Treadmill training effects on walking acquisition and motor development in infants at risk of developmental delay

Efeito da intervenção em esteira motorizada na aquisição da marcha independente e desenvolvimento motor em bebês de risco para atraso desenvolvimental

Efecto de la intervención en caminadora automática en la adquisición de la marcha independiente y desarrollo motor en bebés de riesgo para retraso de desarrollo

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ABSTRACT

Objective: To examine the effect of motorized treadmill intervention on independent walking acquisition and other motor milestones in infants at risk of developmental delay.

Methods: Experimental study with 15 infants, observed since the 5th month of age: five infants at risk of developmental delay submitted to both physiotherapy sessions and intervention in motorized treadmill (Experimental Group); five infants at risk of developmental delay submitted to physiotherapy sessions only (Risk Control Group); and five infants without risks of developmental delay (Typical Control Group). Physiotherapy sessions occurred twice a week, followed by motorized treadmill intervention for the Experimental Group. Motorized treadmill intervention began when infants acquired cephalic control and was interrupted by independent walking or at 14 months post-conceptual age. All babies were monthly assessed with Alberta Infant Motor Scale and the Experimental Group was filmed during the exercise on the motorized treadmill. Comparisons among groups and months were performed using analysis of variance (ANOVA) and multivariance (MANOVA).

Results: Experimental Group infants acquired independent walking at 12.8 months and the Risk Control Group infants at 13.8 months of corrected age, which was delayed compared to the Typical Control Group (1.1 months; $p<0.05$). Experimental Group of infants showed alternated walking steps on the treadmill, which increased during the intervention period ($p<0,05$). They also improved their global motor development compared to Risk Control Group of infants.

Conclusions: Motorized treadmill intervention facilitates independent walking acquisition and improves global motor development of infants at risk of developmental delay.

Key-words: child development; motor activity; developmental disabilities.

RESUMO

Objetivo: Examinar o efeito de intervenção em esteira motorizada na idade de aquisição da marcha independente em bebês de risco para atraso de desenvolvimento.

Métodos: Estudo experimental com 15 lactentes a partir do 5º mês de idade, sendo cinco deles com risco de atraso de desenvolvimento submetidos a sessões de fisioterapia e intervenção em esteira motorizada (Grupo Experimental); cinco com risco de atraso de desenvolvimento submetidos apenas a sessões de fisioterapia (Grupo Controle de Risco); e cinco bebês sem risco de atraso (Grupo Controle Típico). As sessões de fisioterapia ocorreram duas vezes por semana, seguidas de intervenção em esteira motorizada para o grupo

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experimental. Todos os bebês foram avaliados mensalmente pela *Alberta Infant Motor Scale* e os participantes do grupo experimental foram filmados durante a realização das passadas na esteira. Comparações entre os grupos ao longo do tempo foram realizadas por análise de variância (ANOVA) e de multivariância (MANOVA).

Resultados: Os bebês do Grupo Experimental adquiriram a marcha independente aos 12,8 meses e os do Grupo Controle de Risco aos 13,8 meses de idade corrigida, sendo que a aquisição do Grupo Controle de Risco ocorreu mais tarde em relação ao Grupo Controle Típico (1,1 meses; $p<0,05$). Os bebês do grupo experimental apresentaram padrão alternado das passadas na esteira, que aumentou ao longo da intervenção ($p<0,05$), e mostraram melhora do desenvolvimento motor global em relação aos bebês do Grupo Controle de Risco.

Conclusões: A esteira pode ser considerada um agente facilitador para a aquisição do andar independente e do desenvolvimento motor global de bebês com risco de atraso de desenvolvimento.

Palavras-chave: desenvolvimento infantil; atividade motora; deficiências do desenvolvimento.

RESUMEN

Objetivo: Examinar el efecto de intervención en caminadora automática en la edad de adquisición de la marcha independiente en bebés de riesgo para retraso de desarrollo.

Métodos: Estudio experimental de 15 lactantes a partir del 5º mes de edad, siendo 5 con riesgo de retraso de desarrollo sometidos a sesiones de fisioterapia e intervención en caminadora automática (grupo experimental); 5 de riesgo de retraso de desarrollo sometidos solamente a sesiones de fisioterapia (grupo control de riesgo); y 5 bebés sin riesgo de retraso (grupo control típico). Las sesiones de fisioterapia ocurrieron 2 veces en la semana, seguidas de intervención en caminadora automática para el grupo experimental. Todos los bebés fueron evaluados mensualmente por la Alberta Infant Motor Scale y los del grupo experimental fueron filmados realizando los pasos en la caminadora. Comparaciones entre los grupos a lo largo del tiempo fueron realizadas utilizando análisis de variancia (ANOVA) y de multivariancia (MANOVA).

Resultados: Los bebés del grupo experimental adquirieron la marcha independiente a los 12,8 y los del grupo control de riesgo a los 13,8 meses de edad corregida, siendo que la adquisición del grupo control de riesgo ocurrió más tarde que en el grupo control típico (1,1 meses; $p<0,05$). Los bebés del grupo experimental presentaron estándar alternado de los pasos en la caminadora, que aumentó a lo largo de la intervención ($p<0,05$) y mostraron mejora en el desarrollo motor global respecto a los bebés del grupo control de riesgo.

Conclusión: La caminadora puede ser considerada un agente facilitador para la adquisición de la marcha independiente y del desarrollo motor global de bebés de riesgo de retraso de desarrollo.

Palabras-clave: desarrollo infantil; actividad locomotora; caminadora automática/utilización; trastornos de retraso del desarrollo.

Introduction

Babies who are at risk of developmental problems exhibit delayed acquisition of a range of different motor milestones and one of the most important of these is independent walking. Among babies with typical development, acquisition of walking is at around 12 months[1], whereas, in premature and low birth weight children, acquisition is at 14 months of corrected age[2-4]. This delay is caused by the baby's immobility when in an ICU bed[5-7], by the environment of the Neonatal ICU, which is rich in stimuli that are prejudicial to babies' development, and by asymmetries in muscle tone, which manifest as passive and active muscle imbalances and by excessive increases in muscle tone around the trunk[5,7-9].

Babies who are at risk of developmental delay do not therefore receive stimulation from their environment and, in particular, stimulation of motor actions that are indispensable to the process of development, in the same way that babies with typical development do[10,11]. As a result, babies at risk of developmental delay have greater difficulty in learning and acquiring new motor abilities, with a negative influence on motor, social and cognitive development[5,7].

Since acquisition of new behavior is dependent on modifications to cerebral connections[12], and since environmental stimuli induce cerebral restructuring and maintenance of the central nervous system[13,14], appropriate stimulation can promote babies' development and, especially so, the development of babies at risk of delay. Therefore, intervention protocols come to play a decisive role in creating favorable conditions that are designed to aid motor ability acquisition.

Babies with Down Syndrome who underwent a longitudinal intervention program using a treadmill acquired independent walking 3 months before their peers who did not participate in the intervention[15]. In the case of babies with Down Syndrome, the treadmill intervention led to better postural control and increased muscle strength in the legs and stimulated the nervous connections involved in generating the movements of walking[15]. One of the advantages of the treadmill is the ability to induce voluntary control of leg movements while taking steps, which should preferably be alternated[16-18]. The treadmill can therefore facilitate transition from one behavior to another and babies who are unable to take steps similar to walking in a normal environment exhibit coordinated steps when exposed to the treadmill[17,19].

The treadmill's effect on acquisition of independent walking in babies with Down Syndrome and the need for early intervention with babies at risk of developmental delay raise two questions. Firstly, can treadmill intervention affect the age of acquisition of independent walking in high-risk babies? Also, does this type of intervention have an influence on the global motor development of such babies? The objective of this study was to investigate the effect of treadmill intervention with babies at risk of developmental delay on the age at which they acquire independent walking and on other motor development milestones that make up the infant motor repertoire during the first year of life.

Methods

Fifteen babies were enrolled on the study and classified into one of three groups. Five babies who had been defined as at risk of developmental delay were allocated to the Experimental Group (EG - 5.8±0.4 months corrected age), five babies who had been defined as at risk of developmental delay were allocated to an At-Risk Control Group (RCG - 6.1±0.4 months corrected age) and 5 babies free from any diagnosis of developmental risk made up the Typical Control Group (TCG - 7.4±0.9). The babies at risk of delay were recruited from babies screened at the *Centro de Habilitação Infantil "Princesa Vitória"*, Rio Claro, SP, and at the rehabilitation center in Araraquara, SP. These babies were allocated either to the EG or RCG after random selection and with the approval of their parents or guardians. Sample size was estimated using Cohen's table[20] in order to test three means, with moderate estimates of magnitude (over 0.60) for the effect on dependent variables and statistical power of 0.80, returning a sample size of 5-7 babies in each group.

Babies were classified as at risk of developmental delay and so eligible for inclusion if one or more of the following factors were part of their clinical history[6,21,22]: moderate prematurity (gestational age from 31 to 34 weeks); low birth weight (< 2500g); the occurrence, during the neonatal period, of respiratory distress syndrome; intrauterine growth restriction (small for gestational age – according to the Williams curve)[23]; neonatal convulsions; cardiorespiratory arrest; prolonged mechanical ventilation (more than 7 days); prolonged oxygen therapy (more than 28 days); prolonged parenteral nutrition (administration of nutritional components intravenously); fetal suffering during birth (meconium aspiration and 5-minute Apgar of less than 3); apnea and first and second degree intraventricular and periventricular hemorrhage. Babies were excluded from the study if they were diagnosed with extensive brain damage, confirmed by diagnostic tests and examinations, or if they had poor attendance at the intervention sessions. Babies without a diagnosis of risk of development were selected from family contacts and acquaintances and visits to daycare centers and schools in the city of Rio Claro.

Participation of each baby was conditional on signature of a consent form, by a parent or guardian. The study design was experimental and prospective, was approved by the Institutional Ethics Commission and complies with the norms and directives governing research involving human beings (ACTRN clinical trials registration number: 12609000518268).

Babies in the EG were given physiotherapy at the rehabilitation centers by professionals who were trained and specialized in physiotherapy applied to infant neurology and underwent the treadmill intervention twice a week. The treadmill intervention was conducted at the rehabilitation centers, after the physiotherapy session, and lasted 8 minutes. The babies were positioned vertically over a reduced-size treadmill, with weight loading their legs. A weight-support system was used to aid with maintaining an erect posture and the physiotherapist or guardian stayed in front of the baby holding their hands. The treadmill belt was run at a velocity of 0.28 m/s[24], in common with previous studies[15,25].

Babies in the RCG were given similar physiotherapy treatment to that given to the EG babies, but they did not do the treadmill intervention. Babies in both groups started these treatments at around 6 months – cephalic control was a prerequisite for starting treatment – and were followed-up until acquisition of independent walking and/or a corrected age of 14 months. The physiotherapy sessions were based on the neurodevelopmental concept of motor development proposed by Bobath[26].

Finally, the 5 babies who were allocated to the TCG did not undergo physiotherapy or treadmill treatment, but were also followed-up until acquisition of independent walking and/or 14 months of age.

Babies in all three groups were assessed monthly using the *Alberta Infant Motor Scale* (AIMS) and babies in the EG were also assessed during their treadmill sessions. At these assessments the babies were positioned on the treadmill, at the same velocity as during the intervention sessions (0.28m/s), and filmed for 2 minutes as they took the steps triggered by the treadmill[24]. A Panasonic AG-DVC7P digital camera was positioned in the sagittal plane in order to film the babies' legs talking steps on the treadmill[27]. These assessments were conducted monthly until the babies achieved independent walking or reached 14 months of (corrected) age.

The video footage was then used to analyze the steps of babies in the EG, triggered by the treadmill, using a program that allowed viewing frame-by-frame. This analysis was to identify the total number of steps each baby took at each session and also to quantify the number of each different type of step triggered off by the treadmill (single, alternate, double or parallel).

Analysis of variance (ANOVA) was used to detect possible differences in age of acquisition of independent walking between the groups. ANOVA was also used to test for possible differences in the number of each type of step at each monthly session, with the dependent variable being the number of steps triggered by the treadmill, of the alternate, single, parallel and double types. Finally, ANOVA was used to test for possible differences between groups and monthly assessments (3 groups and 5 monthly assessments, treated as repeated measures) with the following dependent variables: AIMS score, AIMS percentile and age at each motor milestone. All of the assumptions for these tests were checked and met and, when necessary, univariate and post hoc (Bonferroni) tests were used. All analyses were performed using SPSS (version 10.0) and the significance level was set at $p \leq 0.05$.

Results

Table 1 lists the final composition of each of the study groups, with information on gender, age at study outset and developmental risks.

The age of acquisition of independent walking and other motor milestones for the babies in all 3 groups are shown in Figure 1. Differences were observed between groups for age of acquisition of independent walking, with babies in the RCG being older at acquisition of walking than babies in the TCG ($p<0.05$). No difference was observed in age of acquisition of independent walking between EG and RCG or between EG and TCG. With regard to the age of acquisition of other motor milestones, such as rolling over, sitting without support, crawling, standing with assistance and standing without assistance, it was observed that they were acquired at a more advanced age among the RCG babies ($p<0.05$), but no significant differences whatsoever were observed between groups nor any interaction between group and age for these milestones.

Figure 2 illustrates the number of steps triggered off by the treadmill for the EG babies. From 8 to 12 months of age the EG babies were predominantly exhibiting alternate steps, with increases in the number of alternate steps observed from 8 to 9 months and from 9 months onwards ($p<0.05$). Furthermore, there was a trend for the number of parallel steps triggered by the treadmill to reduce along the months ($p=0.09$).

Figure 3 illustrates AIMS scores (Figure 3A) and percentiles (Figure 3B) for the babies in all three groups 6 to 14 months, with significant difference between assessments (effect over time: $p<0.05$), a borderline group effect ($p=0.07$) and no interaction between group and assessment. Tukey's post hoc test indicated a difference between the RCG and the TCG, but no differences between EG and RCG or between EG and TCG. Analyzing Figure 3A, it is observed that the RCG had lower scores than the TCG throughout the study. In contrast, although the EG scored lower than the TCG during the initial months, by the final months of the intervention, it was scoring close to the TCG.

Analyzing the AIMS percentiles, there were differences between different assessment times ($p<0.05$), but no differences between groups nor any interaction between group and assessment. Percentiles increased over the initial months up to 8 months, plateaued until 11 months and then began to increase once more from 12 months on. Figure 3B shows that the babies at risk of delay (EG and RCG) began below the 50th percentile and that the EG babies had lower percentiles than the RCG babies up to 10 months. After 10 months, the percentiles for the EG babies were superior to the RG babies' and the EG babies exceeded the reference for normality from 12 months onwards.

Discussion

The results of this study indicate that treadmill interventions change the age of acquisition of independent walking

Table 1 - Initial and final composition of the Experimental Group, characteristics of the sample, and developmental risks.

Subject	Sex	Excluded**	Corrected Age (months) Initial	Corrected Age (months) Final	Developmental risks
Experimental Group – EG					
1	M		5.5	13.0	Prematurity
2	M		5.4	13.0	Prematurity, LBW*, Prolonged MV*, IUGR*
3	F		6.5	12.2	Fetal Suffering, Prolonged MV
4	M		5.7	13.0	Prematurity, Prolonged oxygen therapy
5	F		5.8	13.0	Prematurity, IUGR, LBW
6	F	X	7.0	X	Prematurity , LBW
7	M	X	6.6	X	Prematurity, LBW, IUGR
8	M	X	8.1	X	Prematurity, Fetal Suffering
9	M	X	6.5	X	Prematurity, LBW
10	M	X	5.8	X	Prematurity, LBW
11	M	X	6.7	X	Prematurity, lung disease, prolonged MV
12	M	X	6.7	X	Prematurity, Fetal Suffering, CRA*
13	F	X	6.0	X	Prematurity
AT-Risk Control Group – RCG					
Subject	**Sex**	**Excluded****	**Corrected Age (months) Initial**	**Corrected Age (months) Final**	**Developmental risks**
1	M		5.2	15.0	Prematurity, LBW
2	M		5.2	15.0	Prematurity, LBW
3	M		6.0	12.2	Prematurity, LBW, Fetal Suffering, IUGR
4	F		6.0	14.1	Prematurity, LBW, Fetal Suffering
5	F		6.0	13.0	Prematurity, LBW
6	F	X	7.8	X	Prematurity
7	M	X	8.4	X	Prematurity, LBW
8	M	X	6.0	X	Prematurity, Fetal Suffering
Typical Control Group– TCG					
Subject	**Sex**	**Excluded****	**Chronological age (months) Initial**	**Chronological age (months) Final**	**Developmental risks**
1	M		7.6	12.1	No developmental risk
2	F		7.3	12.4	No developmental risk
3	F		6.5	12.2	No developmental risk
4	F		6.7	12.4	No developmental risk
5	F		8.9	13.5	No developmental risk
6	F	X	7.8	X	No developmental risk
7	M	X	7.4	X	No developmental risk
8	F	X	6.7	X	No developmental risk

in babies at risk of developmental delay, who achieved independent walking at a similar age to babies with typical development. The intervention also provoked an increase in the number of alternate steps taken. Finally, the treadmill intervention improved acquisition of other motor milestones, encouraging global motor development in these at-risk babies, bringing their results closer to what is observed among babies with typical development.

Babies at risk of developmental delay learn to walk later than babies with typical development, at around 14 months of corrected age[2-4], which was corroborated in this study by the age of acquisition of independent walking of the at-risk

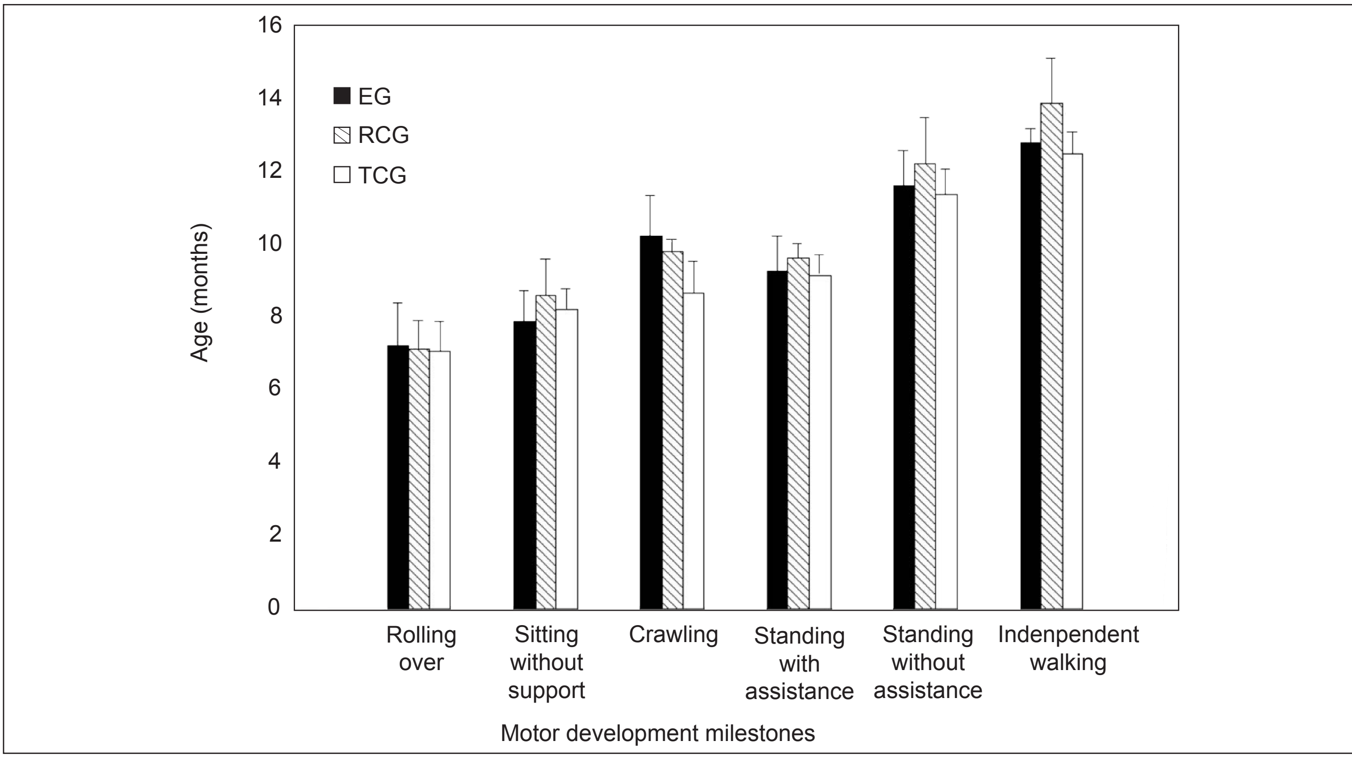

Figure 1 - Mean and standard deviation for age of acquisition of the motor milestones rolling over, sitting without support, crawling, standing with assistance, standing without assistance and independent walking for the Experimental Group (EG), At-Risk Control Group (RCG) and the Typical Control Group (TCG). The ages given for the Experimental group and the At-Risk Control Group are corrected. * indicates a difference between groups (p<0.05).

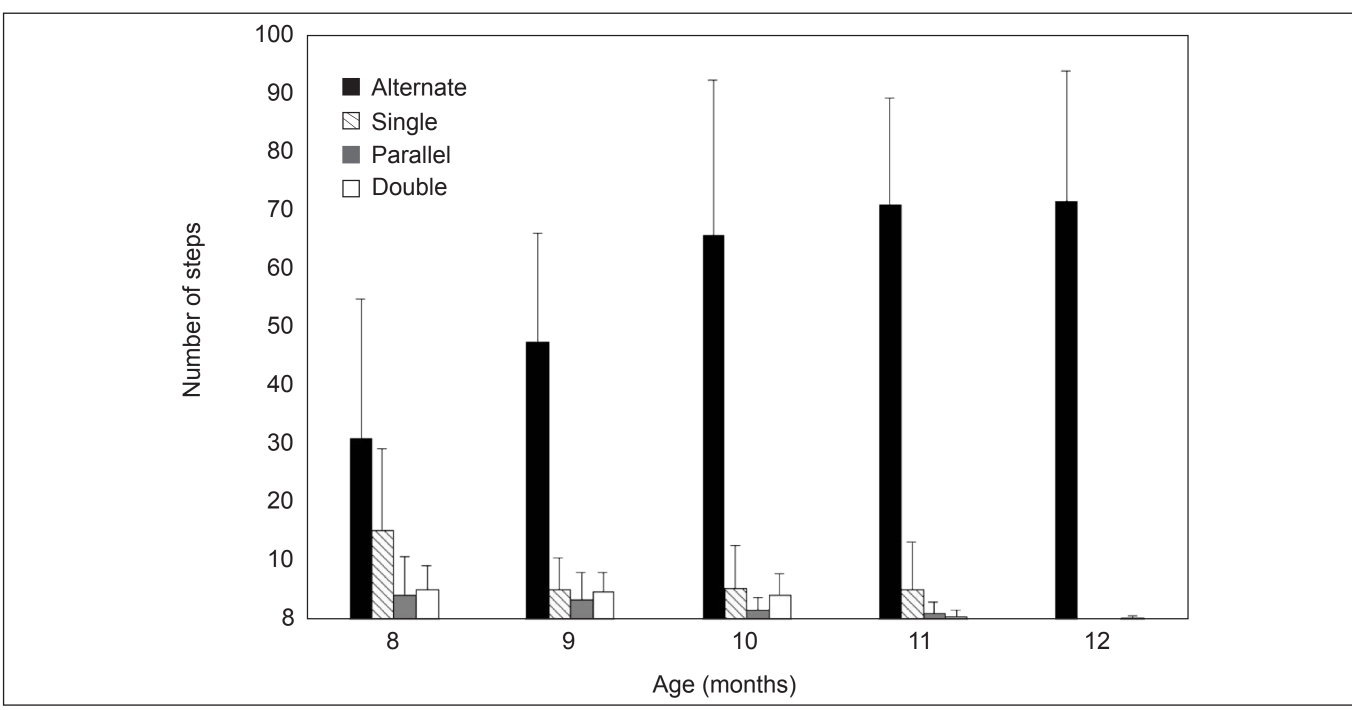

Figure 2 - Mean and standard deviation for number of alternate, single, parallel and double steps taken by the babies in the Experimental Group from 8 to 12 months of corrected age. "A" indicates statistical difference from 8 to 9 months, and "B", "C" and "D" indicate statistical differences between 9 months and 10, 11, and 12 months of age for babies in the 3 groups (p<0.05).

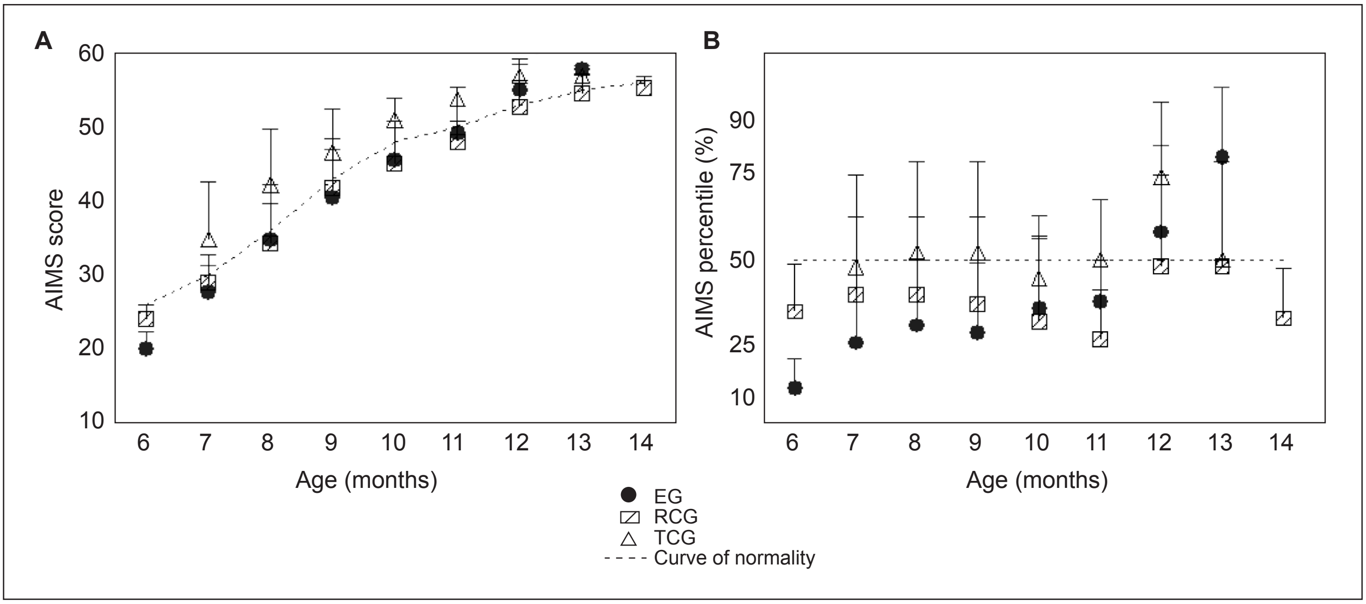

Figure 3 - Mean and standard deviation for Alberta Infant Motor Scale score (A) and Alberta Infant Motor Scale score as percentile (B) for the babies in the Experimental Group (EG), At-Risk Control Group (RCG) and Typical Control Group (TCG) over the months of intervention. The ages given for the Experimental group and the At-Risk Control Group are corrected. * indicates a difference between groups (p<0.05).

babies who did not undergo treadmill intervention. Even when they are given special care, such as physiotherapy, at-risk babies have reduced motor development velocity, at least for acquisition of independent walking, than those with typical development. Considering that the ability to walk offers a different relationship with the physical and interpersonal environments[28], delay in reaching this milestone can impose a restriction on the global development of babies at risk of developmental delay.

The results of this study indicate that this motorized intervention facilitates acquisition of independent walking in at-risk babies, at an age similar to that observed among babies who are not at risk (a non-significant difference of just 10 days in age of acquisition of independent walking). In contrast, babies at risk of developmental delay who were not stimulated using the treadmill acquired independent walking at an age that was statistically older than the babies with typical development. These results, therefore, replicate the effect of treadmill interventions on the acquisition of independent walking that has been observed with other populations[15], and could serve as the basis for the construction of treatment protocols for the promotion of the acquisition of independent walking in babies at risk of delay.Considering that the treadmill intervention facilitates acquisition of independent walking, it is important to discuss the reasons for and causes of this effect. Although no direct comparison between groups was possible, the babies at risk of developmental delay who were exposed to the treadmill intervention increased the number of alternate steps they took during the initial months. According to Thelen *et al*[28,29], the treadmill triggers at least four types of steps, but it is alternate steps, with a similar pattern to that of independent walking, that are preferable for full term babies[28], premature babies[19], and babies with cerebral palsy[27] and Down syndrome[15]. As age increases and the infant gets closer to acquiring independent walking, the total number and the number of alternate steps triggered by the treadmill increases, as the number of other types of step reduces[28-30]. The results observed here corroborate those observations, since the at-risk babies who underwent the intervention did not only increase the number of steps on the treadmill, but also increased the number of alternate steps during the first months of intervention and maintained this acquisition during the months that followed. Therefore, the treadmill intervention provided the conditions for independent walking to be executed and repeated under similar conditions to those in which this milestone is reached independently.

Considering that the babies at risk of delay differ from those with typical development in terms of the age of acquisition of independent walking, when they are not exposed to a treadmill intervention, it could be suggested that the specificity and similarity between the intervention conditions and the prerequisites for achieving independent walking are crucial elements that determine the efficacy of the intervention, as has been suggested for other populations[15]. However, treadmill intervention also impacts on the acquisition of other motor and cognitive milestones, at least in the case of babies with Down syndrome[31].

This study suffers from certain limitations, such as, for example, the small number of subjects analyzed and composition and formation of study groups. Furthermore, there are many doubts about the efficacy of the intervention protocol employed: weekly frequency, length of sessions, treadmill velocity, and other factors. Despite these limitations and facts, the results indicate trends differentiating the babies at risk of delay, both in terms of age of acquisition of the milestones and in terms of global motor development on the basis of exposure to the treadmill. More specifically, when babies at risk of developmental delay were exposed to the treadmill intervention they exhibited ages of acquisition of certain modes of milestones, those that are reached during the first year of life, close to the edge of acquisition of the babies with typical development and also exhibited a level of global motor development that was closer to what is observed among babies with typical development. In contrast, babies at risk of delay who were not exposed to the treadmill intervention tended to differ from the babies with typical development and even from their peers at risk of developmental delay.

On the basis of the findings described above, the treadmill does not only facilitate acquisition of independent walking earlier among babies at risk of developmental delay, as has been shown among babies with Down syndrome[15] and preterms[19], but also promotes improvements in other aspects of motor development. One possible explanation for the effect on other motor abilities is that the treadmill stimulates development of muscle strength and postural control, encouraging the babies to seek new sensory-motor experiences in other positions. Despite the speculative character of these proposals, exposure to a treadmill appears to provide the baby with a new relationship with the environment in a wide range of contexts. In the case of babies at risk of developmental delay, the treadmill intervention does not only provide the opportunity to take steps and experience postures and relationships with surroundings, but may also play the role of "removing" one possible contention related to executing certain modes of activities that would not be performed without the intervention.

Finally, the AIMS proved capable of identifying global motor changes in babies at risk of developmental delay. Individual scores and percentiles for the experimental group approached the results of the typical control group in the last months of the intervention. Therefore, the AIMS indicated a positive effect from the treadmill intervention on the global motor development of babies at risk of delay. Bearing in mind the good sensitivity, specificity and accuracy offered by the scale for the identification of motor delays in babies[32], it can be concluded that the treadmill and AIMS are accessible resources that are effective for identification of and intervention with babies at risk of developmental delay.

Summing up, the treadmill promoted the acquisition of independent walking by babies at risk of developmental delay at an age compatible with what is observed among babies with typical development. Furthermore, the treadmill intervention also provoked improvement in the global development of babies at risk of delay. Despite the limitations of this intervention protocol, which is aimed at promoting the development of babies in the initial months of life, its results are promising and support the use of treadmills for promoting the acquisition of independent walking and global development of babies at risk of delay. Further studies should be conducted with the objective of better understanding and answering questions related to improving the application and effects of this type of intervention.

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