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Linking Sensory Processing and Fine Motor Function to Daily Living Skills: A Comparative Study Among Children with Autism Spectrum Disorder, Down Syndrome and Typically Developing Peers

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ABSTRACT

Purpose: This study examined the relationship of sensory processing and fine motor abilities with daily living skills (DLS) among children with autism spectrum disorder (ASD), Down syndrome (DS), and typical development (TD) in Malaysia. Understanding these relationships can inform culturally relevant and effective rehabilitation approaches. Methods: A comparative cross-sectional design was employed with 120 children aged 5-6 years (40 ASD, 40 DS, 40 TD). Sensory processing was assessed using the Short Sensory Profile-2 (SSP-2), while fine motor skills and DLS were measured using the Vineland Adaptive Behavior Scales, Third Edition (VABS-3). Group differences were analyzed using the Kruskal-Wallis test, and relationships among domains were examined with Spearman's correlations. Results: Significant group differences were observed across sensory, fine motor, and adaptive domains ($p < .001$). Children with ASD demonstrated the greatest sensory modulation difficulties, while those with DS showed milder but distinctive under-responsive patterns. TD children exhibited the best performance across all measures. Fine motor skills were strongly associated with DLS in all groups ($\rho = .907$, $p < .01$). Among children with ASD, all sensory quadrants were significantly correlated with DLS ($\rho = .722$-$.908$, $p < .001$), indicating a strong sensory-functional link. Conclusions: Sensory and fine motor domains contribute differently to adaptive functioning (DLS) across diagnoses. Early, integrated sensory-motor interventions may enhance daily independence, particularly for children with ASD. These findings provide culturally specific evidence to guide pediatric rehabilitation practice in Malaysia.

Keywords: *sensory processing, fine motor skills, daily living skills, autism spectrum disorder, Down syndrome, rehabilitation*

Introduction

The development of fine motor and sensory processing abilities is fundamental to children's engagement in daily activities and their progression toward functional independence. As children mature, they gradually gain control over the small muscles of the hands, fingers, and wrists. This control enables them to perform complex fine motor tasks such as writing, buttoning, and feeding (Matheis & Estabillo, 2018). These fine motor abilities support daily living skills (DLS), which include self-care and object manipulation, both of which are essential for autonomy and social participation (Skaletski et al., 2024). Similarly, sensory processing refers to the brain's ability to receive, interpret, and organize input from various sensory modalities. It forms the foundation for postural control, spatial orientation, and purposeful movements (Allen & Casey, 2017). Effective sensory integration facilitates motor learning, attention, and adaptive behavior. In contrast, impairments in either sensory or motor domains can significantly restrict participation in home, school, and community environments, thereby reducing independence and quality of life.

Children with autism spectrum disorder (ASD) and Down syndrome (DS) might experience challenges in both sensory processing and fine motor function. ASD is a neurodevelopmental condition characterized by persistent deficits in social communication and the presence of restricted and repetitive behaviors (American Psychiatric Association, 2022). Beyond these core features, children with ASD frequently demonstrate difficulties in manual dexterity, perceptual-motor coordination, and motor planning (Kaur et al., 2017; Skaletski et al., 2024). Likewise, children with DS often present with poor hand coordination, reduced grip strength, and slower motor execution, which collectively affect their ability to perform self-care and school-related tasks (Cepeda Acosta et al., 2024; Lersilp et al., 2016).

In addition to motor challenges, both groups exhibit atypical sensory processing. Children with ASD commonly display heightened patterns of hyperresponsiveness, hyporesponsiveness, and sensory-seeking behaviors. Children with DS also show sensory modulation difficulties, although these are typically milder and follow a different profile (Israelowitz et al., 2022). While these differences are most prominent among children with neurodevelopmental disorders, subtle variations in sensory responsivity and motor proficiency are also observed among typically developing (TD) children (Israelowitz et al., 2022; Ringold et al., 2022).

DLS, which include dressing, grooming, toileting, and meal preparation, are central to adaptive functioning and contribute to a child's autonomy and quality of life. However, numerous studies report that children with ASD and DS demonstrate significant delays in DLS compared to their TD peers (Kilincaslan et al., 2019; Van Deusen et al., 2024). Despite the extensive literature describing sensory and motor impairments, few studies have investigated their combined or relative contributions to functional outcomes across different diagnostic groups, particularly in non-Western populations.

This gap is especially relevant to rehabilitation and clinical practice. Understanding how sensory and motor domains influence DLS can inform the development of more effective, individualized intervention strategies. Therefore, this study aimed to examine the relationship of fine motor and sensory processing abilities with DLS among children with ASD, DS, and typical development within the Malaysian context. Specifically, this study addressed the following research questions: (1) Do fine motor and sensory processing abilities significantly relate to DLS among children with ASD, DS, and typical development? (2) Are there significant differences in these domains (fine motor, sensory processing, and DLS) across diagnostic groups?

Literature review

Development of Sensory and Fine Motor Skills in Children

Child development relies on the integration of sensory input and motor control to support

purposeful interaction with the environment (Florio, 2025). Fine motor skills involve the use of small muscle groups in the hands and fingers to perform precise tasks such as writing, dressing, and self-feeding (Ahn et al., 2004; Scharf et al., 2016). These skills emerge progressively from infancy, beginning with grasping and shaking objects at three months and advancing to pincer grasp, self-feeding, and drawing by the age of six (Sutapa et al., 2021; Syafril et al., 2018). Alongside this, children's DLS such as eating, dressing, toileting, and grooming develop in parallel, reflecting increasing independence (Daryl & Cempron, 2021).

Sensory processing plays a fundamental role in child development by enabling the brain to organize and interpret information from multiple systems, including tactile, vestibular, proprioceptive, auditory, and visual inputs, to plan and execute movements efficiently (Allen & Casey, 2017). According to Piaget's sensorimotor stage, early sensory exploration is key to motor learning and cognitive development (Sanghvi, 2020). Effective sensory integration supports postural control, spatial awareness, and eye-hand coordination, all of which are essential for fine motor precision and adaptive behavior (Awalludin & Akbar, 2020). These interdependent systems form the foundation for functional participation in everyday life.

Sensory Processing and Daily Living Skills

Sensory processing is essential for successful participation in daily activities such as self-care, play, and learning. Sensory processing disorder (SPD) refers to difficulties in regulating and responding to sensory input, which may lead to over- or under-responsiveness to environmental stimuli. Among typically developing children, approximately 5 to 13 percent of kindergarten-aged individuals exhibit sensory difficulties that affect behavior, emotional regulation, motor coordination, and social functioning, ultimately limiting their adaptive skills (Ahn et al., 2004). These challenges can disrupt performance across multiple occupational domains, including education, self-care, and social participation (Pfeiffer et al., 2018).

Children with neurodevelopmental disorders such as ASD and DS demonstrate significantly higher rates of sensory processing difficulties. Comparative studies consistently show that children with ASD exhibit the highest levels of atypical sensory behaviors, followed by children with DS and then their TD peers (Israelowitz et al., 2022; Ringold et al., 2022). In ASD, sensory dysfunction has been shown to significantly impact fine motor coordination and daily functioning (Muthusamy et al., 2021). Malaysian data reflect these trends, with 68.8 percent of children with ASD exhibiting sensory processing difficulties compared to 21.5 percent of TD peers, particularly in tactile and auditory domains (Loh et al., 2020).

Sensory-seeking behaviors are observed in nearly half of children with ASD but in fewer than one-third of TD children (Pérez et al., 2019). These sensory modulation difficulties, particularly in the tactile and auditory systems, are associated with challenges in self-care routines such as dressing, bathing, toileting, and grooming (Ahmed et al., 2020). Children with DS may also display mild to moderate sensory atypicalities, often linked to hypotonia and delayed sensory integration (Israelowitz et al., 2022). However, research on sensory processing in children with DS remains relatively limited. Overall, these findings highlight the critical role of sensory processing in supporting daily functioning across diagnostic groups.

Fine Motor Skills and Daily Living Skills

Fine motor control contributes directly to the performance of adaptive and self-care behaviors. Tasks such as buttoning clothes, using eating utensils, and writing require strength, bilateral coordination, and precise hand movements. Numerous studies have shown that children with ASD and DS perform significantly lower in fine motor proficiency compared to their TD peers (Mohd Nordin et al., 2021). These deficits are often compounded by underlying sensory processing differences, which are more prominent in ASD (Pérez et al., 2019).

Children with ASD and DS commonly present with reduced hand dexterity, slower response times, and impaired coordination. However, patterns of fine motor impairment differ between groups. For example, children with ASD tend to have greater difficulties in bilateral coordination and visual-motor integration, while children with DS often exhibit uncoordinated and variable movements, primarily due to hypotonia and deficits in sensorimotor integration (Saber et al., 2023; Schott & Holfelder, 2015). Both conditions affect self-care and academic participation, albeit through distinct mechanisms.

Motor proficiency is a strong predictor of adaptive behavior. For instance, fine motor skills were found to account for up to 50 percent of the variance in DLS among boys with developmental disabilities, emphasizing the foundational role of motor competence in functional skills (Macdonald et al., 2017). These findings highlight the therapeutic value of early fine motor intervention within rehabilitation frameworks.

Research Gap

While both sensory processing and fine motor skills are known to influence DLS, few studies have examined their combined or relative contributions across ASD, DS, and TD groups. Most existing evidence is based on Western populations, with limited research conducted in Southeast Asia. To address this gap, the present study investigates how sensory processing and fine motor performance jointly relate to DLS in children with ASD, DS, and typical development in Malaysia. This work contributes to a more culturally contextualized understanding of adaptive behavior (DLS) and informs the design of targeted rehabilitation strategies.

Methodology

Study Design

This study employed a comparative cross-sectional design to examine the relationships between sensory processing, fine motor skills, and DLS among children with ASD, DS, and TD peers in Malaysia. This design enabled the identification of intergroup differences and relationships among developmental domains within a defined period, consistent with the comparative research principles used to explore similarities, distinctions, and underlying mechanisms across populations (Esser & Vliegenthart, 2017; Iranifard & Roudsari, 2022). Ethical clearance was obtained from the Research Ethics Committee of Universiti Teknologi MARA (UiTM) (Approval No.: ERC/FSK/MR/2024/00350), and additional permission was granted by each participating center prior to recruitment.

Sampling Method and Study Participants

Participants were recruited using purposive sampling to ensure the inclusion of children with distinct developmental profiles relevant to the study's objectives. This non-probability sampling method was appropriate for selecting cases with specific diagnostic characteristics (Campbell et al., 2020). Recruitment was conducted in Selangor, Malaysia, across special education centers and preschools serving both developmental and typically developing populations.

A total of 120 children aged 5 to 6 years participated in the study. The sample comprised three groups of equal size: 40 children with ASD, 40 with DS, and 40 typically developing children. Children with ASD were recruited from the Occupational Therapy Clinic, Faculty of Health Sciences, UiTM Puncak Alam. The DS group was recruited from the Kiwanis Down Syndrome Foundation in Petaling Jaya, and the TD group was drawn from Genius Sinar Impian Preschool, Puncak Alam.

Sample size was determined using G*Power version 3.1.9.7. A one-way fixed-effects ANOVA with a medium effect size (f = 0.29), alpha level of 0.05, and power of 0.80 indicated that 120 participants would be sufficient to detect significant group differences ($\lambda = 10.09$, critical F = 3.07, df = 2, actual power = 0.81).

Inclusion criteria required that participants be Malaysian citizens aged 5 to 6 years, with a diagnosis of ASD or DS confirmed by a qualified clinician or typically developing without

neurodevelopmental conditions. Caregivers were required to understand Malay and English. Children with severe physical disabilities, co-occurring neurological or psychiatric disorders, or non-Malaysian residency were excluded.

Study Instruments and Data Collection Procedure

Demographic Questionnaire

A structured demographic form was developed to collect information about the child's age, gender, diagnosis, parental background, and daily routines. Additional questions addressed functional areas such as feeding, dressing, social interaction, sensory responses, and fine motor behavior.

Short Sensory Profile-2 (SSP-2)

Sensory processing was assessed using the Short Sensory Profile-2 (SSP-2), a standardized caregiver-report tool for children aged 3 to 14 years (Dunn, 2014). Based on Dunn's Sensory Processing Framework, the SSP-2 evaluates behaviors across four sensory quadrants: seeking, avoiding, sensitivity, and registration. Each quadrant represents a distinct sensory processing pattern. Sensory Seeking reflects a child's active pursuit of sensory experiences such as frequent touching, movement, or exploration of objects. Sensory Avoiding indicates a tendency to withdraw from or become overwhelmed by sensory input, leading to avoidance of noisy or crowded environments. Sensory Sensitivity describes a low threshold for sensory input in which children notice and react quickly to sensations such as textures, sounds, or movements. Low Registration, also referred to as Sensory Registration, captures under-responsiveness to sensory stimuli, where children may appear unaware of their surroundings or slow to respond to cues.

The SSP-2 includes 34 items rated on a 5-point Likert scale, with higher scores reflecting more frequent atypical sensory responses. The SSP-2 has demonstrated good internal consistency, with Cronbach's alpha values of 0.69 for seeking, 0.83 for avoiding, and 0.75 for both sensitivity and registration (Simpson et al., 2019). Higher scores indicate more frequent atypical sensory responses.

Vineland Adaptive Behavior Scales-Third Edition (VABS-3)

Fine motor skills and DLS were measured using the parent-report form of the Vineland Adaptive Behavior Scales, Third Edition (VABS-3) *(Pepperdine & McCrimmon, 2018; Sparrow et al., 2016)*. The fine motor domain includes 12 items focused on dexterity and hand use, while the DLS domain comprises 41 items covering personal, domestic, and community functioning. Responses are scored as "Usually," "Sometimes," or "Never." Raw scores are converted to v-scale scores using the VABS-3 manual. This instrument has high internal consistency ($\alpha = 0.86$ to 0.97) and strong concurrent validity with the Adaptive Behavior Assessment System-Third Edition ($r = 0.43$ to 0.73) (Pepperdine et al., 2018).

Data Collection Procedure

Parents and caregivers were invited to participate through announcements distributed at the participating school and therapy centers. Those who expressed interest received an information sheet and consent form outlining the study's objectives, procedures, and confidentiality safeguards. Data collection was conducted using either paper-based or online formats, depending on participant preference. Each caregiver completed the demographic questionnaire, SSP-2, and the relevant domains of the VABS-3. The principal researcher reviewed returned forms for completeness and ensured that all responses met the inclusion criteria. Data collection took place between December 2024 and May 2025.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 29.0. Descriptive statistics (means, standard deviations, frequencies, and percentages) were calculated to summarize demographic characteristics and domain scores. The Shapiro-Wilk test revealed that the data were not normally distributed ($p < 0.05$), warranting

the use of non-parametric statistical methods. To examine group differences in sensory processing, fine motor skills, and DLS, the Kruskal-Wallis test was used. Pairwise comparisons were conducted using the Mann-Whitney U test with Bonferroni correction. Relationships among sensory processing, fine motor skills, and DLS were explored using Spearman's rank correlation. A p-value less than 0.05 was considered statistically significant.

Results

Participants Characteristics

A total of 120 children aged 5 to 6 years participated in this study, with 40 children in each of the ASD, DS, and TD groups. Gender distribution was identical across groups (52.5% male, 47.5% female), and the Chi-square test confirmed no significant difference in gender proportions ($\chi^2(2) = 0.000$, p = 1.000). Age distribution between 5- and 6-year-old participants was also comparable across groups ($\chi^2(2) = 1.869$, p = .393). However, a significant difference was found in race distribution ($\chi^2(4) = 14.676$, p = .005). The TD and DS groups were predominantly Malay, whereas the ASD group had a more diverse ethnic composition, with notably higher proportions of Chinese and Indian participants. Table 1 presents the demographic characteristics and group comparisons.

Table 1
Demographic characteristics of participants (N = 120)

Characteristic	TD (n = 40)	ASD (n = 40)	DS (n = 40)	χ^2 (df)	p-value
Gender, n (%)					
Male	21 (52.5)	21 (52.5)	21 (52.5)		
Female	19 (47.5)	19 (47.5)	19 (47.5)	0.000 (2)	1.000
Age, n (%)					
5 years old	16 (40)	22 (55)	20 (50)		
6 years old	24 (60)	18 (45)	20 (50)	1.869 (2)	.393
Race, n (%)					
Malay	28 (70)	13 (32.5)	25 (62.5)		
Chinese	7 (17.5)	14 (35)	11 (27.5)	14.676 (4)	.005 *
Indian	5 (12.5)	13 (32.5)	4 (10)		

Sensory Processing Profiles

Group comparisons using the SSP-2 revealed significant differences in sensory processing across the four quadrants. Children with ASD consistently exhibited the highest scores, indicating greater sensory modulation difficulties. Mean scores for the ASD group were: Seeking (M = 21.20, SD = 7.67), Avoiding (M = 31.25, SD = 4.41), Sensitivity (M = 27.85, SD = 9.56), and Registration (M = 24.25, SD = 3.46). Children with DS showed intermediate levels of sensory difficulty, while TD children demonstrated the lowest scores, reflecting more typical sensory responses.

The Shapiro-Wilk test indicated non-normal data distributions ($p < .05$). Kruskal-Wallis analyses indicated significant group differences across all SSP-2 quadrants: Seeking, $\chi^2(2) = 13.53$, $p = .001$; Avoiding, $\chi^2(2) = 57.02$, $p < .001$; Sensitivity, $\chi^2(2) = 11.91$, $p = .003$; and Registration, $\chi^2(2) = 51.97$, $p < .001$. Post-hoc Mann-Whitney U tests with Bonferroni correction showed that TD children scored significantly lower (indicating better sensory processing) than both ASD and DS groups ($p < .01$), and children with ASD displayed significantly greater sensory difficulties than those with DS ($p < .01$). Descriptive and comparative statistics are presented in Table 2.

Table 2. Descriptive and Comparative Statistics for Sensory Processing (SSP-2) Across Quadrants

Quadrant	Group	Mean (M)	SD	n	Shapiro-Wilk (p)	Mean Rank	χ^2 (df)	p-value
Seeking	ASD	21.20	7.67	40	< .05	76.86		
	DS	14.68	4.85	40	< .05	52.91		
	TD	13.73	2.88	40	< .05	51.73	$\chi^2(2) = 13.53$	.001
Avoiding	ASD	31.25	4.41	40	< .05	94.16		
	DS	19.18	6.68	40	< .05	42.99		
	TD	19.05	6.20	40	< .05	44.35	$\chi^2(2) = 57.02$	< .001
Sensitivity	ASD	27.85	9.56	40	< .05	73.99		
	DS	22.75	5.85	40	< .05	60.31		
	TD	20.05	4.49	40	< .05	47.20	$\chi^2(2) = 11.91$	.003
Registration	ASD	24.25	3.46	40	< .05	92.00		
	DS	16.77	5.12	40	< .05	50.31		
	TD	15.05	4.48	40	< .05	39.19	$\chi^2(2) = 51.97$	< .001

Fine Motor and Daily Living Skills

Group comparisons revealed significant differences in both fine motor skills and DLS across diagnostic groups. As summarized in Table 3, typically developing (TD) children recorded the highest scores for both domains, fine motor (M = 23.40, SD = 1.19) and DLS (M = 19.48, SD = 1.24), followed by children with ASD (Fine Motor: M = 21.80, SD = 1.51; DLS: M = 17.63, SD = 1.03), and children with DS (Fine Motor: M = 15.45, SD = 2.72; DLS: M = 14.03, SD = 2.85). Shapiro-Wilk tests indicated non-normal distributions ($p < .05$), so

non-parametric tests were used. Kruskal-Wallis tests showed statistically significant group differences for both fine motor skills ($\chi^2(2) = 84.18$, $p < .001$) and DLS ($\chi^2(2) = 93.57$, $p < .001$). Post-hoc Mann-Whitney U tests with Bonferroni correction confirmed that all pairwise group comparisons were significant (TD > ASD > DS) for both domains (all $p < .001$), indicating a consistent functional hierarchy aligned with developmental status.

Table 3. Fine motor skill and DLS scores and non-parametric comparison

Domain	Group	Mean (M)	SD	n	Mean Rank	χ^2 (df)	p-value
Fine Motor	TD	23.40	1.19	40	94.79	84.18 (2)	<.001
	ASD	21.80	1.51	40	62.04		
	DS	15.45	2.72	40	24.68		
DLS	TD	19.48	1.24	40	94.68	93.57 (2)	<.001
	ASD	17.63	1.03	40	65.70		
	DS	14.03	2.85	40	21.13		

Relationships Among Sensory, Fine Motor, and Daily Living Skills

Spearman's rank correlation analysis examined the associations between sensory processing, fine motor skills, and DLS within each diagnostic group. Among children with ASD, all four sensory quadrants were strongly correlated with DLS (ρ = .722 to .908, $p < .001$). Fine motor skills were also strongly associated with daily living performance ($\rho = .907$, $p < .01$). In contrast, no significant correlations were found between sensory processing and DLS in the DS or TD groups. However, fine motor skills remained significantly associated with DLS across all groups.

Table 4. Spearman correlations among sensory processing, fine motor, and daily living skills (N = 120)

Variable	Daily Living Skills		
	ASD	DS	TD
Seeking (SSP-2)	.862 (p < .001)	-.113 (p = .486)	-.006 (p = .968)
Avoiding (SSP-2)	.867 (p < .001)	.209 (p = .197)	-.198 (p = .220)
Sensitivity (SSP-2)	.722 (p < .001)	.109 (p = .502)	-.100 (p = .540)
Registration (SSP-2)	.908 (p < .001)	.239 (p = .138)	-.107 (p = .512)
Fine Motor (VABS-3)	.907 (p < .01)	.907 (p < .01)	.907 (p < .01)

Discussion

Group differences in sensory, motor, and adaptive functioning

This study examined sensory processing, fine motor skills, and DLS among children with ASD, DS, and TD peers. Findings revealed clear group differences, with children in the TD group outperforming both neurodevelopmental groups across all domains. Children with ASD exhibited the most pronounced sensory processing difficulties across all quadrants of the SSP-2. These results are consistent with previous studies reporting elevated sensory reactivity and modulation challenges in ASD (Meguid et al., 2020; Monday et al., 2023). Sensory irregularities may interfere with emotional regulation, attention, and task engagement, thus limiting participation in daily activities. Children with ASD also showed moderate deficits in fine motor skills, likely reflecting difficulties in motor planning and praxis (Bhat & Narayan Bhat, 2020; Mohd Nordin et al., 2021). These impairments may hinder the execution of multi-step or precision-based tasks such as dressing or feeding, even among children with average cognitive abilities.

In contrast, children with DS displayed milder but distinctive sensory processing patterns, characterized by lower sensory-seeking behavior and under-responsiveness, features commonly linked to hypotonia and reduced sensory feedback processing (Fidler et al., 2019; Will et al., 2019). These sensory profiles, combined with joint laxity, muscle weakness, and slower neuromotor development, likely contributed to the DS group's lower fine motor and daily living activities performance (López Resa & Moraleda Sepúlveda, 2024; Schott & Holfelder, 2015).

TD children demonstrated well-regulated sensory responses, superior fine motor coordination, and the highest scores in DLS. This pattern supports prior evidence suggesting that effective sensory integration facilitates smoother task transitions, adaptive behavior, and greater functional independence (Allen & Casey, 2017; Osório et al., 2021). These cross-group differences suggest that both neurophysiological and cognitive mechanisms underpin the varying degrees of functional independence observed.

Relationships among sensory, fine motor, and DLS

Across the full sample, fine motor skills were strongly associated with daily living performance. This finding reinforces the central role of motor competence in supporting independence, particularly in self-care tasks. Similar associations have been reported in previous research, highlighting the importance of motor-focused interventions in promoting adaptive functioning among children with neurodevelopmental disorders (Volkan-Yazici et al., 2018).

Within the ASD group, all sensory processing quadrants showed strong positive correlations with DLS. These findings highlight the importance of sensory modulation for adaptive behavior and align with earlier work linking improved sensory regulation with better self-care outcomes in children with autism (Hosseiny et al., 2023). In contrast, no significant correlations between sensory processing and DLS were found in the DS or TD groups. This suggests that, for children with DS, functional performance may be more strongly influenced by other factors such as cognitive ability, language development, or environmental support (Piccardi & Gliga, 2022; Van Deusen et al., 2024). Taken together, these findings indicate that both sensory and motor domains contribute to adaptive functioning, but their relative importance varies by diagnosis. Sensory modulation appears to play a particularly salient role for children with ASD, whereas fine motor may be more critical for children with DS.

Implications for clinical practice

From a rehabilitation perspective, these findings highlight the importance of integrated, sensory-motor interventions that address both sensory and fine motor domains. For children with ASD, therapy should focus on sensory modulation, motor planning, and environmental adaptation, while for children with DS, emphasis should be placed on strengthening, coordination, and simplified task sequencing. Early screening of sensory and motor challenges can inform individualized plans that support foundational skills and long-term independence. This study also offers culturally relevant insights for Malaysian rehabilitation practice, emphasizing the need to align interventions with local developmental norms and family routines.

Limitations and Future Directions

Several limitations should be considered when interpreting these findings. First, the cross-sectional design precludes causal inferences regarding the developmental interactions between sensory, motor, and adaptive domains. Longitudinal studies are needed to track how these relationships evolve across early and middle childhood. Second, although parent-reported measures such as the SSP-2 and VABS-3 are well-validated, caregiver perceptions may be influenced by subjective bias; future research could combine observational or performance-based assessments for triangulation. Third, the sample was limited to children aged 5-6 years from selected centers in Malaysia, which may constrain generalizability to other age groups or cultural settings. Expanding future studies to include larger, more diverse samples and additional contextual factors, such as cognitive ability, socioeconomic background, and environmental supports, would strengthen validity. Finally, future research should examine the effectiveness of integrated sensory-motor interventions on functional outcomes using experimental or cohort designs to determine how improvements in sensory modulation and fine motor coordination translate to gains in DLS.

Conclusion

This study provides empirical evidence that both sensory processing and fine motor abilities are critical for DLS among children with ASD, DS, and TD. The findings highlight the need for early, integrated rehabilitation approaches that address both sensory and motor foundations of daily life participation. For clinicians, incorporating sensory-motor screening into routine assessments can guide more individualized, functional-oriented interventions. Future research should further evaluate how targeted sensory-motor programs enhance real-world independence and participation across developmental conditions.

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Ethics approval and consent to participate

Ethical approval for this study was obtained from the Research Ethics Committee, Universiti Teknologi MARA (Reference No.: ERC/FSK/MR/2024/00350). Written informed consent was obtained from all parents or legal guardians prior to participation.

Consent for publication

Not applicable. This article does not contain any individual person's data in any form.

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AZCD conceptualized and designed the study. NNR and IA collected and analyzed the data, with input from AZCD. NAMN drafted the initial manuscript. All authors critically reviewed and revised the manuscript for intellectual content, approved the final version, and agreed to be accountable for all aspects of the work.

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