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Relationship between motor coordination and executive function in adults and older adults

Relação entre a coordenação motora e a função executiva em adultos e idosos

Relación entre la coordinación motora y la función ejecutiva en adultos y ancianos

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ABSTRACT | Brazilian older adults present a relatively low schooling level when compared with other populations. In clinical practice, defining if more subtle alterations observed in executive function (EF) and motor coordination tests in older adults are due to an initial neurological condition or low schooling level is difficult. This study aimed to evaluate the possible differences in motor coordination and EF between adults and older adults with high and low schooling level as well as the possible correlations between motor coordination and EF in this sample. A total of 75 healthy individuals (aged from 30 to 89 years) were evaluated. EF was assessed by the trail making test (TMT) whereas motor coordination was assessed by the upper limb diadochokinetic test, which is the rapid alternation between supination and pronation of the forearms (right, left, both performing in-phase movements, and both performing anti-phase movements). Analysis of variance showed that age and schooling level possibly influenced EF and motor coordination. Possible relationships between EF and diadochokinesis were calculated by Pearson's correlation. Older adults with low schooling level were significantly slower on the TMT part B (cognitive and motor) and delta TMT (cognitive). All groups were slower performing the anti-phase movement, especially those with low schooling level. Results showed only weak correlations between EF and motor coordination. Age and schooling level influenced executive function and motor coordination. However, the EF and motor coordination tests presented no correlation when these two factors were statistically corrected.

Keywords | Psychomotor Performance; Schooling Level; Cognition; Older Adult; Executive Function.

RESUMO | A população idosa brasileira possui escolaridade relativamente baixa, quando comparada a outras populações. Na prática clínica, torna-se difícil decidir se alterações mais sutis, observadas nos testes de função executiva (FE) e coordenação motora de idosos, devem-se a um quadro neurológico inicial ou à baixa escolaridade. O objetivo do trabalho foi investigar: (1) possíveis diferenças na coordenação motora e FE de adultos e idosos com escolaridade alta e baixa; e (2) possíveis correlações entre coordenação motora e FE nessa amostra. Foram avaliados 75 indivíduos saudáveis, com idade entre 30 e 89 anos. A FE foi avaliada por meio do *trail making test* (TMT) e a coordenação motora foi avaliada com o teste de diadococinesia dos membros superiores, que consiste na alternância rápida entre supinação e pronação do antebraço (direito, esquerdo, de ambos os antebraços em fase, e ambos em antifase). A análise de variância investigou possíveis influências da idade e da escolaridade na FE e coordenação motora. O teste de correlação de Pearson investigou possíveis relações entre FE e diadococinesia. Idosos com escolaridade baixa foram significativamente mais lentos na parte B (cognitivo-motora) e no delta (cognitiva) do TMT. Todos os grupos foram mais lentos na condição antifase, sobretudo os idosos com escolaridade baixa. Encontramos apenas correlações fracas entre FE e coordenação motora. A idade e a escolaridade

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influenciaram na FE e na coordenação motora; porém, os testes de FE e coordenação motora não apresentaram correlação quando esses dois fatores foram corrigidos estatisticamente.
Descritores | Desempenho Psicomotor; Escolaridade; Cognição; Idoso; Função Executiva.

RESUMEN | La población anciana brasileña tiene un bajo nivel educativo en comparación con otras poblaciones. En la práctica clínica es difícil decidir si las alteraciones más sutiles, observadas en pruebas de función ejecutiva (FE) y coordinación motora en ancianos, son provenientes de una condición neurológica inicial o de un bajo nivel educativo. El objetivo de este estudio fue examinar: (1) posibles diferencias en la coordinación motora y la FE de adultos y ancianos con altos y bajos niveles educativos; y (2) posibles correlaciones entre coordinación motora y FE en esta muestra. Se evaluaron a 75 individuos sanos, con edades entre 30 y 89 años. Para la FE se aplicó la Prueba de creación de senderos (TMT en inglés), y la coordinación motora se evaluó con la prueba de diadococinesia de miembros superiores, que consiste en una alternancia rápida entre supinación y pronación del antebrazo (derecho, izquierdo, ambos antebrazos en fase y ambos en antifase). El análisis de varianza analizó las posibles influencias de la edad y la educación en la FE y la coordinación motora. La prueba de correlación de Pearson evaluó las posibles relaciones entre FE y diadococinesia. Los ancianos con bajo nivel educativo fueron significativamente más lentos en la parte B (cognitivo-motora) y delta (cognitiva) de la TMT. Todos los grupos fueron más lentos en la condición antifase, especialmente los ancianos con bajo nivel educativo. Se encontró únicamente correlaciones débiles entre FE y coordinación motora. La edad y el nivel educativo influyeron en la FE y la coordinación motora; sin embargo, las pruebas de FE y de coordinación motora no mostraron correlación cuando estos dos factores fueron corregidos estadísticamente.
Palabras clave | Desempeño Psicomotor; Escolaridad; Cognición; Anciano; Función Ejecutiva.

INTRODUCTION

The Brazilian population is aging and still presents a relatively low schooling level when compared with other countries. According to the Brazilian Institute of Geography and Statistics (IBGE)[1], in 2016, 51% of the population aged 25 years old or older in Brazil had completed at most, elementary education. Moreover, individuals aged over 60 years in the labor market presented, on average, five to seven years of schooling. Thus, a difficulty in clinical practice is defining if more subtle alterations observed in executive function (EF) and motor coordination tests are due to an initial neurological condition or low schooling level.

Executive function is responsible for solving everyday problems, in an integrated and organized way[2]. EF is mediated in the prefrontal cortex, helping individuals to adapt to environmental requirements and can be assessed by the trail making test (TMT). TMT uses sequences of letters and numbers and requires mental flexibility[3], change of direction, and motor agility, as well as in limb diadochokinesis.

According to the literature, EF directly interferes in motor performance[4-6]. Moreover, formal schooling improves individuals' ability to develop strategies to perform tasks[7]. Although the literature presents good age and schooling level classifications for EF, it presents no data for the assessment of motor coordination.

Diadochokinesis is the ability to perform fast and alternating movements in speech or upper limbs[8] and can be tested by quickly alternating pronation and supination movements in the forearms[9]. Clinical neurology, physical therapy, and speech therapy frequently use this method, since it offers greater detail and reliability of the data obtained in relation to other methods to evaluate the coordination of voluntary movements[10].

Diadochokinesis can be performed with one or both hands. Its neural processing involves thalamus, basal ganglia, cerebellum, and brainstem, which bind with other cortical structures[11]. In its divisions, the cerebellum performs an extremely important modulation of voluntary movements and the neocerebellum receives impulses to modulate contraction and muscle tone. This modulation controls muscle activity to perform the planned movement, triggering agonist, antagonist, and synergistic muscles[12].

Daneault et al.[11] evaluated the alternation of fast movements in patients with Parkinson's and Huntington's disease, who presented deficits in the coordination of both hands. Within a population of healthy older adults, Pierce, Cotton, and Perry[8] observed differences in oral diadochokinesis between older adults and even older adults, but they did not assess the motor aspect. In 2010, Haaxma et al.[13] assessed the upper limb diadochokinesis between patients with Parkinson's disease and a control-group. Healthy individuals performed, on average, two more repetitions per limb in comparison with individuals with Parkinson's disease.

The cognitive and motor assessment is extremely important in clinical practice, since it reflects daily activities more accurately[6,14,15]. However, changes in motor coordination typical of aging or due to low schooling levels may be confused with neurological deficits, since diadochokinetic tests for older adults with low schooling level are not standardized. This study aimed to assess the influence of age and schooling level in EF and motor coordination tests and to evaluate possible correlations between motor coordination and EF in this sample.

METHODOLOGY

This is a cross-sectional, observational study, which used a sample calculator provided by the University of British Columbia. Considering an average of 60 seconds for the EF TMT for adults and 120 seconds for older adults and a standard-deviation of 50 seconds, with 0.50 alpha and 0.90 sample power, each subgroup (adults with high schooling level, adults with low schooling level, older adults with high schooling level, and older adults with low schooling level) was composed of 15 participants.

A total of 100 healthy volunteers, aged from 30 to 89 years old, of both sexes, from the university community (professors, students, patient companions, employees) participated in this study. As inclusion criteria, participants should have at least two years of formal study as well as normal vision or vision corrected by lenses. Score below the standardized score according to schooling level, upon the Portuguese version of the Mini-Mental State Examination (MMSE)[16], were the exclusion criteria. Also, volunteers with neurological and/or psychiatric diseases, with speech or cranial nerve disorders, or any dental problem were excluded. A total of 75 participants met all criteria and were evaluated in this study. All participants read and signed an informed consent form. Table 1 presents the participants' profile.

Table 1. Characterization of age and schooling level of the participants

		Age (years old)		Schooling level (years)	
	N	Mean (SD)	Min-Max	Mean (SD)	Min-Max
30–64 years old	47	46.1 (10.6)	30–63	14.9 (4.7)	3–30
65–89 years old	28	74.9 (16.9)	65–89	9.8 (0)	2–24
TOTAL	75	56.6 (16.9)	30–89	13.0 (5.5)	2–30

SD: standard-deviation; Min: minimum value; Max: maximum value.

Procedures

Volunteers answered a brief questionnaire on age, schooling level, and the presence of associated diseases. Later, the MMSE was applied. This test is used in clinical environments for screening cognitive decline and for the follow-up of dementia cases. The score ranges from 0 to 30 and 30 is the best possible score for cognitive ability.

Assessment of executive function with the trail making test

The test was explained to the volunteers and a prior training was offered, with a simplified version of each part. In the part A training, eight circles, numbered from 1 to 8, were arranged on paper and volunteers should connect them as soon as possible, without removing the pen from the paper. In the assessment with TMT part A, volunteers received the same instruction, but they had 25 numbered circles and a time limit[17].

In the part B training, volunteers also had eight circles, four of them numbered from 1 to 4 and four of them with letters A to D, but they should connect them alternately, in ascending order (1-A-2-B-3-C-4-D). In the assessment with TMT part B, volunteers received the same instruction, however, the sequence continued up to 12-L. The test was interrupted when the individual failed to complete within 300 seconds, which was the maximum possible score for each part[17].

The test score was based on the time for concluding. Part A mainly assessed the motor component of the task and part B assessed cognitive and motor components simultaneously. Another measure, delta TMT, was obtained by subtracting TMTA from TMTB. Delta TMT is a measure of the isolated cognitive component, since it eliminates the time spent with the motor component from both tasks[17].

Diadochokinesis assessment

For the upper limb diadochokinesis assessment, volunteers seated in a chair without armrest with their forearms resting on their thighs. In order to exclusively evaluate the right upper extremity, the forearm was placed on the ipsilateral thigh and performed supination and pronation, whereas the other limb was behind the torso. After evaluating the right upper extremity, the left upper extremity performed the same task. Then, in order to assess bilateral movements, the two forearms were placed on the thighs and performed symmetrical or in-phase supination and pronation and, later, asymmetric or anti-phase supination and pronation. Figure 1 shows the positioning of the volunteers and the sequence of tests.

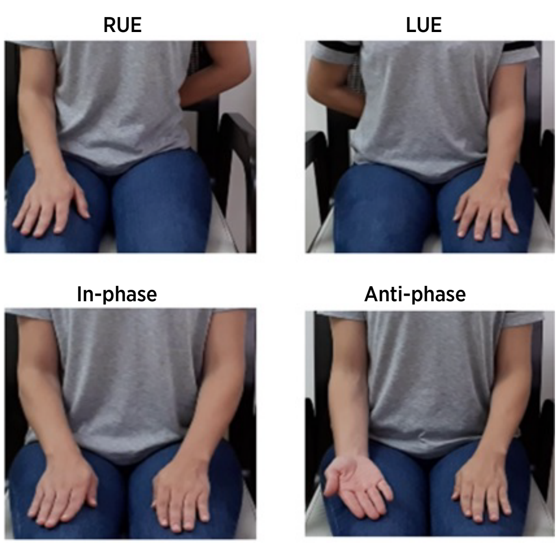

Figure 1. Positioning of the volunteers and the sequence of diadochokinesis tests

RUE: right upper extremity; LUE: left upper extremity; IN-PHASE: upper limbs performing an in-phase or mirrored movement; ANTI-PHASE: upper limbs performing an anti-phase or alternating movement.

All tests were previously performed by the examiner and each participant repeated it a few times (maximum of five repetitions). Tests were recorded by an Android smartphone and images were analyzed with Kinovea® 0.8.26-win32, a free and open-access software. Each part of the test was recorded for 12 seconds. The first two seconds of recording were excluded and the number of repetitions of each complete movement cycle (a supination movement and a pronation movement) were counted in the total of 10 seconds.

Statistical analysis

To assess the influence of age and schooling level on EF and motor coordination, the sample was subdivided in adults (30–64 years old) and older adults (65–89 years old), which were subdivided into two groups: those with low schooling level (2–10 years of schooling) and those with high schooling level (11–30 years of schooling). Thus, four subgroups were created: adults with high schooling level; adults with low schooling level; older adults with high schooling level; and older adults with low schooling level.

The Statistica 13.0 software was used. After the homogeneity and homoscedasticity of the sample were proven, an analysis of variance (ANOVA) compared EF and motor coordination of all groups. The significance level adopted was alpha<0.05. When necessary, a Tukey's post hoc test was used. In order to evaluate possible correlations between performance in EF and diadochokinesis, both with normal distribution, the Pearson's correlation test (r) was used. For analysis, the following convention was adopted: $r>0.6$ (strong correlation), $0.4<r<0.6$ (moderate correlation), and $r<0.4$ (weak correlation). Data were controlled by age and schooling level.

RESULTS

ANOVA showed the influence of age and schooling level on EF ($F_{6.142}=15.047$; $p<0.001$) (Figure 2). The Tukey's post hoc test showed that older adults with low schooling level were significantly slower on the TMT part B and delta TMT than older adults with high schooling level, who, in turn, were slower than adults with low schooling level. The fastest group was adults with high schooling level ($p<0.05$ for all comparisons).

ANOVA showed the influence of age and schooling level on the number of diadochokinetic repetitions ($F_{9,213}=1.298$; $p=0.024$) (Figure 3). The Tukey's post hoc test showed that all groups were slower performing anti-phase movements, especially older adults with low schooling level ($p<0.05$ for all comparisons).

We used the Pearson's correlation test to evaluate correlations between EF and motor coordination. Table 2 presents the correlation coefficients. We found no moderate or strong correlations between EF (TMT) and motor coordination (diadochokinesis).

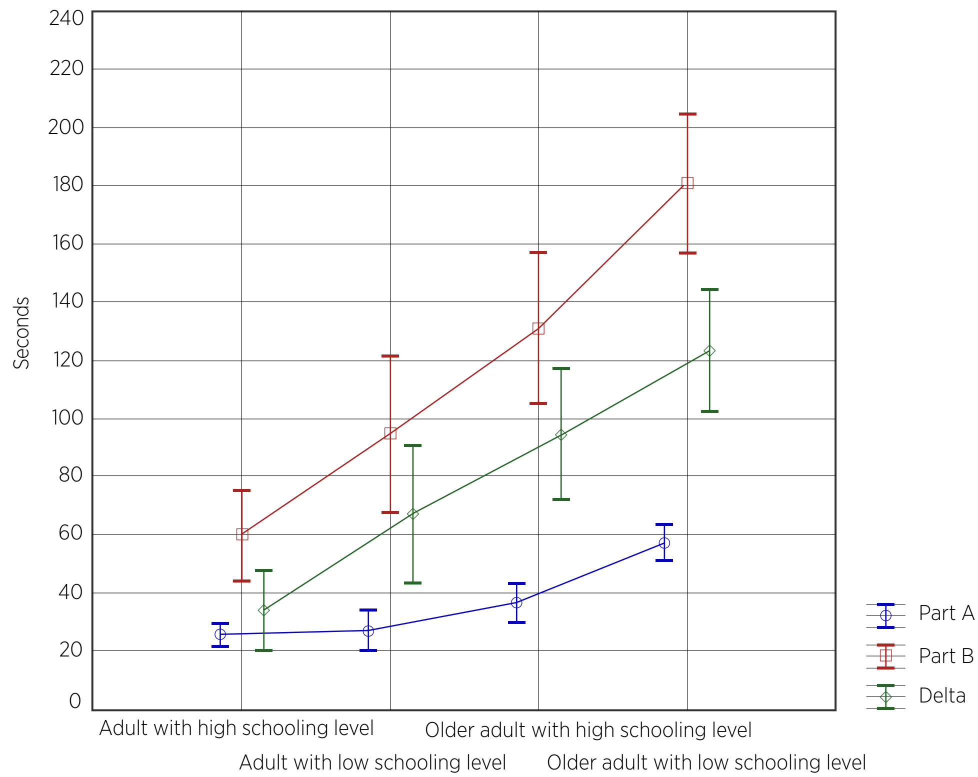

Figure 2. Performance of the four groups on the trail making test parts A and B and delta trail making test

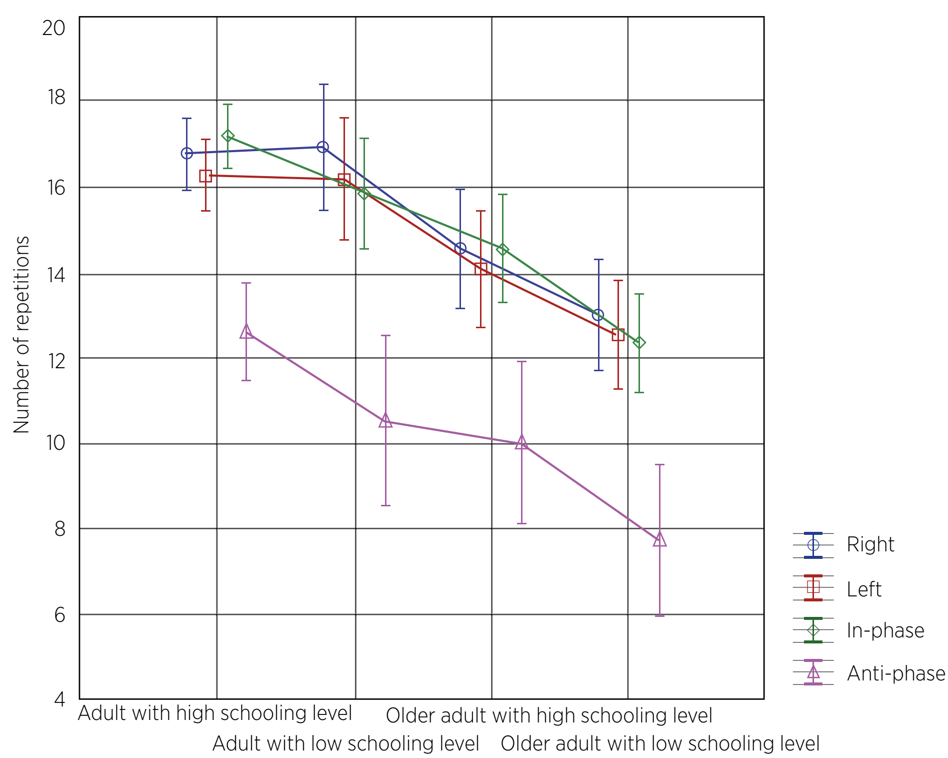

Figure 3. Performance of the four groups in diadochokinetic tests

Figure 3 shows the movement cycles performed in the 10-second right upper limb, left upper limb, in-phase upper limb, and anti-phase upper limb tests.

Table 2. Correlations between executive function tasks and upper limb diadochokinetic tasks.

		TMTA	TMTB	Delta TMT	Right	Left	In-phase	Anti-phase
TMTA	r		*0.532*	0.257	−0.152	−0.141	−0.160	−0.317
	p		*0.001*	0.028	0.200	0.234	0.177	0.006
TMTB	r	*0.523*		**0.955**	−0.242	−0.166	−0.210	−0.327
	p	*0.001*		**0.001**	0.039	0.160	0.075	0.005
Delta TMT	r	0.257	**0.955**		−0.223	−0.140	−0.184	−0.262
	p	0.028	**0.001**		0.058	0.237	0.120	0.025
Right	r	−0.152	−0.242	−0.223		**0.823**	**0.767**	*0.411*
	p	0.200	0.039	0.058		**0.001**	**0.001**	*0.000*
Left	r	−0.141	−0.166	−0.140	**0.823**		**0.803**	*0.450*
	p	0.234	0.160	0.237	**0.001**		**0.000**	*0.001*
In-phase	r	−0.160	−0.210	−0.184	**0.767**	**0.803**		0.389
	p	0.177	0.075	0.120	**0.001**	**0.001**		0.001
Anti-phase	r	−0.317	−0.327	−0.262	*0.411*	*0.45*	0.389	
	p	0.006	0.005	0.025	*0.001*	*0.001*	0.001	

TMTA: trail making test part A; TMTB: trail making test part B; Delta TMT: difference between TMTB and TMTA; r: Pearson's correlation coefficient.
Data in bold represent strong correlation and data in italics represent moderate correlation with p<0.05.

DISCUSSION

EF is a guide for all daily tasks and cognition is one of its components. Individuals often perform automation movements and, when the complexity of a motor task increases, for example, due to the inclusion of a cognitive activity, their performance can be impaired[15]. Our hypotheses are that, in the assessment of motor coordination—as well as in the assessment of EF—an increasing complexity would compromise the performance, and that the performance in motor coordination and EF tasks would be correlated.

In this study, diadochokinesis and EF presented dissociated results, probably because diadochokinesis requires more strategies to control the range, direction, force, or speed of a movement, that is, a motor planning and not specifically cognitive planning, corroborating Daneault et al.[11], who state that diadochokinetic tasks are considered simple enough to practically not to be influenced by cognitive deficits.

The movements assessed in our study do not require large muscle groups or a great synergy among body structures, thus, they are not influenced by deficits in executive functions. Rosado-Artalejo et al.[18] observed that in a Spanish older adult population, some signs of executive dysfunction (including performance in TMTB) are associated with a sedentary lifestyle and inability, increasing sarcopenia in older adults and directly impairing their motor function.

Our data showed that volunteers at an older age and with lower schooling level were slower. It may be due to some physical limitation, but individuals with a better EF, even with some motor limitation, develop strategies to perform the movement: using more strength, more intense use of the proximal joint, among others.

Previous studies support our outcomes regarding the influence of schooling level on EF. Voos[19] assessed EF in adults and older adults and observed that individuals with lower schooling level took longer to learn and to perform tests involving cognitive and motor development. Custodian et al.[14] also observed greater changes in the balance of older adults with low schooling level due to the impairment of the EF influence by the schooling level.

Similarly to Voos, Custódio and Malaquias[20], and Voos et al.[21], we verified that older adults with lower schooling level took longer to perform TMT part B. However, those individuals presented a good performance in the part A. Movement is not always expected to change under cognitive influence, but in the case of TMT, EF was significantly impaired when a cognitive component was added to the motor task, in accordance with Dalton, Sciadas, and Nantel[6], who observed changes in the gait of healthy older adults when adding a cognitive task. This is due to the EF performance in the planning and integration of tasks[2,4].

CONCLUSION

This study assessed the influence of age and schooling level on EF and motor coordination tests and evaluated the correlations between these two variables. The cognitive and motor assessment reflects daily activities in clinical practice. However, changes in motor coordination associated with aging or due to low schooling levels may be confused with neurological deficits, since diadochokinetic tests are not standardized.

Our results showed that age and schooling level influenced EF. Older adults with low schooling level were significantly slower on the TMT part B (cognitive and motor) and delta TMT (cognitive). Age and schooling level also interfered in the number of repetitions in the motor coordination test. However, we found no moderate or strong correlations between EF (TMT) and motor coordination (diadochokinesis).

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