Psychometric analysis of items of Assessment of Motor Coordination and Dexterity (Acoordem) for 4-year-old children

ORIGINAL ARTICLE

Análise psicométrica dos itens da Avaliação da Coordenação e Destreza Motora (Acoordem) em crianças de 4 anos

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ABSTRACT: The Assessment of Motor Coordination and Dexterity - ACOORDEM is a standardized motor assessment for Brazilian children aged 4-8 years. This study aimed to investigate the validity and reliability of the test for 4-year-old children. Eighty children of 4 years old, divided into equal groups by sex and school type (public or private), were evaluated. Parents and teachers also answered the questionnaires. The retest was applied to 10 participants. Few items showed a statistically significant difference associated with sex and school type. The test-retest reliability presented good indexes. ACOORDEM is suitable for the motor assessment of 4-year-old children; however, some items need to be revised or discarded to improve the instrument reliability and reduce the administration time.

KEYWORDS: Motor skills disorders; Child; Child, preschool; Reproducibility of results; Evaluation.

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RESUMO: A Avaliação da Coordenação e Destreza Motora - ACOORDEM é um teste motor criado para crianças brasileiras de 4 a 8 anos. O objetivo desse estudo foi investigar a validade e confiabilidade da ACOORDEM para crianças de 4 anos. Foram avaliadas 80 crianças, divididas em grupos iguais por sexo e tipo de escola. Os pais e professores também participaram da pesquisa respondendo questionários. O reteste foi feito com dez participantes. Poucos itens apresentaram diferença estatisticamente significativa associada ao sexo e tipo de escola. A confiabilidade teste reteste apresentou bons índices. A ACOORDEM é adequada para avaliação motora de crianças de 4 anos, contudo alguns itens necessitam ser revisados para melhorar a confiabilidade do instrumento e reduzir o tempo de aplicação.

DESCRITORES: Transtornos das habilidades motoras; Criança; Pré-escolar; Reprodutibilidade dos testes; Avaliação.

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INTRODUCTION

Motor evaluation can identify changes in motor performance, enabling the provision of proper support to children and their families to reduce the impact of difficulties in motor skills on daily routine and school activities. It is important to detect such difficulties early, preferably before starting the primary school, to minimize the effects of these difficulties on the academic performance and socialization[1]. On the other hand, when deficits on motor performance are observed in preschool children, there is no consensus in the literature on whether the evaluation outcome characterizes a disorder, such as the Developmental Coordination Disorder (DCD), or a developmental delay caused by lack of opportunities to experiment and practice motor activities that increase the motor repertoire and, consequently, support a good performance in the evaluations[2].

There are tests with good psychometric qualities for motor performance evaluation[1,3] that present various characteristics, covering the development of motor skills from birth to adolescence. However, all of them were developed abroad, so they have to be translated, adapted and investigated in terms of validity and reliability for Brazilian children. The Movement Assessment Battery for Chidren-2 (MABC-2) has been recently translated and presented good reliability with Brazilian children[4]; however, the test still has obstacles to clinical application such as high cost of importation and difficulty to replace the test's materials.

It should be noted that the main motor performance tests do not include relevant activities to the school context that require motor performance, such as writing and participation in classroom tasks. For this reason, criterion B of the Diagnostic and Statistical Manual of Mental Disorders-5 (DSM-5) [5] for the diagnosis of DCD is not always evaluated. Criterion B specifies that such diagnosis is only relevant if motor difficulties (criterion A), without adaptation, have an impact on the academic performance. The evaluation of handwriting skills is especially important, as it is one of the most frequent intervention goals for these children[6], since handwriting difficulty can impair academic performance, with impact on self-esteem, personal relationships and on the perceptions of the child and others of the child's skills[7].

Given the difficulties to access imported tests and the absence of standardized motor assessment for the Brazilian children, in particular tests that include all diagnostic criteria for DCD, the Assessment of Motor Coordination and Dexterity (ACOORDEM, from the acronym in Portguese)[8] was created. ACOORDEM is a descriptive test for motor diagnosis of children aged 4 to 8 years, also aiming at being an evaluative instrument to measure changes over time as a result of intervention[9]. The test development process was based on the International Classification of Functioning, Disability and Health[10,11], and studies on the validity and reliability of the instrument for children aged 6 to 8 years have already been conducted[9,11,12,13].

ACOORDEM is comprised of items to assess aspects of motor and functional development that are relevant to social participation and school performance. Besides the motor coordination assessment items and the questionnaires for parents and teachers, ACOORDEM includes two writing tests – copy of the alphabet and simple sentence – that assess aspects such as speed and legibility and also register the pencil grasp pattern, classified according to the ten patterns described by Schneck and Henderson[14]. Although there is no consensus in the literature about the influence of different pencil grasp patterns in the quality of handwriting[15], a higher frequency of atypical patterns is observed among children with motor coordination disorders[16]. Then, it is important to record the pencil grasp patterns observed in Brazilian children, as they may contribute to motor disorder diagnosis.

This study continues the ACOORDEM's development process and has the following objectives: (a) to investigate the test-retest reliability of this instrument; (b) to identify factors that may influence the validity, investigating if significant differences are observed in the ACOORDEM performance related to sex and school type; (c) to establish preliminary standards of motor performance for Brazilian children aged 4 years old; and (d) to describe pencil grasp patterns observed in the writing tests of ACOORDEM.

METHODOLOGY

Participants

The participants of this study were 80 children aged 4 years old, randomly recruited from three public schools (40 children) and seven private schools in Belo Horizonte (40 children), with an equal number of male and female students. The sample calculation was based on a prior study on ACOORDEM[12], which calculated that, for an effect size of 0.32 and statistical power of 0.90, a sample of 62 children by age group would be required.

Inclusion criteria were: 4-year-old children, of both sexes, born full-term, in primary school, with no sign of motor, visual, hearing and/or cognitive disorder, whose parents or guardians had concluded the primary and middle school and the teachers of the children agreed to participate in the study. Children wearing glasses for visual correction were included, but not the ones requiring hearing aids. Children born before 37 completed weeks of pregnancy and birth weight under 2,500 grams, in specialized motor therapy, with history of school failure/grade repetition, and with signs of cognitive deficit were excluded.

The parents or guardians and the teachers of all participants signed an Informed Consent Form. This study was approved by the Research Ethics Committee of UFMG (protocol nº ETIC 0647.0.203.000-10) on March 23, 2011.

Instruments

The purpose of ACOORDEM is to detect difficulties in motor coordination in children aged 4 to 8 years. The test is subdivided in the following areas: (1) Manual Coordination and Writing Skills (16 items), (2) Body Coordination and Motor Planning (26 items), and (3) Participation in Home and School Activities (questionnaire for parents with 54 items and for teachers with 30 items); some observational items are duplicated (e.g., right and left leg balance), totaling 60 items for the ages of 6 to 8 years. Some tests were altered or deleted for children aged 4 years old to adjust the test complexity to the age. Writing tests for preschool children were adapted to include a copy of simple geometric figures and vowels, instead of a copy of the alphabet and one sentence, as proposed for children aged 6 to 8 years. Then, the test for children aged 4 years old has 51 items. Areas (1) and (2) are comprised of tests performed by children considering the time or acuity of task execution. During the writing tests, execution time and pencil grasp pattern were recorded. Regarding the questionnaires, the questionnaire for parents is divided into four subscales: mobility, daily life activities, student role, and behavior. The questionnaire for teachers is divided into two subscales: motor and behavior. Answers provided on both questionnaires are scored on a four-point scale recorded in frequency, ranging from 1 = rare/never to 4 = always.

Although ACOORDEM is still in development, prior studies have reported good reliability indexes for the ages of 6 to 8 years 9,11,12,13. The average time of test application is approximately 60 minutes.

The Columbia Mental Health Maturity Scale (CMMS) is a test validated for Brazilian children[17] that aims to provide an estimate of the intellectual ability of children of mental age of 3 years and 11 months to 9 years and 11 months. The reasoning ability is evaluated through nonverbal responses, using cards with drawings. This test was used to exclude children with signs of intellectual disability.

Procedures

For sample selection, children were drawn in each school classroom, followed by sending the envelopes to the parents containing the Informed Consent Form, a brief questionnaire about the child's developmental history, ACOORDEM parents´ questionnaire and the CCEB (Criteria Brazil for Economic Classification). The children who met the inclusion criteria participated in the study. They were evaluated with MABC-2, CMMS and ACOORDEM at their school facilities, at times defined by the teachers. Children were invited to the assessment room in pairs, as this strategy increased collaboration and retention in the test room, but the assessment was performed individually. During the handwriting tests, children's hands were photographed to record their pencil grasp pattern. The evaluations were conducted on two days, with sessions of 40 to 60 minutes.

Before data collection, the examiners were trained on MABC-2 and ACOORDEM. To investigate the test-retest reliability of ACOORDEM, 10 children, among the total 80 children who participated in the study, were selected after convenience sampling in different schools. The selection of these children considered the time availability, the space in the schools, and the possibility to schedule the reevaluation 7 to 14 days after the first evaluation. The Intraclass correlation coefficient (ICC) (2.1) consistency was used to measure the test-retest reliability, with interpretation according to CICCHETTI[18]: poor correlation (<0.40), moderate correlation (between 0.40 and 0.59), good correlation (between 0.60 and 0.74) and excellent correlation (>0.75). However, when considering the difficulty to achieve an absolute agreement for the quantitative variables measured in terms of time in seconds and number of errors, the paired t-student test was used to evaluate the test-retest reliability of these variables.

The statistical program SPSS, version 17.0, was used for data analysis. The sample description (age, sex, school type, economic classification, test scores and pencil grasp pattern) was performed in frequency,

mean, and standard deviation. ANOVA was used to compare quantitative variables regarding sex (female and male) and school type (public and private). The Mann-Whitney test was used to compare the qualitative variables. In all analyzes, alpha significance level of 0.05 was considered.

RESULTS

Of all 145 envelopes distributed, 98 returned to the schools. Of these, 80 were included in the sample. Of the 18 excluded children, 16 parents did not meet the education level criteria, one was a premature child and one did not score enough in the CMMS.

The 80 children evaluated presented mean age of 54.0 (±0.7) months and mean birth weight of 3.210 (±99) grams. Regarding the dominant hand, 88.8% were right-handed. Regarding the CMMS, no statistically significant difference was observed when comparing the performance between sexes (p=0.506), but children from private schools presented higher score than those from public schools (p = 0.016).

Table 1 – Quantitative and qualitative items of ACOORDEM

Manual coordination and motor skills		**Bilateral coordination and motor planning**	
Quantitative items	**Qualitative items**	**Quantitative items**	**Qualitative items**
Insert pin in wood – preferred hand §	Copy of figures – square ¢	Grab a sand bag ¢	Drums 1¢
Insert pin in wood – non-preferred hand §	Copy of figures – X ¢	Bounce a ball 20 cm ¢	Drums 2¢
Change pins in line – preferred hand §	Copy of figures – fish ¢	Grab a ball on the wall ¢	Drums 3¢
Change pins in line – non-preferred hand §	Copy of figures – 3 crossed lines ¢	Square labyrinth – preferred hand §	Drums 4 ¢
Stitch §	Copy of figures – circle/open square ¢	Square labyrinth – non-preferred hand §	Hopscotch 2 lateral feet ¢
Insert coins in safe box – preferred hand §	Copy of figures – 3 circles ¢	Tree labyrinth – preferred hand §	Hopscotch 1221¢
Insert coins in safe box – non-preferred hand §	Copy of figures – circle and triangle ¢	Tree labyrinth – non-preferred hand §	Hopscotch 12112¢
Distribute cards §	Copy of figures - horizontal lozenge ¢	Prone extension – time £	Jumping jack ¢
Thumb of preferred hand §		Supine flexion – time £	Prone extension acuity ¢
Thumb of non-preferred hand §		Balance OAD £	Supine flexion acuity ¢
Straight line #		Balance OAE £	
Curved line #		Balance OFD £	
Copy of figures – total score ¢		Balance OFE £	
Copy of symbol §		Total circuit time §	
Copy of vowels §		Tandem gait – number of steps ¢	
Straight cutting – 4 years old #		Rabbit number of leaps ¢	
Curve cutting – 4 years old #			

Note: § = time in seconds: lower score, better performance; £ = time in seconds: higher score, better performance; # = number of errors: lower score, better performance; ¢ = number of successes: higher score, better performance.

Table 2 – Mean values and comparison of quantitative items of ACOORDEM – Manual coordination and motor skills – by sex and school type

	Female	Male	p value	Private school	Public school	p value
	Mean (Standard deviation)	Mean (Standard deviation)		Mean (Standard deviation)	Mean (Standard deviation)	
Insert pin in wood – preferred hand §	22.6 (5.00)	23.3 (6.5)	0.604	23.1 (6.60)	22.8 (4.80)	0.839
Insert pin in wood – non-preferred hand §	27.4 (7.00)	28.8 (7.20)	0.405	26.8 (6.60)	29.4 (7.50)	0.136
Change pins in line – preferred hand §	28.8 (6.20)	32.4 (8.20)	0.054	30.0 (7.70)	31.4 (7.20)	0.457
Change pins in line – non-preferred hand §	33.1 (6.00)	36.2 (7.30)	0.112	34.6 (7.40)	34.7 (6.00)	0.961
Stitch §	52.7 (26.0)	46.3 (18.60)	0.242	45.6 (20.60)	53.2 (24.20)	0.168
Insert coins in safe box – preferred hand §	9.55 (3.17)	9.31 (3.51)	0.749	8.89 (2.48)	9.93 (3.92)	0.175
Insert coins in safe box – non-preferred hand §	11.0 (4.20)	9.6 (2.60)	0.094	10.0 (2.50)	10.6 (4.30)	0.511
Distribute cards §	24.4 (7.70)	31.6 (11.60)	**0.002**	27.8 (9.70)	27.9 (11.1)	0.975
Thumb of preferred hand §	17.1 (6.70)	21 (10.20)	0.064	20.5 (10.20)	17.4 (6.70)	0.154
Thumb of non-preferred hand §	19.5 (9.80)	22.3 (12.40)	0.308	21.8 (12.30)	20.0 (10.10)	0.507
Straight line #	4.3 (5.23)	5.25 (6.77)	0.485	4.63 (6.40)	4.93 (5.72)	0.826
Curved line #	16.3 (12.30)	17.3 (11.50)	0.695	16.1 (10.3)	17.6 (13.3)	0.576
Copy of figures – total score ¢	1.55 (1.26)	1.53 (1.15)	0.927	1.8 (1.34)	1.28 (0.99)	**0.05**
Copy of symbol §	18.7 (7.10)	23.8 (9.40)	**0.009**	20.3 (8.90)	22.2 (8.40)	0.349
Copy of vowels §	20.7 (5.70)	24.4 (12.0)	0.083	21.8 (8.70)	23.3 (10.40)	0.478
Straight cutting – 4 years old #	1.54 (2.34)	1.59 (2.07)	0.921	1.49 (1.80)	1.66 (2.57)	0.744
Curve cutting – 4 years old #	4.77 (4.23)	6.94 (6.37)	0.096	4.22 (3.59)	7.57 (6.56)	**0.009**

Note: § = time in seconds: lower score, better performance; # = number of errors: lower score, better performance; ¢ = number of successes: higher score, better performance. Bold numbers indicate significant difference.
Source: Study data.

The comparative results of ACOORDEM regarding sex and school type are specified by subareas of the test. Table 1 presents the quantitative and qualitative variables. Tables 2 and 3 show, respectively, a comparison of ACOORDEM quantitative items in the motor coordination and dexterity subarea, and in the subarea of bilateral coordination and motor planning. Table 4 shows the qualitative items of the ACOORDEM.

When comparing the performance in relation to sex, only three items (5.9%) (highlighted in Tables 2 and 4) of total 51 items applied to 4-year-old children showed a statistically significant difference, with female children presenting better performance in the three items.

Table 3 – Mean values and comparison of quantitative items of ACOORDEM – Bilateral coordination and motor planning – by sex and school type

Quantitative items of ACOORDEM	Sex			School type		
	Female	Male	p value	Private	Public	p value
	Mean (Standard deviation)	Mean (Standard deviation)		Mean (Standard deviation)	Mean (Standard deviation)	
Grab a sand bag ¢	2.30 (1.40)	2.45 (1.45)	0.639	2.33 (1.38)	2.43 (1.47)	0.755
Bounce a ball 20 cm ¢	1.83 (1.69)	2.08 (1.82)	0.526	1.93 (1.79)	1.98 (1.73)	0.899
Grab a ball on the wall ¢	0.03 (0.16)	0.10 (0.44)	0.315	0.05 (0.32)	0.08 (0.35)	0.738
Square labyrinth – preferred hand §	5.73 (2.08)	6.76 (4.44)	0.207	6.34 (3.97)	6.14 (2.94)	0.804
Square labyrinth – non-preferred hand §	5.73 (2,38)	5.86 (3.73)	0.853	5.61 (2.71)	6.0 (3.51)	0.588
Tree labyrinth – preferred hand §	14.2 (5.40)	13.4 (4.80)	0.56	13.8 (4.80)	13.8 (5.40)	0.299
Tree labyrinth – non-preferred hand §	15.1 (7.80)	14 (5.30)	0.532	15.5 (8.10)	13.6 (4.60)	0.248
Prone extension – time £	14.0 (9.00)	11.1 (8.10)	0.142	12.2 (8.90)	12.9 (8.50)	0.744
Supine flexion – time £	10.28 (7.60)	8.0 (6.44)	0.171	9.32 (7.75)	8.92 (6.42)	0.808
Balance OAD £	8.08 (6.04)	6.43 (5.89)	0.22	6.3 (4.70)	8.2 (6.97)	0.157
Balance OAE £	5.43 (3.85)	6.43 (5.95)	0.375	5.58 (4.60)	6.28 (5.42)	0.535
Balance OFD £	2.4 (1.03)	2.2 (1.26)	0.441	2.15 (0.83)	2.45 (1.40)	0.247
Balance OFE £	2.69 (2.07)	2.03 (1.22)	0.087	2.47 (1.97)	2.25 (1.46)	0.569
Total circuit time §	29.1 (7.90)	27.4 (10.3)	0.394	28.5 (8.20)	28.0 (10.0)	0.789
Tandem gait – number of steps ¢	3.4 (3.69)	2.3 (2.29)	0.113	2.98 (2.89)	2.73 (3.34)	0.721
Rabbit number of leaps ¢	4.18 (1.15)	3.68 (1.47)	0.095	3.98 (1.49)	3.88 (1.18)	0.741

Note: § = time in seconds: lower score, better performance; £ = time in seconds: higher score, better performance; # = number of errors: lower score, better performance; ¢ = number of successes: higher score, better performance. Bold numbers indicate significant difference.
Source: Study data.

When comparing the performance in relation to school type, a statistically significant difference was observed in seven items (13.7%) (highlighted in Tables 2 and 4). In these items, children from private schools presented a better performance than children from public schools. Tables 2 to 4 show that some items received a minimum score, indicating that they were very difficult for the sample.

Regarding the test-retest reliability of the quantitative items, the score of 10 (30.3%) of the 33 items – "thumb of preferred hand" (p=0.008), "thumb of non-preferred hand" (p=0.001), "straight cutting" (p=0.049), "tennis ball grabbing with preferred hand" (p=0.001), "square star labyrinth with preferred hand" (p=0.009), "square star labyrinth with non-preferred hand" (p=0.003), "tree complex labyrinth with preferred hand" (p=0.001), "tree complex labyrinth with non-preferred hand" (p = 0.046), "total time circuit" (p=0.005), "rabbit leap number" (p=0.001) – showed a statistically significant mean difference for the application on both occasions. The other items presented similar mean values in the test-retest. In the qualitative items, the ICC identified that 17 (94.4%) of the 18 items presented moderate to excellent reliability, with rates varying from 0.47 to 0.98. Only one item, "drums 1" (p=0.102), presented poor reliability.

Table 4 – Description and comparison of qualitative items of ACOORDEM – by sex and school type.

Qualitative items of ACOORDEM	Sex					School type				
	Female		Male		p value	Private		Public		p value
	Mean (Standard deviation)	Median	Mean (Standard deviation)	Median		Mean (Standard deviation)	Median	Mean (Standard deviation)	Median	
Manual coordination and motor skills										
Copy of figures – square ¢	0.80 (0.41)	1.0	0.72 (0.46)	1.0	0.397	0.78 (0.42)	1.0	0.74 (0.44)	1.0	0.745
Copy of figures – X ¢	0.13 (0.33)	0.0	0.30 (0.46)	0.0	0.057	0.25 (0.44)	0.0	0.18 (0.38)	0.0	0.415
Copy of figures – fish ¢	0.23 (0.42)	0.0	0.05 (0.22)	0.0	**0.024**	0.18 (0.38)	0.0	0.10 (0.30)	0.0	0.333
Copy of figures – 3 crossed lines ¢	0.00 (0.0)	0.0	0.03 (0.16)	0.0	0.317	0.03 (0.15)	0.0	0.00 (0.00)	0.0	0.317
Copy of figures – circle/ open square ¢	0.28 (0.45)	0.0	0.23 (0.42)	0.0	0.608	0.33 (0.47)	0.0	0.18 (0.38)	0.0	0.124
Copy of figures – 3 circles ¢	0.10 (0.30)	0.0	0.15 (0.36)	0.0	0.502	0.18 (0.38)	0.0	0.08 (0.27)	0.0	0.179
Copy of figures – circle and triangle ¢	0.03 (0.16)	0.0	0.08 (0.27)	0.0	0.308	0.08 (0.27)	0.0	0.03 (0.16)	0.0	0.308
Copy of figures – horizontal lozenge ¢	0.03 (0.16)	0.0	0.00 (0.0)	0.0	0.317	0.03 (1.34)	2.0	0.00 (0.0)	0.0	0.317
Bilateral coordination and motor planning										
Drums 1¢	2.03 (0.89)	2.0	2.25 (0.87)	3.0	0.251	2.33 (0.83)	3.0	1.95 (0.90)	2.0	0.061
Drums 2¢	2.15 (0.97)	3.0	2.20 (0.91)	3.0	0.871	2.33 (0.88)	3.0	2.03 (0.97)	2.0	0.166
Drums 3¢	1.40 (0.77)	1.0	1.33 (0.62)	1.0	0.985	1.53 (0.78)	1.0	1.20 (0.56)	1.0	**0.022**
Drums 4 ¢	1.97 (0.98)	2.0	1.95 (0.99)	1.5	0.912	2.30 (0.94)	3.0	1.62 (0.90)	1.0	**0.002**
Hopscotch – 2 lateral feet ¢	2.30 (0.64)	2.0	2.38 (0.70)	2.5	0.525	2.45 (0.67)	3.0	2.23 (0.66)	2.0	0.105
Hopscotch 1221¢	1.78 (0.80)	2.0	1.80 (0.82)	2.0	0.909	2.00 (0.85)	2.0	1.58 (0.72)	1.0	**0.022**
Hopscotch 12112¢	1.83 (0.78)	2.0	1.68 (0.83)	1.0	0.333	1.98 (0.83)	2.0	1.53 (0.72)	1.0	**0.013**
Jumping jack ¢	1.25 (0.54)	1.0	1.30 (0.61)	1.0	0.111	1.30 (0.61)	1.0	1.05 (0.22)	1.0	**0.021**
Prone extension acuity ¢	1.88 (0.68)	2.0	1.78 (0.66)	2.0	0.348	1.78 (0.66)	2.0	1.83 (0.67)	2.0	0.790
Supine flexion acuity ¢	2.14 (0.85)	2.0	2.08 (0.86)	2.0	0.304	2.08 (0.86)	2.0	1.97 (0.69)	2.0	0.688

= number of errors: lower score, better performance; ¢ = number of successes: higher score, better performance. Bold numbers indicate significant difference.
Source: Study data.

Regarding pencil grasp patterns, of the ten patterns described in the literature[16], six were identified in this sample: palmar supinate pattern 1.3%, crossed thumb 1.3%, static tripod in 3.8%, four fingers 28.8 %, lateral tripod 27.5%, dynamic tripod 21.3%, and other types 16%. When analyzing the school type, 45% of the children from public schools presented a mature grasp pattern, that is, lateral tripod or dynamic tripod, compared with 52.5% of the children from private schools. Regarding the children's sex, 55% of boys presented mature grasp patterns, while only 42.5% of girls presented these patterns.

DISCUSSION

In the application of ACOORDEM to 4-year-old children, the test maintained the quality presented in the studies conducted with children aged 6 to 8 years. The test was well accepted by children, many items presented acceptable test-retest reliability indexes, with a small influence of sex and school type on motor performance.

Considering prior studies on ACOORDEM[12,13], when comparing motor performance by sex in younger children, a decrease in items with a significant

statistical difference was observed. At 7 and 8 years of age, differences were observed in 11 items[12], and at 6 years old, in nine items[13]. In this study, only three items presented a statistically significant difference. Younger children are acquiring motor skills and, therefore, it is difficult to differentiate motor behavior based on their sex. In a study on perceptions of competence and motor development, Valentini[19] also did not find any significant difference in motor performance of boys and girls aged 5 to 10 years. However, the boys showed superiority in object control skills. This difference is greater starting at age 6, when boys present a better performance in motor tasks that require muscular power, while girls are better in tasks that require balance and flexibility[20]. Thus, the findings of this study agree with previous studies on the validity of ACOORDEM indicating that there is no need to create normative tables differentiated by sex.

In the comparison of motor performance by school type, a reduction in the number of items with a statistically significant difference was also observed when compared with prior studies on ACOORDEM. However, the performance of children from private schools remained higher than that of children from public schools, as observed in prior studies on ACOORDEM[12,13], which seems to be influenced by environmental issues. Environmental factors may have influenced this result, since private schools offer a higher number of different motor activities such as ballet, swimming, basketball and soccer. Santos et al.[21], when investigating the fine and gross cognitive and motor skills of preschool children enrolled in public and private day care centers in the countryside of São Paulo, also found a statistically significant difference for the three skills investigated, with children from private schools presenting a better performance. This difference in motor behavior was attributed to environmental stimulus at school and at home, since the physical structure and stimulation possibilities of children from private schools were greater. Barbosa et al.[22] describe that the classroom breaks are the main moment of physical activities in municipal schools, since there are no other sources of physical activities such as sports and extracurricular activities. Despite these environmental differences, it is important to emphasize that there is no direct relationship between the socioeconomic level and good motor performance, as children of higher social class do not always present a better performance because of their access to different activities and resources[23]. Further studies are required to clarify the relationship among socioeconomic level, environmental factors and motor performance.

Regarding the pencil grasp pattern, a high number of the evaluated children (48.8%) presented mature grasp patterns, mostly lateral tripod (27.5%), followed by dynamic tripod (21.3%). This is an interesting finding, since transitional patterns[14] are expected at this age, such as the grasp using four fingers, which in this study was observed in 28.8% of the children. It suggests that Brazilian children are being encouraged to use the pencil earlier, a fact that requires further investigation. In the literature, the prevalence of dynamic tripod, a pattern that is considered as more ergonomically stable, varies from 33 to 67% in children over 7 years of age and adults[24].

Considering the retest, the analysis of ACOORDEM's quantitative items indicates temporal stability, since 78% of the items presented good consistency. The same applies to the qualitative items, of which 94.4% presented moderate to excellent test-retest reliability. In prior studies, the test-retest reliability of the items of body balance and bilateral coordination/motor sequencing were investigated in children of 4, 6 and 8 years old, obtaining 0.80 in 62.5% of the items, 0.60 to 0.79 in 35% of the items, and above 0.60 in only 45.7% of the items, respectively. It is a similar result to that obtained at 6 years[13] when only 40% of the bilateral coordination and motor planning items obtained good to excellent ICC[9,13].

In this study, the test-retest reliability of the quantitative items was probably higher due to the use of the paired t-student test, since it does not require absolute agreement of the items such as the ICC. In future studies, the raw data should be transformed into standardized scores to be submitted to the ICC. Despite the acceptable indexes found, the time spent to administer the test and the complexity of some items are aspects that still require further analysis.

Considering the test length, ACOORDEM is extensive to be applied to 4-year-old children, since children at this age tend not to be collaborative. The evaluation had to be conducted in pairs to encourage engagement throughout the test application period.

We also detected items of high complexity for the age of 4 years, such as "copies of figures." Amundson[25] reports that 4-year-old children are able to draw horizontal, vertical and diagonal lines, crosses, circles and squares, a skill that is already required in one of the handwriting tests in which children reproduce these symbols. However, the item "copy of figures" requests the reproduction of more elaborate figures, which resulted in poor performance of the analyzed sample, as it was a requirement above what is expected for the age. Then, it is important to define a criterion for interruption, to prevent children of 4 and 5

years old from taking test items for which they have no ability. Other tests, such as the Developmental Test of Visual-Motor Integration (VMI), interrupt the test after three consecutive errors. Other items, such as "Jumping jack," "Bounce a 20 cm ball," "Throw ball to the wall," "Supine flexion – time" and "Prone extension – time," presented very low scores, which also indicates high complexity. Therefore, it is necessary to carefully analyze the score pattern of each item to understand the item suitability to 4-year-old children. A shorter test would facilitate the clinical management of the evaluation.

Regarding study limitations, the schools that comprised the sample were recruited by convenience, not necessarily presenting a representative sample of the school universe in the country. However, the children were recruited by drawing to ensure an equal chance of recruitment in each class in all participating schools.

CONCLUSION

ACOORDEM was shown to be a valid motor test to evaluate the motor coordination and dexterity of 4-year-old Brazilian children. Few significant differences were observed in the performance of ACOORDEM items when comparing sex and school type, suggesting that the standardization process of the test can follow a single normative table, without differentiation by sex or school type, a finding which should be confirmed with the total sample of test´s validation studies. The test-retest reliability of the ACOORDEM items was satisfactory, with most of them presenting good reliability indexes.

Some limitations were evidenced in the ACOORDEM; thus, the adequacy of item complexity and reduction of test application time to preschool children are recommended.

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REFERENCES

1. Piek JP, Hands B, Licari MK. Assessment of motor functioning in the preschool period. Neuropsychol Rev. 2012;22(4):402-13. http://dx.doi.org/10.1007/s11065-012-9211-4.
2. Gottlieb G. The relevance of developmental-psychobiological metatheory to developmental neuropsychology. Dev Neuropsychol. 2001;19(10):1-9. http://dx.doi.org/10.1207/S15326942DN1901_1.
3. Linde BW, Netten JJ, Otten E, Postema K, Geuze RH, Schoemaker MM. A systematic review of instruments for assessment of capacity in activities of daily living in children with developmental co–ordination disorder. Child Care Health Dev. 2015;41(1):23-34. http://dx.doi.org/10.1111/cch.12124.
4. Valentini NC, Ramalho MH, Oliveira MA. Movement Assessment Battery for Children-2: Translation, reliability, and validity for Brazilian children. Res Dev Disabil. 2014;35(3):733-40. http://dx.doi.org/10.1016/j.ridd.2013.10.028.
5. American Psychiatric Association. Manual diagnóstico e estatístico de transtornos mentais: DSM-V. 5a ed. Porto Alegre: Artmed; 2013.
6. Prunty MM, Barnett AL, Wilmut K, Plumb MS. Handwriting speed in children with developmental coordination disorder: are they really slower? Res Dev Disabil. 2013;34(9):2927-36. http://dx.doi.org/10.1016/j.ridd.2013.06.005.
7. Graham S, Weintraub N. A review of handwriting research: Progress and prospects from 1980 to 1994. Educ Psychol Rev. 1996;8:7-87. http://dx.doi.org/10.1007/BF01761831.
8. Magalhães LC, Nascimento VCS, Rezende MB. Avaliação da coordenação e destreza motora- ACOORDEM: etapas de criação e perspectivas de validação. Rev Ter Ocup Univ São Paulo. 2004;15(1):17-25. http://dx.doi.org/10.11606/issn.2238-6149.v15i1p17-25.
9. Cardoso AA, Magalhães LC. Bilateral coordination and motor sequencing in Brazilian children: preliminary construct validity and reliability analysis. Occup ther in. 2009;16(2):107-21. http://dx.doi.org/10.1002/oti.273.
10. Cardoso AA, Magalhães LC, Lacerda TTB, Andrade PMO. Relação entre a Avaliação da Coordenação e Destreza Motora (Acoordem) e a Classificação Internacional de Funcionalidade, Incapacidade e Saúde (CIF). Fisioter Mov. 2012; 25(1):31-4. http://dx.doi.org/10.1590/S0103-51502012000100004.
11. Cury RLM, Magalhães LC. Criação de um protocolo de avaliação do equilíbrio corporal em crianças de quatro, seis e oito anos de idade: uma perspectiva funcional. Rev Bras

Fisioter. 2006;10:346-53. http://dx.doi.org/10.1590/S1413-35552006000300015.

12. Cardoso AA, Magalhães LC. Análise da validade de critério da avaliação da coordenação e destreza motora ACOORDEM para crianças de 7 e 8 anos de idade. Rev Bras Fisioter. 2011;16:16-22. http://dx.doi.org/10.1590/S1413-35552012000100004.

13. Agostini OS, Magalhães LC, Campos AF. Assessment of motor coordination and dexterity of six years old children: a psychometric analysis. Motriz Rev Educ Fís. 2014;20(2):167-76. http://dx.doi.org/10.1590/S1980-65742014000200006.

14. Schneck C M, Henderson A. Descriptive analysis of the developmental progression of grip position for pencil and crayon control in nondysfunctional children. Am J Occup Ther. 1990;44(10):893-900. http://dx.doi.org/10.5014/ajot.44.10.893.

15. Schwellnus H, Carnahan H, Kushki A, Missiuna C, Polatajko H, et al. Effect of pencil grasp on the speed and legibility of handwriting in children. Am J Occup Ther. 2012; 66:718–726. http://dx.doi.org/10.5014/ajot.2012.004515

16. Schneck CM. Comparison of pencil-grip patterns in first graders with good and poor writing skills. Am J Occup Ther. 1991;45(8):701-6. http://dx.doi.org/10.5014/ajot.45.8.701.

17. Alves ICB, Duarte JLM. Padronização Brasileira da Escala de Maturidade Mental Colúmbia. In: Burgemeister BB, Blum LH, Lorge I. Escala de Maturidade Mental Colúmbia – Manual para Aplicação e Interpretação. 3th ed. São Paulo: Casa do Psicólogo; 1993.

18. Cicchetti DV. Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. Psychol Assess. 1994;6(4):284. http://dx.doi.org/10.1037/1040-3590.6.4.284.

19. Valentini NC. Percepções de competência e desenvolvimento motor de meninos e meninas: um estudo transversal. Movimento. 2002;8(2):51-62.

20. Malina RM, Bouchard C, Bor-Or O. Growth, maturation, and physical activity. Champaign Illinois: Human Kinetics; 2004. http://dx.doi.org/10.1249/00005768-199207000-00018.

21. Santos MM, Corsi C, Marques LAP, Rocha NACF. Comparison of motor and cognitive performance of children attending public and private day care centers. Braz J Phys Ther. 2013;17(6):579-87. http://dx.doi.org/10.1590/S1413-35552012005000126.

22. Barbosa SC, Coledam DHC, Neto AS, Elias RGM, Oliveira AR. Ambiente escolar, comportamento sedentário e atividade física em pré-escolares. Rev Paul Pediatr. 2016. http://dx.doi.org/10.1016/j.rpped.2016.01.001.

23. Nascimento Junior JRA, Ferreira L, Vissoci JRN, da Silva, PN, Caruzzo NM, Vieira JLL. Nível socioeconômico e affordances do ambiente domiciliar: implicações para o desempenho motor infantil. Rev Edu Fís/UEM. 2015;25(4):651-62. http://dx.doi.org/10.4025/reveducfis.v25i4.26529.

24. Koziatek SM, Powell NJ. Pencil grips, legibility, and speed of fourth-graders' writing in cursive. Am J Occup Ther. 2003;57:284-8. http://dx.doi.org/10.5014/ajot.57.3.284.

25. Amundson SJ. Prewriting and handwriting skills. In: Case-Smith J. Occupational therapy for children. 5th ed. St Louis, MO: Mosby Elsevier; 2005. p.587-614.

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