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Dual Task and Split-Belt Adaptation in Young Boys

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Abstract

Background: While it is thought that normal walking can operate almost completely under spinal control, adaptation to changes in the environment may require higher-level cognitive resources. In adults, the addition of a secondary task resulted in changes in the adaptation to a split-belt walking task that supported a division between spinal and supraspinal mediation of gait adaptation. However, children are still developing both physical and cognitive abilities, and may not be able to employ the same strategies as adults.

Objective: The purpose of this study was to examine the role of attention during adaptation to split-belt treadmill walking in young boys as well as to determine which parameters of gait adaptation require more cognitive resources than others.

Methods: Using a Dual Task Model, eight boys aged 8-10 years old completed three experimental conditions. The first was an auditory attention task. The second was a split-belt walking task. In the third task, participants completed both tasks simultaneously. Gait variables double support time, step length, stance time and stride length were analyzed. Double support time and step length are presumed to be moderated by supraspinal processes and were hypothesized to be the most affected by the Dual Task condition.

Results: A repeated measures ANOVA revealed that, contrary to our hypothesis, stance time and stride length both increased with the addition of the attention task, whereas double support time and step length were not affected.

Conclusions: The results suggest that maturing children utilize different control strategies than adults for split-belt adaptation.

Keywords: Dual-task; Split-belt treadmill; Adaptation; Attention; Children; Gait; Neuromotor control

Introduction

Locomotion by its very nature is an adaptive process, requiring cognitive intervention to successfully navigate through complex and variable environments. One must avoid obstacles, change pace and adjust to varying surface textures all while maintaining balance and avoiding collision. It seems intuitive that attention and cognitive resources are required for successful locomotion. However, early studies of spinal animals reported that reciprocal stepping could occur without cognitive input [1,2]. The Dual Task model has been used to evaluate the role of supraspinal networks and attentional capacity in locomotion of humans. The Dual Task Model is based on the idea that humans have a limited capacity for attention, so then performing two tasks requiring cognitive resources at the same time will result in reduced performance in one or both tasks [3]. To date, studies using the Dual Task Model have failed to clarify how task and environmental context may shape the role of cognition during locomotion. Support has independently been found for prioritization of both walking and the secondary attention task. To add to the disparity, these studies vary by population, methodology and dependent variables tested, making them difficult to compare [4-8]. There is some evidence that attentional demands of walking may be specific to the gait phase in healthy young adults [4]. For instance, single limb stance, when only one limb is in contact with the ground, requires more attention than double limb stance. Finally, it is likely that more attention is required when patterns of limb motion require adaptation to account for changes in a dynamic environment [9]. Some studies of locomotor adaptation, such as those examining split-belt walking, have suggested cognitive control plays an important role during the adaptation phase in adults and children [10-12]. Split-belt walking is an abnormal walking condition in which each lower limb is forced to move at different speeds. Adaptation to split-belt walking involves a reduction in the difference in gait kinematics between limbs from the beginning, i.e. Early Adaptation, to the end of the adaptation process, i.e. Late Adaptation. Reisman and colleagues have utilized the split-belt adaptation task to speculate which specific parameters of adaptation may require increased supraspinal support and which parameters seem to be dominated by spinal processes [10,13]. They labeled these feed forward and feedback control, respectively. Feedback adaptation

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is characterized by quick changes in gait parameters such as stance time and stride length.

Feed forward adaptation seems to result in changes in coordination between legs as measured by double support time and step length. They are presumed to involve the control of supraspinal centers such as the cerebellum [10]. The cerebellum plays a role in both motor adaptation and working memory, so it is reasonable to speculate that feed forward parameters of gait would be affected by the addition of a cognitive task during dual task conditions. However, separate Dual Task studies of adults performing split-belt treadmill walking in conjunction with a secondary attention task have independently found Support for the role of cognition in both feed forward and feedback parameters [11,12]. Therefore, split-belt locomotor adaptations may require various degrees of cognitive support. Some insight may be gained by examining the ability of developing children to adapt to split-belt walking because this ability is still developing in children as old as 11, and may be directly related to maturation of the cerebellum [14,15]. Approximately half of children observed between 3-15 years old were not able to adapt to split-belt walking. Of those who did show adaptation, children under 9 years old were significantly slower than adults in adapting step length symmetry, and children under 12 years old were significantly slower at adapting the center of oscillation [15]. These differences in adaptation to split-belt walking between young children and adults could possibly be due to immaturity of cortical areas responsible for both movement and cognition.

Cognitive and neuromotor ability continues to develop throughout adolescence and into adulthood. While myelination of the sensory afferents and motor efferents are completed within the first two years of life, cortical myelination, including areas of the brain important for attention, continues into adulthood [16]. Because of these reasons it is thought that children are less adept at appropriately allocating attention when simultaneously performing multiple tasks.

To this point, there have been no studies examining the ability of children to multi- task during split-belt adaptation. Since children do not possess the attentional resources and neuromotor strategies of adults, and because the ability to adapt to an abnormal walking task such as split-belt walking is not fully matured, they may be differentially affected by the addition of a secondary task during a split-belt adaptation task. Therefore, studying children provides an opportunity to observe the impact of dual task performance on locomotor adaptation in a system that is not fully matured.

The purpose of this study was to evaluate the role of attention in adaptation to split- belt walking by young boys, aged 8-10 years old. It was hypothesized that the addition of a secondary cognitive task will affect feed forward parameters as these variables are thought to employ supraspinal supervision during locomotor adaptation [10,13]. Specifically, the hypothesis was that the Dual Task would inhibit the process of adaptation exhibited by a reduction in the difference between the two leg parameters from the Early to Late adaptation periods, as compared to the single task split-belt walk. This would be reflected by a significant interaction effect of adaptation period (Early adaptation vs. Late adaptation), with leg (slow leg vs. fast leg) and condition (single task vs. dual task) for double support time and step length.

Methods

In order to investigate the role of attention in adaptation to split-belt walking, a dual task protocol requiring participants to perform an auditory attention task while adapting to split-belt walking was performed. Temporal and spatial gait parameters were compared across experimental conditions. This study was performed in accordance with ethical standards and approved by the University of Houston Committee for Protection of Human Participants. Informed child assent as well as parental consent was obtained from all participants prior to beginning the study.

Participants

Eight healthy boys, ages 8 - 10 years, were recruited to participate in this study. Participants were excluded if their parents reported that they had been diagnosed with a learning disability, cardiorespiratory problems, and lower limb injuries in the last year or other muscular or neurological disorders. Six of the eight boys were right foot dominant. Limb dominance was determined by asking the subject which leg they would use to kick a ball [17].

Procedures

Data collection was performed at the Center for Neuromotor and Biomechanical Research. Before beginning the tasks, the participants were given time to acclimate to threadmill walking for approximately five minutes. During this time, participants chose their comfortable ‘fast’ walking speed. Participants were instructed to choose a speed that they would use if they were in a hurry, walking down a hallway at school, walking fast but not running. During the experimental tasks involving split-belt walking, the ‘slow’ speed was set at 50% of the fast speed. There is evidence that a speed ratio of 2:1 is sufficient to induce changes in gait characteristics [11]. The dominant limb belt was set at the fast speed, and the non-dominant limb set at the slow speed. Upon completion of the treadmill acclimation period, participants began completion of three tasks presented in random order. There was a five-minute break between tasks.

The Single Task (Cognition) required that the seated participants perform a phoneme monitoring task, in which they would count the number of times they heard a key word in a story that was read aloud. The key word and instructions were provided prior to the initiation of the task. They were instructed to “count in your head and not aloud”. Participants were also informed that they would be questioned about the content of the story after the task was completed. This task was adapted from a previously established protocol of dual task walking with children [18] and has been shown to significantly affect gait performance of children, healthy young and older adults and older adults diagnosed with Parkinson’s Disease [19,20]. The investigators took care to select a key word that was an important term for the story and was repeated multiple times. For Story One, the key word was repeated 14 times, and for Story Two, the key word was repeated 11 times. Content questions were adapted from an online database for the selected book. Each story was a chapter selected from a book at a third grade reading level. Each story was played on an iPod (Apple Inc., CA, USA) and participants listened to the story through earphones. After each story was finished, participants reported the number of times they remembered hearing the key word and then answered four multiple-choice content questions about that story.

The Single Task (Motor) involved walking on a split-belt treadmill containing two belts that were set to different speeds for five continuous minutes. An 11camera Vicon (Vicon, Oxford, UK) motion capture system was used to collect kinematic data from reflective markers placed bilaterally on the greater trochanter, lateral knee joint, calcaneus, lateral malleolus and fifth metatarsal. Vicon Nexus (Vicon, Oxford, UK) software was used to record and filter kinematic data (see details below). During this time the belt speeds were changed by the investigator at predetermined times using the treadmill's user interface [13] (Figure 1). The treadmill maintained an acceleration of 1 m/s2 for all speed changes. Limb dominance was controlled because it has been suggested that functional differences exist in the lower extremities for support and mobility and thus the preferred and non-preferred limbs may adapt differently to the task [17] (Figure 1).

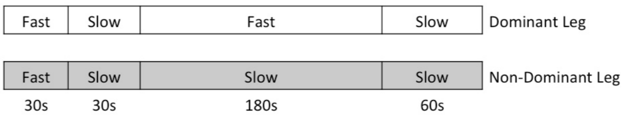

Figure 1: Single Task (Motor). Subjects walked on the split-belt treadmill continuously for 5 minutes while the belt speeds were changed. During the first 30 seconds both belts were moving at the fast speed, followed by a 30 second period where the belts were both moving at the slow speed, then a 3 minute period where the belts were split with the dominant leg moving at the fast speed, and non-dominant limb moving at the slow speed, and finally both belts were returned to the slow speed for 60 seconds.

The Dual Task (Cognition-Motor) required participants to perform the cognitive task simultaneously with the split-belt task. The story was started immediately before the threadmill was activated. A different chapter section from the same book was used for each presentation of the cognitive task. The chapter sections were randomized among participants so that the same chapter section was not always used for the dual task. Each hapter section was also assigned a different key word. No instructions were provided about how to prioritize the tasks, as we wanted the participants to naturally adapt to the conditions in a manner they were comfortable with.

Measures

Single task (cognition), measures of performance included the percent of questions answered incorrectly and word count error. The word count error was calculated as the percent difference between the number of times the subject indicated the word was spoken and the actual number of times the key word was repeated in the story. For the single task (motor), feedback measures of performance included stance time and stride length while feed forward measures of performance included double support time and step length. Stance time was defined as the amount of time from heel contact to toe off for each leg. Stride length was defined as the distance traveled from toe off to heel contact of the same limb. Double support time was defined as amount of time per gait cycle that both legs were in contact with the ground. Step length was defined as the distance between the lateral malleolus of each limb at heel contact of the leading leg. The dual task (cognition-motor) used the same measures of performance as the cognition and motor single tasks.

Analysis

Raw 3-D kinematic data were filtered through Vicon Nexus with a Low Pass, 4th order, zero lag Butterworth filter with a cut off frequency of 6 Hz. Each stride cycle was normalized such that the time from one heel strike to the next represented 100%. A custom Matlab (Mathworks, Natick, MA) code was used to derive stance time, double support time, step length, and stride length for the portion of the split-belt task where the belts were moving at different speeds. Stance and double support time were normalized and presented as a percent of the gait cycle. The strides during each of the adaptation periods were averaged within participants and then grand means were calculated for each variable. The four gait variables obtained during the first five strides (Early Adaptation) and the last five strides (Late Adaptation) of the split-belt task was compared to the same periods of the dual task [13].

SPSS (IBM, NY) software was used for statistical analysis. A within participants repeated measures analysis of variance (ANOVA) was used with the factors leg (slow leg and fast leg), adaptation period (Early or Late adaptation) and condition (Single Task and Dual task). For the Single Task (cognition), a paired T-test was used to test the potential difference in the percentage of questions answered incorrectly, and word count error to determine whether differences exist between the Single Task (Cognition) and the Dual Task. For all analysis, the acceptable level of significance was set at p <0.05.

Results

All data were analyzed to evaluate the assumption of normality. Shapiro-Wilks test revealed that one factor of double support time and two factors of stance time violated the assumption of normality. Data were examined for outliers and data was reanalyzed with potential outliers removed from the data set. Excluding the outliers did not change the outcome of any of the results listed below therefore the outliers were retained in the final analysis. All other assumptions were met (Table 1).

Feedback Parameters			
Stance Time (%)	**F**	**p**	**n2**
Adaptation Period	1.883	0.212	0.212
Leg	122.708	<.001*	0.946
Condition	9.038	0.02#	0.564
Adaptation Period*Leg	0.379	0.558	0.051
Adaptation Period*Condition	0.43	0.533	0.058
Leg*Condition	2.62	0.15	0.272
Adaptation Period*Leg*Condition	1.142	0.321	0.14
Stride Length (M)			
Adaptation Period	1.626	0.243	0.188
Leg	44.258	<.001*	0.863
Condition	8.163	0.0248	0.538
Adaptation Period*Leg	1.866	0.214	0.21
Adaptation Period*Condition	0.291	0.606	0.04
Leg*Condition	1.344	0.284	0.161
Adaptation Period*Leg*Condition	0.638	0.451	0.084
Feedforward Parameters			
Double Support Time (%)	F	p	n2

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Adaptation Period	0.377	0.559	0.051
Leg	67.455	<.001*	0.906
Condition	4.811	0.064	0.407
Adaptation Period*Leg	35.876	0.001*	0.837
Adaptation Period*Condition	0.223	0.651	0.031
Leg*Condition	0.154	0.706	0.022
Adaptation Period*Leg*Condition	0.194	0.673	0.027
Step Length (M)			
Adaptation Period	6.765	0.035#	0.49
Leg	20.325	0.003+	0.744
Condition	1.499	0.26	0.176
Adaptation Period*Leg	13.192	0.008+	0.653
Adaptation Period*Condition	0.106	0.755	0.015
Leg*Condition	3.002	0.127	0.3iXJ
Adaptation Period*Leg*Condition	0.174	0.689	0.024

Table 1: Repeated measures Analysis of Variance Table of Results. F statistic, p value and partial eta squared (n2) of each factor of analysis. *p < .001, + p<.01, # p<.05.

Analysis of motor task performance

Effects of condition: It was hypothesized that the adaptation of the feed forward gait parameters (double support time and step length) would be inhibited by the addition of the cognitive task in the Dual Task Condition. Results of a three way repeated measures ANOVA are reported in Table 1. There was no effect of condition for either double support time or step length. There were no interaction effects of condition with adaptation period or leg. There was a significant effect of condition for feedback parameters stance time (Figure 2B) and stride length (Figure 2A), however the changes were small. Post hoc Bonferroni pairwise comparisons reveal that the percent of the gait cycle spent in stance time was 0.53% longer during the Dual Task condition (Mean=65.82%; SE=0.28) than under the Single Task (Motor) condition (M=65.29%; SE=0.22). The main effect of condition explained 56.4% of variance in stance time (Table 1). In addition, Stride length was 0.06m longer in the Dual Task condition (M=0.90 m; SE=0.05) than the Single Task (Motor) condition (M=0.84 m; SE=0.04). The main effect of condition explained 53.8% of the variance in stride length (Table 1 and Figure 2).

Effects of adaptation period: There was a significant leg x adaptation period interaction effect for feed forward gait parameters, double support time and step length (Figure 3 and Table 1). Consistent with the literature, post hoc pairwise comparisons revealed the difference in mean double support time percentage between legs reduced by 6% from Early (Difference of 8.89%) to Late Adaptation (Difference of 2.59%). The interaction of leg and adaptation period explained as much as 83.7% of the variance in double support time (Table 1). The difference in mean step length between legs reduced by 0.1m from Early (Difference of .15m) to Late Adaptation (Difference of 0.05 m). The interaction of leg and adaptation period explained 65.3% of the variance in step length (Table 1). The interaction of leg and adaptation period reflected a 15% reduction in double support time in the slow leg and a 26% increase in double support time in the fast leg during the Single Task (Motor) from Early to Late adaptation. During the Dual Task, double support time of the slow leg reduced by 18% and the fast leg increased by 27% of the value of the Early Adaptation period (Table 2). The interaction of leg and adaptation period for step length was likely driven by changes in the fast leg. The step length of the fast leg increased by 0.07m, a change of 25% from Early to Late adaptation during the Single Task (Motor) and a change of 23% during the Dual Task condition (Table 2). There were no effects of adaptation period or an interaction of adaptation period with leg or condition for stance time or stride length.

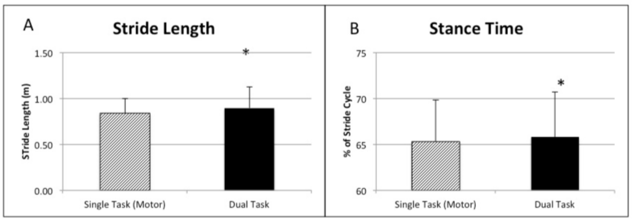

Figure 2: Main effect of condition on gait parameters. A) stride length and B) stance time. Error bars represent standard deviation. *Significant difference between Single Task (Motor) and Dual Task conditions. p<0.05.

	Single Task (motor)		**Dual Task**	
	Early	**Late**	**Early**	**Late**
Stance time				
Slow leg	69.0 (1.95)	69.36 (1.67)	70.33 (1.76)	69.72 (1.51)
Fast leg	61.87 (2.66)	60.94 (2.18)	62.10 (1.08)	61.11 (2.01)
Stride length				
Slow leg	0.68 (0.15)	0.73 (0.17)	0.69 (0.21)	0.70 (0.18)
Fast leg	0.95 (0.13)	1.01 (0.11)	1.07 (0.20)	1.12 (0.15)
Double support time				
Slow leg	19.34 (1.49)	16.50 (2.01)	20.94 (3.09)	17.10 (1.67)
Fast leg	10.98 (0.06)	13.85 (0.98)	11.51 (2.22)	14.57 (3.04)
Step length				
Slow leg	0.45 (0.08)	0.42 (0.06)	0.44 (0.10)	0.42 (0.05)
Fast leg	0.28 (0.06)	0.35 (0.05)	0.31 (0.07)	0.38 (0.06)

Table 2: Dependent Variables Summary Table. Measures of gait adaptation for each leg in Early and Late Adaptation during Single and Dual Task conditions. Mean (standard deviation).

Analysis of cognitive task performance

A paired T-test was performed to compare the measures of cognitive performance between the Single Task (Cognition) and Dual Task conditions. There was no significant difference for either word

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count error (df=7; p=0.097) or percent of questions answered incorrectly (df=7; p=1.00) although the word count error during the dual task was 0.76 errors greater than during the single task (Figure 4).

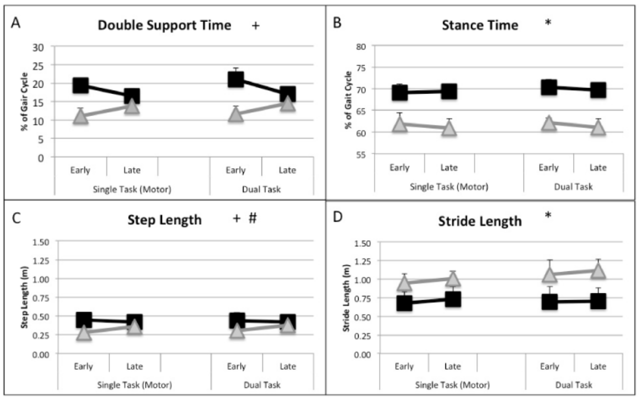

Figure 3: Interaction effect of adaptation period and leg on gait parameters. A) Double support time as a percent of gait cycle; B) Stance Time as a percent of the gait cycle; C) Step Length (m); D) Stride Length (m) of the Slow (Gray square) and Fast Leg (Black triangle) for Early and Late Adaptation periods of both the Single Task (Motor) and Dual Task Conditions. Error bars represent the standard deviation. *p<0.05 significant effect of condition; #p<0.05 significant effect of adaptation period; +p<0.01 significant adaptation period x leg interaction.

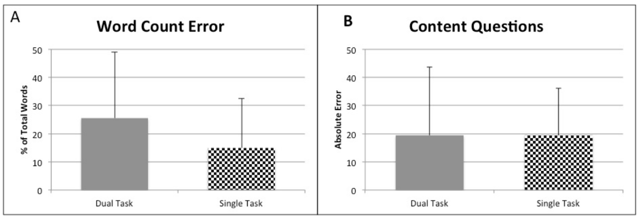

Figure 4: Results of Attention Task Performance for Single Task (Cognition) and Dual Task Conditions. A) Mean percent difference between reported and actual word count, B) Mean percent of questions answered incorrectly. Errors bars represent the standard deviation.

Discussion

This study was performed in order to investigate the role of attention in the adaptation to split-belt walking by young boys. It was hypothesized that adaptation of feed forward parameters: double support time and step length, would be impacted by the addition of an cognitive task, since there is evidence to suggest that these parameters are influenced by supraspinal control centers for both motor learning and attention tasks such as the cerebellum [10,21].

Motor task performance

Effect of condition: In contrast to the hypothesis, these results, showed no impact of condition on either double support time or step length. However, there was a trend toward an effect of the dual task on adaptation of double support time. Had this effect reached significance it would have supported our hypothesis implying that supraspinal centers such as the cerebellum were involved in both the adaptation of double support time and attention to the cognitive task. Instead the two feedback parameters, stance time and stride length, were affected by the addition of the cognitive task in the Dual Task condition. Since the Dual Task model suggests that an impact on either or both the motor or cognitive tasks would indicate that both tasks require attentional resources, these results suggest that attentional resources are required for split-belt locomotor adaptation in young boys. However, the results do not support the hypothesis that feed forward parameters are impacted by the requirement of additional attentional resources, but rather feedback parameters of split-belt adaptation are affected.

Currently, the literature on the division between supraspinal and spinal control of split-belt locomotor adaptation is inconsistent. Reisman et al. [13] found that double support time and step length took longer to adapt to split-belt walking. In addition, they concluded that these parameters may be controlled by supraspinal nuclei, while stance time and stride length were adapted immediately, suggesting increased spinal mediation [13]. Morton & Bastian [10] followed up with a comparison of healthy adults to those with cerebellar lesions. Cerebellar lesions were associated with impaired adaptation of feed forward but not feedback gait parameters, indicating that the cerebellum may have a role in feed forward split-belt adaptation. However, the lack of impairment in feedback adaptation does not completely rule out supraspinal control of stance time and stride length, it merely demonstrates that these parameters can be fully adapted without a fully functioning cerebellum. An additional study by Reisman, et al. [22], examined the role of the cortex in split-belt adaptation. They found that stroke patients had no difficulty in adapting either feed forward or feedback parameters suggesting that split-belt adaptation can operate without full operation of cortical areas [22]. Choi et al. [23] argued that small lesions of the cortex, spatially dispersed between participants, do not provide enough evidence to rule out a cortical role in split-belt adaptation. They found that children with hemispherectomy exhibited impaired adaptation of double support time but not step length during split-belt adaptation. Their results suggest that only temporal feed forward adaptation relies on cortical control [15]. Furthermore, Malone & Bastian [12] reported that the rate of step length adaptation to split-belt walking was impacted by performing an auditory and visual attention task while adults simultaneously walked on a split-belt treadmill. They suggested that spatial parameters of split-belt walking may be controlled by the lateral cerebellum and temporal parameters controlled by spinocerebellum. Although, there is a wide range of explanations for the control of split-belt adaptation in adults, they do not fully explain the role of attention in the split-belt adaptation of children.

One explanation for these results is that young boys use different mechanisms of control for split-belt locomotor adaptation than adults. Vasudevan et al. [15] compared split-belt adaptation of adults to a wide age range of children. They found that children tend to adapt slower to split-belt walking, especially the measures of step length and relative phasing between limbs. After finding comparable results in participants with cerebellar lesions, they concluded that the delays in adaptation might be related to the maturation of the cerebellum [15]. The cerebellum develops relatively late in childhood not reaching maturation until after 15 years of age in males [24]. The cerebellum while most well-known for its role in motor learning, is also important for cognitive tasks such as learning complex associations or working memory [21]. Since the cerebellum, which is important for both the cognitive and split-belt walking task, is not fully matured, children may not be able to use cerebellar cortical networks effectively to adapt to the split-belt task in the same manner as adults.

For example, increasing stance time is well established as a strategy used when one feels that his or her stability is compromised. McFadyen et al. [11] found that adults increase stance time in response to split-belt walking and suggested it was a method of increasing stability. Sutherland, et al. [25] also agrees that percent of stance time is an indicator of stability. Stance time is noted as one of the major factors in determination of mature gait and is yet to reach adult values in children as old as seven [25]. Because children have an immature cerebellum among other cortical structures, automaticity of gait may not be achieved, and therefore adaptation to perturbations in locomotion such as split- belt walking may require more attention in children than adults, making distractions more detrimental to a child's stability. Moreover, structures important for attention and planning are also lacking in maturity, further contributing to the detrimental effect of distraction on children's stability. For example, the prefrontal cortex, which plays a role in attention, planning and execution, is among the last cortical areas to mature, not reaching maturity until early adulthood [26]. The reticular formation, also associated with selective attention does not complete myelination until after 20 years of age [16]. In the current study, there was a statistically significant change in stance time when an additional cognitive task was added. However, the increase in stance time was minimal, and while statistically significant, may not reflect a clinically significant change. Additionally, the increase in stance time was countered with an increase in stride length, where as a decrease in stride length is more commonly observed when an individual perceives that they are unstable [27]. Thus young boys may not be able to make appropriate corrections to their movement strategy if they are undergoing adaptation to new conditions of their walk while also engaged in a working memory task.

Effects of adaptation period: In this study only feed forward parameters, double support time and step length showed evidence of adaptation to the split-belt as displayed by a reduction in the differences between limbs from Early adaptation to Late adaptation. It was interesting that this was true in both the split-belt alone and dual task condition since the authors had hypothesized that feed forward adaptation would be affected by the addition of the attention task. This suggests that double support time and step length can be adapted without withdrawing cognitive resources. This is in contrast to the hypothesis that feed forward parameters would be impacted by withdrawing cognitive resources away from the adaptation to split-belt treadmill walking [10,13]. Malone & Bastian [12] found that a similar attention task resulted in delayed adaptation of step length, which was not replicated in young boys. Again, these differences may simply reflect a difference in control mechanisms utilized by the immature neuromotor networks of children.

Cognition task performance

The results revealed no significant effect of dual task on either word count error or the percent of content questions answered incorrectly. This is in contrast to the literature that predicts that gait and balance are prioritized over attention task performance in children. For example, Shaefer, et al. [28] reported children prioritized a postural task over paired cognitive tasks in order to improve balance during dual task conditions. However, in the present study, the cognitive task was measured continuously, and the adaptation to the splitting of the belt speeds was only evaluated during very brief periods of time. The possibility still remains that cognitive performance was disrupted during the initial adaptation period but after this point attention was returned to the story and the word count task. This is discussed further as a limitation to this study below.

One limitation of this study is that the timing of the attention task was not controlled for. The attention task was continuous but required participants to report the key word count and answer content questions only after the task was completed. Therefore, researchers were not aware of the quality of performance of the attention task until after the task was complete. While it is assumed that the task required attention during the whole trial, it is not clear whether the errors in the word count task occurred only during the initial reaction to the split-belt perturbation, or were spread out over the whole trial. A continuous task such as the serial 7 subtraction task would have provided more insight into which time periods of adaptation were most affected by the addition of an attention task. Further, Abbud et al. [8] has suggested that the dual task cost is greatest during single leg stance, and an attention task that controlled for timing of stimuli based on gait phase may have had a greater effect on performance of both the attention and split-belt adaptation task.

A second limitation of this study is the low number of participants due to the many obstacles in recruitment of children for research. Although the age range was limited to two years in attempt to reduce the effect of maturation and avoid the onset of puberty, the impact of developmental differences between participants on either end of the age bracket on the experimental outcomes remains unpredictable because growth and development is ongoing.

Conclusion

The purpose of this study was to evaluate the attentional demands of adaptation to split-belt walking by young boys, age 8-10 years old. In contrast to our hypothesis, we found that feedback but not feed forward parameters were influenced by the addition of a secondary attention task. In fact, only the feed forward parameters double support time and step length were adapted in both the split-belt only and dual task condition. Our results provide support for the idea that attentional resources are necessary for split-belt adaptation, but not adaptation of the feed forward gait parameters double support time and step length.

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