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Effects of Modern Diapers on Early Walking Patterns

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Introduction

Most children are expected to walk without support at 8 to 18 months (most probably at 12 to 15 months) [1–3]. At the beginning of walking without support, children show rather inexperienced type of gait which is slower with wider, shorter steps, and more falls. After 3 to 6 months of walking experience, they begin to walk faster with narrower and longer steps [4–6]. Finally, at ages of 7 to 8, an adult type gait is accomplished [4].

Possible extrinsic limitations to early walking development are worn clothes, additional weights carried and diapers. All were shown to negatively affect early gait patterns [7,8]. Diapers, for example, were shown to cause children to walk with broader, shorter steps and assume the gait pattern of less mature subjects [9,10]. Modern single use diapers might have improved in design after those first reports, against their effects of gait. Therefore, the aim of this study is to determine the effects of modern single-use diapers on early walking by comparing gait patterns of small children without any diaper and with a single-use diaper.

Materials and Method

After receiving institutional review board (IRB) and ethical approval, the parents and healthy children were invited randomly from a group of volunteers after being informed about the research and gave consent. Inclusion criteria were ability to walk unsupported, age between 12 and 24 months, and a history of normal pediatric development. Medical history of each child was confirmed by obtaining their pediatric follow-up records. The exclusion criteria were any recorded developmental delay or abnormality, and any active acute or chronic illness. Child selection aimed to compose two groups with the same number of children and the same gender distribution. First group included children aged 12 to 18 months and the second group included children 19 to 24 months of age. Information about the age, time to walk independently, duration of diapering during a day were recorded. The criterion for independent walking was defined as being able to walk 3 meters without support [9].

The study was conducted in the visual gait analysis laboratory. The room also had a force plate (or pedobarograph) of 50 cm to 1,5 meters on the floor. In each session, the children walked 3 to 5 regular steps barefoot and unsupported on the force plate for at least three times. Each walking session was also recorded using a camera. In each time the child started walking towards one of the parents from the beginning of the walkway, then walked on the foot plate and finally made a few more steps on the walkway. Each sequence of walking was repeated until a regular stepping was observed.

Each child walked without any diaper, wearing only thin cotton briefs and with each of the two most-selling diaper alternatives (X and Y) in the country. Maxi or number 4 diaper size of each brand was used during the study. Presence of the author team inside the room was limited against any bias. During each session, the physician team visited the room only when asked, to control the process or consult the parents and the technicians. Additionally, authors were blinded against the numeric naming of each session (0-2). The order of sessions was changed randomly by technicians, against any misleading effect of tiredness or familiarity with the environment on the results.

During whole sessions, a peaceful, playground-like environment was provided and the parents were allowed to freely interact with their child. It was strictly indicated that the

same parent used the same entertaining item (e.g. toy, cell phone) in each time and session of walking.

After all walking sessions, the authors measured average step width, step length, left and right strides for each session. Step width is the distance between lines of progression of two feet during one step. Step length is the distance between two heel strikes of two consecutive steps along the line of progression. Stride is the distance between two heel touches of the same side foot (Figure 1).

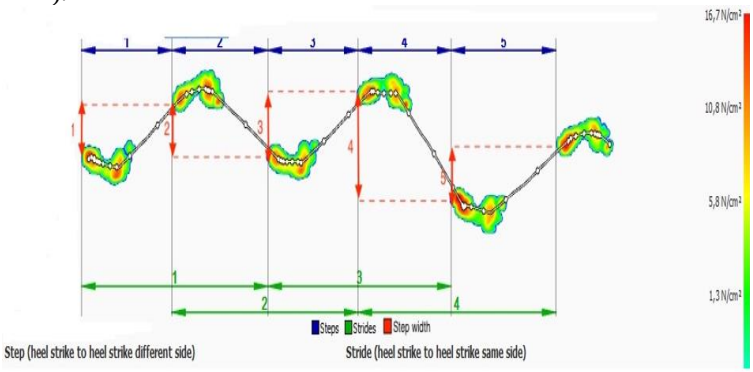

Figure 1: Pedobarographic view of 5 consecutive steps of a child. Step width (red arrows) is the distance between lines of progression of two feet during one step. Step length (blue arrows) is the distance between two heel strikes of two consecutive steps along the line of progression. Stride (green arrows) is the distance between two heel touches of the same side foot.

Statistical analyses of the measurement differences between the sessions were done using repeated measures ANOVA. The differences of repeated measures of a single variable were analyzed using one-way repeated measures ANOVA. Comparison of repeated measures of a single variable between different groups was performed using mixed design ANOVA.

Before repeated measures ANOVA, compatibility of the data with required conditions were controlled. Measurements were confirmed to be compatible with normal distribution by the Shapiro-Wilk test and Q-Q Plot graphs. Bonferroni correction was applied for pairwise comparison. Overall effect size of differences between measurements, ω^2 and effect size of advanced level coupled comparisons, Cohen's d or Hedges' g were measured.

Results

The study involved 82 children, aged between 12 and 24 months. The median age was 19, the mean age was 18,8 months (SD; 3,3). 43 children were female (52,4%), 39 were male (47,6%). The independent walking experience of children was between 1 month and 15 months (median: 6,5).

Numbering of each session was done as follows. Number 0: non-diapered walk; number 1: walking with dry diaper X; number 2: walking with dry diaper Y. The effect of diapers on walking was evaluated based on the four parameters of gait measured with a force plate. They were step width, step length, and right and left strides.

Session 0 was taken as the baseline normal walking or reference. The mean values of step width, step length and stride measurements were given in Table 1. Not all of the included children were able to perform regular steps in entire sessions due to distraction or tiredness. During statistical analysis, they were omitted for more accurate comparisons and the valid sample sizes decreased to 60.

Gait Variable	Mean ± SD (mm)
Step width	85 ± 28
Step length	236 ± 43
Stride (left)	468 ± 88
Stride (right)	471 ± 91

Table 1: Average values for walking without any diaper, taken as the normal values.

There was not any statistically significant difference between step widths, step lengths or strides of session 1 or 2 and 0 (Figure 2). The study also evaluated the differences of measured normal gait parameters between two age groups. There was a significant difference in all 4 variables depending on the age group of the children (Table 2). Older children showed narrower and longer steps which was considered as more mature pattern.

Gait Variable (mm)	Group 1; ≤18 mo (SE)	Group 2; >18 mo (SE)	Sig.
Step width†	102 (3)	94 (4)	0,023
Step length†	227 (6)	246 (6)	0,020
Stride left†	453 (12)	495 (13)	0,019
Stride right†	454 (12)	497 (12)	0,015

Table 2: Comparison of mean gait variables between children younger than 18 months and older than 18 months. (n:32 for Group1; n: 29 for Group2; SE: standard error; Sig.: significance; mo: months; †: variable with significant change)

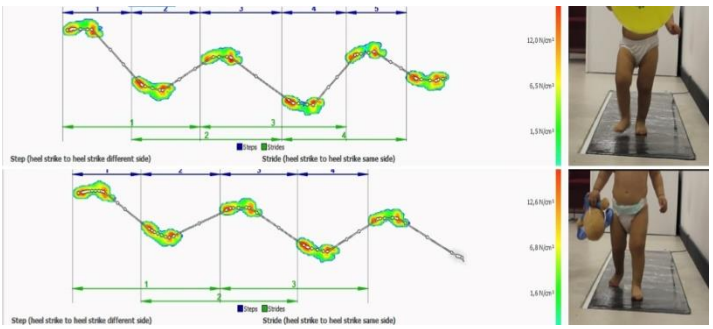

Figure 2: Analyses of a child while walking without any diaper (only a cotton underwear) and with a dry single-use diaper. There was no statistical or obvious difference in measured gait variables or the walking pattern of the child.

The whole sample group was divided again into two groups (experienced and inexperienced <6 months) depending on the independent walking experience, and the gait parameters were compared. There was a significant difference in all 4 variables except step width depending on the walking experience of the child (Table 3). Children with longer experience in independent walking showed gait with longer steps.

Gait Variable (mm)	Group 1; ≤6 mo walk (SE)	Group 2; >6 mo walk (SE)	Sig.
Step width	101 (3)	93 (4)	0,115
Step length†	223 (5)	250 (6)	0,002
Stride left†	448 (11)	501 (12)	0,002
Stride right†	448 (11)	503 (12)	0,001

Table 3 Comparison of normal gait variables between children inexperienced in walking and walking for longer than 6 months. (n:32 for Group1; n: 29 for Group2; SE: standard error; Sig.: significance; mo: months; †: variable showing significant change)

Additionally, the effect of the age of the child or the duration of independent walking on changes in step width and step length depending on the diapering condition was evaluated using mixed design ANOVA analysis. There was not any significant effect detected.

Discussion

Independent walking is one of the major gross motor developmental steps in early childhood [7]. It is defined as walking without any support or fall for at least 10 feet or 10 steps. As the musculoskeletal and neurological systems develop or the child gets experienced, she/he becomes able to walk longer, more steadily, with less fall episodes [11]. Afterwards, the child begins running, jumping, climbing and going over obstacles on the ground. Finally, by the end of 7th year, a child attains an adult type walking pattern [4].

During the early 3 to 6 months of walking maturation, children show some obvious changes in walking pattern. They begin walking faster with a narrower base, longer step, shorter duration of stance and decreased double support time [6,8]. Likewise, our findings show that after 18 months of age or 6 months of walking experience, children exert a more maturated walking pattern. These suggest a normal motor development for that child. Like delayed walking, inability to achieve a more adult like walking pattern may be an indication of an organic condition.

In addition to possible internal organic blocks, it was shown that external conditions might affect a child to perform mature walking pattern. Binding light loads on legs, trunk or arms of children showed that they started walking with slower, shorter steps [7]. Also, choice of clothes and diapers had negative effects on walking, causing more falls and less mature gait [7,8,10]. Heavy clothing and restrictive habits in child rearing were also shown to cause the child to attain some skills later than their peers [9]. In our study, it was shown that dry diapers did not have an immediate effect on early walking pattern or ability of small children younger than 2 years old.

It was certain that single-use diapers had facilitated child rearing [12]. With advances in technology, companies have renewed their designs and ingredients to improve comfort, effectivity and hygiene [10]. However, there were only a few studies about their effects on child movement. Considering that a child wears a diaper almost all day, it was 23 hours a day in our study, some authors interested in their possible effects on walking. In one study [9], authors compared the effects of traditional cotton fabric diapers and single-use diapers on early walking. They studied force plate measurements and evaluated step width, step length, dynamic base of support, walking speed and number of missteps. They concluded that both types of diapers caused the child to walk with wider base and shorter steps, and more falls. They found that children wearing cloth diapers walked like a child 7,5 weeks younger, while those wearing disposable diapers showed a 4,7 weeks younger pattern. In another study, diapering was shown to result in increased step width but had no impact on velocity or step length [8]. The hypothesis of our study was based on our clinical observation that modern single-use diapers did not seem to affect walking patterns, which might be a result of changes in diaper designs or technology during the last decade. Contrary to the aforementioned articles, our study showed that single-use diapers did not have any effect on walking compared to walking with a thin cotton underwear.

In our study, we were able to detect expected normal values and distributions of step width, step length and strides of children between ages 12 to 24 months. Because there has not been any consensus on standards of measured variables in this age period, these finding might be valuable in following gait maturation. Additionally, because wet diapers might affect these measurements, it can be recommended not to evaluate walking pattern of a child when the worn diaper is dirty or wet.

Limitations of our study can be listed as comparison of only two diapers out of a wide variety of brands in the market, relatively a smaller number of steps or times of walking in each session. However, the most sold two diaper brands were chosen against increasing the burden for the children during study, considering that the design of the study already required about 15 times of walking for each child. Additionally, it was considered that two most sold brands might be a suitable representative of the modern design of single-use diapers. The short duration of walk for each child was because of the length of the force plate, which was the longest available at the time of the study. Future studies using longer force plates and comparing more diaper designs may give more convincing results regarding the effects of diapers on early walking pattern.

In conclusion, we did not find any effect of dry single-use diapers on step-width, step length or stride measurements of walking in children between 1 to 2 years of age. Therefore, diapering may not be counted among constraints against performing age-matched gait pattern in small children.

Conflict of interest and source of funding:

Authors Erdal, Gorgun, Sarikaya and Inan declare that they have no conflict of interest. The authors also declare that they did not receive any external funding regarding the results of this study.

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