# Gait Characteristics of Children Born Preterm

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## Education Gaps

Preterm birth is associated with high rates of subsequent motor impairments. Walking is a central part of most basic and leisure daily activities; therefore, knowledge of the timing of walking onset and any variation of gait from normal is essential to understand the needs of children born preterm.

## Abstract

Walking is a central skill of daily living. A delay in the onset of walking can be a sign of abnormal motor development. Further, abnormalities in gait can also affect physical functioning. Children born preterm are at significant risk for neurodevelopmental impairments; however, little is known about how preterm birth affects walking. This review describes current evidence of walking in children born preterm with a focus on the age at onset of walking and comparisons of gait characteristics of children born preterm with those born full-term.

## Objectives After completing this article, readers should be able to:

1. Describe the age at onset of independent walking in infants born preterm compared with their full-term peers.
2. Identify infants who may be at increased risk for delayed walking onset.
3. Explain the various aspects of gait characteristics that have been investigated in children born preterm.
4. Recognize when a child born preterm should be referred to a physical therapist for further motor assessments and/or intervention.

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**ABBREVIATIONS**

| | |
|---|---|
| CP | cerebral palsy |
| DCD | developmental coordination disorder |
| GA | gestational age |
| VPT | very preterm |
| VLBW | very low birthweight |

## INTRODUCTION

### Preterm Birth and Motor Development

Children born preterm (ie, <37 weeks' gestational age [GA]) are at significant risk for neurodevelopmental problems ranging from mild motor impairment, such as developmental coordination disorder (DCD) to cerebral palsy (CP). (1)(2) Prevalence of CP among children born preterm ranges from 7 to 82 per 1,000 live births, and increases with decreasing GA. (3) Furthermore, preterm children are at high risk for mild and moderate motor impairments. (1)(4)(5) Milder motor impairments present in preterm children in early infancy and childhood, persist in adolescence, (5)(6) and influence the child's function and quality of life. (7) Non-CP motor impairment in children born preterm is estimated to range from 19% for moderate motor impairments to 40.5% for mild-moderate impairments including DCD and minor neurologic dysfunction. (8) A recent study has reported an increased prevalence of non-CP impairment in children born preterm from 23% in 1991-1992 to 37% in 2005. (9) Being born very preterm (VPT; <32 weeks' GA) and/or with very low birthweight (VLBW; <1,500 g) presents an even greater risk for motor deficits compared with those born late preterm and/or with normal birthweight. (5)

Walking is fundamental to the development of motor skills in children. A few small studies have examined the onset of walking in children born preterm and suggest that they have a later onset than their full-term peers. Despite the large body of literature about gait characteristics of appropriately developed children born at term and those with significant motor impairments, the evidence investigating gait characteristics in children born preterm is scarce and yet to be synthesized. (10)(11)(12) In this review, we present available evidence from the last 3 decades about the age at onset of walking in children born preterm compared with those born full-term. We also describe the gait characteristics of children born preterm compared with their full-term peers throughout childhood.

## WALKING ONSET

Walking is an inherently complex task that requires the neural control systems to generate highly coordinated movements of the limbs. (13) There are several characteristics that describe walking (14):

- Spatial gait parameters
  - Step length: Distance between heel contacts of one foot to another
  - Stride length: Distance between 2 successive heel contacts of the same foot
  - Step width: Distance between the 2 center lines of the feet
- Temporal gait parameters
  - Cadence: Stepping rate or "number of steps per minute"
  - Single support time: Time spent with only one foot in contact with the ground over a gait cycle
  - Double support time: Time spent with both feet in contact with the ground over a gait cycle
  - Stride time: Time spent between 2 consecutive contacts of the same foot
- Stride-to-stride variability: Gait fluctuation and variation from stride to stride

For infants, walking begins with a very wide base, fast stepping rate, and variation in the step length and step time from one step to another. As the child grows, and the neurologic system matures, the walking pattern becomes more regular and coordinated, with less step-to-step variation. Understanding the acquisition of motor abilities, including walking, provides insight into an infant's motor development rate and expected motor performance through childhood. (15)

The age by which walking commences is a significant developmental milestone, with delayed walking potentially indicating a neurodevelopmental delay. (16)(17)(18) Although walking attainment ranges from 9 to 18 months of age, (19) the age at onset is an important predictor of later motor impairment. For instance, the onset of walking at 15 months or later has been shown to be a predictor of DCD at 7 years of age. (20)

## WALKING ONSET IN CHILDREN BORN PRETERM

In the last 3 decades, 14 studies have been published in English that investigated the walking onset age in infants born preterm, with the studies ranging in quality from low (15)(16)(21)(22)(23)(24)(25)(26) to moderate (18)(27)(28)(29)(30)(31) using the Newcastle-Ottawa Scale. (32) A description of the participants' characteristics and the age of walking attainment are provided in Table 1. Across these 14 longitudinal studies, 1,436 infants born preterm (mean GA 30.54 weeks, SD 2.74) and 1,317 infants born full-term (mean GA 39.08 weeks, SD 1.33) were included. Two studies recruited only VPT infants (mean GA 28.3 weeks, SD 1.94), (25)(33) and 5 studies recruited only VLBW preterm infants (mean GA 29.76 weeks, SD 2.75; mean birthweight 1,162.15 g, SD 245.65).

A clear definition of independent walking was provided in most of the studies, with the majority of them using 5 consecutive unsupported steps as a definition of independent walking. (16)(18)(21)(22)(23)(25)(29)(30) The definition of independent walking in the other studies ranged from taking 3 unsupported steps (24) to 10 consecutive unsupported steps (28) to walking independently over 5 m. (31) Three studies did not provide a specific definition. (15)(26)(33) In all the studies, walking onset was established through parental report.

A delay in the onset of walking in preterm children was reported in all of the comparison studies with full-term peers, (16)(18)(21)(22)(23)(29)(30)(31)(33) with the exception of 1 study that reported similar onset. (28) Preterm infants

TABLE 1. **Characteristics and Findings of 14 Studies on Walking Onset (Corrected Age)**

| | PRETERM GROUP | | | | FULL-TERM GROUP | | | | | | PRETERM WALKING ONSET | FULL-TERM WALKING ONSET |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REFERENCE | N | CHARACTERISTICS | GA MEAN±SD (WK) | BW MEAN±SD (G) | N | CHARACTERISTICS | GA MEAN±SD (WK) | BW MEAN±SD (G) | ONSET ASSESSMENT | INDEPENDENT WALKING ONSET DEFINITION | MEAN±SD (MO) | MEAN±SD (MO) |
| Cahill-Rowley et al (33) | 69 | Inc VPT (GA ≤32 wk)<br>Exc genetic disorders or congenital brain abnormalities | 28.6 ± 2.3 | NR | 41 | Inc full-term<br>Exc not walking by 14 mo | 39.5 ±1.2 | NR | Parent report | NR | 13.1±2.6 | 11.9 ±1.5 |
| Nuysink et al (25) | 90 | Inc GA <30 wk<br>Exc chromosomal, genetic, major neurologic or sensory abnormalities | 28±1.57 | 1,064±241 | — | — | — | — | Parent report at visits or by email | Five successive steps without support | 15.7[a] | — |
| Angulo 2013/ Taiwan | 13 | Inc preterm with moderate hypo/ hypertonia or developmental delay (without CP)<br>Exc congenital, neurologic or genetic disorders<br>Received physiotherapy | 29.0 ±4.8 | 1,465±1012 | — | — | — | — | Parent report | Five successive steps without support | 14.6±2.3 | — |
| | 15 | Received treadmill training | 30.8 ±4.8 | 1,596 ±944 | | | | | | | 15.1±3.0 | |
| de Souza et al (30) | 30 | Inc GA ≤34 wk and BW ≤1,500 g<br>Exc neurologic damage, intellectual disability, or sensory deficiency, orthopedic problems, congenital malformations | 30.0±2.3 | 1,178±193 | 30 | Inc GA ≥37 wk and BW ≥2,500 g<br>Exc history of acute and/or chronic prenatal or perinatal hypoxia | 39±1.3 | 3,270±400 | Parent report on biweekly calls | Five successive steps without support | 13.8±2 | 12.3±2 |

*Continued*

TABLE 1. (Continued)

| REFERENCE | PRETERM GROUP | | | | FULL-TERM GROUP | | | | ONSET ASSESSMENT | INDEPENDENT WALKING ONSET DEFINITION | PRETERM WALKING ONSET | FULL-TERM WALKING ONSET |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | CHARACTERISTICS | GA MEAN±SD (WK) | BW MEAN±SD (G) | N | CHARACTERISTICS | GA MEAN±SD (WK) | BW MEAN±SD (G) | | | MEAN±SD (MO) | MEAN±SD (MO) |
| Ana 2012/ Brazil | 77 | Inc GA <37 wk<br>Exc ≤3 consecutive consultations, OR presence of congenital or chromosomal anomalies, or major neonatal diseases | 31.9 (25.7–36.0) | 1,505 (590–2,500) | 49 | Inc singleton, GA 37–42 wk, BW ≥2,500 g<br>Exc abnormal neurologic examination; delayed adaptive, language, or social development; ≤3 consecutive consultations | 39.6 (37.1–42.0) | 3,178 (2,500–4,020) | Confirmed by monthly evaluation assessments | Five successive steps without support | 12.51[b] (9.44–15.4) | 12.08 (9.8–14.3) |
| Karagianni et al (26) | 41 | Inc GA ≤34 wk<br>Exc genetic or syndromic disease, gross chromosomal abnormalities, or intraventricular hemorrhage<br>Small for GA | 32 (26-34) | 1,221± 328 | — | — | — | — | Parent report | NR | 13[a,b] | — |
| | 41 | AGA | 32 (26-34) | 1,724.6± 433 | | | | | | | 13[a] | |
| Volpi et al (15) | 143 | Inc GA ≤34 wk, BW ≤1,500 g, and absence of neurologic abnormalities<br>Exc <4 consultations in 1st year, neuromotor intervention, sensory deficiency, or conditions compromise development | 30±2 | 1,130± 222 | | — | — | — | Parent report at visit every 2 months and calls if unable to attend | NR | 12.8±1.9 | — |

*Continued*

TABLE 1. (Continued)

| REFERENCE | PRETERM GROUP N | PRETERM GROUP CHARACTERISTICS | PRETERM GROUP GA MEAN±SD (WK) | PRETERM GROUP BW MEAN±SD (G) | FULL-TERM GROUP N | FULL-TERM GROUP CHARACTERISTICS | FULL-TERM GROUP GA MEAN±SD (WK) | BW MEAN±SD (G) | ONSET ASSESSMENT | INDEPENDENT WALKING ONSET DEFINITION | PRETERM WALKING ONSET MEAN±SD (MO) | FULL-TERM WALKING ONSET MEAN±SD (MO) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hong 2009/ Taiwan | 29 | Inc <37 wk<br>Exc congenital abnormalities | 29±4 | 1,200±600 | 20 | Inc GA 38–42 wk<br>Exc perinatal complications | 39±1 | 3,400±500 | Parent report on biweekly calls | Five successive steps without support | 12.8[a] (9.8- >18)[b] | 11[a] (10–14.5) |
| Marin 2009/ Spain | 694 | Inc VLBW (BW <1,500 g), attend follow-up program<br>Exc abnormal neurologic examination or failed to attend follow-up in first few years | 29.6±2.89 (2 SD)[c] | 1,123±257.8 (2 SD)[c] | 1,000 | WHO motor development study population<br>≥37 wk | NR | NR | Parent report at follow-up visits | Five successive steps without support | 13.6±2.8[c] | 12.1±1.8 |
| Jeng et al (18) | 29 | Inc GA <37 wk, BW <2,500 g<br>Exc congenital or chromosomal anomalies, major neonatal diseases | 32±2.7 | 1,800±600 | 29 | Inc GA 38–42 wk, normal intrauterine growth<br>Status, normal newborn examination | 38.8±1.2 | 3,300±400 | Parent report | Five successive steps without support<br>For 3 consecutive days | 12.8[a] (9.8–16.5) | 12[a] (10–14.5) |
| Jeng et al (21) | 22 | Inc VLBW (<37 wk and BW ≤1,500 g)<br>Exc congenital/ chromosomal abnormality, and severe cranial ultrasonographic abnormalities | 31.1±2.5 | 1,180±243 | 22 | Inc GA 38–42 wk, AGA, and normal status at birth<br>Exc maternal/ perinatal complications | 39.1±3.1 | 3,298±219 | Data recorded within 1 week | Five successive steps without support | 14[a,b] | 12[a] |
| Jeng et al (16) | 96 | Inc VLBW (<37 wk and BW ≤1,500 g)<br>Exc chromosomal absence or genetic anomalies | 30.13±3 | 1,144.3±248.3 | 82 | Inc GA 38–42 wk, normal delivery, and normal newborn examination | 39.2±1.1 | 3,346.5±330.7 | Parent report at monthly calls | Five successive steps without support | Median 14 (10-18)[b] | 12[a] (9.5–16) |

*Continued*

TABLE 1. (Continued)

| REFERENCE | PRETERM GROUP N | PRETERM GROUP CHARACTERISTICS | PRETERM GROUP GA MEAN±SD (WK) | PRETERM GROUP BW MEAN±SD (G) | FULL-TERM GROUP N | FULL-TERM GROUP CHARACTERISTICS | FULL-TERM GROUP GA MEAN±SD (WK) | BW MEAN±SD (G) | ONSET ASSESSMENT | INDEPENDENT WALKING ONSET DEFINITION | PRETERM WALKING ONSET MEAN±SD (MO) | FULL-TERM WALKING ONSET MEAN±SD (MO) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| de Groot et al (31) | 33 | Inc low-risk preterm<br>Exc major neonatal diseases or neurologic disorders | 30.6[a] (27.1-34.4) | 1,536[a] (765-2370) | 19 | Inc GA 38–42 wk with appropriate BW for GA<br>Exc abnormal examination at age 1 wk | 39.1[a] (38.1–41.4) | 3320[a] (2,960–4,000) | Parental report by call + visit to confirm 14 days later | Five successive steps without support | 15.77±1.6 | 14.3±1.98 |
| Cioni et al (28) | 25 | Inc low-risk preterm (<37 wk)<br>Exc abnormalities or neurologic disorders in 1st year | 33.8±2.7 | 2,100±600 | 25 | Inc GA >37 wk<br>Exc pre- or perinatal complications, or abnormal examination at birth or 1st mo | 38.4±1 | 3,100±300 | Parent report | Ten successive steps without support | 12.2±1.2 | 12.6 ±1.6 |

*AGA=appropriate for gestational age; BW=birthweight; CP=cerebral palsy; Exc=exclusion criteria; GA=gestational age; Inc=inclusion criteria; NR=not reported; VLBW=very low birthweight; VPT=very preterm; WHO=World Health Organization.*

[a]*Median.*

[b]*Not all participants were walking at the end of follow-up.*

[c]*Data obtained from authors.*

attain walking (mean 13.67 months, SD 1.12) at an older age compared with their full-term peers (mean 12.24 months, SD 0.83) (Fig).

Mean walking onset was significantly later (mean 1.43 months; 95% confidence interval [CI] 0.59–2.28) for preterm infants compared with full-term infants (Fig). From studies limited only to VPT and/or VLBW infants, attainment of independent walking for the preterm group was further delayed, compared with full-term children, by approximately 2 months (VPT mean 2.16 months, 95% CI 0.47–3.85; VLBW mean 1.98 months; 95% CI 1.0–3.0) (Fig).

When interpreting the data, it is important to note the follow-up period. In the majority of studies, children born preterm were followed to at least 18 months to assess walking onset age; however, not all children were able to walk by 18 months. (16)(21)(22)(26)(29) Interestingly, 26 children born preterm did not achieve walking by age 18 months and were excluded in these studies. (16)(21)(22)(26)(29) The exclusion of these nonambulant children born preterm might underestimate the actual delay in the age at onset of walking. However, it is also possible that neurologic impairments such as CP may have been identified later in the development of these children. In comparison, all children born full-term walked by 18 months, except in 1 study, which followed full-term infants to 14 months and excluded children who did not walk by this age. (33)

## GAIT DEVELOPMENT IN CHILDREN

Understanding the timing of gait changes and how gait relates to other neurologic and behavioral events provides information about the primary mechanisms of childhood development. (34) The gait pattern of children continually changes and develops with age throughout childhood and adolescence. (35) Gait is not a constant because it fluctuates from step to step, also known as gait variability. Some evidence suggests that gait development continues to be refined until the underlying pattern becomes mature, at age 7 years. (35) However, cumulative evidence suggests that the gait continues to stabilize throughout childhood and adolescence. (13)(36)

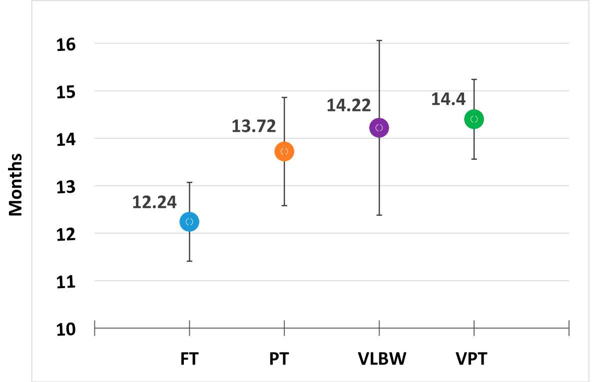


**Figure.** Age at onset of walking in months, mean ± standard deviation. FT=full-term; PT=preterm; VPT=very preterm; VLBW=very low birth weight.

Spatiotemporal parameters measure the time and distance characteristics of gait, (34) and are sensitive indicators to detect gait abnormalities. (14)(34) As noted earlier, spatial gait parameters include measures of step size and stride length while temporal gait parameters include cadence and double support time. (14) These spatiotemporal parameters are associated with changes related to growth and walking experience. (37) For instance, in the months following the attainment of independent walking, there is an increase in walking speed, stride length, and single limb support time, as well as a decrease in the cadence and double support time. (38) As the child continues to grow, further developments in the spatiotemporal characteristics of gait occur with changes in the size of the child's body segments. (37) Therefore, while many parameters reach maturation by the age of 3 to 4 years, speed, cadence, single leg stance, and step length continue to change with increasing age and leg length. (34)(37) Cadence measures in 7-year-old children are still 26% higher than the normal values of healthy adults. (38) Stride-to-stride variability and stride time values are also reported to continually change until age 14 years. (13) Spatiotemporal gait parameters are a valid and reliable method for assessing gait in children, (39)(40) and are sensitive measurements to assess for gait abnormalities. (37)

Kinetic and kinematic measures are also important parameters to consider when assessing the gait of children. Kinetic measures assess the forces generated across the joints during walking, whereas kinematic measures assess joint movements. Kinetic measures are reported to continually alter throughout childhood with evidence showing changes until age 9 years. (34) Comparatively, kinematic measures are reported to stabilize earlier in childhood, with major changes in joint angles occurring between 1 and 2.5 years of age, followed by minimal changes up to age 4 years. (37)

In addition to walking as a single task activity, the ability to perform additional concurrent activities such as talking, carrying objects, or thinking is part of everyday function, and of interest across childhood. Dual-task activities require the person to maintain constant performance of a task while performing additional tasks such as a cognitive or motor task. (41) Dual-task walking has an influence on the gait characteristics of children, including those who are developing appropriately. (42)(43) Not surprisingly, dual-task walking conditions have greater influence on the gait of children with attention and executive function problems at school age. (44)

### Gait Assessment

Gait assessment provides important clinical data for assessing function and determining intervention goals, as well as monitoring the result of medical treatment. (14) To assess a child's gait pattern and identify variation in gait characteristics, it is essential to use normative or reference gait data sets of full-term children who are developing appropriately. (36)(37) Different techniques are available to minimize the variability of gait data by accounting for height and leg length differences and including conventional normalization with body mass. (34) With advances in technical assessments, spatiotemporal gait characteristics can be calculated through instrumented walkways. (33) Similarly, kinetic and kinematic parameters can be derived from 3-dimensional motion systems and force platforms. (33)

## GAIT CHARACTERISTICS OF CHILDREN BORN PRETERM

All 6 studies comparing spatiotemporal, kinematic, and/or kinetic gait characteristics of independent walking among 244 children born preterm (mean GA 30.62 weeks, SD 2.45) and 179 children born full-term (mean GA 39.08 weeks, SD 1.23) are summarized in Table 2.

### Gait Characteristics from Instrumented Assessment

In the studies summarized in Table 2, different instrumented gait assessment tools were used to assess the gait of children, including the GAITRite electronic walkway system (CIR Systems, Inc., Sparta, NJ), (33)(43) a Balance Master computerized force plate (NeuroCom, Clackamas, OR, USA) (27), and kinematic analysis with reflective markers. (18) Step width was significantly wider in preterm children (mean 10.4 cm, SD 2.2) compared with their full-term peers (mean 9.4 cm, SD 1.5) at 18 to 22 months of age. (33) Similarly, stride length was significantly shorter in preterm infants (mean 54 cm, SD 6) compared with their full-term peers (mean 57 cm, SD 7) at age 18 months. (18) All studies were of high (18) or moderate quality (33)(43) using the Newcastle-Ottawa Scale. (32)

When describing gait characteristics in preterm children who were not diagnosed with CP but had mild to moderate developmental delay based on their Bayley Scales of Infant Development, 3rd edition, scores, 1 study found that children born preterm had a significant increase in step width (mean 11.0 cm, SD 3.0) compared with full-term children (mean 9.4 cm, SD 1.5); increased step length asymmetry (mean 0.12 cm, SD 0.1) compared with full-term children (mean 0.05 cm, SD 0.04); and longer step time (mean 0.39 s, SD 0.11) compared with full-term children (mean 0.34 s, SD 0.04). (33) In contrast, there were no significant differences between gait characteristics of children born preterm and their full-term peers when they were walking at a self-selected speed and walking directly on a line at age 7 years, (27) and walking while doing a concurrent task at 9.5 years of age. (43) There was a trend of increased gait variability when walking while doing a concurrent activity for VLBW children compared with full-term peers. (43)

### Gait Characteristics from Observational Assessment

Gait characteristics have also been described in 2 studies using observational gait assessment determined by 2 assessors. (28)(31) The authors described gait characteristics of children during the first few weeks after walking and they found no differences in gait characteristics between children born preterm and those born full-term. (28) The other study, a high-quality study that used an observational assessment tool with a scoring system to assess independent walking, found that children with lower birth GA and birthweight were overrepresented in the near-poor and poor scores. (31)

In conclusion, limited evidence was available for whether and how the gait of children born preterm differs from children born full-term, and importantly, whether any differences persist. The available evidence concentrates on 2 distinct periods, the first few months after the child attains walking and school age. Furthermore, the finding of gait characteristics should be interpreted with caution as a result of the small number of participants; wide GAs and age range of participants at assessment time points; and the variability of the spatiotemporal characteristics tested in the studies. Furthermore, the variable methodologic quality and study design of the included studies need to be considered.

## CLINICAL RECOMMENDATIONS

The onset of independent walking is most commonly defined as the time when an infant can take 5 successive

TABLE 2. **Characteristics and Findings of 6 Studies on Gait Characteristics**

| REFERENCE | AGE | PRETERM GROUP: N | PRETERM GROUP: CHARACTERISTICS | PRETERM GROUP: GA MEAN±SD (WK) | PRETERM GROUP: BW MEAN±SD (G) | FULL-TERM GROUP: N | FULL-TERM GROUP: CHARACTERISTICS | FULL-TERM GROUP: GA MEAN±SD (WK) | FULL-TERM GROUP: BW MEAN±SD (G) | ASSESSMENT TOOLS AND CONDITIONS | GAIT CHARACTERISTICS | CS | MAIN FINDINGS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cahill-Rowley et al (33) | 18–22 mo[a] | 81 | Inc VPT<br>Exc genetic disorders or congenital brain abnormalities<br>Exc 1 infant walked with assistance | 28.6±2.3 | NR | 43 | Inc appropriately developing<br>Exc parent gait concerns or walked >14 mo | 39.5±1.2 | NR | GAITRite<br>Pref walk | Speed, cycle time, step width, step length, and time asymmetry; stance %, single support %, and double support % | | Wider step width in preterm children; longer step time and higher step length asymmetry in preterm children with low gross motor scores |
| Hagmann-von Arx 2015 (43) | 9.5 y | 44 | Inc VPT<br>Exc M-ABC <16th percentile and low IQ | 30.1±2.1 | 1,423±421 | 44 | Inc GA >37 wk<br>Exc M-ABC <16th percentile and low IQ | 39.6±1.5 | 3,353±429 | GAITRite<br>Pref and dual-task walks | Speed, cadence, stride length, single and double support time, SVV, SLV | CS | Higher variability in VLBW in dual-task conditions<br>SVV and SLV significant for prematurity |
| Kluenter et al (27) | 7 y | 44 | Inc infants with VLBW<br>Exc major neurologic disorders | 28.6[b] (23.4–34.1) | 1,095[b] (380–1,480) | 21 | Inc healthy FT from Department of Otorhinolaryngology<br>Exc abnormal otolaryngology or vestibular status, or major neurologic disorders | NR | NR | Balance master<br>Pref and line walks | Step width, step length, speed, and the step length symmetry | | No significant differences |
| Jeng et al (18) | 18 mo[a] | 29 | Inc GA <37 wk, BW <2,500g<br>Exc congenital or chromosomal anomalies, major neonatal diseases | 32±2.7 | 1,800±600 | 29 | Inc GA 38–42 wk, normal growth status, normal newborn examination | 38.8±1.2 | 3,300±400 | Kinematic analysis<br>Pref walk | Stride length, stride period, stance time, swing time, interjoint coordination, and interlimb coordination | CS | Shorter stride lengths in preterm children<br>Speed slower in preterm children (not significant) |
| de Groot et al (31) | 14 d[a] after onset | 33 | Inc low-risk preterm<br>Exc major neonatal diseases or neurologic disorders | 30.6[b] (27.1–34.4) | 1,536[b] (765–2,370) | 19 | Inc GA 38–42 wk with appropriate weight for GA<br>Exc abnormal examination at 1 wk | 39.1[b] (38.1–41.4) | 3,320[b] (2,960–4,000) | Videotape 2 assessors<br>Pref and fast walks | Step width and asymmetry | | Preterm children with lower GA and small for GA overrepresented in near-poor and poor scores |
| Cioni et al (28) | 3-4 wk[a] and 4 mo[a] after onset | 25 | Inc low-risk preterm, GA<37 wk<br>Exc abnormalities or neurologic disorders in 1st year | 33.8±2.7 | 2,100±600 | 25 | Inc GA >37 wk<br>Exc pre/perinatal complications, or abnormal examination at birth or first months | 38.4±1 | 3,100±300 | Videotape 2 assessors<br>Pref walk | Base of support, asymmetry, and foot-strike asymmetry | | Asymmetry more in FT (12/25) than preterm children (6/25) not significant |

*BW=birthweight; CS=correct for body size; Exc=exclusion criteria; FT=full-term infants; GA=gestational age; Inc=inclusion criteria; NR=not reported; M-ABC=Movement Assessment Battery for Children; Pref walk=walking at self-preferred speed; SLV=stride length variability; SVV=stride velocity variability; VLBW=very low birthweight; VPT=very preterm.*

[a]*Corrected for prematurity.*

[b]*Median.*

steps without support. We believe that this definition should be standardized in clinical and research practice to ensure effective communication between professionals and families. Because the age at onset of walking provides insight into a child's motor development and expected motor performance, a child born preterm with a delayed walking onset of more than 14 months should be monitored closely because the average walking onset age in this population is 13.67 months. Children who fail to attain walking by the age of 18 months (which is the normal upper limit for walking onset) should be referred to physical therapy for motor assessment. Further attention should be directed to children born VPT and/or with VLBW because they are at higher risk of experiencing delays and variations in gait. Children born preterm, who have functional difficulty with walking in daily life, need to be referred to health professionals who are trained in gait assessments.

Although there is no clear evidence on how we can facilitate and train children born preterm to improve their gait, there is evidence that early intervention can benefit the motor outcomes of children born preterm. (45) Furthermore, there is emerging evidence that intervention to facilitate walking onset including treadmill training might be of benefit. (24)

## CONCLUSION

This review highlights that children born preterm walk at least 1 month later than those born full-term. The 1-month gap in walking onset increases to more than 2 months when limited to children born VPT and/or with VLBW compared with infants born at term. This delay in walking onset is found in children born preterm without known neurologic impairments such as CP. Further research is needed to understand the relationship between delayed onset of walking and long-term developmental problems in children born preterm. It is also unclear whether affected children catch up later or continue to have issues.

Despite the large body of literature describing the gait characteristics of children born at term who are developing appropriately and those with significant motor impairments, the evidence of gait characteristics in children born preterm is scarce. The available evidence solely concentrates on the first few months after the child attains walking and at school age, while the gait of preschool age children born preterm has not yet been investigated. In the first few months after the onset of walking, up to 22 months of age, children born preterm appear to walk with wider step width and shorter step length, and those with mild to moderate motor delay have increased step length asymmetry and longer step time compared with children born at term. However, it is not clear if these differences persist as children reach preschool and school age. Dual-task walking conditions are a potential area of challenge for children born preterm and, to date, evidence suggests that preterm children at school age have a higher degree of gait variability compared with their full-term peers. Further prospective studies that investigate the gait of children born VPT and/or with VLBW are warranted. There is also a gap of knowledge in whether the early differences in gait resolve with age and greater walking experience. Understanding the development of the gait of children born preterm is important because walking is a critical daily task that influences the child's general function, academic performance, self-esteem, and participation.

## American Board of Pediatrics Neonatal-Perinatal Content Specification

- Know the risks of neurodevelopmental impairments in term infants, late preterm infants, moderately preterm infants, and extremely preterm infants, with and without neurologic risk factors.

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