REVIEW ARTICLE

Systematic Review on the Performance of the Movement Assessment Battery in the Preschool Assessment of Preterm Infants

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Abstract

Introduction: Children born before 38 weeks gestation are considered preterm. According to the World Health Organization, there are several subgroups according to the gestational age and several risks related to the preterm status have been reported. Premature birth may cause changes in motor performance and particularly, at a more specific level, in motor coordination. Our study aimed at carrying out a systematic review on the performance of the movement assessment battery and developmental coordination disorders in preschool age in preterm infants.

Methods: Four databases (PubMed, ScienceDirect, Web of Science, Scopus) were systematically investigated and publications from 2008 to 2016 were included if the movement assessment battery band 1 tests were used. All of the studies found less performance on the results of preterm children. Three authors independently assessed the eligibility of the studies.

Results: A total of 236 publications were found, with 15 publications being selected according to the criteria included in the research. Only seven articles were selected after the application of the eligibility criteria.

Discussion: Movement assessment battery shows that premature children are at a higher risk of having changes in motor coordination, resulting in lower preschool performance and, consequently, hampering daily routines, both at home and in school compared to their peers that were born full term. It is pivotal for motor difficulties to be detected as early as possible, so that they can be attenuated or even eliminated during the transition to school.

Keywords: Child Development; Child, Preschool; Infant, Premature Motor Skills; Motor Skills Disorders; Movement; Movement Disorders; Reproducibility of Results; Systematic Review as Topic

Introduction

In recent years, there has been a significant increase in the number of premature infants worldwide.[1] Preterm infants with a gestational age (GA) of < 37 weeks comprise 12% of all live births. The literature and the World Health Organization report that preterm birth is based on the gestation time.[2] They also define very preterm infants, less than 28-32 weeks gestation, moderate and late preterm infants, between 32 and 37 weeks gestation, and term infants, between 38 and 40 weeks of GA.[3]

About 5%-6% of all births are premature,[4] which has been worrying the community due to future implications,[5] including costs of promoting intervention programs that are appropriate for this type of problem.

The literature has currently been concerned about preterm infants and the different aspects that may be related to the process of the child development in all areas. The literature has also studied the repercussions of prematurity in the development of motor coordination and in the performance of daily activities and routines.[6,7] There are several studies on very preterm infants[8] as well as on low birthweight babies,[9] but the literature is a little scarcer about commonly named moderate preterm infants. Prematurity seems to have consequences at various levels, namely in fine motor skills development. Regarding balance in children with developmental coordination disorders (DCD), some of them may have difficulties in motor coordination. The knowledge about premature children is extremely important so that an intervention plan can be developed and organized in preschool education as early as possible so as to minimize difficulties as a child begins his or her journey in school education.[10]

Considering that the development of central nervous system structures and their maturational process take place as the child increases gestational time,[11,12] we can speculate that the changes in the development of motor coordination will be more evident and more prevalent with the decrease of gestation weeks.

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Later preterm children have a reduced long-term neurodevelopmental outcome and higher cognitive risk that can persist over time.[13] There are references to some motor skills problems or even other types of problems.[14-16] Generally, 6% of children worldwide are estimated to have DCD. This disorder is a neurodevelopment condition characterized by reduced motor competence and results in difficulties in the motor performance of the child in activities in which motor coordination is required in fine and gross motor skills, and their motor performance is usually slower.[15] In preterm children, the coordination competence difficulties are clearly lower for their age, which is reflected later in writing, cutting, cycling,[17,18] or even in the bilateral use of cutlery during eating times. These motor difficulties continue at a later age and if intervention is implemented, the program applied could probably reduce motor difficulties.[19]

It is well known that children with DCD have problems that interfere with school learning or daily activities and routines, and sometimes parents are the first to report this situation. At times, teachers refer to children with DCD as being clumsy, but these children, according to Diagnostic and Statistical Manual of Mental Disorders (DSM-5) classification, have motor coordination problems when compared to their counterparts.

The movement assessment battery for children (MABC-2)[20] is an internationally standardized test of motor coordination for children. This test is divided into three bands according to age, but for this systematic review, only band 1 (3-6 years of age) was used. A total of eight subtests that evaluate three domains, manual dexterity, aiming and catching, and balance give a total test result, and were scored according to the best attempt to receive the raw score. The total score was calculated according to standard scores equating to the percentiles of each domain and classifies a child with a total test score ≥ 67 (> 15th percentile) as without DCD, with a total test score between 57 and 66 (> 5th to 15th percentile) as being at risk of DCD, and with a total test score ≤ 56 (≤ 5th percentile) as probable DCD. These three components can also be considered and analyzed individually.

Many recent studies use the MABC-2 test, but they mainly investigate the DCD associated with cognitive outcomes and academic performance in very preterm infants. Few studies address motor performance and its relationship with gestational age and, specifically, its impact on preschoolers and the subsequent repercussions.[21]

The aim of our study was to present a systematic review in preterm children, in preschoolers, and the differences in motor performance in studies using only the MABC-2, band 1.

Methods

The strategy used for this study was based on the model defined in preferred reporting items for systematic reviews and meta-analysis (PRISMA) statement.[22] This model is widely used for systematic reviews and as a resource in evidence-based practice.

Search strategy

The strategy used was to look for systematic searches in the literature from the databases PubMed, ScienceDirect, Web of Science, and Scopus.

The research was conducted from 2008 to December 2016, for all the articles available using a filter for the period referred to above.

The following keywords were used for the systematic review: gestational age, preterm, premature, child development, motor coordination, motor coordination disorder, manual dexterity, fine movements, gross movements, balance, and MABC-2. All possible combinations were used to increase the number of articles available.

Eligibility criteria

Three reviewers independently assessed the eligibility of the studies according to the defined criteria to carry out this study independently.

The following studies were considered eligible in this systematic review:

- Conducted with preterm infants, male and female, up to 6 years of age;
- Subjects had no other disorders like cerebral palsy, attention deficits, or hyperactivity, stroke, or intellectual disability;
- Published in English, Portuguese, or Spanish;
- Accessible on search sites and with the possibility of being downloaded. Unpublished work or conference proceedings were excluded.

Selection of articles

All publications were collected and placed in a database for analysis and subsequent verification of the studies was shared by different authors, allowing for easy reading and quick access.

The procedures adopted for the reading of the articles were ordered by title and abstract. Then, the reading was done, and the pre-defined eligibility criteria applied. The articles were included when the title and abstract comprised the words MABC-2 band 1, preterm between 3 and 6 years, and DCD. All the papers that met the inclusion criteria were included and their references were reviewed to determine if a relevant paper was missed. After selecting the articles, all three reviewers

assessed the full text of all the papers not eliminated in the screening step. The selected period began in 2008, considering that the second version of the MABC-2 was only published in 2007. However, many studies found in this period used MABC, the previous version, but only empirical studies using the second version of the MABC-2 were included.

Data extraction

After the completion of the previous steps, two of the authors organized the data as follows:
- Identification (title and author);
- Year of publication;
- Country where the study was conducted;
- Methodological design;
- Age of the subjects;
- Population characteristics;
- Outcomes;
- Tools;
- Results/conclusions.

All decisions, in different stages were made independently by three of the authors. The results were reviewed in all stages only after full consensus was reached. Thus, there was a total agreement in all stages and final articles.

Results

The search had a total of 236 articles with potentially relevant studies. After the review, 213 met our relevant criteria. However, after the eligibility criteria were applied and repetition avoided, the results were narrowed down to 15 articles, and only these were used for this study.

After reading the articles in full and having finished the research in the databases through the previously described method, only seven articles remained for our systematic review. In Fig. 1, we present the steps regarding the flow of article selection.

By analyzing the articles in Fig. 1, seven papers were published in the last four years of the revision period. The studies were conducted in several countries: Australia (two studies), China (two studies), New Zealand (one study), the Netherlands (one study), and Brazil (one study).

Concerning the studies included in this systematic review, three were cross-sectional, one was a prospective descriptive cohort study, two were prospective cohort studies, and one was a prospective longitudinal cohort study using a preschool sample. The sample sizes varied from n = 50,[23] to n = 5601.[24]

The participant ages ranged from 3 to 6 years: two studies with 3 to 6-year-old children, two with 5-year-old children, one with 2-year-old children and 4.5-year-old children, another with 4.5-year-old children, and one with

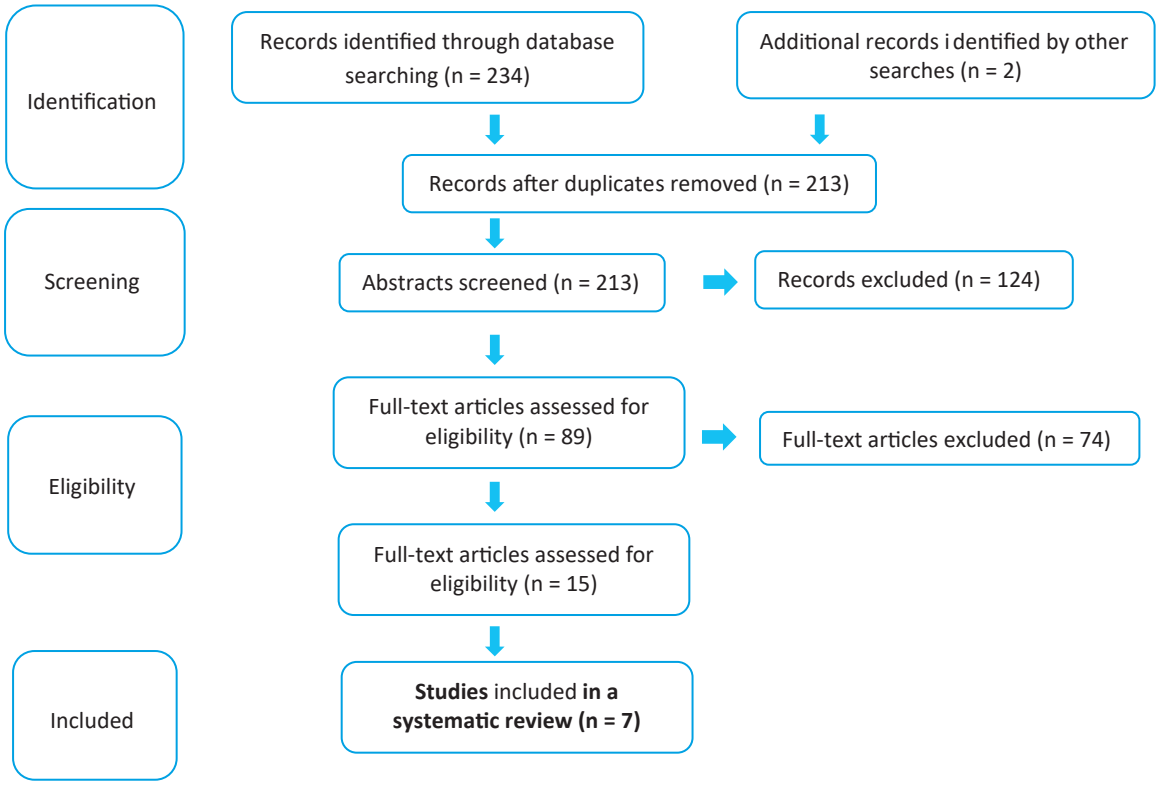

Figure 1. Flow chart of the article selection.

4-year-old children. Six studies matched for gender and one study does not refer to the gender variable. Three studies compared the groups between preterm and full-term children, and the other four have a preterm child in the sample. According to the total score of MABC-2, only four studies presented the results of the total test score and three present each domain of the MABC-2 results. Although the MABC-2 band 1 was used in all the studies to identify children at risk of DCD or probable DCD, as defined in the keywords, some selected studies used other complementary tools: pediatric evaluation of disability inventory (PEDI) (one study), Touwen neurological examination (one study), and other tests (*i.e.* cognitive or postural stability). The outcomes of the seven studies included more than one domain (Table 1).

For all seven studies, as recommended by the MABC-2 manual, the cut-off points used to identify children with motor difficulties were as follows:

- At or below the 5th percentile, the child denotes significant movement difficulty;
- Between the 6th and 15th percentile inclusive, the child is at risk of having movement difficulty, and some monitoring is required;
- At or above the 16th percentile, the child presents no movement difficulty.

All the studies point to a higher risk of DCD in preterm infants considered apparently normal, without associated neurological damage,[25] especially in the large preterm group.[26,27] In one study,[24] of the 4,001 children included, 330 had DCD (significant movement difficulty and were at risk of having difficulties) and 39 were born with gestational age equal to or below 37 weeks. In another study, the children who were born before 37 weeks gestational age may have a risk for DCD. It should be noted that two studies have mentioned in their results the total score and the three components of the test (manual dexterity, aiming and catching, and balance).

All studies state that preterm children have a risk or probable risk for DCD, and in three studies comparing between preterm and term, the preterm group has poor motor performance, and when the GA is less than 34 weeks, there is more prevalence in the group born preterm. In the results of three studies, the males have lower scores compared with females.

Discussion

The literature shows the differences between full-term and preterm children, and that the extremely preterm infants (< 28 GA) have a higher risk for DCD. This is consistent with the results observed in our systematic review and with the objective of the study. The most reported prevalence of DCD in the children population is 5%-6%[4], but there is currently less information on preschool children. The presence of DCD may be more common in extreme preterm[29] than in late preterm infants, suggesting that the prevalence of DCD is related with the degree of prematurity[19] and it was found[30] that the prevalence of preterm children with DCD was 12.5%. The poorer performance of the male gender compared to the females may also be explained by girls doing more daily fine tasks, usually participating in more activities at home that can improve the advantage of manual dexterity.[23,24,30] The literature begins to draw attention to the problems in motor coordination in preschoolers, but such studies are still scarce. Our systematic review found a higher relation between DCD and children born under 30 weeks. Some authors reinforced the evidence that preterm children have more coordination problems compared with term peers and states that these problems can be detectable before school age.[25]

We present the results using the standardized test MABC-2 band 1, which is one of the most commonly used instruments for identifying children with DCD or probable DCD. Cut-off points used to identify children as having DCD or probable DCD range from the 5th to 15th percentile (*i.e.* applying DSM-5 criterion A).

The cross-sectional study design and preschool samples were the most frequent. Although these types of studies can give us the perception of the differences between the groups, it would be more interesting to emphasise and develop the longitudinal design studies that highlight not only performance between the groups of preterm and full-term children, but also especially the groups' evolution or processes.

According to the articles reviewed, full-term children have superior performance in all components of the MABC-2 band 1. In preterm children, the fine movements are more affected compared with the other motor abilities in the domain of the manual dexterity component.[26] However, in a study comparing the results of school age preterm children with school age full-term children showed a greater prevalence of motor impairment in all sub tests of manual dexterity regarding the preterm group.[31] In one study,[23] 30% scored less than the 15th percentile, with a *p* value of 0.003, and a low average of motor coordination was observed in the non-disabled early low birth weight (ELBW). In another study, the prevalence of DCD was 15.6%, and the gender ratio was 1.9:1 males to females, and in different classified groups, the younger group (3 to 5 years old) has more children with DCD and the children who are born before 37 weeks gestation are

Table 1. General characteristics of identified studies in the current systematic review

Reference	Year	Country	Type of study	Children age (years)	Sample	Outcomes	Instruments	Results/Conclusion
23	2015	Australia	Prospective cohort study	4 to 5	50 preterm infants less than 28 weeks gestation, 26 males and 24 females, birthweight less than 1000 g	Motor, behavior	MABC-2; SLS; lateral reach test; standing long jump test; CBCL	The results indicate the non-disabled early low birth weight children in this study have low average motor co- coordination, postural stability, limb strength, and behavioral and emotional characteristics at four to five years of age. It seems that, with time, these children are at risk of problems emerging. In this study, the non-disabled early low birth weight children performed in the lower range of normal. These children continue to be at risk and need continued monitoring and assessment for planning intervention programs to minimize the development.
32	2016	New Zealand	Prospective cohort study	2 and 4.5	333 preterm children, 171 males and 162 females, 32-36 completed weeks of gestation	Motor	Bayley-III; MABC-2	The 89 children with MABC-2 total score at or below the 15th centile at 4.5 years, only three (2%) had a Bayley - III motor score lower than 85 at 2 years. Similarly, of 54 children with total scores at or below the 5th centile at 4.5 years, only two (1%) had a Bayley - III motor score lower than 85 at 2 years. In this study, the data suggest that, although routine neurological examinations at 2 years may be useful in detecting major neurological deficits, it is not a useful tool for predicting skilled motor performance or minor neurological abnormalities in children at 4.5 years.
26	2013	Netherlands	Prospective cohort study	5	165 children, 81 very preterm < 30 weeks gestation and with birthweight < 1000 g, 40 males and 41 females; 84 term babies, born after 37 weeks gestation and birthweight > 2500 g, 34 males and 50 females	Motor, behavior	MABC-2; Towen (neurological examination); WPPSI processing speed (ANT); visual motor coordination (ANT); behavior (SDQ)	Motor impairment (≤ 15th centile) occurred in 32% of very preterm infants compared with 11% of their term peers. The study confirms the high frequency of motor impairment and deficits in other developmental domains in very preterm children at 5 years corrected age.
27	2016	Australia	Prospective longitudinal cohort study	0 to 5	150 preterm infants, < 30 weeks gestation; 151 full-term children born > 36 completed weeks gestation and weight > 2499 g	Motor, cognitive, learning ability, behavior and emotional	MABC-2; magnetic resonance images; gait rite-walkway; dynamic postural (Microsoft Kinect); dynamometer; accelerometery; WPPSI; SDQ; DWA; PEDI; PQLQ; QLDCQ	Persistent motor impairments during the neonatal period will be assessed as a predictor of the severity of motor impairment at 5 years of age in children born < 30 weeks. Understanding the developmental precursors of motor impairment in children born before 30 weeks is essential for limiting disruption to skill development and potential secondary impacts on physical activity, participation, academic achievement, self-esteem, and associated outcomes (such as obesity, poor physical fitness, and social isolation).
25	2014	Brazil	Cross-sectional study	4	124 children, 62 preterm infants with gestational age ≤ 34 weeks, birthweight ≤ 1500 g, 31 males and 31 females; 62 full-term children with gestational age ≥ 37 weeks and birthweight ≥ 2500 g, 31 males and 31 females.	Motor, self-care, social, functional performance	MABC-2; PEDI; CMMS	Preterm children had worse performance in all tests, and 29% of the preterm children and 6.5% of term groups had scores on the MABC-2 indicative of motor coordination disorder. The results of the present study demonstrated that a significant proportion of apparently normal preterm children had worse motor, cognitive, and functional performance as preschoolers than their peers born at full term. This study emphasizes the importance of early assessment, as these changes are already detectable in preschoolers.
28	2015	China	Cohort study	3 to 6	5,691 children, 3210 males and 2391 females; 336 with birthweight < 2500 g and born before 37 weeks gestation, 231 males and 105 females.	Motor	MABC-2; WPPSI-III	In this study of 5,601 children, 336 met the criteria for DCD, resulting in a prevalence of 6%, with a mean age of (4.94 ± 0.80) years. There were 231 boys and 105 girls, with a gender ratio of 2.2 to 1. Additionally, 540 children were considered as suspected of having DCD, resulting in a total suspicious prevalence of 15.6%. The children with birthweight < 2500 g or born before 37 weeks gestation are more likely to suffer from DCD. In order to develop effective prevention and targeted intervention strategies, future longitudinal research should aim to identify which of these children are at risk in a long-term outcome.
24	2014	China	Population-based study	3 to 6	4,001 children, 2,067 males and 1,934 females, 3,867 full-term children and 134 preterm children ≤ 37 weeks gestation and low birth weight ≤ 2500 g. With DCD 207 males and 123 females	Motor	MABC-2; WPPSI-III	In this study, 330 children met the criteria for DCD. Maternal age, miscarriage, fetal distress during labor, preterm birth, chronic lung disease and new-born pathological jaundice were related with DCD (odds ratio 1.72, 2.72, 9.14, 5.17, 1.43, and 2.54, respectively). These risk factors may provide clues to an ethology of DCD.

ANT - Amsterdam neuropsychological task; CBCL - child behaviour checklist for preschoolers; CCMS - Columbia mental maturity scale; DCD - developmental coordination disorders; DWA - developmental wellbeing assessment; MABC-2 - movement assessment battery for children; PEDI - pediatric evaluation of disability inventory; PQLQ - pediatric quality of life questionnaire; QLDCQ - little developmental coordination questionnaire; SLS - single leg stance test; SDQ - strengths and difficulties questionnaire; WPPSI-III - Wechsler preschool and primary scale of intelligence (3th edition).

more likely to have DCD. In the study,[24] the preterm children are more likely to have DCD compared with full-term children (odds ratio 5.17; 95% confidence interval 3.39-7.88). In another study,[26] 32% of very preterm children compared with 11% full-term children have motor impairment (≤ 15th percentile, p = 0.001.

Other authors,[32] reported scores of 89(27%) ≤ 15th and 54 (16%) ≤ 5th percentile on MABC-2, and this study found that the neurological examination at 2 years of age is poorly predictive of motor difficulties at 4.5 years of age as detected by the MABC-2. In another study,[25] preterm children showed worse performance compared with full-term children in all tests, 29.1% of the preterm group and 6.5% of the term group scored in the MABC-2 with a p = 0.002.The articles refer to the fine task of motor coordination as the main problem, and this reflects in daily activities at home and at kindergarten, additionally showing differences according to genders.[32] The balance shows differences between the preterm group and the term group,[25,26] which can have influences in many activities in preschool, such as physical activity, motor planning, and speed.

At ages 3 to 6 years-old, manual skills and balance have an important development because of the maturational process, accompanied by the different and various numbers of experiences and motor activities that children go through as they become more autonomous. The coordination between upper limbs, vision, and lower limbs also present a clear development, enabling the child to perform better visual-motor coordination tasks. The development of these relations depends on the variety and quantity of activities that the child experiences, namely those that involve the exploration of space. According to the literature, children with DCD or those who are at risk of DCD, perform fewer exploring activities.[9] Due to the loss of balance, they fall many times,[24] and they also have difficulty in fine motor tasks. In other words, skill difficulties imply less motor participation, which results in more and higher skill difficulties.

The literature consistently states the existence of greater risk of DCD in preterm children, mainly in the very preterm.[33] The number of late preterm infants has increased, and they show some potential risk of DCD. The most likely explanation is the level of maturity of the neurological structure,[10,34] the environment,[19] and some articles discuss the sociocultural views and families. This can be reflected in the child development and on their opportunity to experience. Other tools were used besides the MABC-2 to assess different domains, e.g. cognitive, academic performance, social, and behavioral domains.

All of the articles in the systematic review found differences in preterm children compared with full-term children.[25,26,28] It is recognized that preterm children compared to full-term children present a greater prevalence of DCD (the group of so-called late preterm children are still not studied very much). With this prevalence, early recognition is extremely important, so that it is possible to implement evaluation programs and insert these cases to individually outline the appropriate strategies.

This study may suggest future areas of research to understand the lifelong implications these children will have, more specifically those concerning the adjustment, according to the problems found, to organize the admission of children in school education, and help the family and teachers in the educational plans.

The main limitation of this study was that some of the presented studies neither include children from the entire age band nor have the results of each domain, most of them having only the total score points, and we found it to be heterogeneous in terms of study design. In this review, we have a small number of studies, consequently we must be careful in inferring the results. This systematic review highlights the relation between prematurity and DCD, assessed by the MABC-2 band 1, from 3 to 6 years-old.

The differences between very preterm children and late preterm children need more studies to be conducted because the results are not currently conclusive in the parameter of the main differences. The results show a great tendency for disorder in fine motor tasks, which is more present in manual dexterity.

Considering the evidence found in recent years, very preterm infants are more susceptible to having DCD. However, moderate and later preterm infants need research studies to be conducted that add more information regarding the impact on motor performance. Therefore, early intervention is necessary to plan the specific strategies in order to minimize the difficulties of motor coordination during the child's development.

WHAT THIS STUDY ADDS

- This study strengthens MABC-2 band 1 usefulness as a tool for detecting and assessing developmental coordination disorder in preschoolers.
- It reinforces, at an earlier age, the possibility of predicting the risk for developmental coordination disorder, considering the total score of MABC-2 band 1, the respective percentile.
- It highlights the importance of implementing an adequate intervention program in order to overcome motor difficulties and to prepare preschoolers for a pleasant participation in daily life routines and school activities.

Conflicts of Interest

The authors declare that there were no conflicts of interest in conducting this work.

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There were no external funding sources for the realization of this paper.

Protection of human and animal subjects

The authors declare that the procedures followed were

in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Provenance and peer review

Not commissioned; externally peer reviewed

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Revisão Sistemática Sobre o Desempenho da Bateria de Avaliação do Movimento na Avaliação Pré-Escolar de Prematuros

Introdução: Crianças nascidas antes das 38 semanas de gestação são consideradas pré-termo. Segundo a Organização Mundial da Saúde, existem vários subgrupos de acordo com a idade gestacional e vários riscos têm sido descritos relacionados com a prematuridade. A prematuridade pode causar alterações no desempenho motor e particularmente, ao nível mais específico, na coordenação motora. O objetivo deste estudo, foi uma revisão sistemática sobre o desempenho da bateria de avaliação do movimento e a perturbação do desenvolvimento da coordenação na idade pré-escolar em recém-nascidos prematuros.
Métodos: Quatro bases de dados (PubMed, ScienceDirect, Web of Science, Scopus) foram sistematicamente investigadas e para publicações entre 2008 e 2016 apenas foram incluídas as que utilizaram a bateria de avaliação do movimento banda 1. Todos os estudos apresentaram resultados com menor desempenho, em crianças prematuras. Três autores avaliaram de forma independente a elegibilidade dos estudos.
Resultados: Foram encontrados 236 artigos, sendo selecionados 15 artigos de acordo com os critérios incluídos na pesquisa. Apenas sete artigos foram selecionados após a aplicação dos critérios de elegibilidade.
Discussão: A bateria de avaliação do movimento banda 1 mostrou que as crianças prematuras apresentam maior risco de alterações na coordenação motora, resultando num menor desempenho na idade pré-escolar e, consequentemente, dificuldades nas rotinas diárias em casa e na escola, relativamente às crianças que nasceram de termo. É fundamental que as dificuldades motoras sejam detetadas o mais cedo possível, para que possam ser atenuadas ou mesmo eliminadas durante a transição para a escola.

Palavras-Chave: Desenvolvimento da Criança; Destreza Motora; Pré-Escolar; Movimento; Perturbações das Habilidades Motoras; Perturbações do Movimento; Recém-Nascido Prematuro; Reprodutibilidade dos Testes; Revisão Sistemática como Assunto