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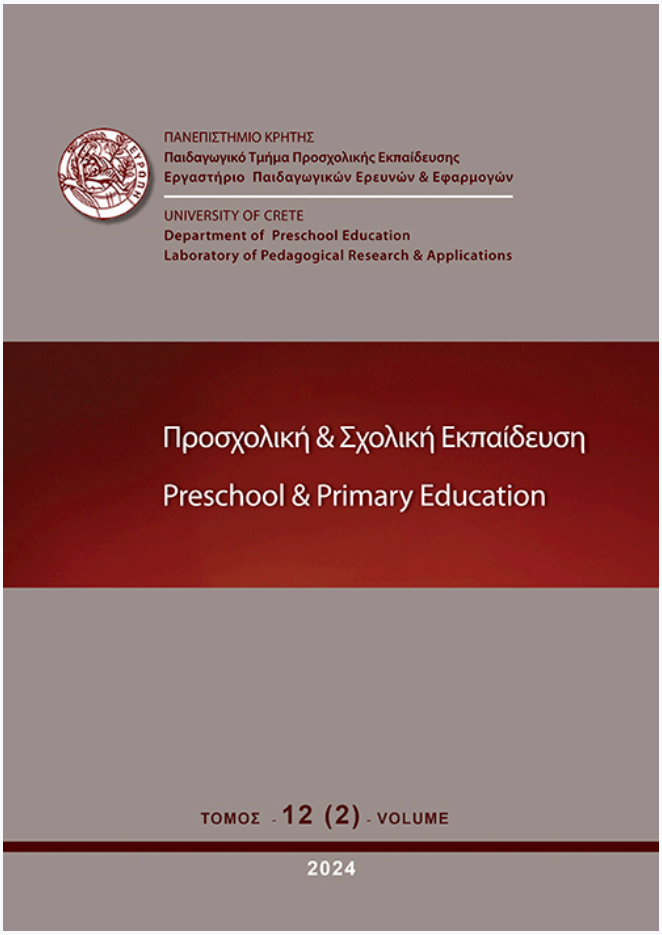

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The relationship between social and gross motor skills in children with Autism Spectrum Disorder (ASD) in Greece: implications for practice

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Abstract. Children with Autism Spectrum Disorder face significant difficulties in their social and motor development. Previous research has shown that motor difficulties are associated with and may predict social impairments in young children with the Autism Spectrum Disorder (ASD). The aim of this study was to examine the relationship between the development of gross motor and social skills among children with ASD between seven and eleven years old. A cross-sectional research design was applied with a group of 31 children (21 boys-67.7%, 10 girls) with ASD, and mean chronological age 9.3 ± 1.4 years old, from four primary special education schools in Greece Social skills were assessed by the classroom teacher in charge using the Educational Evaluation Tool for Social Skills (EET-SS) in children with autism, developed by Apteslis et al. (2012), and the children's gross motor development was measured, by the researcher using the Test of Gross Motor Development (TGMD-3) (Ulrich, 2019). Data analysis revealed that there was a moderate correlation between children's social and gross motor skills. Additionally, the developmental age children's scores on the TGMD-3 ball skills, were found to be associated with most of the children's EET-SS scores. The study showed that children's specific social skills were correlated with specific gross motor skills, such as the skills associated with object manipulation. Overall, the relationship between social skills and gross motor skills in children with ASD should be taken into consideration when designing and implementing assessment practices and educational programmes for children with ASD so that the children can improve both their gross motor skills and social skills, and ultimately the quality of their everyday functioning, in school or any other setting.

Keywords: Autism Spectrum Disorder; gross motor skills; social skills; TGMD-3; EET-SS

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that affects all areas of human development. ASD is mainly a term used to describe persistent difficulties in social interaction and communication, together with restricted, and repetitive behavioural patterns that are common in such diagnoses. The term ASD refers to a spectrum disorder because the severity and presentation of symptoms can vary greatly among individuals (American Psychiatry Association, 2013; WHO, 2019), as well as within the same individual over time (Missouri Autism Guidelines Initiative, 2010)

The prevalence of autism in the early 2000s was estimated based on literature to be around 6 persons per 1000 in Western countries (Europe and North America) (Centers for

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Disease Control and Prevention (CDC), 2006; Johnson et al., 2007). A more recent publication estimates a global median prevalence of 6.2 per 10.000 children (Jullien, 2021) with an increased tendency over time (Sharma et al., 2018).

A list of difficulties that a child or person with ASD demonstrates are usually linked to interaction and/or communication skills, such as eye contact, facial expression and many others (Johnson et al., 2007; Lord et al., 2020). The literature also indicates that the two skill categories, social and communication skills, are interconnected in children with ASD (Hansen et al., 2014). However, various other abnormalities may coexist in individuals with ASD, such as psychiatric and sleep disorders or sensory deficits (Chen et al., 2015).

Stereotyped behaviours, in speech or movement, which is a diagnostic category in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5™) may well be the result of not understanding or refusing to do something the teacher/or another person asks the child to do. Nauman & Ingersoll, (2023) discovered that attention difficulties are related to movement stereotypies in children with ASD, while Saleem Khasawneh, (2023) proved that stereotyped behaviours can be reduced after accredited intervention programmes such as Applied Behavior Analysis (ABA), and Sensory Integration Therapy (SIT), emphasizing the importance of their utility in preventing such behaviours (Khasawneh, 2023; Nauman & Ingersoll, 2023).

Social and motor deficits in ASD

Based on the definition of ASD, social skills are very restricted in children with this disorder. Children's inability to respond to the social environment is related to their inherent weakness in cognitive function (Barbeau et al., 2013; Dawson et al., 2007; Rutter, 1983) and their inability to understand the opinion and thinking of other people (Baron-Cohen, 1995; Frith & Happé, 1994). The difficulty in understanding and processing stimuli from the environment results in inappropriate social behaviours from children with autism. Understanding sensory processing patterns could be a diagnostic index in neurodevelopmental disorders (Schulz et al., 2023). The poor social behaviour observed in children with ASD can lead to reduced social relationships with peers, isolation and low friendship quality (Chamberlain et al., 2007; Howlin et al., 2000). Additionally, in research that studied preschool-aged autistic twins who attended a preschool special education school in Greece, researchers found that the children took social initiative in dyadic interaction with their peers in the school environment, but not with their teachers (Kypriotaki & Markodimitraki, 2018).

The above data increase the need for early evaluation and implementation of appropriate educational programmes focused on movement and motor development within the school environment, so as to facilitate the everyday life of children with ASD. Moreover, the varied motor difficulties of individuals with autism that are evident from infancy may signal the need for scientific and clinical discussions to include a separate diagnostic category for motor development in ASD in diagnostic and classification manuals of mental disorders. Additionally, Ketcheson et al. (2021) mentioned that the dysfunctions in motor coordination are pervasive among individuals with autism, which justifies the need to include early identification and early intervention for the motor behaviour of children with ASD (Ketcheson et al., 2021).

The relationship between social and motor skills in children with ASD

In recent years, researchers have focused their attention on the relationship between social and motor skills in children with ASD. Several studies have been conducted for this

purpose. The systematic review by Ohara et al. (2019), revealed that social and motor skills in children with ASD have a high correlation, with the skills related to object control (catch-throw a ball and kick) being superior in this relationship (Ohara et al., 2019). Another study (Wilson, Enticott et al., 2018) revealed the importance of the development of motor skills is in relation to the development of cognitive and social functioning in people with ASD, while in a study by Craig et al. (2018), a significant negative correlation was found between social skills and motor skills, and more specifically with the skills of aiming and grasping (Craig et al., 2018).

Existing literature suggests that deficits in specific motor skills, such as accuracy in motion, object control and stability were predictive of social behaviour (Holloway et al., 2021). Similarly, Zhou et al. (2022) mentioned that weakness in gross mobility is a predictor of the severity of difficulties in the social communication domain, and Wang at al. (2022) concluded that motor deficits are associated with the core symptoms of ASD (Wang et al., 2022; Zhou et al., 2022).

It is well documented that social and gross motor skills are key pillars for daily living skills and independence of individuals with autism. On the one hand, the role of the social domain is decisive for human relations, since one's social ability also determines the way one interacts with "others". On the other hand, early motor stimuli and experiences provide the trigger for exploration, acquisition of knowledge, as well as the obtainment of control over movements (Zimmer, 2007).

Purpose of the study

The aim of this study was to examine the relationship between gross motor and social skills development in children between the ages of seven and eleven years old, with a diagnosis of moderate autism, attending primary special education schools in Greece. The potential of such a relationship will further strengthen the need for assessment and intervention practices that cater for the development of both gross-motor skills and social skills, as gross-motor skills development may enhance children's social skills, and vice-versa. Previous studies have shown such a relationship to exist in different age groups of children with ASD in special education in different countries. For the purposes of this study, the latest version of the Test of Gross Motor Development (TGMD-3) (Ulrich, 2019) was used to measure children's gross-motor skills, and the Educational Evaluation Tool for Social Skills (EET-SS) in children with autism, was used for the assessment of children's social skills (Apteslis et al., 2012). Based on our literature review, this is the first attempt to concurrently use these tools to assess gross-motor skills and social skills in children with ASD in Greece.

Materials and Methods

Sample characteristics

Thirty-one children with ASD (21 boys, 67.7% and 10 girls) participated in this study, selected from four special educational school units in the Heraklion prefecture in Crete, Greece. Most of the children (n=22, 71.8%) lived in the city of Heraklion and the rest of the children lived in the suburbs of the city. The sample size was based on the availability of children with moderate severity of ASD attending the primary special education schools in the city of Heraklion. This sample size is comparable to the sample size of children with ASD who have participated in previous studies (Allen et al., 2017; Hirata et al., 2014; Prieto et al., 2023; Zamani Jam et al., 2018).

The children's ASD clinical diagnoses were issued by child psychiatrists and developmentalists who worked in private child psychiatric assessment services or in public hospitals and/or mental health centres, based on clinical assessments, using the International Classification of Diseases 10th Revision (ICD-10) and Autism Diagnostic Observation Schedule (ADOS) tools. Inclusion criteria to participate in the study were: a) the age of the child ranging between 7 to 10.11 years old, b) the diagnosis of ASD (according to the official diagnostic evaluations by multidisciplinary assessment, counselling, and support centres), c) the ability to participate in motor assessment, and thus children could not, and actually did not have any other neurological and movement disorders, or hearing or visual deficits and finally, d) the functionality level, as the children who would be selected, had to, and were actually able to comprehend and follow instructions.

At the same time, two exclusion criteria were set: a) parent's retreat from the accepted informed consent and b) a child's difficulty in following any of the instructions given during the experimental procedure.

The Educational Evaluation Tool for Social Skills (EET-SS)

The Educational Evaluation Tool for Social Skills (EET-SS) in children with autism was developed in the Greek language to assess social skills (Apteslis et al., 2012). EET-SS is a questionnaire that is completed by the child's special education teacher, and it is based on his/her view of the child's ability to perform social skills such as "observe the faces of others" (eye contact), perform an activity alone, standing or sitting without disturbing others (parallel activity) etc.

The EET-SS was selected because it is a tool specifically used with children with autism based on evaluation methods of the international literature (Hobson, 2019; Quill, 1995) as well as the TEACCH (Treatment and Education of Autistic and related Communication handicapped Children) method in terms of the social programme area (Olley, 1986).

The EET-SS questionnaire consists of nine categories (60 items) related to social skills: 1) proximity closeness (6 items), 2) eye contact (4 items), 3) parallel activity (4 items), 4) social response (18 items), 5) social initiative (3 items), 6) keeping order (7 items), 7) following rules (3 items), 8) reciprocity (10 items), 9) adaptation to change (5 items). Each of the 60 items have three responses (no, emerging and yes). "No" or "yes" refer to the lack of or presence of the social skill respectively. "Emerging" refers to when the student did not achieve the examined response independently but needed help to complete the activity. The scoring system of each section and for all sections was 0 for no, 1 for emerging and 2 for yes.

In a recent study in Greece, (Marouli et al., 2021) the EET-SS was used to measure the development of social skills in children with ASD between the ages of six and fourteen years old after an intervention programme of Greek traditional dance was implemented. In another recent study by Karpoutzaki et al. (2023), a few items from the Educational Evaluation Tool (EET) for children with autism were utilized to structure a questionnaire to study the effect of a therapy dog programme as a means of therapy in ASD children's social behaviour. (Karpoutzaki et al., 2023).

Test of Gross Motor Development (TGMD-3)

The TGMD-3 is the latest version of the TGMD inventory, a well-known and widely used tool for measuring gross mobility, developed by Ulrich (Ulrich, 2019). It consists of 50 items which are divided into two major sections: a) Locomotor Skills and b) Ball Skills activities. Locomotor Skills include the following measures: Run, Gallop, Slide, Horizontal Jump, Skip, Hop, and each of them consists of 3 or 4 items. Similarly, Ball Skill includes: two-hand strike (stationary ball), Kick (stationary ball), Underhand throw, two-hand Catch, Overhand throw, one-hand forehand (self-bounced ball), one-hand (stationary dribble) and

each of them consists of 3, 4 or 5 items. In this tool, each of the activities show a gradual increasing difficulty starting from "easier" gross motor skills (like run) to more complicated skills (like overhand throw). Each item has a binary response (0-not achieved, 1-achieved). Each section's score and the total score are calculated as the sum of specific score items.

The TGMD-3 is a valid and reliable tool that has been used in research with typical populations (Magistro et al., 2020; Webster & Ulrich, 2017), and ASD populations (Soleymani et al., 2019) and it is clinically sensitive to detect deficits in fundamental motor skills of children with disabilities (Pitchford & Webster, 2021). A systematic review (Rey et al., 2020) showed moderate-to-excellent internal consistency, good-to-excellent inter-rater reliability, good-to-excellent intra-rater reliability, and moderate-to-excellent test-retest reliability.

Moreover, Allen et al. (2017) applied the tool's visual support protocol to demonstrate the valid and reliable assessment of gross motor performance of children with autism, while Copetti et al. (2021) investigated the content validity of sequential pictures through a mobile application for testing the TGMD-3 test in children with autism and found it to be a supportive educational technique, especially in ball skills (Copetti et al., 2021). Also, several researchers have used this test to evaluate gross motor development after the implementation of intervention programmes in people with autism (Columna et al., 2021; Morales et al., 2022)

Procedure

Before the beginning of data collection, appropriate research licence was acquired from the local Ministry of Education authorities (19555/18-11-2022) in Crete, Greece. The primary researcher informed the school authorities, as well as the responsible classroom teachers regarding the study, and a Parental/guardian consent form was signed for all the participating children. In particular, the parents were informed about the protection of the children's personal data, as well as about their optional participation in the research. Additionally, the present research study was approved as following the ethics regulations for conducting research in schools in the framework of the Doctoral Studies programme at the researchers' university.

After appropriate communication with the responsible special education teacher of each class that the participating children attended, the gross-motor tests were performed during the teaching sessions on predefined school-working days. Each child performed each of the test tasks 3 times (one trial and 2 to evaluate performance), in the school area using the appropriate apparatus (balls, plastic bat, cones etc) under the supervision of the researcher. The physical education teacher of each school, who was specialized in adapted physical education, or the teacher in charge of each class was present for the TGMD-3 measures, so that the measurements were reliable.

It is worth reporting here that the researcher made an accurate translation, in the Greek language, of the verbal instructions of the images of the TGMD-3 test (Allen et al., 2017) and then printed and laminated them as small cards. Images included the 13 gross motor skills (6 locomotor skill subscales and 7 ball skill subscales). Before the performance of the task, the children were shown the pictures using an A4 card, step-by-step for each skill, so that they could understand, focus on all points of movement, and achieve the best possible performance. The motor sequence, through the visual demonstration, in terms of performance criteria, informed the child about what followed next, but also what he/she would be expected to perform, and in that way, it contributed to the best motor response. In a recent research literature review of twenty-seven research studies, it was reported that cards with picture tasks, as well as visual prompts in physical education lessons can be a useful method in educational practice for children with autism (Forbes & Yun, 2023).

At the same time, the classroom's special educator completed the EET-SS questionnaire for each child, in respect to his/her social skills. All data were recorded during the research process, specifically between November and December of 2022.

Statistical Analysis

Subscales and total scale of EET-SS questionnaire scores were calculated using sum of each item, and they were expressed as means and standard deviations. Additionally, more descriptive statistics, such as mode, median and minimum, maximum were performed to present continuous variables. TGMD-3 inventory skills, and gross mobility scores were also summed and expressed as mean and standard deviation based on the test developer's proposal (Ulrich, 2019). Normality tests were applied using the Shapiro-Wilks test which is more appropriate for small sample sizes (Ghasemi & Zahediasl, 2012). Spearman's rho was used to establish possible associations between subscales and total scores of EET-SS and TGMD-3 scales. Scatterplots of TGMD-3 and EET-SS scales and subscales were used to graphically describe associations between those scales. The statistical analysis was performed using IBM SPSS Statistics 24.0 and a level of acceptance was set at 0.05.

Results

The children with ASD who participated in this study were from four schools for children with special needs. Only three children (9.7%) were overweight. Twenty-one (67.7%) were boys. Six children (19.4%) and five children (16.1%) were left-handed and left-footed respectively. The mean chronological age was 9.3 ± 1.4, ranging from 7 up to 11 years old.

Descriptive statistics, including mean, median, mode, min-max, SD values of TGMD-3 (Locomotor Skills) and TGMD-3 (Ball Skills) are shown in **Table 1**. The mean total score of Locomotor Skills activities was 21.1±9.3 with a median 18 and a mode of 16, while the corresponding descriptives of Ball Skills activities were 21.5±8.1, median 22 and mode 12. Among the Locomotor Activities, "Run" showed the highest mean 5.7±1.5 and median (mode) 5 (5), while "Gallop" followed (mean: 4.0±2.3, median (mode): 4(3)).

Regarding the Ball Skills activities, the higher means were 4.6±2.2 and 4.2 ±1.6 for the "2-hand strike (stationary ball)" and "Kick (stationary ball)" respectively. Under a mean score of 4 and over 3.0 two skills were identified: "Underhand throw" (3.9 ± 2.0) and "2-hand Catch" (3.6 ± 1.1). The lower scores were found for "Overhand throw" (2.4 ± 1.3), "1-hand forehand (self-bounced ball)" (1.6 ±1.8) and "1-hand (stationary dribble)" (1.2±1.8). Average scores of each Locomotor skill were: "Run" (0.71), "Gallop" (0.50), "Slide" (0.45), "Horizontal Jump" (0.44), "Skip" (0.37), "Hop" (0.25) and total score (0.46). Thus, the average score of each Ball Skill activity were: "2-hand strike" (stationary ball) (0.46), "Kick" (stationary ball) (0.53), "Underhand throw" (0.49), "2-hand Catch" (0.60), "Overhand throw" (0.30), "1-hand forehand strike" (self-bounced ball) (0.20), "1-hand stationary dribble" (0.2) and total score (0.41).

Normality of TGMD-3 Locomotor and Ball Skills score was tested using Shapiro-Wilks test (S-W) an appropriate test for small sample sizes. Based on S-W test normal distribution was found for "Gallop" (z=.944, p=.107), "Skip" (z=.933, p=.052) and Total Locomotor Score (z=,943, p=.099) between the Locomotor Skills. Additionally, for the Ball Skills inventory normal distribution was found for "2-hand strike" (stationary ball) (z=.938, p=.071), "Overhand throw" (z=.935, p=.059) and "Total Ball Skills" score (z=.970, p=.510).

Descriptive statistics of TGMD-3 scales reveal that there are certain deficits in gross mobility skills, based on the presented scores. Taking into consideration the fact that the highest score on each Locomotor activity, based on performance criteria, were 8 for "Run", "Gallop", "Hop", "Horizontal Jump" and "Slide" activities, 6 was for "Skip", while the highest total score could be 46. In the Ball Skills section activity the highest scores could be 10 for "2-

hand strike" (stationary ball), 8 for "1-hand Forehand strike" (self-bounced ball), "Kick", "Overhand throw" and "Underhand throw" and 6 for "2-hand Catch" and "1-hand stationary dribble", while the total highest could be 54 (Rey et al., 2020). Both Locomotor and Ball Skills inventory scores showed that there are deficits in gross motor domain in children with ASD.

Previous metanalyses and systematic reviews in the literature support the existence of deficits in children with ASD when compared to typically developing children (Allen et al., 2017; Kangarani-Farahani et al., 2024).

Table 1 Descriptive statistics of TGMD-3 Locomotor Skills and Ball Skills

Activities	TGMD-3	Mean ± SD	Median (mode)	Min-Max	S-W z	S-W p
Locomotor Skills	**Run**	5.7 ± 1.5	5 (5)	3 - 8	.914	.016
	Gallop	4.0 ± 2.3	4 (3)	0 - 8	.944	.107
	Slide	3.6 ± 2.6	4 (3)	0 - 8	.931	.046
	Horizontal Jump	3.5 ± 1.7	4 (4)	0 - 7	.919	.022
	Skip	2.2 ± 1.6	2 (2)	0 - 6	.933	.052
	Hop	2.0 ± 2.2	1 (0)	0 - 7	.824	<.001
	Total Locomotor Skills Score	21.1 ± 9.3	18 (16)	8-42	.943	.099
Ball Skills	**2-hand strike** *(stationary ball)*	4.6 ± 2.2	5 (5)	0 - 8	.938	.071
	Kick *(stationary ball)*	4.2 ± 1.6	4 (4)	0 - 6	.907	.011
	Underhand throw	3.9 ± 2.0	5 (6)	0 - 6	.866	.001
	2-hand Catch	3.6 ± 1.1	4 (3)	1 - 6	.931	.047
	Overhand throw	2.4 ± 1.3	2 (2)	0 - 5	.935	.059
	1-hand forehand *(self bounced ball)*	1.6 ± 1.8	1 (0)	0 - 6	.823	<.001
	1-hand *(stationary dribble)*	1.2 ± 1.8	0 (0)	0 - 6	.713	<.001
	Total Ball Skills Score	21.5 ± 8.1	22 (12)	7-40	.970	.510

Note: Mean ± SD: Mean score and standard deviation, M (mode): median and mode of distribution, Min-Max: Minimum and maximum scores of the sample, S-W z: Shapiro – Wilks test z-value statistic, S-W p: Shapiro-Wilks test p-value.

Children's social skills were measured using the scale presented in the methodology section (no=0, emerging=1, yes=2). In Table 2, the mean scores and standard deviations for all the factors are presented. Since the number of items was different in each EET-SS scale and in order to estimate the levels of social skills in ASD children, the total score was divided by the number of scale item, producing a mean score per item. The average score per item was higher for "Eye Contact" 1.5, for "Parallel Activity" 1.5, for "Proximity/Closeness" 1.4, for "Social Response" 1.4 and for "Adaptation to Change" 1.4. Score 1.2 per item was calculated for "Reciprocity", 1.1 for "Keeping Order" scale, 1.0 for "Social Initiative" and 0.8 for "Following Rules", while the total score per item was 1.3. Additionally, the ranges of each social skill of the EET-SS scale were: Proximity-Closeness (0-12), Eye contact (0-8), Parallel Activity (0-8), Social Response (0-36), Social Initiative (0-6), Keeping Order (0-14), Following Rules (0-6), Reciprocity (0-20), Adaptation to Change (0-10) and Total EET-Score (0-120).

Based on the results, all the children who participated in this study have a certain pattern of social skills deficits in many of the examined skills, although there are certain skills items on which children scored sufficiently. Comparing the maximum scores to the mode and median scores, we notice that the main skills that showed deficit were: Social Initiative, Keeping Order, Reciprocity and Adaptation to Change. The children's scores cannot be

compared to other scores found in other similar studies due to the limited use of the inventory in the existing literature.

Normality of the EET-SS Skills scores are also presented in Table 2.

Table 2 Descriptive statistics of each factor and number of items

	Mean ± SD	M (mode)	Min-Max	S-W z	S-W p
Proximity/Closeness	8.6 ± 2.1	9 {9)	4 – 12	**.949**	**.147**
Eye contact	6.1 ± 2.1	7 {8)	0 – 8	.844	<.001
Parallel Activity	5.8 ± 2.4	7 {8)	0 – 8	.843	<.001
Social Response	25.7 ± 6.9	25 {36)	13 – 36	**.948**	**.137**
Social Initiative	2.9 ± 2.0	2 {2)	0 – 6	.919	.022
Keeping Order	7.6 ± 3.7	7 {5)	0 – 14	**.963**	**.344**
Following Rules	2.5 ± 1.8	2 {5)	0 – 6	.891	.004
Reciprocity	12.0 ± 4.0	12 {5)	4 – 20	**.976**	**.683**
Adaptation to change	6.9 ± 2.9	8 {5)	0 – 10	.869	.001
Total EET-SS Score	79.2 ± 18.5	74 {5)	47 - 116	**.959**	**.283**

Note: Mean ± SD: Mean score and standard deviation, M (mode): median and mode of distribution, Min-Max: Minimum and maximum score of the sample, S-W z: Shapiro-Wilks z- value statistic, S-W p: Shapiro-Wilks test p-value

In **Tables 3** and **4** the correlation coefficients, Spearman's r were estimated between TGMD-3 skills scores and the teachers' perceived social skills scores of children with ASD. Based on the results, the total score of EET-SS was correlated with motor skills scores, specifically the "Run" skill (r=.40) and the "Horizontal Jump" skill, but not with the total TGMD-3 score. "Social response" was correlated with most of the items of the TGMD-3 inventory such as "Run", (r=.42) "Hop" and "Horizontal Jump". (r=.49). "Social initiative" was correlated with TGMD-3 Locomotor scores (r=.37). "Hop" (r=.36), "Skip" (r=.43), "Horizontal Jump" (r=.50). Other correlations were found with: a) EET-SS "Eye contact" with TGMD-3 "Run" (r=.40) and with "Horizontal Jump", (r=.44), b) "Adaptation to Change" with "Hop" (r=.38) and with "Skip" (r=.46). All other bivariate associations were not significant (p>0.05), as shown in **Table 3.**

Furthermore, the EET-SS Social Skills scores were correlated with specific motor skills scores (ball skills), such as: "2-hand strike" (stationary ball) (.39) "1-hand forehand" (self-bounced ball) (r=.30) "1-hand stationary dribble" (r=.38), "Overhand throw" (r=.43) and the Ball Skills score (r=.47). The "Social initiative" scale of the EET-SS questionnaire is the subscale which correlated with most of the TGMD-3 scales: "2-hand strike" (stationary ball)(r=.40)), "1-hand stationary dribble" (r=.39) "kick" (stationary ball) (r=.38)"overhand throw" (r=.36) and Total Ball Skills score (r=.48). Additionally, the EET-SS "Following Rules" scale, the "Eye contact" scale, the "Parallel activity" scale, and other EET-SS scales were also correlated with specific motor skills scores, as shown in Table 4. The EET-SS scales "Proximity/closeness" and "Reciprocity" were not correlated with any of TGMD-3 scales.

Table 3 Correlation of TGMD-3 Locomotor Skills scores with teachers' perceived Social Skills scores for children with ASD

	TGMD-3 Locomotor skills						
	Run	**Gallop**	**Hop**	**Skip**	**Hori-zontal Jump**	**Slide**	**Locomotor Skills Score**
EET-SS	**r**	**r**	**R**	**r**	**r**	**r**	**r**
Proximity/closeness	.16	-.16	.02	-.03	.13	-.07	-.05
Eye contact	**.40**	.20	.18	.12	**.44**	.05	.20
Parallel activity	.29	.08	-.06	-.10	.19	-.01	.01
Social response	**.42**	.04	**.45**	.34	**.49**	.24	.36
Social initiative	.18	.27	**.36**	**.43**	**.50**	.22	**.37**
Keeping order	.21	.07	.06	.18	.23	.001	.08
Following rules	.22	-.04	.20	.26	.07	.08	.15
Reciprocity	.03	-.02	.12	.27	.11	-.08	.02
Adaptation to change	.33	.02	**.38**	**.46**	.19	.19	.30
Total EET-SS	**.40**	.05	.26	.31	**.38**	.09	.23

Note: Bold values refer to statistically significant correlations ($p<.05$) between paired variables r: Spearman's rho coefficient

The correlation between the children's age based on the TGMD-3 Locomotor score and their calculated age based on TGMD-3 Ball Skills is shown in **Figure 1**. Spearman's r indicates a positive moderate correlation of children's ages (rs=.54, p=.002). This finding shows that there is a moderate to strong correlation between the equivalent ages of TGMD-3 Locomotor and Ball Skills activities. There is no significant difference between the mean equivalent Locomotor age (4.5 ± 2.1) and TGMD-3 equivalent Ball Skill age (4.2 ± 1.2) (Mann Whitney z=-.855, p=.393). Differences in equivalent ages are also shown in Figure 2. Data showed that there are cases where there is a higher difference between Locomotor and Ball skills equivalent ages, thus documenting the differences that can be present in children with ASD.

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Table 4 Correlation of TGMD-3 Ball Skills scores with teachers' perceived Social Skills scores for children with ASD

	TGMD-3 Ball Skills							
EET-SS	**2-hand strike** r	**1-hand forehand** r	**1-hand stationary dribble** R	**2-hand catch** r	**Kick** r	**Overhand throw** r	**Underhand Throw** r	**Ball Skills score** r
Proximity/closeness	.21	.04	.05	-.10	.27	.23	.13	.22
Eye contact	.18	.19	**.49**	.20	.25	.42	.17	**.40**
Parallel activity	.18	.14	.05	.08	.09	**.39**	.16	.28
Social response	**.43**	.26	.29	-0.05	.20	**.50**	.07	**.43**
Social initiative	**.40**	.27	**.39**	.14	**.38**	**.36**	.14	**.48**
Keeping order	.10	.17	.33	.10	.19	.35	-12	.22
Following rules	**.34**	**.47**	**.41**	.09	.12	.03	.21	**.39**
Reciprocity	.04	.14	.16	.08	.08	.16	.09	.15
Adaptation to change	.36	.30	.20	.04	.22	.18	.33	.41
Total EET-SS	**.39**	**.30**	**.38**	.04	.24	**.43**	.15	**.47**

Note: Bold values refer to statistically significant correlations ($p<.05$) between paired variables r: Spearman's rho coefficient

Figure 2 shows the mean chronological age, the mean estimated TGMD-3 developmental age, along with their SDs as a measure of dispersion are shown. We see that there is a mean deficit in children's developmental ages based on the TGMD-3 Locomotor scores and Ball Skills scores compared to children's chronological ages. The mean reduction between chronological age and TGMD-3 Locomotor age was 4.8 years and between children's chronological age and TGMD-3 Ball Skills it was 5.1 years. The diagram shows that the equivalent ages of children with ASD, with a moderate autism diagnosis, attending primary special education schools, were about 5.0 years lower than their chronological age, indicating certain mobility deficits.

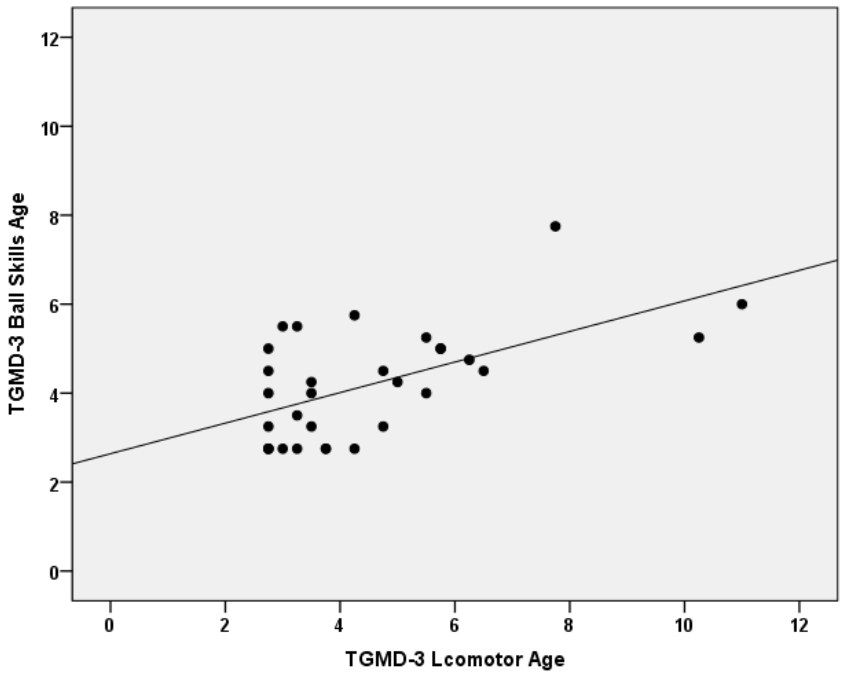

Figure 1 Correlation of TGMD-3 Locomotor Age with Ball Skills Equivalence Age

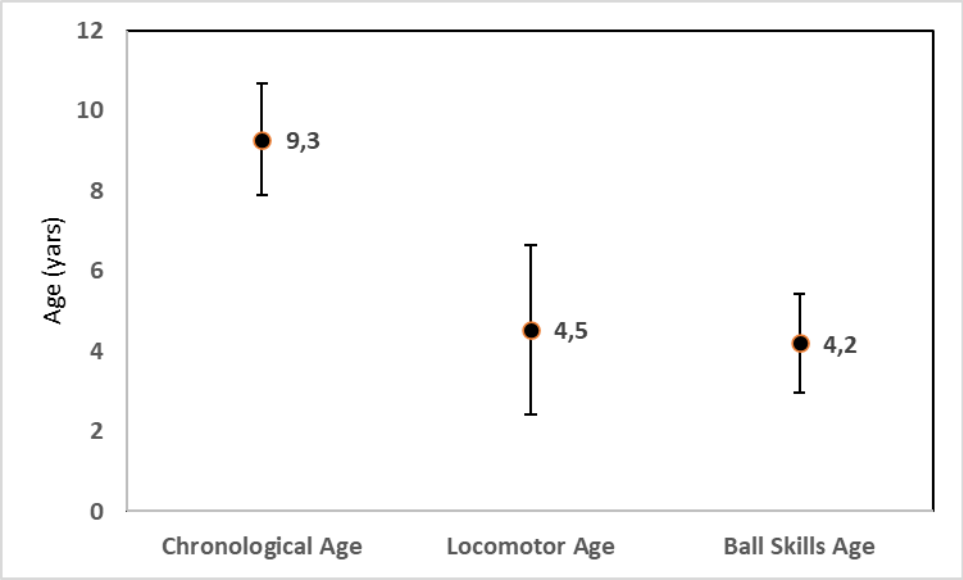

Figure 2 Chronological and equivalence ages based on TGMD-3 scores

The correlation between the developmental ages as estimated from TGMD-3 Locomotor or TGMD-3 Ball Skills scores are shown in **Table 5**. Locomotor equivalent ages correlated only with EET-SS "Social Initiative", (r=.377, p=.036) while tendencies for a correlation (.05 <p<.100) were found with the EET-SS "Social Response" and the EET-SS "Adaptation to Change" (r=.373, p=.070) scores.

The equivalent age based on TGMD-3 Ball Skills score was correlated significantly with the EET-SS "Eye Contact" score (r=.408 p=.023), the "Social Response" score (r=.452, p=.011), the "Social Initiative" score (r=.473, p=.007), "Adaptation to Change" score (r=.373. p=.039)

and Total EET-SS score (r=.462, p=.009). Tendency for significant correlations (.05 <p <.100) was found for the EET-SS "Following Rules" score, as shown in Table 5 (r=.346, p=.056).

Based on the results, the "Social Initiative" scale scores are related to the Locomotor and Ball Skills age scores, while most of the social skills scores were related to the Ball Skills age scores.

Table 5 Correlation of TGMD-3 Locomotor and Ball Skills Age with the Teachers Perceived Social Skills scores (EET-SS scale)

	Equivalent Ages			
	Locomotor Age		**Ball Skills Age**	
EET-SS scales	**r***	**p**	**r***	**p**
Proximity/closeness	-.026	.890	.262	.154
Eye contact	.168	.367	**.408**	**.023**
Parallel activity	.015	.934	.218	.239
Social response	.339	.062	**.452**	**.011**
Social initiative	**.377**	**.036**	**.473**	**.007**
Keeping order	.068	.717	.254	.169
Following rules	.175	.348	.346	.056
Reciprocity	.059	.752	.143	.443
Adaptation to change	.330	.070	**.373**	**.039**
Total EET-SS	.229	.215	**.462**	**.009**

Note: r* Spearman's r

Discussion

The present study, based on the results of the measures of gross mobility and teachers' perceived social skills in primary special education school children with ASD, revealed that there was an association between children's social and gross motor skills scores. This study's results support the fact that there are various components of the measured social skills, as perceived from the participating children's special education teachers in charge, that correlate with children's gross motor skills. Specifically, children' s scores on their initiative in social stimulations (the Social Initiative Scale) seem to associate in a clearer manner with their gross mobility scores. Children's performance on activities such as object manipulation or visual motor coordination (the total Ball Skills score), was also associated with the overall evaluation from the children's teachers regarding children's social skills. Furthermore, an important finding is also the fact that children's developmental ages, as derived from their performance on the Ball Skill activities, were found to be positively correlated with many social skills of children with ASD who participated in this study.

Research has shown that children with ASD exhibit lower gross motor and social skills than typically developing children. This was further supported in an recent experimental study comparing forty children with ASD, aged from 8 to 16 years old, with forty children as control group, in respect to their social and gross motor skills (Pusponegoro et al., 2016). Other studies, experimental or review-based, focused on children's social skills, showing deficits in children with Asperger's (Cappadocia & Weiss, 2011) or ASD disorders in general (Kozlowski et al., 2012). Similar findings can be found for gross mobility, including gait deviations, in children with ASD, compared to those without ASD (Kindregan et al., 2015; Shetreat-Klein et al., 2014). Although the design of the present study did not include any comparison between the scores of children with ASD to children without ASD, there is an indirect comparison that

can be assumed between children's chronological and developmental ages, based on their gross mobility score (TGMD-3 scores). A reduced developmental age of around 5 years of age found in the present research study shows the delay of gross motor skills development in children with ASD who participated in the study, due to the fact that those ages are based on nomograms of children without ASD (Ulrich, 2019).

Also worth noting is the evaluation of children's social skills development and the measures of children's gross mobility. Scholarly literature in the area of autism includes the use of a number of mobility tests, such as the Movement Assessment Battery for Children-2 (MABC-2) (Brown & Lalor, 2009), the Mullen Scales of Early Learning (MSEL), the Bayley Scales of Infant and Toddler Development (Bayley-III), and the Peabody Developmental Motor Scale-2 (PDMS-2) (Wilson, McCracken et al., 2018).

Similarly, different social skills measurement instruments have also been used in research studies, where two main categories of these instruments can be found: a) instruments that are "objective" measures of social skills and b) instruments that assess children's social skills development as perceived by children's parents or teachers. Such instruments are the Social Responsiveness Scale (SRS), the Social Communication Questionnaire (SCQ), the Autism Spectrum Screening Questionnaire (ASSQ) and others (McMahon et al., 2013). Although this variety of instruments share similarities, it is difficult for the researchers to conduct a direct comparison or correlation of the skills that they measure.

Overall, one of the main findings of our study was the correlation between children's social skills scales scores and their gross mobility scales scores. Ohara et al. (2019) had similar conclusions through their review research, where they found that children's social skills were related to children's object control skills, specifically kicking, catching, and throwing a ball. Furthermore, Hirata et al. (2014) mentioned that social difficulties were related to fundamental motor skills, specifically with children's manual dexterity, in a study where the Social Responsiveness Scale (SRS) and the Movement Assessment Battery for Children-2 (MABC-2) were used as measurement scales respectively, in a Japanese population (Hirata et al., 2014). Also, in a study that has examined the relationship between gross motor delay and behavioural problems, it was found that the presence of internalized problem behaviour is a factor in the existence of difficulties in the gross mobility of children with ASD (Hedgecock et al., 2018).

Furthermore, previous studies have shown that motor dysfunctions were highly correlated with the severity of autism (Hilton et al., 2012), while Fournier et al. (2010), after performing a meta-analysis research, found that difficulties in motor coordination, gait and movements of the arms, were some of the basic features in the autism spectrum disorder (Fournier et al., 2010). Similar results were found by Wang et al. (2022) regarding the relationship between motor difficulties and the main symptoms of ASD (Wang et al., 2022).

Additionally, through a meta-analysis research West (2019) found that motor ability was related with communication skills in infants with ASD, and that there was a difference in motor ability between infants with and without ASD (two different groups) which grew with increasing age (West, 2019).

It is becoming evident that the field of motor skills development in children with ASD has been of considerable interest to researchers over the last years. Notwithstanding that motor dysfunction is not a distinct category in the diagnostic features of ASD, it is indeed very common in these children. Literature supports the fact that ASD children show a delay in achieving motor milestones, as well as the fact that there is a difference in the quality of movement of children with ASD (Battah et al., 2023; Gandotra et al., 2020; Mohd Nordin et al., 2021). Furthermore, many researchers have previously explored the variability in the motor impairments of individuals with ASD (Fournier et al., 2010; Fuentes et al., 2009; Gong et al., 2020), while Zampella et al. (2021) also found that intervention programmes targeting motor

function may have an impact on social communication (Zampella et al., 2021). Gonzalez et al. (2019) concluded that fine and gross motor skills reinforce the development of language skills in ASD children up to early childhood (Gonzalez et al., 2019). Additionally, a review study found that over 50% of children with ASD studied had motor deficits in motor tests (Kangarani-Farahani et al., 2024) and additional research showed that early motor dysfunction may be a prognostic marker for autism (Harris, 2017; Posar & Visconti, 2022; West, 2019).

Based on the present study, as well as on previous research results, and in parallel with research literature concerning primary-school students with ASD, it may be well supported that children's gross motor skills and their social skills development should be considered crucial components of the overall development of children with ASD. Furthermore, the relationship between gross motor skills and social skills development highlights the need to introduce and include assessment of motor skills development by specialists in the Greek interdisciplinary assessment, counselling, and support centres, who undertake the assessment of children with ASD in Greece, so that greater emphasis is placed on educational intervention programmes focusing on motor skills development in school environments. Additionally, Adapted Physical Education may play an important role in enhancing motor skills development in children with ASD, as special physical education teachers in schools are responsible for helping students' gross mobility and health development through teaching and promoting physical activity.

Within this context, contemporary educational systems' teaching programmes are being implemented in different parts of the world using educational software to develop various skills in children. According to previous research, digital technology provides equal learning opportunities, and it is a useful tool for quality education (Haleem et al., 2022). Here, we should mention that the present research study is part of another ongoing study conducted by the researchers. The broader study involves an experimental educational intervention programme, using a digital kinetic software aimed at improving the social and mobility skills development of children with ASD in Greece.

Regarding the limitations of this study, we acknowledge the fact that the use of the EET-SS as a measure of teacher's perceptions of the students' social skills is a non-validated instrument. Specifically, the EET-SS which was used in this study, has not been examined for its external and internal validity compared with other measurement instruments for social skills development, and it was not previously tested for repeatability. Additionally, so far, it has not been used extensively in research, as is the case with other social skills development tools. On the other hand, one of the strengths of this study is the use of version 3.0 of the TGMD test with a Greek student population with ASD. This test version is a newly released version, and thus it has not been yet used extensively within this research area. Based on our review of previous documented research studies, this is the first, or at least one of the first attempts, to measure gross mobility development in Greek students with ASD using the TGMD-3.

Overall, we believe that our study supports previous research findings, and reveals a moderate correlation between the social skills and the gross motor skills development of children with ASD between the ages of seven and eleven years old, specifically, and more prominently, in respect to the relationship between children's specific social skills development and their object manipulation skills development.

As a conclusion, research studies that assess gross-motor skills development and social skills development of children with ASD may offer meaningful information regarding this disorder. As far as we know, no previous research using the combination of these assessment tools has been conducted in Greece before. Therefore, knowledge of these research results may well guide special education professionals, such as special educators, therapists, and psychologists to more targeted interventions that could provide better and quicker outcomes for children with Autistic Spectrum Disorders, and ultimately improve the quality of these children's everyday functioning in school or any other setting.

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