

Relationship between sit-to-walk performance and visual perception in children with typical development: A preliminary study

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ABSTRACT

Background: Performance of sit-to-walk (STW) is developed along with improvement in neuromuscular control. Visual development plays an important role for motor learning and function in childhood. There was little evidence to indicate the relationship between visual function and motor performance.

Objective: This study aims to examine the relationship between STW performance and visual perception in children with typical development.

Materials and methods: Fifteen healthy children aged 7 to 12 years participated in the study. They were asked to complete the Development Test of Visual Perception-Third Edition (DTVP-3). Motion capture was used to collect spatiotemporal data from five STW trials. The relationship between these spatiotemporal parameters and visual perceptual scores were analyzed by the Pearson correlation coefficient.

Results: Positive moderate and high correlation were found between the eye-hand coordination sub-score and the first ($r=0.52$, $p<0.05$) and second step width ($r=0.71$, $p<0.01$) of STW, respectively. The second step width also correlated with the visual-motor integration composite ($r=0.55$, $p<0.05$). There was moderate correlation between the stride length and the copying subtest ($r=0.52$, $p<0.05$).

Conclusion: This preliminary study demonstrated that some spatial parameters of STW performance were associated with the visual-motor abilities of the DTVP-3. This suggested that an improvement in motor performance is developed along with visual perceptual function especially motor involving task.

Introduction

Sit-to-walk (STW) is a combined movement between sit-to-stand (STS) and gait initiation (GI). The performance of this transition is affected by age. In older adults, ability to achieve STW relates to the deterioration of physical, physiological, and psychological systems.¹ In contrast, children begin to perform this action at the age of 3 years.² They require greater control and coordination of neuromuscular systems to complete complex movements including STW since these functions are not fully developed.³ With increasing age, better performance of motor control is particularly associated with the improvements of sensory functions, perception, and integration, especially the visual system.⁴

Visual development is important in the improvement of motor control during childhood.⁵ It allows children to learn and engage with the environment which, enhances their movement skills. Information that is perceived from vision is integrated into motor planning. It also provides

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visual feedback that helps individuals to improve their movement performance.⁴ This visual-motor process requires children to recognize, organize, and interpret visual information which is called visual perception. This cognitive function is commonly correlated with reading comprehension and fine motor skills.⁶ A highly positive correlation between each component of visual perception and gross motor skills has been demonstrated in children aged 5 years. The study suggested that therapists should assess this cognitive skill in typically developing children because it may be beneficial in optimizing their movement performance.⁷

The evaluation of visual perception involves activity measurements that require motor ability and motor-free response.⁸ Eye-hand coordination, such as drawing and copying, is the task that reflect visual perceptual involving motor activities. Motor-free visual perception is the ability to recognize objects or words, which is considered a pure form of visual perception, for instance, form constancy and position in space.⁹ These perceptions have been correlated with gross motor skills including, locomotion and hand functions. However, the study focused on the movement process rather than performance outcomes.⁷ Generally, spatiotemporal parameters are used to indicate movement performance. Clarifying that visual perception development is associated with better gross motor performance requires an investigation of the link between these capabilities in school-aged children.

STW is often included in daily activities of individuals but, its performance was rarely be interested.¹⁰ Considering on each component of STW, it has been suggested that visual perception is important for balance control during STS as well as step length of GI in young healthy adults.^{11, 12} Since STW is more complex and it develops in children along with their visual perceptual skills, the objective of this preliminary study was to examine the relationship between STW performance and visual perception in children with typical development (TD). Total movement time, step length, stride length, and step width were calculated to indicate the performance of STW. For visual perception skills, the performance of each ability can be used to indicate strength and weakness of individual.¹³ The correlation of STW parameters with scores of each subtest and composite index of visual perception was determined. Researchers hypothesized that, in children with TD, visual perception would be correlated with spatiotemporal characteristics of STW performance.

Materials and methods

This cross-sectional correlational study was conducted to gather spatiotemporal data of STW performance and visual perceptual level. These data were examined for correlations.

Participants

The sample size was calculated based on the expected correlation coefficient at 0.70 ($\alpha=0.05$, $\beta=0.20$) with considering 10% of dropout rate. This preliminary

study included 15 convenience participants who were healthy children with TD aged 7 to 12 years old (seven boys and eight girls) from the Bangkok metropolitan region. Their means and standard deviations of age, weight, and height were 9.1 ± 1.6 years, 32.05 ± 9.16 kg., and 1.35 ± 0.11 m., respectively. These children were able to perform expecting child-level activities without reporting of cognitive, emotional, and academic problems from their parents.¹⁴ They had no history of surgery or fracture of the trunk or lower limb regions in the past 6 months or visual impairment. Informed consent was obtained from the parent or guardian of each participant. Participants who were unable to complete the testing protocol were allowed to withdraw from the study at any time. However, there was no withdrawal in this study.

Instruments

Three-dimensional (3D) motion analysis system (Motion Analysis Corporation, Santa Rosa, CA, USA) with 8 motion-capture cameras (Raptor E) and motion analysis software (Cortex, version 8.1 and KinTools RT, version 2.0, Motion Analysis Corporation, Santa Rosa, CA, USA) were used to calculate spatiotemporal data. An adjustable chair was used to set the chair height specific to each participant. The Development Test of Visual Perception - Third Edition (DTVP-3) was selected to assess visual perceptual skills. This test was developed to measure both motor-enhanced and motor-reduced abilities. The DTVP-3 has shown its reliability and validity in children with TD aged 4 to 12 years old.⁹ It consists of 5 subtests: eye-hand coordination (EH), copying (CO), figure-ground (FG), visual closure (VC), and form constancy (FC). These subtests are construction of visual perception which indicates the different dimensions of this cognitive skill.¹⁵ The scores from the EH and CO subscales were used to calculate the visual-motor integration (VMI) index, and the rest (FG, VC, and FC) were summed to evaluate the motor-reduced visual perception (MRVP) composition. The sum of the overall scores was converted into the general visual perception (GVP). The difference of these composite indexes was used to indicate that the children encountered with visual perceptual difficulty or they actually had motor deficits.¹³ Each subtest and composite index score were interpreted using the descriptive meanings of the test which presented in Table 1.

Table 1. Descriptive terms of subtest and composite index score of the DTVP-3.

Subtest score	Descriptive terms	Composite score
1-3	Very poor	<70
4-5	Poor	70-79
6-7	Below average	80-89
8-12	Average	90-110
13-14	Above average	111-120
15-16	Superior	121-130
17-20	Very superior	>130

Procedure

The overall testing processes were done by a pediatric physical therapist who is familiar with both DTVP-3 and 3D-motion capture. The demographic data, comprising date of birth, gender, weight, and height were collected at the enrolment. Weight and height were used to calculate body mass index (BMI) based on BMI chart for Thai Children from the Thai Society for Pediatric Endocrinology. The participants were asked to individually complete the DTVP-3 under instruction from the tester. They were then requested to wear a vest and shorts without shoes. Reflexive markers were attached on 29 anatomical landmarks based on the Modified Helen Hayes marker set model. Two additional markers were placed on the adjustable chair and another one at the right greater trochanter for identifying the point of seat-off.¹⁶ The intrasubject and test-retest reliability of the marker placements done in the laboratory prior data collection were demonstrated between good to excellent level ($R=0.846-0.982$, and $0.772-0.967$, respectively). The participants then sat on the chair, which was adjusted in height according to the length of their lower leg with 25% of upper-leg length support, and feet at the shoulder width apart. These settings allowed the hip and knee joints to be flexed close to 90° , as well as ankle dorsiflexion. From the starting position, the participants were instructed to stand and walk toward the end of the walkway approximately 3 meters away with their preferred speed and pattern. They were allowed to practice before data collection to familiarize themselves with the task and environment. The spatiotemporal data from five completed STW trials were used for further analysis.

Data processing and interpretation

Spatiotemporal data comprising total movement time, step length, stride length and step width were computed by using KinTool RT (version 2.0, Motion Analysis Corporation, Santa Rosa, CA, USA). Total movement time was determined from the point that the velocity of the body movement was 0.01 m/s to the first contact of the stance limb. The step length was calculated by the distance between two markers on both heels in the anteroposterior axis, and the step width was measured in the mediolateral direction. The stride length was determined by the distance between the points of initial contact of the marker on the stance heel. For the visual perceptual skills, the scores of each subtest and composite index were used to determine the level of these abilities using the descriptive meanings shown in Table 1.

Data analysis

Descriptive statistics were used to characterize the spatiotemporal data and visual perception scores. The Shapiro-Wilk test indicated a normally distribution of both data sets. Since each subtest and composite index of the DTVP-3 demonstrated the different dimensions of visual perceptual skills, these scores were used to evaluate the correlation with each spatiotemporal parameter by the

Pearson correlation coefficient (r). The findings were translated into the interpretation descriptions.¹⁷

Results

Spatiotemporal parameters

The means and standard deviations (SD) of total movement time, first and second step length, first and second step width, and stride length shown in Table 2. The mean of the first step length was similar to the second, whereas the mean of second step width was narrower than the first.

Table 2. Mean $\pm$ SD of spatiotemporal parameters.

Parameters	Mean $\pm$ SD
Total movement time (sec)	2.06 $\pm$ 0.19
1 st Step length (cm)	47.37 $\pm$ 5.49
2 nd Step length (cm)	48.62 $\pm$ 8.90
Stride length (cm)	96.00 $\pm$ 13.87
1 st Step width (cm)	12.53 $\pm$ 3.50
2 nd Step width (cm)	8.31 $\pm$ 2.73

Visual perceptual scores

The means and SD of each subtest and composite index of the DTVP-3 are shown in Table 3. The mean scores of the EH, FG, and FC subtests and MRVP index were at average levels. The means of the VC subscale and GVP index were above average level. The average VMI index was at the superior level, and the CO subtest was at the very superior level.

Table 3. Mean $\pm$ SD of each subtest and composite index scores.

DTVP-3	Scores
Subtest	
: EH	10.60 $\pm$ 2.63
: CO	18.13 $\pm$ 2.47
: FG	8.87 $\pm$ 1.82
: VC	13.87 $\pm$ 2.63
: FC	10.33 $\pm$ 4.70
Composite index	
: VMI	126.00 $\pm$ 12.38
: MRVP	106.07 $\pm$ 15.54
: GVP	115.33 $\pm$ 12.74

Relationship between spatiotemporal parameters and visual perceptual skills

The correlation between spatiotemporal parameters and visual perceptual scores are shown in Table 4. Positive moderate correlations with statistical significance were found between stride length and CO subtest, first step width and the EH subtest, and second step width and the VMI index. The second step width also demonstrated a highly positive correlation with the EH subtest.

Table 4 Correlation between spatiotemporal parameters and each subtest and composite index score.

Spatiotemporal parameters	DTVP-3							
	Subtests					Composite indexes		
	EH	CO	FG	VC	FC	VMI	MRVP	GVP
1 st SL	0.23	0.51	0.12	0.16	-0.19	0.44	-0.04	0.16
2 nd SL	0.13	0.49	0.17	0.23	-0.19	0.37	-0.01	0.15
StrL	0.17	0.52*	0.16	0.21	-0.20	0.41	-0.02	0.16
1 st SW	0.52*	-0.01	-0.35	-0.49	-0.05	0.34	-0.29	-0.09
2 nd SW	0.71**	0.14	-0.12	0.07	0.37	0.55*	-0.23	0.38
TMT	0.02	0.21	0.33	0.06	0.16	0.14	0.19	0.21

Note: TMT: total movement time, SL: step length, StrL: stride length, SW: step width, EH: eye-hand coordination, CO: copying, FG: figure-ground, VC: visual closure, FC: form constancy, VMI: visual-motor integration, MRVP: motor-reduced visual perception, GVP: general visual perception, * $p < 0.05$, ** $p < 0.01$

Discussion

The relationship between STW performance and visual perception was examined in children with TD aged between 7 and 12 years. A moderate to high positive correlation was demonstrated between some spatial parameters and visual-motor integration dimensions. The results suggested that some parameters of movement are associated with the development of some visual perceptual skills in typically developing children.

The current findings showed moderate and high positive correlations between the first and second step width and the EH subtest ($r = 0.52$, $p < 0.05$ and $r = 0.71$, $p < 0.01$, respectively). Generally, eye-hand coordination relates to hand functions, but it is actually part of the visual-motor coordination that also connects with gross motor activities.¹⁸ This skill requires the ability of the motor system to control movement in relation to visual information without the action of an integrative process.¹⁹ During STW, the base of support (BOS) of individuals was narrower from the starting position. The average first step width was greater than the second. This result is similar to a study of gait analysis that focused on the first four steps of GI.²⁰ It could be explained by the sudden change of the BOS from double- to single-leg contact at the initiation of walking. Participants could maintain their balance by appropriate coordination between the eyes and lower limb movement since the mean score of the EO subtest was at an average level. The second step width also had a moderate correlation with the VMI composition ($r = 0.55$, $p < 0.05$). Since the average of this score was at superior level, this allowed the participants to integrate visual information from the surrounding environment before performing the next action.¹⁹ Consequently, the second step width was narrower, which similar to a study of gait parameters in children aged 2 to 17 years.²¹

A moderate positive correlation was found between the stride length and the CO skill in the current study ($r = 0.52$, $p < 0.05$). Copying is the ability to recognize words or objects and then express them by spelling, writing, or drawing. To reproduce these actions, children must recall specific information from their immediate or long-term visual-spatial memory.²² Speed and accuracy are commonly used to measure the ability of this cognitive function.²³ The CO scores of the participants in this study demonstrated

that their copying skills ranged between average and very superior levels. This indicates good collaboration between working memory and motor outcomes. Although this current study did not provide any visual information related to STW performance to the participants, they reproduced the appropriate stride length from their long-term memory, which may particularly be relevant to their daily walking.

The relationship between these spatial parameters and visual perception involving motor abilities during STW performance may relate to the movement segmentation. STW is a combination of STS, which is the primary movement, and GI. The first segment of movement is proposed to be controlled by motor planning processes, whereas the secondary action is corrected by visual feedback.²⁴ Visual feedback allows individuals to recognize their body position while performing the movement. In a rapid situation, the motor response could be associated with the movement time since the action was performed without the integration of visual information.²⁵ However, weak correlations existed between total movement time and all subscales of visual perception in the current study. This could be because the participants performed this transition with their preferred speed and pattern. They may have fluently initiated their gait while the body was not in the upright position or started to walk after quiet standing (sit-to-stand-and-walk). Therefore, movement time was not constrained, which allowed the participants to use visual feedback to integrate information before they initiated the walk.

The findings in the current study did not demonstrate the relationship between STW performance and all of MRVP scores. These different from the previous study which found moderate to high correlation between gross motor skills and all of visual perceptual abilities except the position in space item.⁷ Although motor-free visual perceptual constructs were necessary for VMI skills, these MRVP abilities were only correlated with motor performance which particularly required speed for action.^{8, 26}

The limitation of the study is small sample size which would not determine the correlation between STW performance and visual perception in overall population of children. It has been suggested that visual perceptual level

in children with TD also related with their socioeconomic status.²⁷ Further study requires larger number of children with the different of socioeconomic status since this factor affects on visual perception outcomes. Furthermore, as the same tester completed the DTVP-3 and 3d-motion capture, tester bias may also exist. Consequently, in order to assist with future research, additional testers might be needed.

Conclusion

This preliminary study demonstrated the relationship between spatial parameters of STW performance including step widths and stride length, and visual perception skills which require motor involvement in children with TD. The moderate to high positive correlation suggests that the development of visual perceptual skills, especially integrative visual-motor functions particularly influence the performance of movement. Involving visual perceptual activities in the classroom and daily life would be beneficial to promote movement performance in school-aged children.

Conflict of interest

The authors declare no conflict of interest in this study.

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Ethical Approval

This study was approved by The Research Ethics Review Committee for Research Involving Human Research Participants, Group I, Chulalongkorn University (COA No. 144/66).

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