J. Phys. Ther. Sci. 37: 95–101, 2025

The Journal of Physical Therapy Science

Original Article

Relationship between visuospatial working memory and fine and gross motor skills in children with developmental disabilities: a preliminary study

Soma Tsujishita[1)]*, Daiki Nakashima[2)], Kazunori Akizuki[3)], Kosuke Takeuchi[1)]

[1)] *Department of Physical Therapy, Faculty of Rehabilitation, Kobe International University: 9-1-6 Ko-yocho-naka, Higashinada-ku, Kobe-shi, Hyogo 658-0032, Japan*
[2)] *Department of Rehabilitation, Faculty of Health Science, Naragakuen University, Japan*
[3)] *Department of Physical Therapy, Mejiro University, Japan*

Abstract. [Purpose] The relationship between fine and gross motor function and visuospatial working memory in children with autism spectrum disorder remains unclear. This study examined whether visuospatial working memory is associated with gross or fine motor skills in children with developmental disabilities and motor coordination disorders. [Participants and Methods] The study included 30 children with autism spectrum disorder (24 boys and 6 girls; mean age: 9.5 ± 2.2 years) enrolled in child development support and after-school daycare service centers in Osaka Prefecture. Fine motor skills, gross motor skills, visuospatial working memory, and developmental disabilities were assessed. Data were analyzed using Spearman's rank correlation and multiple regression analyses. [Results] A significant relationship was observed between fine motor skills and visuospatial working memory, and a positive correlation remained after controlling for age. Multiple regression analysis with fine motor scores as the dependent variable and age, visuospatial working memory, and Strengths and Difficulties Questionnaire scores as independent variables demonstrated a significant association only for visuospatial working memory. [Conclusion] The study findings suggest that factors influencing fine and gross motor skills vary, highlighting the need for skill-specific interventions to address deficiencies effectively.

Key words: Autism spectrum disorder, Motor skills, Visuospatial working memory

(This article was submitted Sep. 24, 2024, and was accepted Dec. 4, 2024)

INTRODUCTION

In recent years, the prevalence of coordination disorder in school-aged children has been estimated at 5–6%[1)]. Although these estimates lack corroboration with previous publications, and thus, accuracy should be considered with caution, they indicate that some children may have cooperative motor disorders. Children with this condition are characterized by an inability to perform age-appropriate fine motor activities (e.g., handwriting and tying shoelaces) and gross motor activities (e.g., playing sports and getting dressed)[1)]. This wide range of impairments affects their performance of daily tasks and contributes to long-term adverse health effects secondary to decreased engagement in physical and social activities, low self-esteem, and increased risk for anxiety and depression[2, 3)]. In particular, 80–90%[4)] of children with autism spectrum disorder (ASD) have been reported to have co-occurring motor coordination disorder, which has become a problem.

As aforementioned, these motor coordination disorders are characterized by difficulties with fine and gross motor skills. The representative of fine motor skills is "hand dexterity"—an exercise wherein an individual manipulates an object touching

---

*Corresponding author. Soma Tsujishita (E-mail: tsujishita@kobe-kiu.ac.jp) their hand while perceiving it visually, and confirms the sensation of actual touch as physical information—while the representative of gross motor skills is dynamic movements using the whole body, such as "ball skills"—exercises involving spatial awareness, wherein an individual judges information about a location away from their body through vision, and performs by coordinating the movements of their fingertips and upper limbs. Thus, the factors required for different types of fine and gross motor skills differ, and an approach tailored to each motor skill may be needed, rather than a common approach to a coordination movement disorder. Hanai$^{5)}$ reported that children with ASD tend to have problems with both hand dexterity and ball skills, among various motor skills.

Moreover, children with ASD and dyscoordination, regardless of age group, exhibit difficulties with complex cognitive functions, including executive functions$^{6–11)}$. In recent years, working memory has been reported to be associated with complex cognitive functions, including executive functions, in children with cooperative motor impairments$^{12–14)}$. Working memory is an aspect of cognitive control, defined as "the ability to keep information in mind and use it to mentally work with it"$^{15)}$. It plays an important role in everyday activities, such as mentally performing mathematical calculations, recognizing objectives and goals, and translating instructions into action plans$^{15)}$. Furthermore, Alloway$^{6)}$ reported that visuospatial working memory is significantly lower in children with cooperative movement disorders$^{16, 17)}$. The difficulty in processing visual information in visuospatial working memory causes deficits in imitation learning and observation learning, hindering motor acquisition$^{18,)}$. Specifically, to execute a movement based on the observed movement, one must observe a model with sustained attention and retain the content of the simulated movement until the actual execution of the movement. The retention of the content of the simulated movement is performed by the visuospatial working memory function. Therefore, visuospatial working memory may be involved in motor coordination disorder.

As described above, hand dexterity and ball skills are likely to be impaired in the cooperative motor deficits associated with children with ASD, but it remains unclear how each motor skill is related to visuospatial working memory. Furthermore, complex cognitive functions, such as visuospatial working memory, may be involved in the development of gross motor skills in typically developing children$^{7)}$. Murray et al.$^{19)}$ reported that gross motor development in steadily developing children is associated with adult executive functions such as visuospatial working memory. Similarly, Piek et al.$^{8)}$ reported a relationship between gross motor development in steadily developing children and their subsequent school-age visuospatial working memory capacity. Furthermore, in a study of 7-year-old typically developing children, a significant association was found between visuospatial working memory and fine and gross motor skills and between visuospatial working memory and postural flexibility; however, no association was found between visuospatial working memory and the pegboard task assessing fine motor skills$^{20)}$. These findings suggest that, the better the development of the nervous system involved in gross motor functions in young children, the better the development of more complex neural circuits involved in executive functions. Moreover, gross motor development and visuospatial working memory are strongly related to steadily developing children.

However, these previous studies only examined characteristics of typically developing children; their findings may not hold true for children with ASD and other developmental disabilities. Despite this, no studies have investigated whether fine or gross motor activities are associated with visuospatial working memory in children with ASD. Thus, in this study, we aimed to clarify the relationship between visuospatial working memory and fine and gross motor performance in children with ASD.

PARTICIPANTS AND METHODS

This cross-sectional study was conducted from March to December 2023. The survey participants' parents were verbally informed of the purpose and content of the survey. They were also informed that participation was voluntary, they would not be disadvantaged if they did not respond to the questionnaire, the survey could be terminated even after they consented to cooperate, they would not be disadvantaged in such cases, and they would not be identified because the data would be statistically processed. The respondents' parents agreed to participate in the survey by signing a consent form. This study was approved by the Ethics Committee of the Department of Physical Therapy, Faculty of Rehabilitation Studies, Kobe International University (approval no. G2023-177; approval date: February 2, 2023).

Participants in the study included school-aged children between the ages of 6 and 15 years with ASD as their physician's diagnosis. Exclusion criteria were the inability to consent to participate in the study; age <6 years; diagnosis of cerebral palsy, muscular dystrophy, hemiplegia, degenerative disease, visual impairment, or intellectual disability; and missing measures. The number of participants in this study is shown in Fig. 1; of the 50 participants, 20 either met the exclusion criteria or were unable to complete some of the measurement items. Thus, 30 participants were included in the final analysis. Participants were recruited from child development support and after-school daycare service centers in Osaka and Hyogo Prefectures in Japan, and detailed materials regarding participant recruitment were distributed to them. Consent was obtained from their guardians.

Owing to the paucity of studies similar to the present one, the sample size was determined using the effect size from the interim analysis, a method in which the analysis is performed at the measurement stage, and how many samples remain to be examined. At the time of measurement, with 15 participants, the sample size for Spearman's rank correlation analysis was calculated using G*Power 3.1 software (Heinrich Heine University, Düsseldorf, Germany) with a power of 80%, alpha error of 0.05, and effect size of 0.47. Accordingly, 30 participants were required for this study. Therefore, the final sample size of 30 participants (24 boys and 6 girls, 9.5 ± 2.2 years old) was used for the remainder of the study.

The items measured were the Purdue Pegboard, a target-hitting task, a Corsi block-tapping task (CBTT), and the Strength and Difficulties Questionnaire (SDQ). As part of the implementation procedure, the Purdue Pegboard, target-hitting task, and CBTT were conducted in a quiet environment. Simultaneously, participants' parents were asked to complete the SDQ in a separate room. Each test was completed within approximately 20 minutes per child. A summary of each measure is provided below.

The Purdue Pegboard test[21)] is an instrument used to measure finger and hand dexterity. The instrument comprises two rows of boards, with 25 holes each. Participant must place as many pins as possible in the 25 holes within 30 s, first with their preferred hand, then with their non-preferred hand, and finally with both hands. Hand dexterity was scored based on the total number of pins successfully placed in each trial.

The target-hitting task was performed as a gross motor test of the upper limbs[22)]. Participants were asked to throw a 2 × 2-in bean bag five times underhand with their dominant hand toward a 36-in "archery-type" target. The target was an 8-in-diameter red circle surrounded by white, blue, and yellow 4-in bands. A hit to the center of the target scored 5 points, and a hit to the outer circle scored lower, with a maximum score of 25 points (Fig. 2). To adjust for the difficulty level of each participant, the baseline distance for each participant was set such that the average score of the five preliminary throws was 1.5 points. Each child performed the target-aiming task five times from that point.

The CBTT was performed as a test of visuospatial working memory[23)]. The validity and reliability of the CBTT have been demonstrated in previous studies[24)]. Nine blocks of squares were presented on paper and the participants pointed to each square sequentially. The participants were asked to memorize the sequence and point to the blocks in the same order for one trial. Two sets were performed per trial, and if at least one of these sets was repeated correctly, the pointing sequence was increased to 3, 4, and so on. Pointing was touched with the index finger at a rate of approximately one per second. The number of successful block sequences was used as the visuospatial working memory score (Fig. 3).

The SDQ[25)] was administered to determine the characteristics of developmental disabilities. It comprises 25 questions across four subscales for difficulties and one subscale for strengths, with five items per subscale. Questions are to be answered by parents. The difficulties subscales included emotional problems, conduct problems, hyperactivity/inattention, and peer problems, and the strengths subscale included prosocial behavior. Each item is scored on a 3-point scale with 0 was assigned for "not applicable", 1 for "fairly applicable", and 2 for "applicable". The score for each subscale ranges from 0 to 10, yielding a total score of 40.

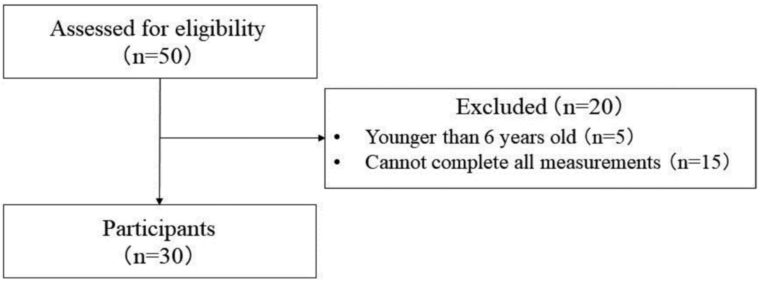

Fig. 1. Flowchart of participant selection.

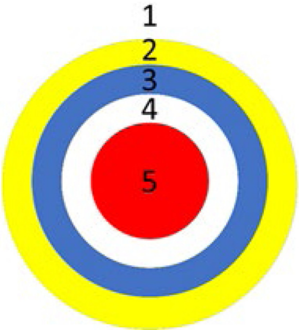

Fig. 2. Gross motor test (targeting task).

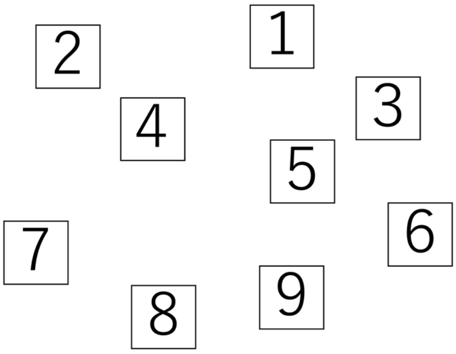

Fig. 3. Visuospatial working memory test (Corsi block-tapping task).

Previous studies have demonstrated sex differences in visuospatial working memory scores (CBTT), fine motor scores (Purdue Pegboard), gross motor scores (target-hitting task), and SDQ[21, 26–28]. Therefore, we divided the participants by sec and conducted a Mann–Whitney U test. Spearman's rank correlation analysis was used to analyze the correlations among age, visuospatial working memory score, fine motor score, gross motor score, total SDQ score, and each SDQ component score. Partial correlation analysis was also conducted with visuospatial working memory scores as the outcome, fine or gross motor scores as the factors, and age as the covariate. Additionally, multivariate analysis was conducted to clarify the strength of the association between fine and gross motor movements and visuospatial working memory, considering the confounding factors of age and SDQ score. Multiple regression analysis was conducted with fine or gross motor scores as the dependent variable and age, working memory, and SDQ scores as independent variables.

The statistical analysis software SPSS version 27 for Windows (IBM, Armonk, NY, USA) was used for statistical processing, and the significance level was set at 5%.

RESULTS

Participants' basic information is presented in Table 1. Comparisons between groups for age, CBTT, Purdue Pegboard, target-aiming task, total SDQ scores, and SDQ component scores were made using the Mann–Whitney U test, and no significant gender differences were found.

Spearman's rank correlation analysis revealed significant correlations between working memory and fine motor score ($\rho=0.456$, $p=0.011$), working memory and age ($\rho=0.411$, $p=0.024$), and fine motor scores and age ($\rho=0.442$, $p=0.014$) (Table 2). No significant correlations were found between the other variables.

Partial correlation analysis revealed a significant correlation between working memory and fine motor scores ($\rho=0.393$, $p=0.035$). No significant correlation was found between working memory and gross motor scores ($\rho=-0.072$, $p=0.712$).

Multiple regression analysis with fine motor scores as the dependent variable and age, working memory, and SDQ scores as independent variables revealed a significant association with working memory ($\beta=0.383$, $p=0.044$) (Table 3). Multiple regression analysis with gross motor scores as the dependent variable and age, working memory, and SDQ scores as independent variables showed no significant association with any of the independent variables (Table 4).

Table 1. Participants' basic information

Gender (persons)	Boys: 24, Girls: 6
Age (years)	9.5 ± 2.2
Working memory score (points)	5.0 ± 1.2
Fine motor score (points)	30.7 ± 7.0
Gross motor score (points)	9.1 ± 3.5
Total SDQ score (points)	21.1 ± 6.2
Emotional symptoms (points)	3.2 ± 2.5
Conduct problems (points)	3.2 ± 2.0
Hyperactivity/Inattention (points)	5.7 ± 2.4
Peer problems (points)	3.8 ± 1.7
Prosocial behavior (points)	5.2 ± 2.1

Mean ± SD. SDQ: strength and difficulties questionnaire.

Table 2. Correlation analysis of working memory with age, fine motor score, gross motor score, and strength and difficulties questionnaire (SDQ)

Variables	Correlation coefficient with working memory	p
Age	0.411	*
Fine motor score	0.456	*
Gross motor score	−0.016	
Total SDQ score	0.230	
Emotional symptoms	0.275	
Conduct problems	0.232	
Hyperactivity/Inattention	0.091	
Peer problems	0.113	
Prosocial behavior	−0.219	

Spearman's rank correlation coefficient, *$p<0.05$.

Table 3. Results of multiple regression analysis on fine motor score

Variables	Standardized partial regression coefficient	Standard error	p
Age	0.251	0.590	
Working memory score	0.383	1.011	*
Total SDQ score	0.181	0.202	

Multiple regression analysis (forced entry method) with fine motor score as the dependent variable and age, working memory score, and total SDQ score as the independent variables. $*p<0.05$. SDQ: strength and difficulties questionnaire.

Table 4. Results of multiple regression analysis on gross motor score

Variables	Standardized partial regression coefficient	Standard error	p
Age	0.013	0.365	
Working memory score	0.003	0.614	
Total SDQ score	0.052	0.121	

Multiple regression analysis (forced entry method) with gross motor score as the dependent variable and age, working memory score, and total SDQ score as the independent variables. SDQ: strength and difficulties questionnaire.

Multiple regression analysis (forced entry method) with gross motor score as the dependent variable and age, working memory score, and total SDQ score median (interquartile range).

DISCUSSION

This study aimed to investigate the relationship between visuospatial working memory and fine and gross motor performance in children with ASD. The findings revealed that visuospatial working memory correlated with age and fine motor scores in children with ASD, and with fine motor scores in an age-controlled partial correlation analysis. However, no association was found between visuospatial working memory and gross motor scores. Multiple regression analysis with fine motor scores as the dependent variable and age, visuospatial working memory, and SDQ scores as independent variables revealed a significant association only with visuospatial working memory. No significant association was found when the gross motor scores were used as dependent variables.

These results indicate that the factors influencing skill types, such as fine and gross motor skills, differ; thus, the method of responding must be changed according to the skill type that the participant is not proficient in. Specifically, while visuospatial working memory may be the target of intervention for fine motor skills, the target of intervention for gross motor skills, such as target shooting, could not be determined in this study.

A previous study reported that visuospatial working memory is associated with fine and gross motor activity in typically developing children[19)]. Other studies have reported a relationship between early gross motor development and later school-age visuospatial working memory capacity in typically developing children[8)]. These findings suggest a relationship between motor and executive functions, such as visuospatial working memory, in typically developing children. Furthermore, previous studies have examined whether fine or gross motor activity is associated with visuospatial working memory in typically developing children. A study of 7-year-old typically developing children reported a significant association between visuospatial working memory and gross motor activity, but no association between visuospatial working memory and fine motor activity[20)]. Other studies have reported similar findings in typically developing children[8)]. These results suggest that visuospatial working memory is important for gross motor development in typically developing children. However, the participants of these previous studies were typically developing children, and no study has investigated the relationship between visuospatial working memory and fine and gross motor skills in children with ASD.

In this study, visuospatial working memory was associated with fine motor skills in children with ASD. This suggests that the relationship between visuospatial working memory and motor skills may differ based on individual characteristics, such as typical development versus ASD. Although the results of the present study alone do not clarify causal relationships between the variables, previous studies have suggested that a common neural network may be associated with ASD in children, visuospatial working memory, and fine motor skills. The neural network problem in children with ASD is that the frontoparietal network (a network of higher brain functions that coordinates and integrates actions and thoughts purposefully to achieve goals) does not function smoothly, which prevents the transfer of information from the external world to the default mode network (a network that is active in a resting state without thinking or exercising and is involved in various cognitive functions such as memory and self-recognition). This may result in individuals' inability to understand the atmosphere around them and others' feelings[29)]. These frontoparietal and default mode networks are also associated with visuospatial working memory and hand dexterity. Previous studies on visuospatial working memory have shown that the activation of the frontoparietal network and deactivation of the default mode network are associated with performance in visuospatial working memory tasks$^{30)}$. These findings suggest that, unlike typically developing children, children with ASD may have difficulty coordinating frontoparietal and default mode networks, which may be associated with low visuospatial working memory and hand dexterity.

Next, the results of the multiple regression analysis in the present study revealed an association only with visuospatial working memory, even when the dependent variable was the fine motor score and the independent variables were age, visuospatial working memory, and SDQ. In other words, even when factors related to fine motor skills, such as age and emotional and behavioral aspects that are likely to be problematic in developmental disorders, were considered as variables for comparison, the association with visuospatial working memory was strong. These findings suggest that skill movement interventions may require intervention to improve visuospatial working memory in particular. Additionally, because this study was conducted on children with ASD, it is necessary to interpret the results by considering the characteristics of ASD. Specifically, children with ASD perform better when exercise instructions are prearranged rather than when they begin and end without foresight$^{31)}$. Furthermore, because children with ASD are more likely to prefer one part of the image over the whole, when comparing target-directed and target-less goal-directed conditions, motor performance improves in the former condition$^{32)}$. In this study, the Purdue Pegboard, the test of hand dexterity, was a target-less task, and the cognitive load may have been high owing to the lack of perspective. Conversely, the target-hitting task, a test of ball skills, is a goal-directed task that is easy to foresee; thus, cognitive load may have been relatively low for the participants in this study. This may have facilitated the recognition of an association between visuospatial working memory, which reflects cognitive function, and fine motor control. Nonetheless, it is important to consider the individual characteristics of children with ASD in future exercise instructions, in addition to the approach to motor coordination disorder.

This study had some limitations. First, the sample size was 30 participants. A post-hoc analysis was conducted after the study to determine whether the sample size was adequate. G*Power 3.1 software was used to calculate the power with an alpha error of 0.05, an effect size of 0.46, and a sample size of 30. The power for this study was 0.782, which is below 0.80. Therefore, future studies should use larger sample sizes. The reasons for the conflicting associations of visuospatial working memory with fine and gross motor skills between children with typical development and those with ASD are also unclear. Therefore, the results of this study should be utilized to conduct longitudinal and intervention studies to clarify causal relationships.

In conclusion, this study aimed to determine the relationship between visuospatial working memory and fine and gross motor performance in children with ASD. The results showed that visuospatial working memory was correlated with fine motor scores and age in children with ASD, and that visuospatial working memory was associated with fine motor scores in age-controlled partial correlation analysis. However, no relationship was found between visuospatial working memory and gross motor scores. In a multiple regression analysis, a significant association was only found between visuospatial working memory and fine motor skills. These results indicate that the factors influencing skill types, such as fine and gross motor skills, differ. This suggests that the method of dealing with poor skills must be adapted to skill type.

Authors' contributions

Study design: S.T., K.A., and K.T. Data collection: S.T. and D.N. Data analysis: S.T., K.A., and K.T. Manuscript writing: S.T. Manuscript editing: D.N., K.A., and K.T. All authors have read and approved the manuscript.

Funding

This study received no external funding.

Conflict of interest

The authors declare that they have no competing interests.

ACKNOWLEDGEMENTS

The authors would like to thank everyone who participated in this study.

REFERENCES

1) Blank R, Barnett AL, Cairney J, et al.: International clinical practice recommendations on the definition, diagnosis, assessment, intervention, and psychosocial aspects of developmental coordination disorder. Dev Med Child Neurol, 2019, 61: 242–285. [Medline] [CrossRef]

2) Zwicker JG, Harris SR, Klassen AF: Quality of life domains affected in children with developmental coordination disorder: a systematic review. Child Care Health Dev, 2013, 39: 562–580. [Medline] [CrossRef]

3) Jarus T, Lourie-Gelberg Y, Engel-Yeger B, et al.: Participation patterns of school-aged children with and without DCD. Res Dev Disabil, 2011, 32: 1323–1331. [Medline] [CrossRef]

4) Bhat AN: Is motor impairment in autism spectrum disorder distinct from developmental coordination disorder? A report from the SPARK study. Phys Ther, 2020, 100: 633–644. [Medline] [CrossRef]
5) Hanai T: Developmental motor coordination disorder in children with Asperger syndrome. Bull Fac Mod Educ, 2009, 1: 81–90.
6) Alloway TP: Working memory, reading, and mathematical skills in children with developmental coordination disorder. J Exp Child Psychol, 2007, 96: 20–36. [Medline] [CrossRef]
7) Michel E, Roethlisberger M, Neuenschwander R, et al.: Development of cognitive skills in children with motor coordination impairments at 12-month follow-up. Child Neuropsychol, 2011, 17: 151–172. [Medline] [CrossRef]
8) Piek JP, Dyck MJ, Francis M, et al.: Working memory, processing speed, and set-shifting in children with developmental coordination disorder and attention-deficit-hyperactivity disorder. Dev Med Child Neurol, 2007, 49: 678–683. [Medline] [CrossRef]
9) Ludyga S, Gerber M, Pühse U, et al.: Systematic review and meta-analysis investigating moderators of long-term effects of exercise on cognition in healthy individuals. Nat Hum Behav, 2020, 4: 603–612. [Medline] [CrossRef]
10) Kramer AF, Colcombe S: Fitness effects on the cognitive function of older adults: a meta-analytic study-revisited. Perspect Psychol Sci, 2018, 13: 213–217. [Medline] [CrossRef]
11) Voelcker-Rehage C, Godde B, Staudinger UM: Physical and motor fitness are both related to cognition in old age. Eur J Neurosci, 2010, 31: 167–176. [Medline] [CrossRef]
12) Kamijo K, Pontifex MB, O'Leary KC, et al.: The effects of an afterschool physical activity program on working memory in preadolescent children. Dev Sci, 2011, 14: 1046–1058. [Medline] [CrossRef]
13) Scudder MR, Drollette ES, Szabo-Reed AN, et al.: Tracking the relationship between children's aerobic fitness and cognitive control. Health Psychol, 2016, 35: 967–978. [Medline] [CrossRef]
14) Kao SC, Westfall DR, Parks AC, et al.: Muscular and aerobic fitness, working memory, and academic achievement in children. Med Sci Sports Exerc, 2017, 49: 500–508. [Medline] [CrossRef]
15) Diamond A: Executive functions. Annu Rev Psychol, 2013, 64: 135–168. [Medline] [CrossRef]
16) Packiam Alloway T, Temple KJ: A comparison of working memory skills and learning in children with developmental coordination disorder and moderate learning difficulties. Appl Cogn Psychol, 2007, 21: 473–487. [CrossRef]
17) Wang CH, Tseng YT, Liu D, et al.: Neural oscillation reveals deficits in visuospatial working memory in children with developmental coordination disorder. Child Dev, 2017, 88: 1716–1726. [Medline] [CrossRef]
18) Reynolds JE, Kerrigan S, Elliott C, et al.: Poor imitative performance of unlearned gestures in children with probable developmental coordination disorder. J Mot Behav, 2017, 49: 378–387. [Medline] [CrossRef]
19) Murray GK, Veijola J, Moilanen K, et al.: Infant motor development is associated with adult cognitive categorisation in a longitudinal birth cohort study. J Child Psychol Psychiatry, 2006, 47: 25–29. [Medline] [CrossRef]
20) Roebers CM, Kauer M: Motor and cognitive control in a normative sample of 7-year-olds. Dev Sci, 2009, 12: 175–181. [Medline] [CrossRef]
21) Lafayette—Instrument LIC: Purdue pegboatd test—model 32020 user instructions. www.lafayetteinstrument.com (Accessed Mar. 22, 2024)
22) Dick MB, Hsieh S, Dick-Muehlke C, et al.: The variability of practice hypothesis in motor learning: does it apply to Alzheimer's disease? Brain Cogn, 2000, 44: 470–489. [Medline] [CrossRef]
23) Kessels RP, van Zandvoort MJ, Postma A, et al.: The Corsi Block-Tapping Task: standardization and normative data. Appl Neuropsychol, 2000, 7: 252–258. [Medline] [CrossRef]
24) Orsini A: Corsi's block-tapping test: standardization and concurrent validity with WISC-R for children aged 11 to 16. Percept Mot Skills, 1994, 79: 1547–1554. [Medline] [CrossRef]
25) Goodman R: The Strengths and Difficulties Questionnaire: a research note. J Child Psychol Psychiatry, 1997, 38: 581–586. [Medline] [CrossRef]
26) Maeland AF: Identification of children with motor coordination problems. Adapt Phys Activ Q, 1992, 9: 330–342. [CrossRef]
27) Moriwaki A, Kamio Y: Normative data and psychometric properties of the strengths and difficulties questionnaire among Japanese school-aged children. Child Adolesc Psychiatry Ment Health, 2014, 8: 1. [Medline] [CrossRef]
28) Farrell Pagulayan K, Busch RM, Medina KL, et al.: Developmental normative data for the Corsi Block-tapping task. J Clin Exp Neuropsychol, 2006, 28: 1043–1052. [Medline] [CrossRef]
29) Buckner RL, Andrews-Hanna JR, Schacter DL: The brain's default network: anatomy, function, and relevance to disease. Ann N Y Acad Sci, 2008, 1124: 1–38. [Medline] [CrossRef]
30) Ishihara T, Miyazaki A, Tanaka H, et al.: Identification of the brain networks that contribute to the interaction between physical function and working memory: an fMRI investigation with over 1,000 healthy adults. Neuroimage, 2020, 221: 117152. [Medline] [CrossRef]
31) Liu T, Breslin CM: The effect of a picture activity schedule on performance of the MABC-2 for children with autism spectrum disorder. Res Q Exerc Sport, 2013, 84: 206–212. [Medline] [CrossRef]
32) Wild KS, Poliakoff E, Jerrison A, et al.: Goal-directed and goal-less imitation in autism spectrum disorder. J Autism Dev Disord, 2012, 42: 1739–1749. [Medline] [CrossRef]