. At 6 months of age, 32% (n = 112) were being placed prone and 48% (n = 168) supine for sleep. Side sleepers decreased to 20% (n = 71). Only 44% of infants consistently slept in the same position from 1 to 5 months of age. Sixteen percent of infants (n = 57) consistently slept in the prone position, and 28% (n = 97) were consistent supine sleepers. To minimize overlap effects, we used the predominantly prone and predominantly supine sleepers for comparison groups when we looked at effect of sleep position on motor milestone acquisition.

Awake Characteristics (Table 1)

All infants, regardless of sleep position, spent increasing amounts of time awake from 1 week of age to 6 months of age. Although the total awake time was similar for all of the infants, there was a significant difference in time spent awake in the prone position. Throughout the first 6 months of life, prone sleepers spent much more time awake in the prone position than the supine or side sleepers. For the first 3 months of life, prone sleepers were awake in the prone position more than twice the amount of time as the other groups.

Milestone Attainment (Fig 1 and Table 2)

In general, prone sleepers acquired motor milestones at an earlier age than their supine sleeping counterparts. There was a significant difference (P < .05) in the age of milestone attainment with the following milestones: rolling prone to supine, tripod sitting, creeping, crawling, and pulling to stand. Mixed/side sleepers, in general, attained milestones before the supine sleepers and later than the prone sleepers but because this group of sleepers represented significant variability, it was not used as a comparison group. There was no significant difference in the age at which the infants rolled supine to prone, sat unsupported, transferred objects, or walked. Twenty-three percent (n = 81) of the study participants never achieved the creeping milestone; 31% (n = 30) of the supine sleepers and 18% (n = 10) of the prone sleepers did not creep.

Because there was an impressive difference in the amount of prone playtime seen in the prone versus supine sleepers, we also analyzed the influence of prone playtime in the small group of supine sleepers. Increased prone playtime was significantly associated with earlier attainment of the following milestones: tripod sitting, sitting alone, creeping, crawling, and pulling to stand (P < .05). However, when maternal education, race, gender, birth weight, and number of older siblings was controlled for, the difference was significant only for the pull to stand milestone (P < .01).

**DISCUSSION**

The attainment of motor milestones has long been used by pediatricians and parents as an outward indicator of the progress of neurologic development during infancy, although there may be little association with general intelligence. Parental perception of normalcy during the first year of life is heavily influenced by the infant’s progressive attainment of motor milestones. Standardized screening tools used daily by general pediatricians stress developmental milestones that occur within a fixed age range in infants with normal development. Because delayed or skipped milestones are thought to place an infant at risk for abnormal development, identifying factors that influence the normal age range for milestone

### Table 1. Awake Characteristics of Study Infants (n = 351)

<table>
<thead>
<tr>
<th>Infant Age</th>
<th>Mean Awake Time (Hours/Day)</th>
<th>Mean Awake Time Spent Prone (Hours/Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supine Sleepers</td>
<td>Mixed/Side Sleepers</td>
</tr>
<tr>
<td>1 Week</td>
<td>7.18</td>
<td>6.57</td>
</tr>
<tr>
<td>1 Month</td>
<td>8.74</td>
<td>4.68</td>
</tr>
<tr>
<td>2 Months</td>
<td>9.47</td>
<td>9.12</td>
</tr>
<tr>
<td>3 Months</td>
<td>10.43</td>
<td>9.98</td>
</tr>
<tr>
<td>4 Months</td>
<td>10.79</td>
<td>10.47</td>
</tr>
<tr>
<td>5 Months</td>
<td>11.30</td>
<td>10.72</td>
</tr>
<tr>
<td>6 Months</td>
<td>11.46</td>
<td>10.90</td>
</tr>
</tbody>
</table>

*Represents P value for prone sleepers versus supine sleepers.
attainment is important. We found that sleep position significantly impacts early motor development. Traditional age ranges for motor milestone attainment in the United States were developed when prone infant sleeping was the norm. As early as 1960, Holt\textsuperscript{18} qualitatively reported that a small sample of prone sleeping American infants achieved certain milestones at an earlier age than the supine sleepers. He observed that the prone sleeping American infants tended to crawl earlier and were more advanced in their prone motor skills than would be expected of English supine sleeping infants.

Since the 1970s, there have been several reports from cultures in Asia and Europe where supine is the

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**TABLE 2.** Mean Age (Months) for Milestone Acquisition

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Prone Sleepers</th>
<th>Mixed/Side Sleepers</th>
<th>Supine Sleepers</th>
<th>$P$ Value* (Linear Regression)$^\dagger$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolls prone to supine</td>
<td>3.93 ± 1.2</td>
<td>4.48 ± 1.8</td>
<td>4.87 ± 1.33</td>
<td>.002 (.02)</td>
</tr>
<tr>
<td>Rolls supine to prone</td>
<td>4.9 ± 1.3</td>
<td>4.97 ± 1.9</td>
<td>5.0 ± 1.6</td>
<td>.95</td>
</tr>
<tr>
<td>Sits supported</td>
<td>4.7 ± 1.3</td>
<td>5.02 ± 1.4</td>
<td>5.13 ± 0.9</td>
<td>.003 (.03)</td>
</tr>
<tr>
<td>Sits unsupported</td>
<td>5.13 ± 1.1</td>
<td>5.17 ± 1.2</td>
<td>5.17 ± 1.0</td>
<td>.80</td>
</tr>
<tr>
<td>Transfers object</td>
<td>5.87 ± 1.2</td>
<td>5.99 ± 6.5</td>
<td>6.23 ± 1.1</td>
<td>.11</td>
</tr>
<tr>
<td>Creeps</td>
<td>6.07 ± 1.9</td>
<td>6.49 ± 1.9</td>
<td>7.23 ± 1.6</td>
<td>.0002 (.001)</td>
</tr>
<tr>
<td>Crawls</td>
<td>7.83 ± 2.0</td>
<td>8.47 ± 2.1</td>
<td>8.6 ± 1.7</td>
<td>.003 (.05)</td>
</tr>
<tr>
<td>Pulls to stand</td>
<td>8.1 ± 1.6</td>
<td>8.7 ± 1.5</td>
<td>8.77 ± 1.6</td>
<td>.01 (.04)</td>
</tr>
<tr>
<td>Walks alone</td>
<td>12.1 ± 2.0</td>
<td>12.2 ± 2.0</td>
<td>12.2 ± 1.7</td>
<td>.4</td>
</tr>
</tbody>
</table>

* Represents $P$ value for prone sleepers versus supine sleepers.

† Multivariate regression analysis controlling for infant size, gender, ethnicity, presence of siblings, and maternal education.
predominant sleep position, demonstrating later attainment of early motor milestones, such as rolling over and sitting up, than would be expected by US norms. These findings have been sufficiently consistent in certain cultures that researchers have adapted and standardized the Denver Developmental Screening Test and the Denver II to fit the cultural norms. The Asian studies specifically refer to supine positioning as a possible explanation for the differences seen in the gross motor milestones.

In this practice-based study, we prospectively followed a cohort of term, healthy infants from birth through their first year of life, using parental logs to document age of attainment of motor milestones and sleep position. To minimize recall bias, a research assistant called families each month to update the logs and to ensure accurate and current documentation. In addition, the medical records of all study infants were reviewed by one of the investigators to verify parental report and to identify any medical problems that would potentially affect motor development. We then analyzed the relationship of sleep position and age of attainment of 8 major milestones (rolling to supine, rolling to prone, sitting tripod, sitting unsupported, creeping, crawling, pulling to stand, and walking).

Despite the fact that all parents were counseled on study entry to place their infants supine for sleep, 12% of 2-week-old infants in our study were being placed prone for sleep, and this number increased to 32% by 6 months of age. Although it is unfortunate that some of the parents in this cohort did not follow the current sleep recommendations, this is consistent with recent studies that demonstrate that one-fourth to one-third of parents who are aware of the sleep recommendations continue to place their infants prone for sleep.

In a retrospective study, Jantz et al. determined that prone sleepers rolled over at an earlier age than nonprone sleepers but did not find significant differences in other milestones. In this and other recent studies looking at effects of sleep position, an assumption was made that infant sleep position did not change during the time period. Thus, the position that parents placed infants at 1 month of age was the position used for assessment, even at 6 months of age. Our study demonstrated variability in sleep position choice during the course of the first 6 months. Despite 88% of parents placing infants in a nonprone position at 4 weeks of age, only 28% of the infants consistently slept in the supine position from 12 to 20 weeks of age. In 1973, Modlin et al. reported that it was difficult to predict the sleep position in 7-month-old infants by their sleep position at birth, and that only 38% of the infants in their sample had slept in the same position since birth. To ascertain more accurately the effects of sleep position, we differentiated from the large group of nonprone sleepers (n = 265) a smaller group of supine sleepers (n = 97) for comparison with the prone sleeping infants. In the predominantly supine sleepers, we found not only a significant delay in rolling prone to supine, but also significant differences between the groups for tripod sitting, creeping, crawling, and pulling to stand.

The AAP, in its most recent statement regarding infant sleep position, recommended that infants spend some time in the prone position while awake and observed. In our survey, however, we discovered that many parents avoided placing their infants prone, even when the children were awake, because they were fearful of the possibility of SIDS. This is consistent with a previous report, in which 26% of parents never placed their infants prone for play. We also noticed that many of the supine sleepers did not want to be placed prone while awake. When we asked parents to determine how much time their infant spent prone while awake, many parents prefaced their response with “My baby doesn’t like his/her tummy!” In our study, the prone sleepers spent significantly more time prone while awake. The amount of prone playtime may be a contributing factor to the effect of supine sleeping on motor development. At the least, it seems to amplify the effect of supine sleeping, and it may be the primary factor that influences motor development. In our small sample of supine sleepers, we found that increased prone playtime did result in earlier milestone attainment. However, further, larger scale studies are indicated to determine if increased prone playtime does indeed accelerate motor development in supine sleepers.

As this study was dependent on parental reporting, the validity of these results is limited by the accuracy of the parents’ responses. Although it is acknowledged that parents may have been unwilling to admit to actual sleep positions, this would have had the effect of minimizing the differences that we found in milestone acquisition. To control for potential differences in sociodemographic characteristics between prone and supine sleepers which we found and which have been reported by others, we conducted a logistic regression analysis and found that sleep position retained a significant effect on early infant motor development. In addition, we attempted to minimize the bias introduced by parental report by also having the physicians assess the infants’ developmental progress at well-child visits. When physician assessment was discrepant with parental report, the former was used in the analysis.

Whereas our study showed that most infants, regardless of sleep position, walk independently close to the time of the first birthday, the developmental progression is affected by sleep position. During infancy, supine sleepers lag behind prone sleepers in milestones that require the use of the upper trunk, specifically the upper extremities and shoulder girdle muscles: rolling prone to supine, tripod sitting, creeping, crawling, and pulling to stand. This upper-extremity muscle development occurs routinely in infants who spend time in the prone position. The milestones in which we did not find significant differences (rolling supine to prone, sitting unsupported, and walking) require less upper body strength and thus may be achievable regardless of upper-extremity muscle development. Other studies have suggested that coordination of fine-motor skills may be advanced in supine sleepers. However, we found no differences between the groups when we looked at the milestone of transferring small objects from one hand to another.
Although supine sleepers attained some motor milestones as much as 1 month later than the prone sleepers, it is important to emphasize that they still attained these milestones within the accepted time range for normal. In fact, even the supine sleepers achieved milestones at ages faster than traditional means. This may be the result of increased parental vigilance and awareness of motor milestone attainment from participating in the study. It is yet unclear if there are any long-term developmental effects from sleep positioning. Because there does not seem to be a difference in attainment of walking skills or of some of the 18-month-old milestones, this difference in milestone attainment may be transient. However, further studies are indicated as this generation of predominantly supine sleepers becomes older.

As more of the US population adopts supine infant sleep positioning, pediatricians need to be able to provide parental reassurance that the differences in milestone acquisition are not developmental delays, but rather are still within well-accepted normal ranges for development. It must be emphasized that this difference in developmental acquisition is not a reason for parents or pediatricians to abandon the AAP sleep recommendations. Pediatricians also need to actively incorporate the encouragement of prone play at the 2- and 4-month well-child visits to maximize development of upper-body strength.

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