Spring 2017

Variability and Stability of 13 to 19 Month Olds Infants' Gait Affect by Wet and Dry Diaper and Underwear

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VARIABILITY AND STABILITY OF 13 TO 19 MONTH OLDS INFANTS' GAIT AFFECTED BY WET AND DRY DIAPER AND UNDERWEAR

by

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(Under the Direction of Li Li)

ABSTRACT

Research has been conducted on motor development, children's walking behavior, differences between adult and children's gait with perturbation, and the effect of diaper perturbation versus unclothed on gait, but there is little research on different diaper perturbations on gait. **PURPOSE:** The purpose of this study was to examine how physical perturbations (a dry and a wet diaper and underwear) affected 13 to 19 month old infant's gait. **METHODS:** Sixty infants (13-19 month old) were recruited for the study. Each infant completed 5 trials for 3 conditions in a single session. Each trial consisted of the infant walking on an instrumented walkway (GaitRite CIR Systems, Sparta, NJ) for at least 5 continuous steps wearing a dry diaper, a wet diaper, and underwear. Step length (m/step), cadence (steps/s), support base (m) and stance time (sec) were analyzed. A mixed model with repeated measures along with a post hoc Tukey test and the Cohen d was used to examine the effect size. **RESULTS:** Significant interaction between age and condition was observed for stance time. Significant differences were found between the 13 month old infants with underwear (0.3874±0.0109) and 19 month old infants in wet diaper (0.2761±0.0102). Significant main effect for age but no significant interaction was observed for step length between 13 month old infants (23.511±.26) and 19 month old infants (31.849±.2432). Significant main effect for age and condition, but no significant interaction was observed for support base and cadence. For support base, ages of 13 months (12.508±.1732) and 19 months (9.682±.1621) were statistically different, as well as underwear (9.991±.1554) dry diaper (10.618±.1554), and wet diaper (11.245±.1554) being statistically different. For cadence, ages of

13 months (194.2±3.4988) and 19 months (299.1±3.2728) were statistically different, while dry diaper (217.29±2.4255) and underwear (208.08±2.4255) were statistically different.

CONCLUSION: The interaction between age and condition was found within the stance time gait parameter. The other gait parameters all had age effects. These factors are impacted by maturation. It is important to understand these affects to better equip the infant with diapers that do not affect their natural balance.

INDEX WORDS: Infants, Gait, Diaper, Perturbation, Biomechanics, Step length, Support base, Cadence, Stance time

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B.S., Jacksonville University, 2015

A Thesis Submitted to the Graduate Faculty of Georgia Southern University in Partial

Fulfillment of the Requirements for the Degree

MASTERS OF SCIENCE

STATESBORO, GA

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May 2017

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The infant years are a transitional period in walking development. Infants begin walking independently between the ages of 12-14 months (Hallemans, De Clercq, & Aerts, 2006). As infants grow, their anatomy and physiology are also rapidly changing thereby affecting their motor development. Learning to walk is part of motor development. The motor control system executes and monitors movement and integrates the central (CNS) and peripheral (PNS) nervous systems (Ives, 2014). This integration is seen when the CNS sends motor commands to the PNS, specifically the muscles that cause movement. Then sensory receptors in muscles send back sensory feedback to the brain. The PNS perceives where the body is in space through proprioception. This integration allows the body to move the hand to touch the nose even with the eyes closed. Motor learning details how the mind learns, plans, initiates, and modifies movement based on the information gathered(Ives, 2014). As motor learning and motor control develop in an infant, walking becomes a skill that integrates both processes. These processes can be examined further by examining different gait parameters.

Although research has been conducted on motor development (Bril & Breniere, 1989), infant's walking behavior (Adolph, et al., 2012), differences between adult and infant's gait with perturbation (Cole, Gill, Vereijken, & Adolph, 2014), and even the effect of a diaper versus unclothed on gait (Cole, Lingeman, & Adolph, 2012) there has been little research found on how diaper perturbations, such as the difference between a wet diaper and a dry diaper and underwear influence gait. Cole and colleagues define perturbation as "something that upsets the natural balance of things" (2014). As a child ages from 12 to 15 months they are beginning to walk well; as they age from 16 to 18 months they can walk backwards and down steps with some help (Kaneshiro, 2016).

Due to the infant's relatively new gait skills, it is expected that the infants are unstable and must compensate for perturbation (Cole, Gill, Vereijken, & Adolph, 2014). Cole and his investigators suggest that because these "novice walkers" must compensate for the perturbation they do so by changing their step length (2014). It has been suggested that maturity of gait is defined by using support base and step length (Cole, Lingeman, & Adolph, 2012). Step length is the distance along the line of progression from the heel of the previous step to the heel of the current step. Support base is the vertical distance from heel center of one step to the line of progression formed by two steps of the opposite foot. . Besides step length and support base, Sutherland and colleagues suggest that cadence (the rate at which a person walks) is also a predictor of gait maturity (1980). They suggest that as an infant grows older their cadence will decrease (Sutherland, Olshen, Cooper, & Woo, 1980). Stance time has also been correlated with increased maturity of gait, with a long stance phase indicating an immature gait (Kimura, et al., 2005). The stance time is the time it takes for an individual to complete the stance phase beginning with foot strike ending with foot off.

As an infant ages through the stages from 13 to 19 months, gait becomes more sure-footed. During this development stage, the infant begins to adapt a more normal gait that will transfer to a mature gait. It is important to understand the effect perturbation has on infants' gait because perturbation may cause them to be more unstable and interrupt the motor development and motor learning process of walking. Infants that have an immature gait have to use recovery strategies enabling them to maintain their balance (Adolph, Vereijken, & Shrout, 2003). If the addition of a perturbation disrupts these recovery strategies, infants will lose their balance or be forced to create other, unnatural recovery strategies. By understanding how a perturbation, in this study a diaper, effects an infant's balance and gait, modifications can be made to the diaper to reduce the upsetting of their natural balance of walking (Cole, Gill, Vereijken, & Adolph, 2014).

This study was designed to examine the progression of development in the gait from 13 to 19 month old infants while examining if there is a perturbation caused by a dry diaper and wet diaper compared to underwear. It was hypothesized that as an infant progresses through the ages of 13 to 19 months their gait will become more mature. This hypothesis will be supported if there is an increase in step length and a decrease in support base, cadence, and stance time. It was hypothesized that with the addition of perturbation (dry diaper, wet diaper) the gait would become less mature. But, as the infants grew older the perturbation would have less of an effect on the gait parameters. This relationship is seen by an interaction between the age groups and the conditions.

CHAPTER 2

METHODS

Participants

For this study, the sample of infants was not randomly selected. Infants were brought voluntarily by parents solicited from local daycares, local events, and word of mouth. Sixty infants ranging from 13 to 19 months old participated in this study. The participants included 33 males and 27 females. Adolph and associates found that there are no gender effects on gait parameters, so the genders were not separated (2003). The infants were split into seven groups based on how many months old they were. Seven age groups were chosen due to population size. The infant's weight, height, length of foot, width of foot, and leg length were measured. The parents were asked: when their infant started walking (more than 10 steps); what type of diaper the infant wears; and if the infant walks around naked for more than 30 minutes a day. All but one infant used disposable diapers. This infant's parents split the infant's wear time between disposable and cloth diapers. Eight of the 60 infants were reported to walk around naked more than 30 minutes a day while most parents commented that they let their infants "air out" after having a bath.

Procedures

Data were collected during a single session that lasted 30-45 minutes. The infant wore commercially bought underwear as well as a commercially bought diapers that were either wet or dry. The conditions were randomized between participants. The wet diaper was wet using 100ml of room temperature water added using a syringe. Room temperature water was chosen to ensure the safety of the infant. The water was added in the middle of the diaper for female infants and towards the front for male infants to simulate their natural urination location. The parents or guardians were present for the entire data collection to change the infant's diapers and to help make the infant more comfortable. The infant was placed at one end of the walkway while the parent or guardian stood at the other end to encourage them to walk. Other parents or guardians started on the same end as the infant then moved to the other end so the infant would follow. Most of the infants were motivated to walk by offering them a toy or food. Some infants walked while holding objects. Researchers have found that carrying objects does not affect infant foot placement, which is the measurement of gait maturity, it only affects arm placement which may help balance the infant more than if they were not holding an object (Adolph & Tamis-LeModa, 2014). Some infants enjoyed the activity of walking back and forth and did so freely without being prompted by the researchers or parents or guardians.

Gait data was collected using a 4.9m GaitRite walkway (CIR Systems, Sparta, NJ.) The infant was prompted to walk 10 steps 5 times for each of the 3 conditions. Trials with the following conditions were excluded from gait parameter analysis: falls (when the body dropped to the floor unsupported or hands are placed on the floor); missteps (trips when the swinging foot failed to clear the ground); double steps (when the same foot stepped twice); back steps (when the leading leg moved backward behind the trailing leg); and lag steps (when the swinging leg moved forward but failed to move ahead of the stance leg). Only trials with at least 5 consecutive steps on the walkway were included in the analyses for gait parameters (Cole, Lingeman, & Adolph, 2012).

Data Analysis

Gait parameters were only calculated in trials where the infant took at least 5 consecutive steps. Support base (vertical distance from heel center of one step to the line of progression formed by two steps of the opposite foot measured in centimeters), step length (distance along the line of progression from the heel of the previous step to the heel of the current step measured in centimeters), cadence (steps taken per minute), and stance time (time from initial foot contact until foot off measured in seconds) were the gait parameters used.

For the statistical analysis Statistix 10 (Analytical Software, Tallahassee, FL, USA) was used to analyze the data. A mixed model with repeated measures was used with 5 repeated trials for each participant within each condition. This mixed model included between subject variables of different age groups as well as within subject repeated variables of the different conditions. A Tukey post hoc test was used to understand the homogeneity of the different conditions and age groups. Homogeneity is defined via letters. Values that share the same letters are statistically similar. Significance is recognized as $p < 0.05$. Effect size was measured using the Cohen's d formula $d = \frac{(x_1 - x_2)}{s}$,where x is the mean and s is the standard deviation (Cohen, 1988). Cohen defines effect size as small (0.2), medium (0.5), and large (0.8) (1988). Using Cohen's equivalence of d table, the nonoverlap (U_1) is reported as a percentage (1988).

CHAPTER 3

RESULTS

The output from the GaitRite was used to determine if there was an effect on the different gait parameters based on age and condition. The data analysis determined that support base and cadence were significantly affected by age and condition, step length was significantly affected by age, and stance time was significantly affected by an interaction between age and condition with p-values all less than 0.05. Using the Tukey post hoc analysis, differences between the age groups and conditions were determined. Homogeneity in Tukey is represented via letters. The anthropometric data can be found in Table 1 where the averages of each parameter have been taken. In general, with increase in age, there is an increase in weight, height, leg length, length of foot, and width of foot.

Table 1: Anthropometric data for infants ages 13 to 19 months

Age	Participants	Mass (kg)	Height (cm)	Leg Length (cm)	Length of Foot (cm)	Width of Foot (cm)	Walking Onset (mo)
13	7	10.34	71.97	36.65	11.43	5.08	11.71
14	9	9.76	74.72	36.59	11.22	5.29	11.61
15	8	11.54	74.14	37.31	11.59	5.35	11.63
16	9	10.74	78.18	39.30	12.77	5.57	11.33
17	14	11.10	75.58	38.96	12.29	5.44	12.39
18	5	11.17	80.77	39.37	12.19	5.72	11.00
19	8	13.28	81.60	41.59	12.30	5.87	11.81

Notes: Height was taken from the top of the infants' head to their heel while they were standing. Leg length was taken from the most posterior part of the infant's leg to the calcaneus while the infant was sitting. Length of foot was measured from the tip of the longest toe to the heel. Width of the foot was measured as the widest part of the foot. Walking onset was indicated by the infant being able to walk more than 10 steps independently.

Support Base

For support base, it was observed that significance occurred within age ($F_{(6, 24)}$=60.05,p<0.05) and between conditions ($F_{(2, 24)}$=16.29, p<0.05). The post hoc analysis revealed for age, the 13 and 14 month old groups had no statistical difference, and the 15, 16, 17, 18, and 19 month old groups had no statistical difference. These results indicate that 13 and 14 month olds are statistically different from the 15, 16, 17, 18, and 19 month olds. The means for the 13 and 19 month olds were 12.51cm±0.2 (A) and 9.68cm±0.2 (BC) respectfully (Figure 1). The effect size was found for age to be 0.19. Based on Cohen's criteria, this effect size is small with 14.7% nonoverlap between the 13 and 19 month olds (1988). For the conditions, the post hoc analysis revealed that all three conditions were statistically different from one another with the means being, underwear 9.99cm±0.2 (C), dry diaper 10.62cm±0.2 (B), and wet diaper 11.25cm±0.2 (A) (Figure 2). The effect size for conditions was found to be 0.04 for underwear and dry diaper, 0.09 for underwear and wet diaper, and 0.00 for wet diaper and dry diaper. Based on Cohen's criteria, these results indicate a small effect size with 0.0% nonoverlap between all the conditions (1988).

Figure 1: Means of the gait parameter Support Base based on age

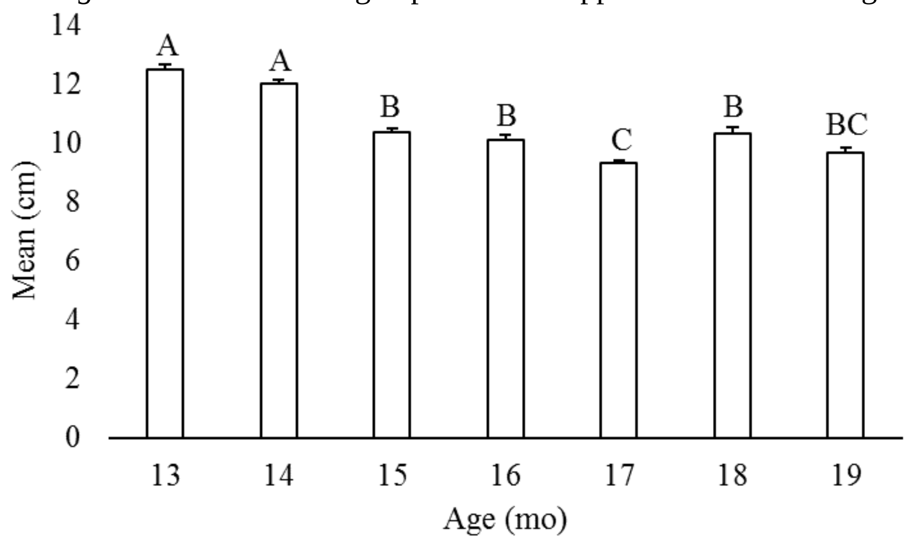
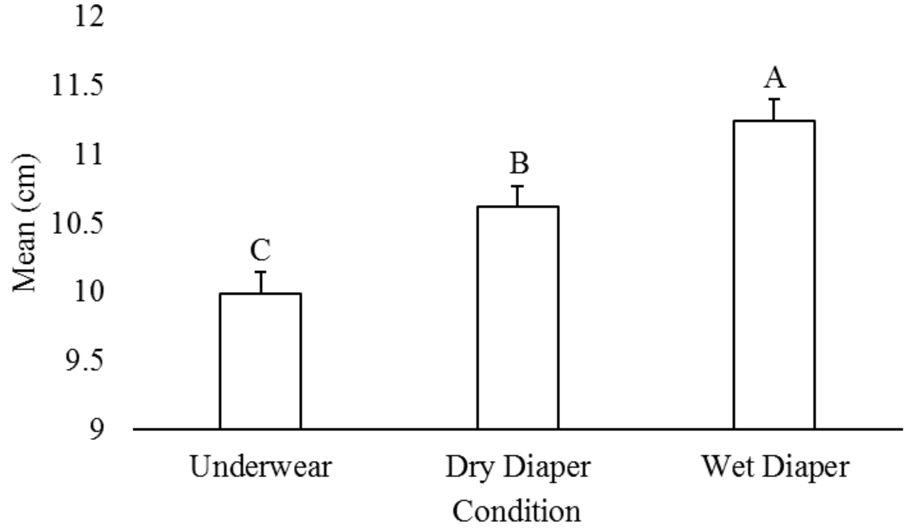


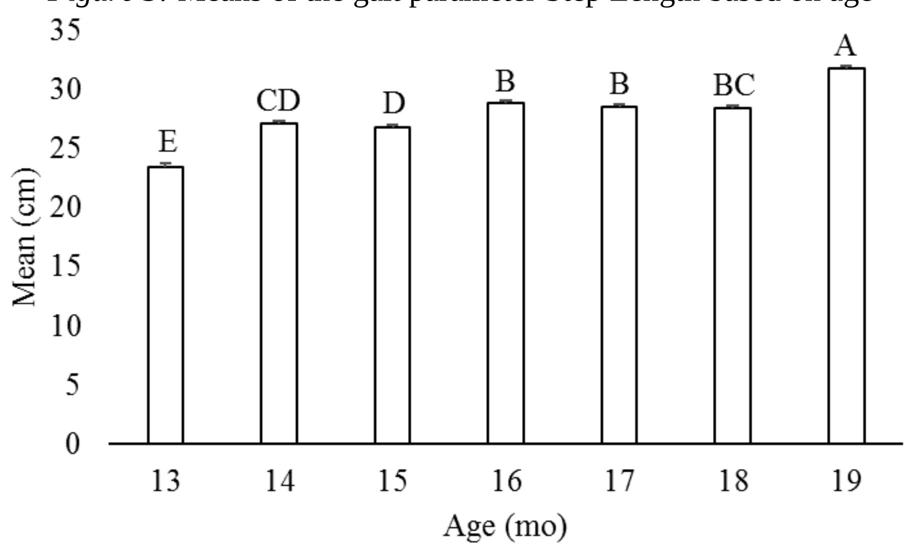
Figure 2: Means of the gait parameter Support Base based on condition



Step Length

For step length, it was observed that significance occurred within age ($F_{(6, 24)}$=102.16, $p<0.05$). The post hoc analysis revealed that there was a difference between 13 and 19 month olds with means of 23.51cm±0.3 (E) and 31.85cm±0.2 respectfully (A) (Figure 3). The effect size was found for age to be 0.2. Based on Cohen's criteria, this effect size is small with 14.7% nonoverlap between the 13 and 19 month olds (1988).

Figure 3: Means of the gait parameter Step Length based on age



Cadence

For cadence, it was observed that there was significance within age ($F_{(6, 24)}$=10.85, $p<0.05$) and between conditions ($F_{(2, 18)}$=3.61, $p<0.05$). For age, the post hoc analysis revealed significant differences between the 13 and 19 month olds with means of 194.2(steps/min)±3.5 (C) and 299.1(steps/min)±3.3 (A) respectfully (Figure 4). The effect size was found for age to be 0.30. Based on Cohen's criteria, this effect size is small with 21.3% nonoverlap between the 13 and 19 month olds (1988). For conditions, the post hoc analysis revealed that there was a significant difference between the dry diaper and underwear, while there were not any observed differences between the wet diaper and dry diaper and the wet diaper and underwear. The means for each are as follows, dry diaper 217.29(steps/min)±2.4 (A), wet diaper 212.89(steps/min)±2.4 (AB), and underwear 208.08(steps/min)±2.4 (B) (Figure 5). The effect size was found for condition to be 0.10. Based on Cohen's criteria, this effect size is small with 7.7% nonoverlap between the underwear and dry diaper conditions (1988).

Figure 4: Means of the gait parameter cadence based on age

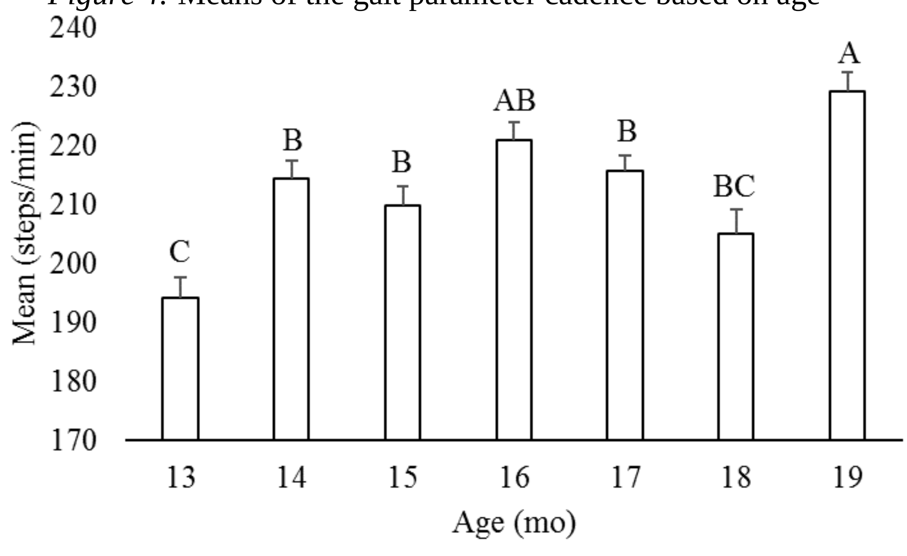
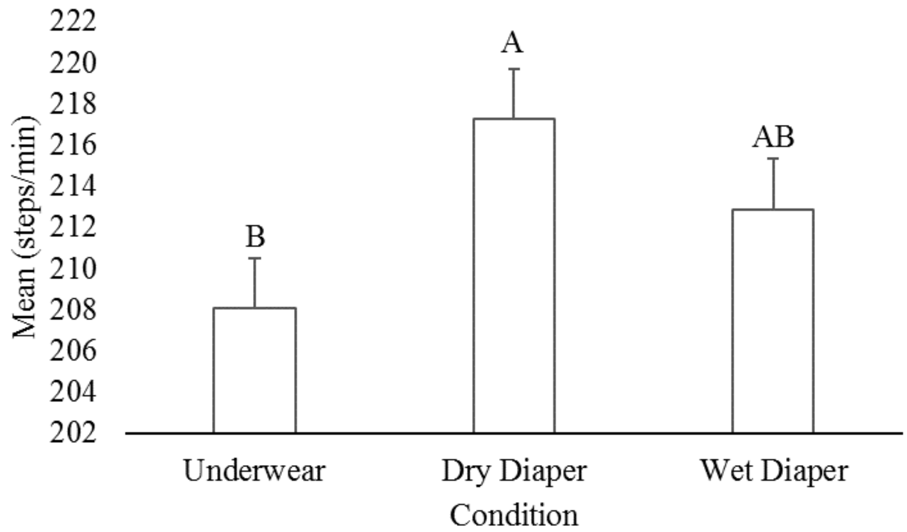


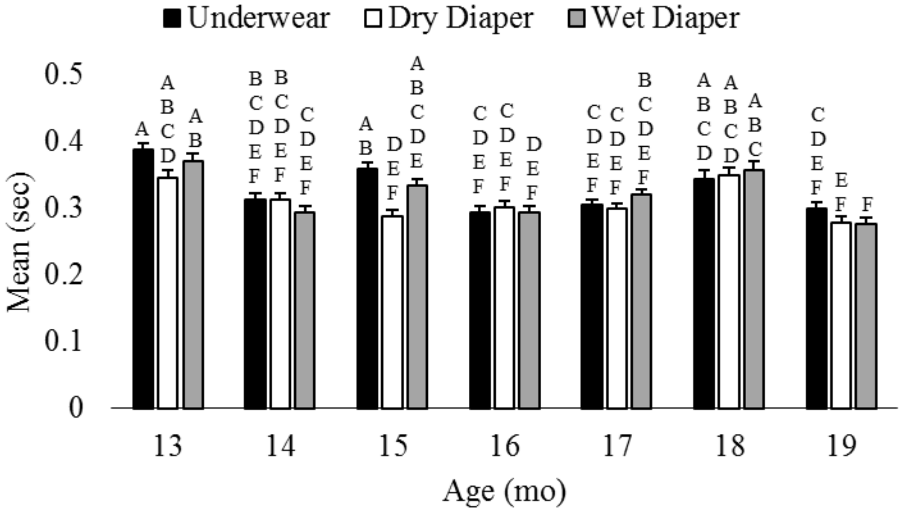
Figure 5: Means of the gait parameter cadence based on condition



Stance Time

Stance time was the only gait parameter where a significant interaction between age and condition was observed ($F_{(12, 28)}$=2.65, p<0.05). The post hoc analysis revealed that the 13 month age group underwear condition and the 19 month age group wet diaper condition were statistically different from each other with means of 0.39(sec)±0.01 (A) and 0.28(sec)±0.01 (F), respectfully (Figure 6). The post hoc analysis also revealed that for the age groups 14, 15, 16, 17, and 18 the conditions of underwear and dry diaper no differences were observed. The effect size was found for the interaction between age and condition to be 0.72. Based on Cohen's criteria, this effect size is large with 43.0% nonoverlap between the 13 month old underwear condition and 19 month old wet diaper condition (1988).

Figure 6: Means of the gait parameter stance time based on the relationship between age and condition



CHAPTER 4

DISCUSSION

The purpose of this study was to examine the effects different perturbations (wet diaper, dry diaper, underwear) have on an infant's gait within different ages. It was hypothesized that older infants would be less affected by the perturbation than their younger counterparts. Meaning, that 19 month old infants' gait should be more mature than 13 month old infants' gait even with the addition of a perturbation. It was hypothesized that there would be an age condition interaction within the gait parameters. For the gait parameters, it was hypothesized that there would be an increase in step length and decreases in support base, cadence, and stance time. It was found, however, that there was only an interaction between age and condition within one of the tested gait parameters.

The stance time was the only gait parameter to present with an age and condition interaction. The results suggest that the 13 month old group underwear condition and the 19 month old wet diaper condition are statistically different from one another. These results indicate that as the infant ages, the perturbation of the diaper is affecting them less. Researchers have suggested that infants clothed in diapers would have a less mature gait despite their age (Cole, Lingeman, & Adolph, 2012). However, this study suggests that the 19 month old gait is mature enough to handle the perturbation of the diaper, as hypothesized.

Both support base and cadence had significance in age and condition but there was not an interaction between the two. For support base, the condition results are similar to those found in previous studies. Cole, Lingeman, & Adolph found that when infants wear a dirty diaper the bulk between their legs increases, meaning that they have a greater support base (2012) This condition was seen within this study as the mean support base increased between underwear and dry diaper and dry diaper and wet diaper. Theveniau, Boisgontier, Varieras, & Olivier found that with an increase in walking experience the support base decreased (2014). Similar results can be found in this study. When looking at the mean difference between the 13 month olds and the 19 month olds, the 19 month olds have a lower mean support base than the 13 month olds, reguardless of condition. This means, based on past research, that the 19 month olds have a more mature gait, in reguards to support base, than 13 month olds (Cole, Lingeman, & Adolph, 2012).

For cadence, it has been stated that a more mature gait pattern is defined as a decrease in cadence (Grimshaw, Margues-Bruna, Salo, & Messenger, 1998). However, in this study the opposite was found to be true. The difference in means between the 13 month olds and the 19 month olds was significantly different with the 19 month olds having a greater cadence than their younger counterparts. Grimshaw and colleagues (1998) and Hallemans (2006) and associates also found that as infants grow older cadence increases. It has been suggested that these results differ from what has been defined as a mature gait (decrease in cadence) due to the different population sizes (Hallemans, De Clercq, & Aerts, 2006). When compared with older individuals, ranging to the age of 8, infants will appear to have a faster cadence that decreases as they grow older (Hallemans, De Clercq, & Aerts, 2006). For condition, the dry diaper and the underwear conditions were significantly different from one another while the dry diaper and wet diaper and the wet diaper and underwear were similar. It can be assumed that the dry diaper and the underwear conditions were different because the infants are used to wearing a dry diaper while underwear was an unfamiliar experience. Wearing a wet diaper could also be said to be an unfamiliar and/or uncomfortable experience making wet diaper and the underwear conditions correlated.

Of the gait parameters tested, step length was the only parameter that was only affected by age. Research has found that step length is positively correlated with walking experience and test age (Adolph, Vereijken, & Shrout, 2003) and (Adolph, et al., 2012)These same results were found in the present study. The mean for 19-month-old infant's step length was significantly greater than the 13-month-old infants. Grimshaw and colleagues suggest that step length increases with age based on the infant's growth and change in body dimensions which helps improve motor coordination (1998).

The statistical analysis determines if there is a difference between the ages and conditions, but the effect size was calculated to determine the magnitude of the difference. Cohen's d was used to determine practical significance of the effect size for age and conditions. Effect size was small for support base, cadence, and step length, while stance time had a large effect size. Although all the gait parameters had significant differences ($p<0.05$), the effect size suggests that for support base, cadence, and step length, the differences are small. This suggests that even though differences were found between the 13 month and the 19 month old age groups, this statistical difference is small, though significant. However, the results suggest that there is a large difference between the 13 month old underwear group and the 19 month old wet diaper group in terms of stance time. These results may suggest that the age and condition interaction has a greater effect on stance time than the other gait parameters.

It is interesting to note that for all the gait parameters tested, the 13 month olds and the 19 month olds were always statistically significant from one another. This study suggests that there is a developmental effect that occurs within these age groups. Consequently, the ages between the 13 and 19-month age groups (14, 15, 16, 17, and 18) seem to be variable. This result could indicate that these ages are very similar and gait maturity is not defined within these age groups.

Research should be conducted to further examine if this is true. Research could also be conducted using the same procedures but within a longitudinal study. Prospective results could show differences between the 14-18 month old groups that where not observed in the present study.

As with all research conducted on humans, there is always going to be some human error that is involved. A delimitation for this study is that room temperature water was chosen over body temperature water. The room temperature water was chosen instead of the body temperature water to protect the infants from injury caused by warming the water. This delimitation could have caused an error as the infant may not respond well to colder than normal liquid. A limitation to the study presented is that it is not a longitudinal study. One infant was not followed through the ages of 13-19 months. Instead, many infants were studied at a single age. It was assumed that the changes observed were due to development but a definitive conclusion cannot be met because it is not a longitudinal study. Another limitation is within the recruiting process. Because the accessible population was so small due to location, the age groups were not of equal size. Because of the system of recruitment, those in the study may not have represented the general population. It was assumed that the parents were providing the correct date of birth as well as the correct medical history. It was assumed that the infant would act as they normally would even though they were in a strange environment. Though this study had some limitations, they do not hinder the interpretation of the data.

CHAPTER 5

CONCLUSION

The purpose of this study was to examine 13 to 19 month old infants' gait when a perturbation (wet diaper, dry diaper, and underwear) was added. Based on the results from this study, it can be concluded that stance time is the only gait parameter that is effected by an age and condition interaction. As an infant grows older, the stance time decreases. This result can be explained by the fact that the gait is becoming more mature, meaning that less time is needed with contact to the ground because the older infants are becoming surer footed. Because of gait maturity, perturbation does not affect the older infants as much as their younger counterparts because they are more experienced with perturbation and have learned how to create strategies to overcome perturbation through motor learning. Age influenced step length, support base, and cadence while the conditions influenced support base and cadence. Based on past research, it is shown than with an increase in age gait parameters change due to physiological and neurological changes. Physiological changes include their limbs getting longer so they can lengthen their strides without having to widen their base; their bodies and heads are becoming more proportional which allows for better balance. Neurological changes include better proprioception as they age. For support base, the wet diaper condition had the largest support base meaning that the infants felt the need to widen their support base to compensate for the perturbation. For cadence, the dry diaper had the fastest cadence due to the dry diaper being the most familiar condition to the infants. The question could be asked if a few centimeters difference makes an impact on an infant's gait or if an increase or decrease is important. Research suggests that changes, even if they are small, negatively affect an infant's gait (Cole, Lingemen, & Adolph, 2012). It is important to understand these affects to better equip the infant with diapers that do not affect their natural balance. The results of this study further the knowledge of how an infant develops, indicating that age has a larger effect on an infant's gait than a condition effect. Further research could be conducted to see if similar results are to be found when the infants are grouped by walking age instead of chronological age. It may be interesting to also examine other gait parameters to see if there is any further age and condition relationship.

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APPENDIX B

DATA OUTPUT

Split-plot AOV Table for StepLength

Source	DF	SS	MS	F	P
tr	4	265.2	66.31		
Age	6	8703.3	1450.55	102.16	0.0000
Error tr*Age	24	340.8	14.20		
Condition	2	66.3	33.15	1.12	0.3273
Age*Condition	12	457.4	38.12	1.29	0.2204
Error	1749	51872.0	29.66		
Total	1797				

Note: SS are marginal (type III) sums of squares

Grand Mean 27.904
CV(tr*Age) 13.50
CV(Error) 19.52

Tukey HSD All-Pairwise Comparisons Test of StepLengt for Age

Age	Mean	Homogeneous Groups
19	31.849	A
16	28.934	B
17	28.587	B
18	28.430	BC
14	27.197	CD
15	26.816	D
13	23.511	E

Alpha 0.05 Standard Error for Comparison 0.2939 TO 0.4028
Critical Q Value 4.542 Critical Value for Comparison 0.9439 TO 1.2936
There are 5 groups (A, B, etc.) in which the means
are not significantly different from one another.

Means of StepLengt for Age

Age	N	Mean	SE
13	210	23.511	0.2600
14	268	27.197	0.2302
15	240	26.816	0.2432
16	270	28.934	0.2293
17	420	28.587	0.1839
18	150	28.430	0.3077
19	240	31.849	0.2432

Error term used: tr*Age, 24 DF

Split-plot AOV Table for StanceTime

Source	DF	SS	MS	F	P
tr	4	0.0747	0.01867		
Age	6	1.1610	0.19350	16.36	0.0000

Error tr*Age	24	0.2838	0.01183		
Condition	2	0.0920	0.04602	5.54	0.0040
Age*Condition	12	0.2642	0.02202	2.65	0.0016
Error	1749	14.5375	0.00831		
Total	1797				

Note: SS are marginal (type III) sums of squares

Grand Mean 0.3202
CV(tr*Age) 33.96
CV(Error) 28.47

Tukey HSD All-Pairwise Comparisons Test of StanceTim for Age*Condition

Age	Condition	Mean	Homogeneous Groups
13	7	0.3874	A
13	9	0.3707	AB
15	7	0.3586	AB
18	9	0.3576	ABC
18	8	0.3490	ABCD
13	8	0.3463	ABCD
18	7	0.3444	ABCD
15	9	0.3337	ABCDE
17	9	0.3205	BCDEF
14	8	0.3127	BCDEF
14	7	0.3124	BCDEF
17	7	0.3061	CDEF
16	8	0.3024	CDEF
19	7	0.2991	CDEF
17	8	0.2991	CDEF
16	7	0.2949	CDEF
14	9	0.2947	CDEF
16	9	0.2932	DEF
15	8	0.2878	DEF
19	8	0.2779	EF
19	9	0.2761	F

Comparisons of means for the same level of Age
  Alpha 0.05 Standard Error for Comparison 0.0109 TO 0.0182
  Critical Q Value 5.046 Critical Value for Comparison 0.0389 TO 0.0651
  Error term used: Error, 1749 DF
Comparisons of means for different levels of Age
  Alpha 0.05 Standard Error for Comparison 0.0132 TO 0.0180
  Critical Q Value 5.290 Critical Value for Comparison 0.0492 TO 0.0675
  Error terms used: tr*Age and Error
There are 6 groups (A, B, etc.) in which the means
are not significantly different from one another.

Means of StanceTim for Age*Condition

Age	Condition	N	Mean	SE	Age	Condition	N	Mean	SE
13	7	70	0.3874	0.0109	16	9	90	0.2932	0.0096
13	8	70	0.3463	0.0109	17	7	140	0.3061	0.0077
13	9	70	0.3707	0.0109	17	8	140	0.2991	0.0077
14	7	88	0.3124	0.0097	17	9	140	0.3205	0.0077
14	8	90	0.3127	0.0096	18	7	50	0.3444	0.0129
14	9	90	0.2947	0.0096	18	8	50	0.3490	0.0129

15	7	80	0.3586	0.0102	18	9	50	0.3576	0.0129
15	8	80	0.2878	0.0102	19	7	80	0.2991	0.0102
15	9	80	0.3337	0.0102	19	8	80	0.2779	0.0102
16	7	90	0.2949	0.0096	19	9	80	0.2761	0.0102
16	8	90	0.3024	0.0096					

Error term used: Error, 1749 DF

Split-plot AOV Table for Cadence

Source	DF	SS	MS	F	P
Trials	4	5274	1318.6		
Age	6	83645	13940.9	10.85	0.0000
Error Trials*Age	24	30848	1285.4		
Condition	2	11725	5862.3	3.61	0.0276
Age*Condition	12	24750	2062.5	1.27	0.2320
Error	851	1383649	1625.9		
Total	899				

Note: SS are marginal (type III) sums of squares

Grand Mean	212.75
CV(Trials*Age)	16.85
CV(Error)	18.95

Tukey HSD All-Pairwise Comparisons Test of Cadence for Age

Age	Mean	Homogeneous Groups
19	229.10	A
16	220.90	AB
17	215.76	B
14	214.37	B
15	209.83	B
18	205.10	BC
13	194.20	C

Alpha	0.05	Standard Error for Comparison	3.9550 TO 5.4203
Critical Q Value	4.542	Critical Value for Comparison	12.701 TO 17.406

There are 3 groups (A, B, etc.) in which the means
are not significantly different from one another.

Tukey HSD All-Pairwise Comparisons Test of Cadence for Condition

Condition	Mean	Homogeneous Groups
8	217.29	A
9	212.89	AB
7	208.08	B

Alpha	0.05	Standard Error for Comparison	3.4302
Critical Q Value	3.314	Critical Value for Comparison	8.0388

There are 2 groups (A and B) in which the means
are not significantly different from one another.

Means of Cadence for Age

Age	N	Mean	SE
13	105	194.20	3.4988
14	135	214.37	3.0856

15	120	209.83	3.2728
16	135	220.90	3.0856
17	210	215.76	2.4740
18	75	205.10	4.1398
19	120	229.10	3.2728

Error term used: Trials*Age, 24 DF

Means of Cadence for Condition

Condition	N	Mean	SE
7	300	208.08	2.4255
8	300	217.29	2.4255
9	300	212.89	2.4255

Error term used: Error, 851 DF

Split-plot AOV Table for SuppBase

Source	DF	SS	MS	F	P
Trials	4	15.30	3.825		
Age	6	1135.59	189.264	60.05	0.0000
Error Trials*Age	24	75.64	3.152		
Condition	2	217.42	108.712	16.29	0.0000
Age*Condition	12	74.57	6.214	0.93	0.5147
Error	851	5679.12	6.673		
Total	899				

Note: SS are marginal (type III) sums of squares

Grand Mean	10.618
CV(Trials*Age)	16.72
CV(Error)	24.33

Tukey HSD All-Pairwise Comparisons Test of SuppBase for Age

Age	Mean	Homogeneous Groups
13	12.508	A
14	12.021	A
15	10.361	B
18	10.330	B
16	10.112	B
19	9.682	BC
17	9.314	C

Alpha	0.05	Standard Error for Comparison	0.1958 TO 0.2684
Critical Q Value	4.542	Critical Value for Comparison	0.6289 TO 0.8619

There are 3 groups (A, B, etc.) in which the means
are not significantly different from one another.

Tukey HSD All-Pairwise Comparisons Test of SuppBase for Condition

Condition	Mean	Homogeneous Groups
9	11.245	A
8	10.618	B
7	9.991	C

Alpha	0.05	Standard Error for Comparison	0.2198
Critical Q Value	3.314	Critical Value for Comparison	0.5150

All 3 means are significantly different from one another.

Means of SuppBase for Age

Age	N	Mean	SE
13	105	12.508	0.1732
14	135	12.021	0.1528
15	120	10.361	0.1621
16	135	10.112	0.1528
17	210	9.314	0.1225
18	75	10.330	0.2050
19	120	9.682	0.1621

Error term used: Trials*Age, 24 DF

Means of SuppBase for Condition

Condition	N	Mean	SE
7	300	9.991	0.1554
8	300	10.618	0.1554
9	300	11.245	0.1554

Error term used: Error, 851 DF

APPENDIX C

IRB APPROVAL

Principal Investigator: Sally Marie Futch, a second year graduate student in the Masters of Kinesiology program at Georgia Southern University. Ms. Futch will be responsible for the project and has full access to all of the data collected in the project.

Faculty Advisor: Ms. Futch will be overseen by Dr. Li Li of the School of Health and Kinesiology. Dr. Li will also have full access to all of the data collected in the project. Dr. Li has more than 30 years' experience in gait and biomechanics related research. Senior undergraduate, Syndi Wilhoite, who is majoring in Exercise Science, will be a student volunteer and will have full access to all of the data collected in the project.

Purpose. As a baby ages through the stages from sixteen to nineteen months their gait is becoming more sure-footed. During this development stage, the baby begins to adapt a more normal gait that will transfer to their mature gait. This project is designed to examine the progression of development in the gait from sixteen to nineteen month old babies as well as examining if there is a perturbation caused by a dry and wet diaper.

Literature Review. It is a known fact that as humans develop their gait improves. Adolf and colleagues showed this by observing infant locomotion of 13 to 19 month olds (2012). They found that older infants took more steps that were longer and more narrow than those of younger individuals showing that their gait had matured (Adolph, et al., 2012). If, as an infant ages their gait becomes more stable, what happens when a perturbation is introduced? Are the older infants still at an advantage, or has the physical perturbation made younger and older infants have the same gait? Cole and colleagues state that introducing the perturbation of a diaper causes an alteration in an infant's gait, causing more falls and missteps as well as producing a less mature gait (Cole et al., 2012). This study would like to examine how a physical perturbation, (a dry and a wet diaper versus underwear), effects the stability and variability of 16 to 19 month old infants.

Adolph, K. E., Cole, W. G., Komati, M., Garciaguirre, J. S., Badaly, D., Lingeman, J. M., ... & Sotsky, R. B. (2012). How do you learn to walk? Thousands of steps and dozens of falls per day. *Psychological science*,*23*(11), 1387-1394.

Cole, W. G., Lingeman, J. M., & Adolph, K. E. (2012). Go naked: Diapers affect infant walking. *Developmental science*, *15*(6), 783-790.

Outcome. Gait measurements will be collected with commercially bought diapers that are dry and wet as well as underwear. The wet diaper will be wet with 3.4 oz (100 milliliter) of room temperature water. During one lab visit, these conditions will be compared and used to calculate descriptive statistics. The knowledge gained from this project will further our knowledge of the development of gait as well as providing information on how diapers effect a baby's gait.

Describe your subjects. Thirty infants, sixteen to nineteen months old will be recruited. The infants will be required to be able to walk at least 10 continuous steps. The infants should have no known neuromuscular impairment.

Recruitment and Incentives. Babies will be recruited from the local community. These babies will be found through conversations with parent/guardians who have a child within the sixteen to nineteen months old age range. Babies will also be recruited through an on campus day care as well as individuals who know of subjects within our age range.

Research Procedures and Timeline: The following data will be collected from the parents: walking experience: days between walking onset day and the first visit to the lab; diapers wearing experience: disposable, cloth, pull-ups, no diaper, and other experience; and daily walking without diaper experience, yes / no, for how long if yes.

There will be one testing session that will last about one hour. The parent/guardian of each child will need to be present during the entire session. Within the session the child will walk on a pressure carpet 10 steps with a wet diaper, a dry diaper, and underwear. The parent/guardian will be responsible for changing the diapers and underwear. There will be three trials conducted to complete all the conditions with each variable. Testing sequence of the dry and wet diaper and underwear will be randomized within each subject.

At the end of the first testing session, an experimenter will measure each infant's leg lengths (from hip to ankle) and recumbent height (crown to heel).

Trials with the following conditions will be excluded from gait parameter analysis: falls (when the body dropped to the floor unsupported or hands are placed on the floor); missteps (trips when the swinging foot failed to clear the ground, double steps when the same foot stepped twice, back steps when the leading leg moved backward behind the trailing leg, and lag steps when the swinging leg moved forward but failed to move ahead of the stance leg). Only trials with at least five consecutive steps on the carpet will be included in the analyses for gait parameters.

Gait parameters will only be calculated in trials where the infant takes at least five consecutive steps a relatively constant velocity. Step width (distance from the heel of the current step to the line of progression formed by the opposite stride), step length (distance along the line of progression from the heel of the previous step to the heel of the current step), dynamic base of support (angle between the heel points of three consecutive steps), and walking speed (distance between the first to last step divided by time) will be calculated.

Data Analysis. Gait parameters collected during the single session will be used to calculate descriptive statistics.

Data will be kept two years after the completion of this project. During the study as well as the following two years all paper documents, informed consent forms, etc, will be kept in a locked cabinet in a locked office. All digital files will be password protected within a computer inside a locked office. Confidentiality will be kept for all information given.

Special Conditions:

Risk. Babies that weigh less than 20 lbs or more than 40 lbs will be excluded from this study. Exclusion can also include: inability to walk 10 consecutive steps, allergic skin reactions, sensitive skin conditions, currently has diaper rash. Children with any physical or neurological disability as reported by the parent will be excluded.

Infants may experience discomfort as they will be in an unfamiliar environment as well as wearing unfamiliar diapers. To reduce the risk of these discomforts the child's parent or guardian must accompany the child during the testing session. The testing will be done when the child is most active and awake. This will probably take place from 9-11am and 2-4pm. Testing will occur during their most active and awake time to prevent psychological intolerance.

Falling during data collection may occur which increases the risk for the infant to be exposed to environmental conditions. To reduce this risk, the testing surface will be disinfected before and after every subject. All surfaces that will come in contact with bodily fluids will be cleaned immediately with detergent and water, rinsed, and disinfected with disinfecting fluid (1/4 cup bleach per gallon of water).

Research involving minors. Infants involved in this project will be recruited through personal conversation with their parents / guardian. A parental consent will be obtained after carefully explain the project and answer all questions satisfactorily.

Medical procedures. In the unlikely event of a child occurring any events or any other health related problems that have been caused by this study it is advised that the parents/guardians seek medical attention. Georgia Southern University will also need to be contacted. The researcher will maintain communication with IRB in order to ascertain whether the study should be limited or stopped due to adverse events of any kind.

PARENTAL INFORMED CONSENT

Dear Parent or Guardian,

My name is Sally Marie Futch and I am a graduate student at Georgia Southern University. I am conducting a study to determine if a child walks differently as they age as well as when wearing a wet diaper or a dry diaper or underwear. The purpose of this study is to understand the stability and variability of gait in 16-19 month old children when they are wearing commercially bought diaper (wet and dry) and underwear. Your child will only be needed for data collection once. This data collection session should take about 1 hour. The child will be asked to walk on a pressure carpet, up and down a few times. Your presence is required at all times. The wet diaper condition will be creating by adding 3.4 oz (100 milliliter) of room temperature water to the diaper. This study is done as a graduate studies thesis at Georgia Southern University.

Your child's participation in this study is completely voluntary. To be eligible to participate in this study, your child must be:

- The child is healthy and between the ages of 16-19 month old infant (male or female);
- The child is able to walk 10 steps or more at home before coming to the lab;
- The child is able to walk 10 steps or more in the lab
- The child weighs between 20 and 40 pounds
- Permission has been given by the parent or guardian

If any of the following conditions apply, your child (is not/ will not be) eligible:

- The child has apparent cognitive or physical disability that can affect walking;
- Allergies or sensitivity to commercially bought disposable diapers;
- Diaper rash;
- The child has started potty training

The risks that your child may exerience are no more than they would encounter in their everyday lives. If you chose to withdraw your child, you may do so at any time without penalty. You have the choice of answering or not answering any questions you are asked.

Be aware that your child may not be comfortable with wearing different diapers or the laboratory setting. To keep your child at ease you will be required to remain with your child during the entire data collection session. The surfaces that your child will come in contact with will be disinfected. These surfaces will be disinfected before and after your child comes into the lab. The surfaces will be cleaned with Clorox wet wipes and disinfected with disinfecting fluid (1/4 cup bleach per gallon of water). If your child has any allergies to the substances being used please let us know immediately.

Although you and your child will not benefit directly from this study, the results of this study will help benefit further research in the progression of infant gait.

To keep your child's anonymity, a number will be assigned to them. This number, not your child's name, will appear on all of the information recorded during the study. Data will be kept for two years after the completion of this project. During the study as well as the following two years all paper documents, informed consent forms, etc, will be kept in a locked cabinet in a locked office. All digital files will be password protected within a computer inside a locked office. Confidentiality will be kept for all information given.

You have the right to ask questions and have those questions answered. If you have any additional questions about this study please contact me (Sally Marie Futch) phone: 912-690-4650, email: sf01260@georgiasouthern.edu or my faculty advisor (Dr. Li) phone: 912-478-0200, email: lili@georgiasouthern.edu.

In the unlikely event of a child occurring any events or any other health related problems that have been caused by this study it is advised that the parents/guardians seek medical attention. Georgia Southern University will also need to be contacted. The researcher will maintain communication with IRB in order to ascertain whether the study should be limited or stopped due to adverse events of any kind.

If you give your permission for your child to participate in the experiment, please sign the form below.

You will be given a copy of this consent form to keep for your records. This project has been reviewed and approved by the GSU Institutional Review Board under tracking number _H17042.

APENDIX A

PROPOSAL

INTRODUCTION

Motor development in infants has been researched as part of the examination of movement across their lifespans. Movement is determined by different factors: the mover, the environment, and the task being undertaken. Movement can be changed or altered based on these factors also. When viewing the motor development of infants, the stages of crawling to walking are of special interest to biomechanists. The study of an infant progressing through these stages, as well as observing gait maturation, involves observing gait development gait as well as the factors that influence it. As an infant ages through the stages from 13 to 19 months, gait becomes more sure-footed. During this development stage, the infant begins to adapt a more normal mature gait. This project is designed to examine the development of gait from 13 to 19 month old infants as well as examining if there is a perturbation caused by a dry and wet diaper compared to simulated nakedness (underwear). Using the GaitRite system, the effect of perturbation on step length, step width, step rate, and dynamic base of support will be measured.

SIGNIFICANCE OF STUDY

Although research has been conducted on motor development (Bril & Breniere, Steady-state velocity and temporal structure of gait during the first six months of autonomus walking, 1898), infant’s walking behavior (Adolph, et al., How Do You Learn to Walk? Thousands of Steps and, 2012), differences between adult and infant’s gait with perturbation (Cole, Gill, Vereijken, & Adolph, 2014), and even the effect a diaper versus unclothed on gait (Cole, Lingeman, & Adolph, 2012) there has been little research found on different diaper perturbations on gait such as between a wet diaper, dry diaper, and simulated nakedness (underwear). Cole and colleagues define perturbation as “something that upsets the natural balance of things” (2014).

As an infant ages from twelve to fifteen months they are beginning to walk well; as they age from sixteen to eighteen months they are able to walk backwards and down steps with some help (Kaneshiro, 2016).

REVIEW OF LITERATURE

Though infants progress in their development as they grow older, there is not a set schedule for when an infant will accomplish each task (Mandleco, 2004). As infants grow, their anatomy and physiology are also rapidly changing from birth. The infant gains one pound per month and after their first year weight is tripled from birth and after the second it is quadrupled from birth (Huelke, 1998). Huelke states that at birth the infant's sitting height is 70% of their total height (1998). This means that the infant is elongated or top heavy creating a slouched posture (Huelke, 1998). For the infant to begin walking there has to be a relationship between the extremities, spine, and pelvis to create a balanced system (Huelke, 1998). When infants are born, they present with a vertebral column that is relatively straight. As the infant ages, a more natural curve is formed that is similar to the curvature found in adults (Huelke, 1998). As infants develop, they are getting stronger and their anatomy transitions to withstand the loads that are required in the bipedal stance and walking.

Learning to walk is part of motor development for all infants. Clark and Whitall define motor development as the change that occurs to motor behavior over a lifespan (1989). Motor behavior is defined as how the mind and body come together to perform movement (Ives, 2014). Another word that means motor behavior is psychophysics which means that the mind and body are integrated into the psychological and physiological parts of motor behavior and work together to perceive and cause movement (Ives, 2014). The physiological part and the sensory part of the body work in combination with each other to execute motor control.

The motor control system executes and monitors movement and integrates the central (CNS) and peripheral (PNS) nervous systems (Ives, 2014). This integration is seen when the CNS, brain sends motor commands to the PNS, specifically the muscles that cause movement. Then sensory receptors in muscles send back sensory feedback to the brain. The PNS perceives where our body is in space through proprioception. This integration allows the body to move the hand to touch the nose even with the eyes closed. Motor learning details how the mind learns, plans, initiates, and modifies movement based on the information gathered (Ives, 2014).

Therefore, as motor learning and motor control develop in an infant, walking becomes a skill that integrates both processes. Bril and Breniere suggest that learning to walk takes place in two different phases (1993). These phases include the initial phase which is focused on learning to master disequilibrium and balance recoveries and the second stage where refinement of locomotion occurs (Bril & Breniere, 1993). As the infant matures and their gait improves, steps will become longer with a smaller step width and a more symmetrical stepping pattern (Adolph, Vereijken, & Shrout, What Changes in Infant Walking and Why, 2003). Infants appear to reach their age of asymptote during the first three to six months after walking onset (Adolph, Vereijken, & Shrout, What Changes in Infant Walking and Why, 2003). This age of asymptote can be defined as the age where the infant reaches the maximum level of gross and fine motor development and this relationship is negative with higher scores at younger ages (Piek, Dawson, Smith, & Gasson, 2008).

As an infant develops in motor learning and motor control, gait matures. Gait is made up of two different phases when looking at one leg, the stance phase and the swing phase. For adults, these two phases remain relatively constant. The stance phase begins with a heel strike and the person’s weight transfers over the center of the foot, ending with toe off. The swing phase begins with toe off. The foot is completely off the ground during this phase and ends when the heel strikes the ground. However, in infants while foot contact does occur, heel strike may not (McCoy & Dusing, 2012). McCoy and Dusing concluded that this may be due to the ever-changing structure of the infant's growing foot (2012). It is not uncommon for infants to walk flat footed without dorsiflexion or to walk on their toes (Adolph, Vereijken, & Shrout, What Changes in Infant Walking and Why, 2003). According to Sutherland and colleagues, infants should be able to walk with support when they reach one year of age, without support at 15 months, and should be able to run at 18 months (1980). Adolf and colleagues reported the same results of development by observing infant locomotion of 13 to 19 month olds (2012). They found that infants that have an older walking age "take more steps, travel farther distances, and fall less" (Adolph et al. 2012, p.1393).

Due to being a relative novice, it is expected that infants will be unstable and must compensate for perturbation (Cole, Gill, Vereijken, & Adolph, 2014). Cole and his investigators suggest that because these "novice walkers" must compensate for the perturbation they do so by changing their step length (2014). Step width is the distance from the heel of the current step to the line of progression formed by the opposite step, step length is the distance along the line of progression from the heel of the previous step to the heel of the current step, dynamic base of support is the angle between the heel points of three consecutive steps, and walking speed is the distance between the first to last step divided by time. Gait is also made up of the single and double support phases. The single support phase occurs when one foot is in contact with the ground. The double support phase occurs when both feet are in contact with the ground simultaneously.

As an infant ages through the stages from 13 to 19 months, gait becomes more sure-footed. During this developmental stage, the infant begins to adapt a more normal gait that will transfer to their mature gait. Adolf and colleagues showed this by observing infant's locomotion of 13 to 19 month olds (2012). They found that older infants took more steps that were longer and narrower than those of younger individuals showing that their gait had matured (Adolph, et al., How Do You Learn to Walk? Thousands of Steps and, 2012). It is expected, that as an infant ages, their step rate will decrease while their step length will increase (Sutherland, Olshen, Cooper, & Woo, 1980). This means that the infant is taking longer, surer footed strides instead of choppy staccato steps in quick succession. For this study on perturbation, the expected results are that older infants will take longer and more narrow steps than their younger counterparts (Adolph, et al., How Do You Learn to Walk? Thousands of Steps and, 2012).

Perturbation has been defined as upsetting the natural balance of something, in this case an infant's gait (Cole, Gill, Vereijken, & Adolph, 2014). Cole and colleagues state that introducing the perturbation of a diaper causes an alteration in an infant's gait, causing more falls and missteps as well as producing a less mature gait (Cole, Lingeman, & Adolph, 2012). In a later study, Cole and associates postulate that infants must compensate for perturbations as they are already at risk to fall without the perturbation (Cole, Gill, Vereijken, & Adolph, 2014).

RESEARCH QUESTION AND HYPOTHESIS

The purpose of this study is to examine how a physical perturbation (a dry and a wet diaper versus underwear) effects the stability and variability of 13 to 19 month old infant's gait. Based on past research as presented above, the hypothesis is that using a diaper as a perturbation the gait from 13 to 19 months should be reduced; therefore, the differences in gait parameters between underwear, dry diaper, and wet diaper for 19 month olds should be less than the 13 month olds.

METHODS

Participants

Sixty infants ranging from 13 to 19 month old will be selected for this study. The infant should be healthy, be able to walk more than 10 steps at home as well as in the lab, and weigh between 9 to 18 kilograms. Infants that have apparent cognitive or physical disability, an allergy to the brand of the disposable diapers, has a diaper rash, or have started toilet training will not be included in this study.

The following data will be collected from the parents: walking experience (days between walking onset day and the first visit to the lab); diaper wearing experience (disposable, cloth, pull-ups, no diaper, and other experience); and daily walking without diaper experience. If they walk without a diaper any time of the day, the parents need to provide a time range (minutes per day) when they are without the diaper. The infant's height, weight, length of foot, width of foot, and leg length will also be measured.

Procedures

Data will be collected during a single session that should last approximately 30 minutes. During each session, the infant will be wearing a commercially-bought diaper (Huggies, Little Movers, 22-37 pounds, Kimberly-Clark Corp. Neenah, WI). The infant will wear a diaper that has been wet, a diaper that is dry, and a commercially-bought pair of underwear. The wet diaper will be wet with 100 ml of room temperature water. The water will be added to the diaper using a syringe. The water will be added in the middle of the diaper for female infants and towards the front for male infants to simulate their natural urination. The parents will need to be present for the entire data collection to change the infant's diapers and to make the infant more comfortable.

Gait data will be collected using a 4.9m GaitRite walkway (CIR Systems, Sparta, NJ.). The infant will be asked to walk approximately ten steps for five trials for each of the three conditions. Trials with the following conditions will be excluded from gait parameter analysis: falls (when the body dropped to the floor unsupported or hands are placed on the floor); missteps (trips when the swinging foot failed to clear the ground, double steps when the same foot stepped twice, back steps when the leading leg moved backward behind the trailing leg, and lag steps when the swinging leg moved forward but failed to move ahead of the stance leg). Only trials with at least five consecutive steps on the carpet will be included in the analyses for gait parameters.

Gait parameters will only be calculated in trials where the infant takes at least five consecutive steps. Step width (distance from the heel of the current step to the line of progression formed by the opposite step), step length (distance along the line of progression from the heel of the previous step to the heel of the current step), dynamic base of support (angle between the heel points of three consecutive steps), and walking speed (distance between the first to last step divided by time) will be calculated. Gait parameters collected during the single session will be used to calculate descriptive statistics. This will include the mean, maximum, and minimum of the gait data. The anthropometric data will be compared between infants to see if there is a trend between this data and the gait data.

Data Analysis

The reliability will be tested using the test-retest method. Each infant will repeat the same conditions five times with in a single session. Test-retest is most reliable when the tests are repeated in a shorter time gap. When conditions are measured more than once, the correlation between the two tests will increase. To analyze the results, a 7x3 two-way ANOVA with four dependent variables (step length, step width, step rate, and dynamic base of support) will be used to test the effects of perturbation over the different age groups. With independent variables of wet diaper, dry diaper, and underwear. The infants will be grouped by age (13, 14, 15, 16, 17, 18, and 19 months). It is assumed that the groups' sample size will be evenly distributed. Stability will be defined as a greater step length and smaller base of support. Tukey's Post Hoc test will be used to determine which groups are different between the age groups and testing conditions. The two-way ANOVAs and Post Hoc test will be performed using SPSS 23.

LIMITATIONS AND ASSUMPTIONS

As this is a study on humans, there is always going to be some human error that is involved. The study has a delimitation because room temperature water was chosen instead of body temperature. The room temperature water was chosen instead of the body temperature water to protect the infants from injury caused by warming the water. This delimitation could cause error as the infant may not respond well to colder than normal liquid. A limitation to the study presented is that it is not a longitudinal study. One infant will not be followed through the ages of 13-19 months. Instead, many infants will be studied that are a single age. It will be assumed that the changes observed are due to development but a definitive conclusion cannot be met because it is not a longitudinal study. Another limitation is within the recruiting process. Because the accessible populaton is so small due to location, there is not a guarantee that the groups will be of equal size. Because of the system of recruitment, those in the study may not necessarily represent the general population. It is assumed that the parents are providing the correct date of birth as well as the correct medical history. It is assumed that the infant will act as they normally would even though they are in a strange environment.

CONCLUSION

Based off of past research, the results of the study should show that as an infant ages their gait is becoming more mature. The older infants should also be able to compensate for the perturbation better than their younger counterparts.

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