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Original Research

Relationship Between Motor Skills and Language Abilities in Children With Autism Spectrum Disorder

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Abstract

Objectives. Few studies have examined the relationship between language abilities and specific motor skills in toddlers with autism spectrum disorder (ASD). The aim of this study was to compare the relationship of receptive language (RL) and expressive language (EL) abilities with motor functioning in toddlers with ASD aged 24 to 36 months and their peers with typical development (TD). Furthermore, the study compared multidimensional motor functioning in toddlers with ASD with delayed RL and EL development and toddlers with ASD and typical RL and EL development. The predictive powers of the motor skills were examined for the group with delayed RL and EL development.

Methods. The language abilities of 38 toddlers with ASD and 38 age-matched toddlers with TD were evaluated using the Receptive and Expressive Language Subscales of the Mullen Scale of Early Learning, and their motor skills were assessed using the Peabody Developmental Motor Scales, Second Edition.

Results. Significant correlations between language ability and motor functioning were observed in the ASD and TD groups. The ASD group with delayed RL and EL development had lower scores for multidimensional motor functioning than the ASD group with typical RL and EL development and the TD group. Moreover, the risks of delayed EL and RL development could be predicted by the lower motor scores in toddlers with ASD.

Conclusions. The positive correlation between language abilities and motor functioning in toddlers with ASD indicated potential connections between the early onsets of motor and speech-language impairments in these toddlers.

Impact. The results may have implications for the development of motor-based interventions targeting language development in young children with ASD.

Keywords: ASD, Toddler, Language, Motor, Development

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Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by primary deficits in social interaction and communication with restricted behaviors and repetitive movements; its symptoms can be observed and it can be diagnosed in children as young as 18 to 24 months.[1–3] Recent changes in the diagnostic criteria for ASD have made it possible for clinical professionals to identify early problems in the development of social-communicative and motor functioning as markers for ASD.[4] Problems with the development of social-communicative functioning include impairments in verbal and nonverbal abilities as well as an intense focus on nonsocial objects; problems with the development of motor functioning comprise repetitive and stereotypic movements with varied perceptuo-motor impairments in balance, gait, and coordination.[5,6] Early identification of problems with language and motor development is crucial for children with ASD to receive timely interventions.[7,8]

Impaired verbal and nonverbal abilities affecting social interactions and communication are suggested to be the fundamental deficits in individuals with ASD. Delayed language development in both comprehension and production have been observed at the age of approximately 30 months in toddlers with ASD.[9,10] Toddlers with ASD produce their first word at an average age of approximately 38 months, which is significantly later than their peers with typical development (TD), whose first words are produced at the age of 8-14 months.[11] Furthermore, delayed language development is observed across various language domains, including vocabulary, morphology, and syntax; such delays affect the development of structural language and are associated with echolalia, misused pragmatics, and unusual articulation in later childhood.[12,13] In addition, toddlers with ASD may exhibit various deficits in their receptive language (RL) and expressive language (EL) abilities. Previous studies have indicated that 25% to 30% of toddlers with ASD aged 2 to 3 years could not use functional language to speak or understand verbal labeling at a 2-year-old level.[10,14–16] Moreover, approximately 50% to 70% of children with ASD manifest varied levels of speaking functional language, and some children with ASD may exhibit typical EL and RL abilities despite impairments in pragmatic usage.[12,17,18] Therefore, the correlates associated with variations in the EL and RL abilities of children with ASD in early childhood should be examined to facilitate the development of early interventions targeting language and other associated abilities.

To date, several studies have suggested that early motor functioning may be correlated with the RL and EL abilities of infants at risk of developing ASD.[19,20] Leonard et al[21] reported a positive association of gross motor (GM) functioning in infants aged 7 months who were at risk of developing ASD with subsequent EL ability. Furthermore, another study reported that fine motor (FM) functioning in toddlers aged 12 to 24 months who were at risk of developing ASD was associated with EL ability.[22] Additionally, LeBarton and Landa[20] reported that GM and FM scores at the age of 6 months were positively related to EL scores at the ages of 30 and 36 months in toddlers with a risk of developing ASD. Furthermore, Mody et al[23] examined language abilities and motor functioning in a large sample of US children with ASD aged 2 to 15.5 years by using the Vineland Adaptive Behavior Scale-Second Edition and the Mullen Scale of Early Learning (MSEL). The results revealed that GM scores were negatively associated with RL scores, but no relation was observed between GM and EL scores; by contrast, FM scores were positively related to both EL and RL scores. Kuhl et al[24] conducted a neuroscientific comparison between children with TD and those with ASD aged from 7 to 12 months and reported that the motor and auditory brain areas were both activated by speech. Moreover, previous studies have revealed that self-organization and synchronous auditory feedback, particularly rhythmic arm movements that require timely, organized actions, promote the acquisition of canonical babbling.[25–27] These findings indicate that early motor functioning can promote and may be correlated with language acquisition in toddlers with TD. Although the findings of the aforementioned studies have supported the correlations between language and motor development, most studies have focused on infants or toddlers at risk of ASD, such as the siblings of children with ASD, who may not receive a diagnosis of ASD. Furthermore, few studies have explored the predictive correlation between motor functioning and language impairments in toddlers with diagnosed ASD, which could provide the knowledge of various developments that are associated with autism for facilitating sensitive and effective early intervention. Moreover, few studies have examined multidimensional motor functioning in young children with ASD through standardized motor tests, which might be related to the precision of motor development.

Therefore, the aims of this study were as follows: (1) to investigate the correlations of RL and EL abilities with multidimensional motor functioning in toddlers with ASD aged 24 to 38 months and compare these relationships with those observed in age-matched toddlers with TD; (2) to examine differences in motor functioning in toddlers with ASD who have delayed RL and EL development and those with typical RL and EL abilities; and (3) to examine the predictive power of motor development scores for language outcomes in an exploratory investigation using a preliminary sample of toddlers with ASD. We hypothesized that RL and EL abilities would be positively correlated with multidimensional motor functioning in both toddlers with TD and toddlers with ASD. Furthermore, we hypothesized that higher motor scores would be predictive of lower risks of delayed RL and EL development in toddlers with ASD. We evaluated language and motor development by using standardized development assessments to provide detailed and reliable results.

Methods

Participants

A total of 76 Taiwanese toddlers (38 toddlers with ASD and 38 toddlers with TD) were recruited from community and clinical settings during 2015 to 2017. The 2 groups were matched by age, sex, and maternal education. Toddlers with ASD were clinically referred by physicians specializing in physical medicine and rehabilitation or child psychiatry at the outpatient clinic of National Taiwan University Hospital. An age-matched group of toddlers with TD was recruited by distributing flyers at a day-care center for infants and toddlers and during child health care visits at National Taiwan University Hospital. Inclusion criteria for toddlers with ASD were: (1) toddler's age between 24 and 38 months; (2) a screen-positive result of the Modified Checklist for Autism in Toddlers, Revised with Follow-Up, Taiwan Version (M-CHAT-R/F-T); and (3) having a clinical diagnosis of ASD. Inclusion criteria for toddlers with TD were: (1) age matched with the ages of toddlers with ASD; (2) full-term gestation with gestational age at least 37 weeks; (3) having a screen-negative result of the M-CHAT-R/F-T for the ASD; and (4) no suspected risk of developmental problems as assessed by their primary caregivers and pediatric physicians. Exclusion criteria for both groups of toddlers were presence of chromosome abnormalities, congenital anomalies, and major neurological sensory impairments or disorders (e.g., cerebral palsy, microcephalus, macrocephalus, severe brain damage, uncorrected vision, or hearing loss). The study was approved by the Institutional Review Board of National Taiwan University Hospital. Written informed consent was obtained from the parents of children after they had received a complete description of the study.

Procedure

Toddlers' parents were asked to complete the M-CHAT-R/F-T[28] to screen for the risk of ASD at enrollment, and they were followed up at clinical visits for a diagnosis of ASD. The M-CHAT-R/F-T is a checklist for autism in toddlers that was translated and validated for Taiwanese culture and terminology. A positive screening result was obtained if a child failed on 2 or more items in the follow-up scoring sheet. Furthermore, child psychiatrists, physical medicine physicians, and rehabilitation specialists performed diagnostic evaluation to integrate the results of the developmental and behavioral assessments. The diagnoses reflected the clinicians' impressions and were confirmed according to the ASD diagnostic criteria listed in the *Diagnostic and Statistical Manual of Mental Disorders*, *Fifth Edition* (DSM-5).[1] We used the MSEL and Peabody Developmental Motor Scales-Second Edition (PDMS-2) to assess language and motor development, respectively. To prevent failed attempts due to fatigue or tantrums, the assessments were completed during 2 separate sessions with a strictly controlled 2-week break, and they were conducted by the same examiners. All assessments were completed in the same laboratory setting with standardized assessment tools and were video recorded to confirm the scoring. Children were seated across from the examiner at a child-sized testing table in the center of a room. They were encouraged to remain seated during the assessments, except for the GM tasks, which required movement.

The participants were tested by 2 research assistants, who were graduate students in clinical psychology or pediatric physical therapy. The examiners were trained regarding the material and procedures of MSEL and PDMS-2, and rehearsed both assessments with 2 senior examiners, who were a pediatric physical therapist and a clinical psychologist with doctoral degrees. The examiners followed the same scoring standards, which were demonstrated and discussed during the training. Later on, practice sessions requiring each examiner to assess 10 children aged 24 to 42 months, including toddlers with TD and toddlers with ASD, were conducted. The training was completed when at least 95% of the items in each examiner's result in the practice sessions were in agreement with the senior examiners' assessments. The interrater reliability for testing items between the examiners and senior examiners revealed high intraclass correlation coefficients (0.96–0.99, all P values $<.05$). In addition, the scores of all assessments were calculated by the examiner and subsequently checked twice by the senior examiners using the recorded assessment videos.

Assessments of Cognitive, RL, and EL Abilities

The MSEL is designed to examine the development of cognitive, language, and motor skills from birth to the age of 68 months.[29] It can be used as a diagnostic instrument for children with limited response capabilities and is widely applied to identify cognitive strengths and weaknesses and developmental delays in children with ASD or special needs.[29] A test of the instrument indicated good convergent validity for the cognitive development of children with ASD.[30] The instrument comprises 5 subscales, namely for visual reception, RL, EL, FM, and GM scales. T scores and developmental age equivalents can be computed separately for the 5 subscales. The total raw scores for each subscale can be transformed into T scores to compare the results with data from a normative sample of American children. The early learning composite score represents overall cognitive function and combines the T scores of 4 of the 5 subscales, excluding the GM subscale. Based on the cutoff scores of normative data for the subscale scores, developmental conditions are classified into 5 descriptive categories: very low, below average, average, above average, and high. The categories of "below average" (T score: 31–39) and "very low" (T score <31) describe scores in the percentile rank less than 15th (1st to 15th percentile), indicating significantly delayed development. Furthermore, the developmental quotient is an indicator expressing a child's growth to maturity so that age-equivalent scores for each domain can be converted to ratios or quotients. A child's developmental quotient is determined by dividing the age-equivalent for each subtest by the child's chronological age and multiplying the result by 100.

We used the assessment results of the RL and EL subscales to differentiate between subgroups with known delays in RL and EL development. The RL subscale reflects understanding of spoken language, ability to follow oral instructions, auditory-visual memory, short- and long-term memory, and retrieval of facts and general knowledge. Assessment of retrieval of facts and general knowledge includes asking "Which tool do you use to eat?" when presenting the child with a variety of objects, including a spoon. Children require prior knowledge of spoons to recognize their function and identify them among other objects. The EL subscale reflects the ability to form language, ability to use speech for communication and expression, vocabulary (eg, naming or describing objects), capacity for abstract thinking and reasoning for the verbalization of concepts (eg, asking "What do you do before crossing the road?"), and auditory comprehension and memory (eg, repeating sentences). The MSEL subscales assessed in the current study were translated and adapted linguistically and culturally from English to Mandarin Chinese. The translation process includes forward translation, blind backward translation, and a subsequent review panel conducted by experts including a pediatric physical therapist, a clinical psychologist, and a pediatric neurologist for the description of individual items and testing procedure. The translated version of MSEL revealed acceptable convergent and discriminative validity for developmental assessments in a Taiwanese sample of toddlers with TD and toddlers with atypical development.[31]

Motor Assessment

The PDMS-2 was developed to measure motor development in children from birth to the age of 60 months.[32] It is a standardized developmental instrument for clinical assessment and intervention planning by pediatric physical therapists. The instrument comprises 6 subscales, namely Reflexes (specifically for infants aged <12 months), Locomotion, Object Manipulation (OM), Stationary, Grasping, and Visual-Motor Integration (VMI) scales. The standard scores of 6 subscales are summed and converted to the total motor quotient (TMQ). The standard scores of Stationary, Locomotion, and OM are summed to obtain the gross motor quotient (GMQ), and the remaining subscales are summed to obtain the fine motor quotient (FMQ). The Stationary subscale reflects the ability to control the body within its center of gravity and maintain equilibrium. The Locomotion subscale reflects the ability to transport the body from one base of support to another (eg, through walking, jumping, and running). The OM (eg, throwing and catching a ball), Grasping (eg, grasping cubes and buttoning), and VMI subscales (eg, drawing, copying, and building with cubes) reflect the abilities of visual-motor coordination, auditory comprehension, and motor imitation.[32] All of the instructions were given by the examiners who interpreted the PDMS-2 subscales culturally and linguistically from English to Mandarin Chinese. Conducting PDMS-2 assessment for Taiwanese children is an essential training required for licensed physical therapists in Taiwan. The PDMS-2 has been reported to exhibit good test-retest reliability and acceptable responsiveness for Taiwanese children with cerebral palsy aged 2 to 5 years.[33] Moreover, high correlations of convergent validity with the motor subtest of the Comprehensive Developmental Inventory for Infants and Toddlers[34] and good diagnostic accuracy for motor disabilities have been reported in a sample of Taiwanese children with motor disabilities and nondisabled children.[35]

Statistical Analysis

The demographic variables and MSEL scores of the ASD and TD groups were compared. Continuous variables were analyzed using t tests, and the χ^2 test was used to analyze categorical variables. The relationships of RL and EL abilities with motor functioning were separately analyzed based on the RL and EL scores for each motor quotient, and the scores for both groups were compared using Pearson correlation. Furthermore, we divided the ASD group into subgroups for delayed RL/EL development (T score <40) and typical RL/EL development (T score >39) based on the cutoff T scores for the RL and EL subscales. The Shapiro-Wilk test was used to determine if a data set is well modeled by a normal distribution in toddlers with ASD and toddlers with TD. These subgroups were then compared with the TD group by using 1-way analysis of variance, with motor quotients and scores for group differences. If a main significant effect was observed among the groups, a post hoc test using Bonferroni correction was conducted to test pairwise comparisons. In addition, for motor variables that differed between groups, odds ratios (ORs) were then calculated using logistic regression analysis to assess their predictive power for delayed language development. All statistical analyses were conducted using SPSS version 22 (IBM, Armonk, New York, USA). Results with $P < .05$ were considered significant.

Results

Participant Characteristics

Table 1 presents the demographic characteristics and basic developmental level of all children in this study. A total of 38 toddlers with ASD and 38 toddlers with TD (35 boys and 3 girls in each group) participated in this study. The mean ages of the ASD and TD groups were similar (33.02 months vs 33.24 months, $P = .98$). For maternal education, a controlled variable, two-thirds of mothers in each group had a bachelor's degree (68%). The M-CHAT-R/F risk scores in the ASD group were significantly higher than those in the TD group ($P < .001$). Similarly, the overall cognitive level of the early learning composite scores in the ASD groups was significantly lower than that in the TD group ($P < .001$); 76% of the toddlers with ASD were below the average level. For the visual reception, RL, and EL subscales, the T scores, age equivalents, and developmental quotients in the ASD group were all significantly lower than those in the TD group (all $P < .001$). According to the RL and EL subscales, 22 toddlers with ASD (58%) were classified as having delayed RL development, and 20 (53%) as having delayed EL development. In addition, approximately one-third of the toddlers with ASD (32%) had both delayed RL and EL developments, whereas two-fifths of toddlers in the ASD group (42%) were classified as typical development in both RL and EL subscales.

Correlation Between Language Abilities and Motor Functioning

Table 2 presents the correlations of RL and EL scores with the motor function subscale scores of the PDMS-2 for the ASD and TD groups. In the ASD group, RL scores were significantly correlated with GMQ, FMQ, TMQ, and several motor function subscales scores, including Locomotion, OM, and VMI ($r = 0.41$–0.55, all $P < .05$). In the TD group, RL scores were significantly correlated with FMQ ($r = 0.41$, $P < .05$) and VMI ($r = 0.46$, $P < .05$). Furthermore, the FMQ, TMQ, OM, and VMI scores were significantly correlated with EL in the ASD group ($r = 0.38$–0.49, all $P < .05$), whereas the toddlers with TD exhibited significant correlations of GMQ, OM, and VMI with EL ($r = 0.2$–0.36, all $P < .05$).

Motor Functioning in Children With Delayed and Typical Language Development

Toddlers in the ASD group were assigned to the delayed RL and EL development and typical RL and EL development subgroups according to their language abilities. The motor scores of the PDMS-2 of these subgroups were compared with those of the TD group. All the motor data in the ASD and TD group passed the test for normality (all $P > 0.05$) and 1-way analysis of variance was subsequently conducted for testing the group differences on motor scores. Table 3 lists the results for each motor variable in the delayed RL and EL development, typical RL and EL development, and TD groups. Figures 1 and 2 provide an overview of the multiple comparisons of the motor variables obtained from the paired comparisons. The results revealed that the motor quotients and subscale scores in the PDMS-2 differed significantly among the 3 groups (all $P < .001$). Furthermore, the GMQ, FMQ, and TMQ scores were significantly lower in the delayed and typical RL development groups than in the TD group (all adjusted $P < .01$; Fig. 1A). Additionally, the GMQ (adjusted $P = .001$) and TMQ (adjusted $P = .01$) scores were significantly lower in the delayed RL development group than in the typical RL development group. Moreover, toddlers in the delayed RL development group exhibited significantly lower Locomotion (adjusted $P = .02$), OM (adjusted $P = .001$), and VMI scores (adjusted $P = .01$) compared with the typical

Table 1. Demographic Characteristics of the ASD and TD Groups[a]

Characteristics	ASD (N = 38)	TD (N = 38)	*P* value[b]
Age, mean [SD], mo	33.02 [3.8]	33.24 [3.4]	.98
Sex			1.0
Boys, n (%)	35 (92)	35 (92)	
Girls, n (%)	3 (8)	3 (8)	
Maternal education, n (%)			1.0
High school, n (%)	3 (8)	3 (8)	
College or university, n (%)	26 (68)	26 (68)	
Master or doctoral program, n (%)	9 (24)	9 (24)	
M-CHAT-R/F-T risk scores, mean [SD]	4.13 [3.27]	0.39 [0.71]	.00
MSEL			
ELC score, mean [SD]	70.97 [20.6]	122.11 [14.8]	.00
Category of cognitive level			.00
Very high, n (%)	1 (3)	12 (32)	
Above average, n (%)	0 (0)	13 (34)	
Average, n (%)	8 (21)	13 (34)	
Below average, n (%)	7 (18)	0 (0)	
Very low, n (%)	22 (58)	0 (0)	
VR subscale			
T score, mean [SD]	35.05 [14.5]	61.66 [8.9]	.00
Equivalent age, mean [SD], mo	26.13 [7.8]	31.89 [9.3]	.00
DQ, mean [SD]	79.85 [23.5]	100.26 [29.4]	.00
Classification of VR development			.00
Typical, n (%)	12 (32)	38 (100)	
Delayed, n (%)	26 (68)	0 (0)	
RL subscale			
T score, mean [SD]	34.47 [13.8]	63.1 [9.2]	.00
Equivalent age, mean [SD], mo	23.76 [10.0]	39.5 [6.4]	.00
DQ, mean [SD]	71.9 [28.2]	127.2 [20.8]	.00
Classification of RL development			.00
Typical, n (%)	16 (42)	38 (100)	
Delayed, n (%)	22 (58)	0 (0)	
EL subscale			
T score, mean [SD]	35.13 [14.3]	63.63 [11.7]	.00
Equivalent age, mean [SD], mo	23.89 [9.3]	40.24 [9.4]	.00
DQ, mean [SD]	72.8 [27.2]	128.9 [28.1]	.00
Classification of EL development			.00
Typical, n (%)	18 (47)	38 (100)	
Delayed, n (%)	20 (53)	0 (0)	
Classification of RL and EL development			.00
Typical RL and EL, n (%)	16 (42)	38 (100)	
Delayed RL and typical EL, n (%)	4 (11)	0 (0)	
Typical RL and delayed EL, n (%)	2 (5)	0 (0)	
Delayed RL and EL, n (%)	12 (32)	0 (0)	

[a]Data are presented as the mean [SD] or n (%). ASD = autism spectrum disorder; DQ = developmental quotient; EL = expressive language; ELC = early learning composite; M-CHAT-R/F-T = Modified Checklist for Autism in Toddlers, Revised with Follow-Up, Taiwan Version; MSEL = Mullen Scales of Early Learning; RL = receptive language; TD = typically developing; VR= visual reception. [b]Continuous variables were analyzed using *t* test, and the χ^2 test was used to analyze categorical variables.

Table 2. Correlations of RL and EL With Motor Scores[a]

PDMS-2 Subscales	ASD (N = 38)		TD (N = 38)	
	RL	EL	RL	EL
Gross motor quotient	0.55[b]	0.45	0.11	0.20[c]
Fine motor quotient	0.41[d]	0.38[c]	0.41[d]	0.16
Total motor quotient	0.51[b]	0.43[d]	0.30	0.22
Stationary	0.31[c]	0.23	0.19	0.18
Locomotion	0.48[b]	0.39	0.18	0.01
Object Manipulation	0.52[b]	0.49[b]	0.25	0.34[c]
Grasping	0.09	0.14	0.20	0.16
Visual-Motor Integration	0.53[b]	0.44[d]	0.46[b]	0.36[c]

[a]Data are presented as the correlation coefficient *r*. ASD = autism spectrum disorder; EL = expressive language; PDMS-2 = Peabody Developmental Motor Scales, 2nd Edition; RL = receptive language; TD = typically developing. [b]$P < .001$ significance level. [c]$P < .05$ significance level. [d]$P < .01$ significance level.

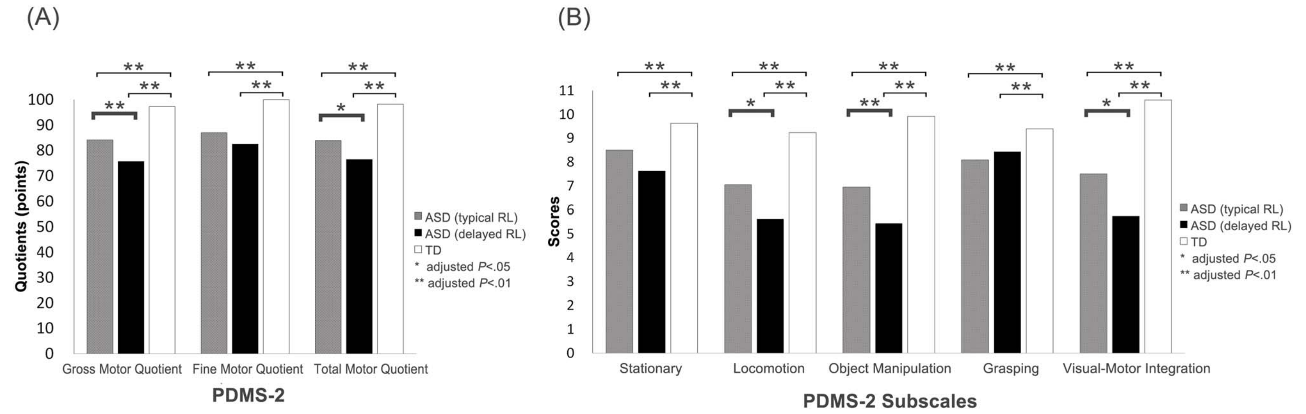

Figure 1. Comparison of PDMS-2 motor quotients (A) and subscale scores (B) in the delayed and typical RL development subgroups of toddlers with ASD and the TD group. ASD = autism spectrum disorder; PDMS-2 = Peabody Developmental Motor Scales-Second Edition; RL = receptive language; TD = typically developing.

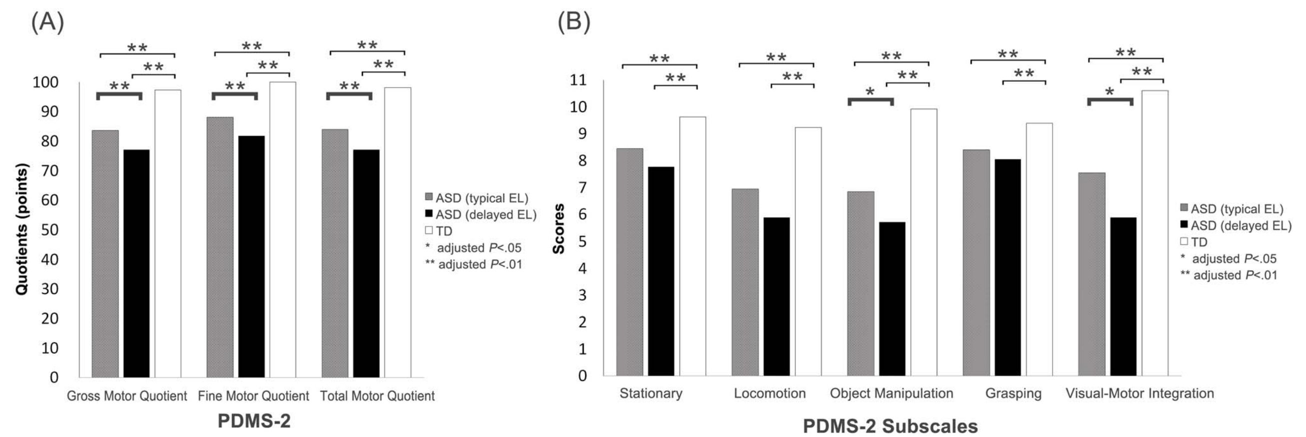

Figure 2. Comparison of PDMS-2 motor quotients (A) and subscale scores (B) in the delayed and typical EL subgroups of toddlers with ASD and the TD group. ASD = autism spectrum disorder; EL = expressive language; PDMS-2 = Peabody Developmental Motor Scales-Second Edition; TD = typically developing.

RL development group (Fig. 1B). Besides, the GMQ, FMQ, and TMQ scores were all significantly lower in the delayed and typical EL development groups than in the TD group (all adjusted $P < .01$). Moreover, the GMQ, FMQ, and TMQ scores were significantly lower in the delayed EL development group than in typical EL development group (all adjusted $P = .01$; Fig. 2A). Toddlers in the delayed EL development group exhibited significantly lower OM (adjusted $P = .02$) and VMI scores (adjusted $P = .01$) compared with those in the typical EL development group (Fig. 2B).

Motor Scores as Possible Predictors of Language Ability

Several motor function variables were examined to determine whether motor quotient and subscale scores are predictive of delayed RL and EL development in toddlers with ASD. The results revealed that increases in GMQ (OR = 0.87, $P = .01$), TMQ (OR = 0.89, $P = .02$), Locomotion (OR = 0.64, $P = .03$), OM (OR = 0.44, $P = .01$), and VMI scores (OR = 0.63, $P = .02$) were associated with decreased risk of delayed RL development (Tab. 3). Furthermore, increases in GMQ (OR = 0.91, $P = .02$), FMQ (OR = 0.9, $P = .03$), TMQ (OR = 0.9, $P = .02$), OM (OR = 0.59, $P = .03$), and VMI scores (OR = 0.66, $P = .02$) were each associated with decreased risk of delayed EL development (Tab. 3).

Discussion

To the best of our knowledge, this study was the first to examine the correlations of RL and EL abilities with multidimensional motor function through standardized developmental assessments. The results revealed positive correlations between language abilities and motor functioning in both the ASD and TD groups. Furthermore, the delayed RL and EL development group exhibited lower scores for the multidimensional motor scales compared with the typical RL and EL development and TD groups. In addition, the risks of delayed RL and EL development could be predicted by lower motor scores in toddlers with ASD. These findings might have clinical implications for the targeting of language and motor interventions in young children with ASD.

The results revealed positive correlations between language abilities and motor functioning in both ASD and TD groups. These findings are consistent with the results of previous studies.[23,36] However, because of differences in methodology, the results for the specific motor subscales could not be compared with those of previous studies that have compared children with ASD with their siblings with TD.[20,23] Additionally, although Mody et al[23] compared the correlations between children with TD and children with diagnosed ASD, their results only reported the linear correlation between language

Table 3. Associations of Motor Performance With Delayed and Typical Language Development[a]

PDMS-2	Delayed RL Development ASD (n = 22)	Typical RL Development ASD (n = 16)	TD (N = 38)	P^b	OR (95% CI)[c]	Delayed EL Development ASD (n = 20)	Typical EL Development ASD (n = 18)	TD (N = 38)	P^b	OR (95% CI)[c]
Gross motor quotient	75.7 [8.8]	84.1 [6.6]	97.3 [9.9]	.00	0.87 (0.79–0.96)	77.2 [8.1]	83.7 [8.1]	97.3 [9.9]	.00	0.91 (0.83–0.99)
Fine motor quotient	82.6 [8.1]	87.0 [8.1]	100 [6.7]	.00	0.93 (0.85–1.01)	81.8 [7.2]	88.2 [8.3]	100 [6.7]	.00	0.90 (0.82–0.99)
Total motor quotient	76.5 [9.1]	83.9 [6.8]	98.2 [8.4]	.00	0.89 (0.80–0.98)	77.2 [8.2]	84.0 [7.8]	98.2 [8.4]	.00	0.90 (0.82–0.98)
Stationary	7.6 [1.3]	8.5 [1.5]	9.6 [1.6]	.00	0.63 (0.83–1.05)	7.8 [1.4]	8.5 [1.5]	9.6 [1.6]	.00	0.71 (0.44–1.14)
Locomotion	5.6 [2.3]	7.1 [1.4]	9.2 [1.9]	.00	0.64 (0.43–0.96)	5.9 [1.9]	6.9 [1.8]	9.2 [1.9]	.00	0.73 (0.51–1.06)
Object Manipulation	5.4 [1.4]	6.9 [1.4]	9.9 [1.9]	.00	0.44 (0.25–0.81)	5.7 [1.5]	6.9 [1.5]	9.9 [1.9]	.00	0.59 (0.36–0.96)
Grasping	8.4 [1.2]	8.1 [1.5]	9.4 [1.4]	.00	1.21 (0.75–1.96)	8.1 [1.2]	8.4 [1.6]	9.4 [1.4]	.00	0.83 (0.52–1.33)
Visual-Motor Integration	5.8 [1.8]	7.5 [2.1]	10.6 [1.5]	.00	0.63 (0.43–0.92)	5.9 [1.8]	7.6 [2.1]	10.6 [1.5]	.00	0.66 (0.46–0.94)

[a]Data are presented as the mean [SD]. ASD = autism spectrum disorder; EL = expressive language; OR = odds ratio; PDMS-2 = Peabody Developmental Motor Scales, 2nd Edition; RL = receptive language; TD = typically developing. [b]Comparison of delayed RL and EL development, typical RL and EL development, and TD groups using 1-way analysis of variance. [c]ORs and 95% CIs obtained through logistic regression analysis for the prediction of language abilities.

and motor scores. The correlation between GM and language ability in their study was different from the current results; this inconsistency might be caused by their wider age range of children with ASD (2–15 years old). The present study assigned children to subgroups according to their language ability because more individual variations could be observed in this domain than in motor function in toddlers with ASD. Following this method, we assessed motor functioning for the entire body instead of for partial movements of the extremities, as has been done in previous studies.[36–38] RL and EL abilities were positively correlated with most of the motor subscale scores in the ASD group, and these results were more robust than those in the TD group. According to the review article by Iverson,[36] certain body movements are correlated with language milestones for the purpose of facilitating developments of relevant language abilities. For example, an infant's motor ability, such as rhythmic arm movements, was found to be a function of time relative to the onset of word babbling; when a child has acquired canonical babbling, the frequency of rhythmic arm movements decreases.[36] Therefore, development of perceptuo-motor skills and the enhancement of motor experiences may provide infants with a rich sensorimotor context for practicing language abilities. Hence, this may support the positive correlations between RL/EL language ability and motor functioning in the ASD and TD groups. Lower motor performance of toddlers with ASD may indicate insufficient sensorimotor stimuli for practicing language abilities, accounting for language delays. Therefore, to develop language abilities, toddlers with ASD need to continuously enhance their motor experiences, which makes the 2 abilities correlate with each other. In contrast, children with TD have well-developed motor functioning, which provides sufficient stimuli to practice language abilities. Thus, they no longer need to enhance motor experiences to facilitate language abilities, accounting for a decrease in the correlation. As a result, the ASD group exhibited more robust positive correlation between motor functioning and language ability than the TD group. The current results may provide useful information for speech-language therapy by enhancing varying motor experiences to practice relevant language abilities.

The motor functioning of the toddlers with ASD in the delayed and typical RL and EL groups differed significantly. Notably, the GMQ, TMQ, Locomotion, OM, and VMI scores were lower in the delayed RL development group than in the typical RL development group, and the GMQ, FMQ, TMQ, OM, and VMI scores were lower in the delayed EL development group than in the typical EL development group. To the best of our knowledge, this is the first study to use standardized motor assessments to examine motor function in toddlers with ASD who have delayed RL and EL development. Previous studies have suggested that lower motor performance in infancy could predict inferior language abilities in children with a risk of developing ASD[19,21]; the opportunities for exploration and language acquisition may be reduced by low motor functioning. However, most of these studies have examined the relationship between motor functioning and language abilities in toddlers with a risk of developing ASD rather than in those with diagnosed ASD. Although our findings may contribute to relevant early interventions, longitudinal investigations for motor functioning and correlated language abilities in toddlers with ASD who have delayed RL or EL development are warranted to obtain a more comprehensive understanding.

The findings of the present study revealed that multidimensional motor functioning may possibly be predictive of the risk of delayed RL and EL development in toddlers with ASD. The results are consistent with those of most other studies that have identified GM as a predictor of RL and EL development and FM as a predictor for EL development.[19,21,39] However, most studies have examined toddlers with a risk of developing ASD over a wide age range, which may have increased the uncontrollable variants and thereby affected the results. For specific motor subscales, we found that OM and VMI could potentially predict both RL and EL abilities. Previous studies have suggested that more complex FM functioning could expand the contexts of movements and thus connect more meanings with objects.[17,18,36] For example, children with more methods of manipulating beads may have more opportunities to perform refined actions and word learning. Children might not only understand that a bead can be placed in a container but also notice the relationship between the hole in the bead and the diameter of a string and then attempt to thread the bead onto the string. This action might provide additional and contextual information concerning the bead, thus enhancing the child's understanding of the specific characteristics of the object and improving their associated language abilities. Nevertheless, we found that OM and VMI scores, rather than Stationary and Grasping scores, were effective predictors for the risks of delayed EL and RL development. These results are inconsistent with those reported by LeBarton and Landa.[20] The inconsistency may be due to the characteristics of the participants in this study; LeBarton and Landa recruited toddlers with a risk of developing ASD and examined their motor functioning and EL ability at the ages of 6 months and 24 to 36 months, respectively. The results may have been affected by the considerable changes in the abilities of children during these stages of development.[20] Therefore, the predictive power of motor functioning for language development should be further examined in toddlers with ASD of different ages in future studies.

To the best of our knowledge, the current study is the first to explore the association between early motor functioning and language ability in 2- to 3-year-old toddlers with ASD. The results may provide preliminary evidence for early developments and give direction for further research in the effectiveness of early intervention for toddlers with ASD. Additionally, the assessments used in the current study are reliable, valid, and applicable in the clinical setting, offering a useful reference for facilitating early intervention in motor and language developments. Although the current results might only provide preliminary findings due to small sample size, our data exhibited normal distribution, and the width of the CI for the associations did not cross 0 in the predictive power of motor scores for language delays, indicating the significance level was reached even with a small sample size. Therefore, it is suggested that further investigation with larger sample sizes and stricter experimental design is worthwhile in support of the current hypotheses.

Apart from the small sample size, there are other limitations to note. First, although several motor variables were found to associate with language outcome in toddlers with ASD, we did not include any potential covariates in the predictive model. For example, the visual reception subscale score that represents a child's nonverbal cognitive ability might need controlling for potential differences. We have further examined any changes of results after controlling the visual reception scores in the logistic regression model along with stepwise model selection. The preliminary result showed that the GMQ, TMQ, and OM scores still remained as optimal predictors for RL ability. Therefore, conducting further study to make a stratification of toddlers' cognitive level or matching cognitive abilities for the ASD groups with or without delayed language might be an optimal method for model prediction. Second, because the toddlers with ASD may have had difficulty sitting through the assessment sessions, the performance and correlation between language ability and motor functioning might reflect a child's attention and willingness to tolerate sitting through testing sessions. Toddlers with ASD can easily become frustrated or have limited abilities to understand and respond to commands, which may be due in part to their poor motivation and limited social interaction skills. Therefore, future studies may be necessary to report the severity of autism symptoms and abnormal behavioral/emotional problems in toddlers with ASD, and to further examine these variables as potential factors to influence the associations between language and motor abilities.

Implications for Future Research and Practice

Given the preliminary evidence for our hypotheses, we would like to encourage further study to focus on the following questions to obtain more supportive evidence for the correlation between motor functioning and language abilities in children with ASD: (1) Will the results remain significant in a more universal and representative sample size? Based on the estimates of ORs in the present study, at least 64 toddlers with ASD and more than 32 toddlers in each subgroup of language delay or typical language ability would be capable of reaching 80% statistical power in predicting an association between motor scores and language delay. (2) Will the correlation between motor functioning and language abilities become stronger with age into childhood? Further investigation may focus on longitudinal observation of motor and language developments after 3 years of age, which may expand the understanding of the age-related changes for the 2 developments and their correlation. (3) What other variables should be controlled to obtain more valid results? Because a participant's performance in the examination might be affected by their attentiveness and ability for social interaction, further research may assess the severity or functional level based on the criteria for ASD in DSM-5, as a potential moderator. (4) What other clinical strategy can be improved by the discovery of the correlation between motor and language developments? Knowing the correlation between RL/EL-delay and specific motor functioning, toddlers with ASD may receive timely motor-oriented intervention targeting language abilities. For example, emphasizing relevant language instructions or expression (eg, to jump, up and down) when doing certain motor activities. Improvements made based on these findings could not only provide a better understanding of motor and language developments in ASD, but also benefit early intervention involving motor and language treatments.

Although the current results might be exploratory in nature and further examination with a larger sample size is warranted, the significance of the current results is unignorable. Furthermore, from the assessment of motor functioning through standardized motor assessments, this study has the advantage of including various domains of motor skills; thus, the results can serve as a foundation for future studies to examine more precise correlations between language abilities and motor functioning in toddlers with ASD.

In conclusion, this study revealed positive correlations between language abilities and motor functioning in the TD and ASD groups; and the positive predictive power of motor functioning for delayed RL and EL development was observed. Our findings may offer insight into the correlations between specific language and motor abilities in toddlers with ASD and toddlers with TD, and could help the early detection of motor problems in young children with ASD. The exploratory nature of some of the results of this study suggest the possibility of generating hypotheses for further study of motor-based interventions targeting language development in young children with ASD.

Author Contributions

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Ethics Approval

The study was approved by the Institutional Review Board of the National Taiwan University Hospital.

Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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