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臺灣自閉症類群障礙幼童之早期行為問題與動作發展的特徵與關聯

Profiles and Associations of Early Behavioral Problems and Motor Development in Taiwanese Young Children with Autism Spectrum Disorder

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中文摘要

研究背景：自閉症類群障礙（以下簡稱自閉症）除核心的社交互動困難與重複、侷限行為外，行為問題與動作發展困難亦為常見共併問題。由於相關發展特徵多於三歲前逐漸顯現，但臨床診斷多在三歲後確認，釐清三歲前後自閉症幼童之行為與動作發展特徵，對早期篩檢與介入具有重要意義。然而，既有研究對特定行為症候與動作發展子面向之發展表現尚未達成一致結論，且臺灣仍缺乏探討三歲前後自閉症幼童行為與動作發展特徵之研究。此外，自閉症幼童之動作發展困難常於臨床上被低估，而行為問題與動作發展之關聯性，可能有助於提升動作發展困難的早期識別與介入。惟過去研究多聚焦於核心症狀或家長填寫問卷，較少同時結合多元行為問題評估與標準化動作測驗。

目的：（1）比較臺灣自閉症幼童與非自閉症典型發展幼童之行為問題與動作發展特徵；（2）分析自閉症幼童行為問題與動作發展之關聯性，並比較上述特徵與關聯性於三歲前後之差異趨勢。

方法：本研究採次級資料分析，納入 2014 年至 2022 年間之自閉症幼童發展追蹤資料，共計 124 名自閉症幼童與 123 名非自閉症典型發展幼童（簡稱非自閉症幼童），年齡介於 18 至 71 個月。行為問題以一歲半至五歲兒童行為檢核表（Child Behavior Checklist for Ages 1.5 to 5）評估；動作發展與動作協調分別以皮巴迪動作發展量表第二版（Peabody Developmental Motor Scales, Second Edition）及兒童動作評估量表第二版（Movement Assessment Battery for Children, Second Edition）進行測量。研究採用共變數多變量變異數分析比較兩組幼童於行為與動作發展特徵之差異，並以多元線性迴歸分析探討行為問題與動作發展之關聯性。**結果：**相較於非自閉症幼童，自閉症幼童呈現顯著較高的行為問題 T 分數（T-score），尤以內化行為問題、注意力問題與總行為問題最為明顯（ηp^2s = 0.03-0.19，ps < 0.01）。三歲以下自閉症幼童的行為差異主要集中於焦慮／憂鬱與退縮症候（ηp^2s = 0.05-0.14，ps < 0.05），三歲以上幼童則於內化、外化、注意力及總行為

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問題皆出現顯著差異（$\eta p^2s = 0.05\text{-}0.30$，$ps < 0.05$）。在動作表現方面，自閉症幼童於總動作、粗大與精細動作發展商數，以及所有動作子面向上，表現均顯著較差（$\eta p^2s = 0.03\text{-}0.10$，$ps < 0.05$）。三歲以下自閉症幼童於總動作和粗大動作發展商數，以及移動與物體操弄能力顯著較差（$\eta p^2s = 0.07\text{-}0.20$，$ps < 0.05$），大於三歲的組別則差異擴及精細動作發展商數、平衡能力和整體動作協調（$\eta p^2s = 0.04\text{-}0.19$，$ps < 0.05$）。自閉症幼童之內化行為問題 T 分數與粗大、精細及整體動作商數呈顯著負相關 ($\beta s = -0.3$，$ps < 0.01$)，外化行為問題 T 分數則與粗大、精細及整體動作商數呈顯著正相關（$\beta s = 0.3$，$ps < 0.01$），而行為問題 T 分數與整體動作協調百分比未達顯著相關。年齡分層結果顯示，三歲以下自閉症幼童僅內化行為問題 T 分數與精細動作商數呈顯著負相關 [$\beta = (-0.5)$，$p < 0.05$]，三歲以上幼童中，內化行為問題 T 分數與粗大、精細、總動作商數之負相關 [$\beta s = (-0.4)\text{-}(-0.3)$，$ps < 0.05$]，外化行為問題 T 分數與粗大、總動作商數呈顯著正相關（$\beta s = 0.3$，$ps < 0.05$）；相較之下，非自閉症幼兒組僅於三歲以下幼童觀察到內化行為問題 T 分數與總動作商數之顯著負相關 [$\beta = (-0.6)$，$p < 0.05$]。

結論：臺灣自閉症幼童之行為與動作發展特徵於三歲前即與非自閉症幼童呈現顯著差異，且在三歲以上組別中，差異進一步擴及更多行為與動作發展面向。此外，自閉症幼童之行為問題與動作發展之間存在顯著關聯性。本研究描繪臺灣自閉症幼童的行為與動作發展特徵，有利於自閉症幼童的早期識別，並支持臨床進行更全面的行為與動作發展評估與追蹤。此外，行為與動作之關聯性可提供臨床判斷線索，協助辨識具有動作困難風險之自閉症幼童，並支持發展結合行為與動作的整合性介入，以更全面提升其發展預後。

關鍵字：自閉症類群障礙、幼童、行為問題、動作發展

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English Abstract

Background: Autism spectrum disorder (ASD) is characterized by core impairments in social interaction and restricted, repetitive behaviors and is frequently accompanied by behavioral problems and motor difficulties. Although behavioral and motor features often emerge before three years of age, clinical diagnosis is typically confirmed after age three, highlighting the importance of characterizing early developmental patterns. However, findings regarding specific behavioral syndromes and motor subdomains in young children with ASD remain inconsistent, and studies in Taiwanese populations are scarce. Importantly, motor difficulties in young children with ASD are often underestimated in clinical practice, and examining the associations between behavioral problems and motor development may provide clinically insights for earlier identification. However, the associations have rarely been examined using comprehensive behavioral and standardized motor assessments in early childhood.

Objectives: This study therefore aimed to compare behavioral and motor profiles between ASD and non-ASD typically developing children, to investigate behavioral-motor associations, and to examine whether these profiles and associations differ before and after three years of age in Taiwan. **Methods:** This was a secondary data analysis study, including developmental follow-up data collected between 2014 and 2022. A total of 124 children with ASD and 123 non-ASD children aged 18-71 months were

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assessed using the Child Behavior Checklist for Ages 1.5-5 (CBCL/1.5-5), the Peabody Developmental Motor Scales-Second Edition (PDMS-2), and the Movement Assessment Battery for Children-Second Edition (MABC-2). Group differences were examined using multivariate analysis of covariance, and behavioral-motor associations were analyzed using multiple linear regression. **Results:** Children with ASD showed significantly higher behavioral problems T-scores than non-ASD children in internalizing domains, attention problems, and total behavioral problems (ηp^2s = 0.03-0.19, ps < 0.01). Behavioral differences were specific to Anxious/Depressed and Withdrawn syndromes in children under three (ηp^2s = 0.05-0.14, ps < 0.05), but involved broader domains including internalizing, externalizing, attention, and total problems in the older group (ηp^2s = 0.05-0.30, ps < 0.01). Children with ASD also demonstrated significantly poorer motor quotients than non-ASD children across PDMS-2 domains (ηp^2s = 0.03-0.10, ps < 0.01). Motor differences were evident in both age groups, however, the older group exhibited difficulties across a broader range including fine motor, balance ability and overall motor coordination (ηp^2s = 0.05-0.19, ps < 0.05). In the ASD group, T-score of Internalizing Problems (βs = −0.3, ps < 0.05) were negatively and T-score of Externalizing Problems (βs = 0.3, ps < 0.05) were positively associated with motor quotients. T-score of behavioral problems were not significantly associated with overall motor coordination percentage. Age-stratified

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analyses showed that in children with ASD under three years, only T-score of Internalizing Problems were negatively associated with fine motor quotient ($\beta = -0.5$, $p < 0.05$). In contrast, among children aged three years and older, T-score of Internalizing Problems were negatively associated with gross, fine and total motor quotient [βs = (−0.4) to (−0.3), ps < 0.05], whereas T-score of Externalizing Problems showed positive associations with gross and total motor quotients (βs = 0.3, ps < 0.05). In contrast, a significant negative association between T-score of Internalizing Problems and total motor quotient was observed only in non-ASD children younger than three years [$\beta = -0.6$, $p < 0.05$]. **Conclusions:** Behavioral and motor developmental differences between Taiwanese young children with ASD and non-ASD children were evident before three years of age and extended to broader domains in children aged three years and older. In addition, associations between behavioral problems and motor development were observed in young children with ASD. These findings support earlier identification and comprehensive behavioral and motor assessment in clinical practice and guide integrated interventions in young children with ASD.

Key words: Autism Spectrum Disorder, Young Children, Behavioral problems, Motor development

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Chapter 1 Introduction

1.1 Background

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by impairments in social communication and restricted, repetitive behaviors. The prevalence of ASD has continued to rise globally, with similar trends observed in Taiwan (Ministry of Health and Welfare, 2025). Beyond core symptoms, ASD in early childhood is frequently accompanied by a broad range of co-occurring conditions, including behavioral problems and motor difficulties (Christensen et al., 2019; Khachadourian et al., 2023; Provost, Lopez, & Heimerl, 2007). The behavioral problems represent important clinical features of ASD, given the strong associations with impaired adaptive functioning and elevated parenting stress (Davico et al., 2022; Y. N. Lin, Iao, Lee, & Wu, 2021; Paynter, Heng, Tucker, & Malone, 2025). Early motor difficulties are likewise clinically significant, as motor skills play a central role in overall development and are closely linked to physical activity levels, physical fitness, general health, obesity risk, and children's motivation for social engagement (Ketcheson, Staples, Pitchford, & Loetzner, 2023; Sammels, Karjalainen, Dahlgren, & Wentz, 2022; Wang, Petrulla, Zampella, Waller, & Schultz, 2022). Despite growing awareness of these early challenges, delays in ASD identification remain common. In Taiwan,

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parental concerns regarding development have been reported to emerge before 3 years of age, whereas formal ASD diagnosis typically occurs after 3 years old, with early intervention initiated at approximately 3.3 years (Chen, 2022). This suggests that age 3 may represent an important developmental milestone in young children with ASD, and that our recognition of early ASD manifestations in young children remain insufficient. Gaining a clearer understanding of behavioral problems and motor difficulties that commonly co-occur with ASD may therefore provide useful supplementary information for early developmental surveillance and for informing early intervention planning.

Accumulating evidence indicates that children with ASD exhibit elevated internalizing and externalizing behavioral problems throughout early childhood (Chericoni et al., 2021; L. Rescorla, Kim, & Oh, 2015; L. A. Rescorla et al., 2019). However, behavioral problems beyond core ASD symptoms show variability across studies, particularly at the level of specific behavioral syndromes. In addition, behavioral problems are influenced by cultural context due to different parental expectations and social norms regarding child behavior. Prior studies had found that Taiwan preschool children had higher behavioral problems than average scores among 24 countries around the world (L. A. Rescorla et al., 2011; Wu et al., 2012). Moreover, research focusing specifically on children younger than three

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years remains relatively limited, constraining understanding of how early behavioral manifestations differentiate ASD from non-ASD typically developing children across early developmental stages. These gaps underscore the need for age-stratified investigations of behavioral problem profiles in Taiwanese young children with ASD.

Motor difficulties are also common in young children with ASD with 6.7% to 80% had motor difficulties from early childhood (Licari et al., 2020; L. Y. Lin et al., 2024). Evidence suggests that motor difficulties may emerge early in life and persist across development, with potential cascading effects on participation, social interaction, and health-related outcomes. Nonetheless, research examining motor development in young children with ASD remains methodologically limited. Many studies have relied on relatively small sample sizes, and relatively few have focused specifically on children under three years of age. Moreover, most investigations have reported group differences at the level of global gross and fine motor domains, with limited delineation of which specific motor subdomains are most affected and whether these patterns vary across early developmental stages. In addition, there is a lack of studies applying standardized motor assessments for coordination such as the Movement Assessment Battery for Children-Second Edition (MABC-2) in young children with ASD. These limitations restrict

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understanding of age-specific and domain-specific motor difficulties during early childhood, a period critical for developmental surveillance and early intervention.

Although high prevalence of motor difficulties in young children with ASD, motor difficulties are often underestimated in clinical practice. Growing evidence suggests that behavioral problems are associated with reduced quality of life, poorer social, cognitive outcomes as well as motor difficulties (Holloway, Long, & Biasini, 2018; Ohara, Kanejima, Kitamura, & Izawa, 2019; Pitzianti, Fagioli, Pontis, & Pasini, 2021; Zhou et al., 2022). Understanding the associations between behavioral problems and motor difficulties may provide clinically insights for earlier identification for motor difficulties. However, prior studies have focused on associations between motor development and core ASD symptoms, with far fewer investigations examining broader behavioral domains such as internalizing and externalizing problems. In addition, research involving young children has often relied on parent-reported motor assessments rather than standardized, performance-based motor assessments. Critically, no published study has examined behavioral-motor associations in Taiwanese young children with ASD across different early developmental stages. Addressing these gaps is essential for advancing early identification and intervention efforts. Accordingly, the present study aimed to characterize behavioral problem and motor development profiles in Taiwanese

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young children with ASD, compared with typically developing peers, and to examine the associations between behavioral problems and motor development across early childhood. By integrating caregiver-reported behavioral assessments with performance-based standardized motor assessments, the study seeks to provides culturally relevant evidence to inform early developmental surveillance and support more comprehensive assessment and intervention planning for young children with ASD in Taiwan.

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1.2 Thesis Purpose

This study aims to (1) compare behavioral problem profiles between young children with ASD and non-ASD typically developing children (non-ASD) in Taiwan; (2) compare motor development profiles between these two groups; (3) investigate the associations between behavioral problems and motor development in Taiwanese young children with ASD.

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Chapter 2 Literature Review

2.1 Behavioral and Motor Profiles in Young Children with ASD

2.1.1 Epidemiology and Core Clinical Features of ASD

Autism spectrum disorder (ASD) is a behavior-based neurodevelopmental diagnosis characterized by deficits in social communication and the presence of restricted and repetitive behaviors, with considerable heterogeneity in symptom severity across individuals. A recent meta-analysis estimated the global prevalence of ASD at approximately 0.72%, with marked geographic variability, reporting prevalence rates of 1.01% in North America and 0.41% in Asia, as well as an especially low estimate of 0.11% in Taiwan (Talantseva et al., 2023). More recent surveillance data from the Autism and Developmental Disabilities Monitoring (ADDM) Network in the United States further demonstrate a substantially higher prevalence of ASD. In 2022, the prevalence among children aged 8 years reached 32.2 per 1,000 (Shaw et al., 2025). National data from Taiwan's Ministry of Health and Welfare indicate a steady rise in ASD diagnoses, increasing from 16,454 individuals in 2020 to 23,055 in 2025 (Ministry of Health and Welfare, 2025). Although national registry data indicate a steady increase in the number of individuals diagnosed with ASD in Taiwan,

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the overall reported prevalence remains relatively low compared with global and Western estimates.

Beyond the core symptoms of social-communication and restricted and repetitive behavior, young children with ASD often exhibit a wide range of co-occurring conditions including behavioral problems and motor difficulties (Christensen et al., 2019; Provost et al., 2007). According to recent large-scale epidemiological evidence, over 15% of autistic children present with comorbid motor difficulties, 35.3% meet criteria for attention-deficit/hyperactivity disorder (ADHD), and more than 15% experience sleep or anxiety disorders (Khachadourian et al., 2023). In addition, intellectual disability (ID) is highly prevalent in ASD, with recent surveillance data indicating that approximately 39-40% of autistic children aged 8 years have co-occurring ID (Shaw et al., 2025). These diverse presentations highlight the heterogeneity of ASD in early childhood and underscore the importance of considering behavioral, motor, and cognitive characteristics simultaneously in early assessment.

Early identification is crucial because timely intervention has been shown to improve cognitive, language, and socio-emotional outcomes and reduce parental stress (Okoye et al., 2023). Despite the growing emphasis on early detection, diagnosing ASD in infancy and toddlerhood remains challenging.

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Evidence suggests that atypical neurodevelopment may begin prenatally but becomes increasingly observable only as social and behavioral demands intensify across the second year of life (Wieckowski, Williams, Rando, Lyall, & Robins, 2023). Such developmental variability contributes to delays in clinical recognition and diagnosis. Although most parents report first noticing differences in their child's social development before 3 years of age (Canu et al., 2021), clinical diagnosis of ASD is often confirmed after 3 years of age. In the United States, the median age of diagnosis is 47 months (Shaw et al., 2025). A meta-analysis spanning Europe, Asia, and the Americas reported a pooled mean diagnostic age of 43.18 months (95% CI: 39.79-46.57) (van't Hof et al., 2021). Taiwan shows a similar pattern of delayed identification. A 2022 study showed that parents typically expressed initial developmental concerns at 2.4 years of age, whereas formal diagnosis occurred at 3.71 years and early intervention began at 3.27 years (Chen, 2022). These findings highlight the need to better understand early developmental profiles in young children with ASD, especially during the first three years of life, as such features may provide valuable information for earlier identification and more timely intervention.

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2.1.2 Behavioral Problems in Young Children with ASD

Behavioral problems can be defined as behaviors that create challenges for the child and that may place significant demands on caregivers and families, ranging from nonspecific behaviors (e.g., aggression, tantrums, non-compliance) to more severe or atypical behaviors (e.g., self-injury) (Hanratty et al., 2015). The behavioral problems in early childhood typically conceptualized within internalizing and externalizing domains. Internalizing problems reflect inwardly directed symptoms such as emotional reactivity, anxiety, depression, somatic complaints, and social withdrawal, whereas externalizing problems include outwardly directed behaviors such as attention difficulties, impulsivity, and aggression. The Child Behavior Checklist for Ages 1.5-5 (CBCL/1.5-5) provides a comprehensive framework for assessing behavioral problems in young children (Aseba, n.d.), and is one of the most widely used caregiver-report measurements in both clinical and research setting. In the present study, the CBCL/1.5-5 was used to characterize and compare behavioral problem profiles between children with ASD and typically developmental (TD) peers. Behavioral problems are clinically important because they are linked to impairments in several areas of adaptive functioning (Davico et al., 2022). They are also more strongly associated with parenting stress than the severity of ASD characteristics (Y. N.

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Lin et al., 2021; Paynter et al., 2025). Taken together, these findings indicate that behavioral problems are both highly prevalent in young children with ASD and exert broad impacts on children's daily functioning, family well-being, and overall quality of life. These patterns underscore the need for early identification and intervention targeting behavioral difficulties.

A substantial body of evidence indicates that children with ASD exhibit elevated behavioral problems across internalizing and externalizing domains. One study reported that approximately one third of children with ASD aged 1.5 to 5.8 years had Total Problem scores in the clinically significant range, highlighting the substantial burden of behavioral problems in this population (Hanratty et al., 2015). And the study in Italy reported that 18-month-year-old children with ASD scored significantly higher than TD children on nearly all subscales in CBCL/1.5-5, except for Sleep Problems and Aggressive Problems. And the Withdrawn presented the largest effect sizes (Chericoni et al., 2021). Similarly, research in USA found that 24-month-old children with ASD displayed significantly higher CBCL/1.5-5 scores than TD peers on all syndromes scales except for Sleep Problems (L. A. Rescorla et al., 2019). Consistent findings were reported in a South Korean study of children aged 3.37-3.54 years, with children with ASD showed significantly higher scores across all

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syndromes except for Somatic Complaints and Sleep Problems (L. Rescorla et al., 2015). These findings reinforce the presence of robust early behavioral differentiation between children with ASD and TD. However, evidence at the syndrome-specific level remains more variable across studies. Moreover, research focusing specifically on children younger than three years remains relatively limited, constraining our understanding of how early behavioral profiles may differ across developmental stages.

Behavioral problems in early childhood also show cultural variation. A large cross-cultural comparison of Taiwanese and American TD preschoolers aged 24-71 months found that Taiwanese children had higher clinical-range prevalence rates for both internalizing and externalizing problems (Wu et al., 2012). In a broader multinational analysis across 24 societies also indicates that Taiwanese preschoolers may exhibit comparatively higher levels of behavioral problems (L. A. Rescorla et al., 2011). These cross-cultural differences may be shaped by varying cultural norms regarding children's behavior. Parents in Taiwan may maintain stricter expectations for behavioral regulation and compliance compared with parents in Western societies. These findings underscore the need for population-specific research in Taiwan to characterize behavioral problem profiles in young children with ASD. Incorporating age-

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stratified analyses may further clarify how behavioral problems vary through early childhood.

2.1.3 Motor Difficulties in Young Children with ASD

Motor development in early childhood encompasses gross and fine motor skills, and each domain further includes several subdomains that reflect diverse aspects of motor development. Gross motor skills include static and dynamic balance, locomotor ability, ball skills and coordination, and fine motor skills involve hand dexterity, grasping, and visual-motor integration. Motor difficulties are common in young children with ASD, with prevalence estimates ranging from 6.7% to 80% (Licari et al., 2020; Mohd Nordin, Ismail, & Kamal Nor, 2021). These difficulties can emerge early in life and may persist across childhood. Early motor difficulties carry clinical importance because motor skills play a central role in children's overall development. Motor difficulties have been shown to influence physical activity levels, physical fitness, and general health, and are associated with increased risk of obesity as well as reduced motivation for social engagement (Ketcheson et al., 2023; Sammels et al., 2022; Wang et al., 2022).

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Evidence from studies involving younger children further supports the presence of early motor delays. One study found that 35% of children under 6 years old showed motor difficulties on the Vineland Adaptive Behavior Scales (Licari et al., 2020). Nordin et al. (2021) examined children aged 12-60 months and found that 6.7% of children with ASD exhibited significant gross motor delay and 38.5% showed fine motor delay, whereas none of the TD children demonstrated delays in these areas (Mohd Nordin et al., 2021). Provost et al. (2007) similarly reported significant group differences in all Peabody Developmental Motor Scales, Second Edition (PDMS-2) subscales among children aged 21-41 months after controlling for cognitive levels. More recent evidence from Taiwan further highlights motor difficulties in children with ASD. Lin et al. (2024) assessed fine motor performance among children aged 48-84 months and reported that children with ASD scored significantly lower than their TD peers across all fine motor subtests of both the MABC-2 and PDMS-2 (L. Y. Lin et al., 2024).

Accumulating evidence indicates that children with ASD exhibit poorer gross and fine motor development than their TD peers from early childhood. However, existing studies have several important limitations. Many investigations have relied on relatively small sample sizes, and relatively few

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have focused specifically on children under three years of age. Moreover, most studies have reported group differences at the level of overall gross and fine motor domains, with limited delineation of which specific motor subdomains are most affected and whether these patterns vary across developmental stages. These limitations constrain our understanding of the developmental patterns of motor difficulties in ASD. As with behavioral problems, early motor difficulties represent a critical target for assessment and intervention, underscoring the need to comprehensively characterize age-specific and domain-specific motor profiles in Taiwanese young children with ASD.

2.2 Associations between Behavioral Problems and Motor Development in Early Childhood

Motor difficulties are highly prevalent in young children with ASD. However, motor difficulties are often overlooked relative to behavioral problems in clinical practice, as clinical attention tends to prioritize behavioral concerns. As a result, motor development may be insufficiently assessed, with only 33.4% and 18.4% of children with ASD receiving occupational therapy and physical therapy, respectively. Therefore, understanding the associations between

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behavioral problems and motor difficulties may facilitate earlier clinical identification of young children with ASD who are at risk for motor difficulties.

2.2.1 Neurodevelopmental and Psychosocial Mechanisms Linking Behavioral Problems and Motor Development

The associations between behavioral problems and motor development in children can be understood from neurobiological-cognitive and developmental-psychosocial perspectives. From a neurobiological standpoint, motor and behavioral functions draw upon partially overlapping neural systems. The frontal cortex encompasses both primary sensorimotor regions and higher-order association cortices involved in executive functioning, emotional regulation, and social cognition, forming integrated networks that support interactions among motor, cognitive, and affective processes (Sydnor et al., 2021; Wang et al., 2022). In addition, while the cerebellum has traditionally been associated with motor coordination, accumulating evidence indicates that it also plays a critical role in attention and socio-emotional functioning (Sathyanesan et al., 2019). And executive function represents another shared mechanism. executive function deficits are frequently observed in children with behavioral problems (Raaijmakers et al., 2008; Teivaanmäki et al., 2020) and are also associated with motor tasks requiring planning, inhibition, and self-monitoring (Houwen, van

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der Veer, Visser, & Cantell, 2017; Sung, McClelland, Massey, Logan, & MacDonald, 2023). These findings suggest that overlapping neural substrates and higher-order cognitive processes may jointly influence behavioral and motor functioning.

From a developmental perspective, motor skills play a foundational role in shaping children's opportunities for learning and behavioral adaptation. Motor skills enable children to explore their environments, engage with objects, and participate in social interactions. The experiences foster perceptual-motor coupling, problem-solving, and adaptive behavioral strategies (Capio, Mendoza, Jones, Masters, & Lee, 2024; Houwen et al., 2017). Theoretical frameworks such as Piaget's cognitive-developmental theory and Gibson's ecological theory emphasize that behavioral regulation and cognitive growth emerge through active interaction with the environment, a process that depends heavily on adequate motor functioning (Houwen et al., 2017). When motor skills are limited, children may have fewer opportunities to develop self-regulation, social competencies, and adaptive responses, thereby increasing their susceptibility to behavioral problems. The Environmental Stress Hypothesis (ESH) proposes another theory that motor difficulties may generate recurrent interpersonal and intrapersonal stressors, including challenges in peer interactions, reduced

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participation in group activities, and diminished self-efficacy. They can accumulate over time and heighten emotional and behavioral problems (Erskine, Barratt, & Cairney, 2024). These mechanisms illustrate how motor development and behavioral problems are associated with each other and together impact social experiences and psychological well-being.

2.2.2 Empirical Evidence Linking Behavioral Problems and Motor Development in Young Children with ASD

Building on these theoretical perspectives, empirical research has increasingly demonstrated meaningful links between behavioral problems and motor difficulties in ASD. Many had focused on associations between core behavioral problems and motor skills, and two recent systematic reviews provide support for these associations. They reported negative associations indicating that greater behavioral severity is associated with poorer motor development. Wang (2022) synthesized findings from 21 studies and reported a modest but significant associations between gross motor development and social deficits in ASD ($r = 0.27$). However, the included studies covered a broad developmental span from 8 months to 21 years (Wang et al., 2022). Similarly, Ohara et al. (2019) drawing on 16 studies comprising 3,355 individuals with ASD with a mean age of 6.7 years, found converging evidence that gross and fine motor

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deficits were associated with core behavioral problems. In a large-scale study of 13,887 children with ASD aged 5-15 years, Bhat et al. (2023) further demonstrated that motor coordination was associated with core behavioral problems. Even after adjusting for cognitive ability, gross motor development was associated with social communication delays, and fine motor development was associated with repetitive behavior severity (Pitzianti et al., 2021).

When focusing specifically on young children, emerging evidence suggests that behavioral-motor associations may already be present in early childhood, although patterns appear more heterogeneous. Holloway et al. (2018) focused on younger children aged 18-42 months supported that poorer scores in stationary control and object manipulation were associated with ASD core behavioral problems. In a large sample of 3,253 children with ASD aged 2-6 years, higher internalizing problems scores significantly associated with poor gross motor development ($\beta = -0.64$, $p < 0.001$), even after controlling for age, sex, IQ, caregiver education, ASD severity, and communication and fine motor scores. Externalizing problems were not significantly associated with motor development in the same study (Hedgecock, Dannemiller, Shui, Rapport, & Katz, 2018). Notably, Tevis et al. (2021) provided a different perspective by examining behavioral subgroups of toddlers with ASD aged 17-37 months. Their

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findings indicated that children without inattention/impulsivity or aggressive behaviors exhibited significantly poorer gross and fine motor development compared to subgroups characterized by inattention/impulsivity and/or aggressive behaviors (Tevis, Matson, Brown, Callahan, & Hong, 2021). These inconsistent findings suggest that the associations between internalizing and externalizing problems with motor development remain inconclusive.

Despite converging evidence supporting behavioral-motor associations in ASD, important gaps remain particularly during early childhood. Existing research has focused on associations between motor development and core ASD behavioral symptoms, whereas far fewer studies have examined associations with internalizing and externalizing behavioral problems. In addition, many of the prior studies rely primarily on parent-report questionnaires for motor development rather than standardized motor assessments. And there was no published study has examined these associations in Taiwanese young children with ASD. These limitations underscore the need for research how behavioral problems associated with motor development in Taiwanese young children with ASD.

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2.3 Research Questions and Hypotheses

Research question 1: What are the group differences in behavioral problem profiles between young Taiwanese children with ASD and non-ASD, for overall and across different age groups (<3 years group vs. ≥3 years group)?

Hypothesis 1: Young children with ASD will exhibit higher scores of behavioral problems than their non-ASD peers across CBCL/1.5–5 broadband and syndrome scales. In addition, the ≥3 years group is expected to demonstrate significant group differences across a broader range of behavioral problem domains.

Research question 2: What are the group differences in gross and fine motor development between young Taiwanese children with ASD and non-ASD, for overall and across different age groups (<3 years group vs. ≥3 years group)?

Hypothesis 2: Young children with ASD will demonstrate poorer gross and fine motor performance than non-ASD children. And the ≥3 years group is expected to demonstrate significant group differences across more widespread motor subdomains.

Research question 3: How are behavioral problems associated with motor development in young children with ASD, and do these associations differ by diagnostic group (ASD group vs. non-ASD group) and age (overall, <3 years group and ≥3 years group)?

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Hypothesis 3: Among children with ASD, higher scores of internalizing problems will be associated with lower motor scores. Associations between scores of externalizing problems and motor scores will be explored, given mixed findings in prior literature. In non-ASD children, higher scores of internalizing and externalizing problems are hypothesized to be associated with lower motor scores. In both ASD and non-ASD groups, these associations are expected to be more evident in children aged ≥3 years.

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Chapter 3 Methods

3.1 Data Source and Selection Criteria

The data used in this study were retrieved from two IRB-approved research projects led by Dr. Yen-Tzu Wu between 2014 and 2022 (IRB numbers: 201412012RIND and 202212053RIND). These projects included an ASD and preterm infant follow-up projects. All data were originally collected during routine pediatric and developmental follow-up visits at National Taiwan University Children's Hospital and the Hsinchu Branch of National Taiwan University Hospital. All subjects in the projects provided written informed consent and were enrolled according to shared inclusion and exclusion criteria.

In these original projects**,** caregivers were required to be the child's primary caregiver, aged 20 years or older, and able to read and understand Mandarin. Exclusion criteria for children and caregivers included major sensory, motor, or neurological impairments (e.g., uncorrected hearing or visual loss, physically incapacitating brain damage) and known genetic syndromes such as Fragile X syndrome or Down syndrome. For the present secondary data analysis, participants were selected from the existing dataset based on the following criteria: (1) children aged 18-71 months, and (2) availability of Child Behavior Checklist for Ages 1.5-

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5 (CBCL/1.5-5) data and Early Learning Composite scores of the Mullen Scales of Early Learning (MSEL).

3.2 Sample Characteristics

Children were categorized into ASD or non-ASD typically developing (non-ASD) groups. ASD diagnoses had been established in the original projects according to DSM-5 criteria by multidisciplinary clinical teams consisting of child psychiatrists, physiatrists, and pediatric neurologists. Children were classified as non-ASD typically developing group if they had no ASD diagnosis and no identified cognitive, motor, or developmental delays.

A total of 247 children aged 18-71 months were included in the study, comprising 124 children with ASD and 123 non-ASD children. Demographic characteristics, cognitive level, behavioral problems, and motor development outcomes are summarized in Table 1. Compared with the non-ASD group, children with ASD were older (mean age: 44.3 vs. 37.8 months, $p < 0.001$), had a higher proportion of boys (83.1% vs. 56.9%, $p < 0.001$), and had parents with a higher proportion of professional occupations ($p = 0.002$). There was no significant difference in parental educational level between groups. Children in the ASD group showed higher severity of autistic traits than non-ASD children ($p <$

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0.001). Cognitive level was significantly lower in the ASD group than in the non-ASD group ($p < 0.001$).

To further characterize developmental patterns across age, the ASD and non-ASD groups were stratified into children younger than 3 years and those aged 3 years or older. Demographic characteristics, cognitive level, and behavioral profiles for these subgroups are also presented in Table 1. Among children younger than 3 years, 38 were in the ASD group and 66 were in the non-ASD group. No significant group differences were observed in age, parental education level, or parental occupation. However, significant group differences were observed in sex distribution, severity of autistic traits, and cognitive level, with patterns consistent with those observed in the overall sample. Among children aged 3 years or older, 86 were in the ASD group and 57 were in the non-ASD group. No significant group differences were found in age or parental education level, whereas significant differences were observed in sex distribution, parental occupation, severity of autistic traits, and cognitive level.

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3.3 Measurements

This study conducted a secondary data analysis using behavioral, cognitive, and motor assessments extracted from the original datasets. The specific assessments utilized are described below.

3.3.1 Behavioral Problems: Child Behavior Checklist for Ages 1.5 to 5 (CBCL/1.5-5)

The CBCL/1.5-5 is one assessment tool of Achenbach System of Empirically Based Assessment (ASEBA). It is a widely used caregiver- or parent-report screening tool designed to assess a broad range of behavioral and emotional problems in young children. Caregivers are asked to rate 99 items based on their child's behavior during the past two months, using a 3-point Likert scale (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true). It is scored by converting raw scores into T-scores (M = 50, SD = 10) based on normative data from a U.S. sample of 700 children aged 18 to 71 months. For syndrome scales, T-scores ≥ 70 are considered to fall within the clinical range, whereas for the broadband scales, the clinical cutoff is a T-score ≥ 64. In terms of psychometric properties, studies in Taiwan have reported good to excellent reliability, including internal consistency (Cronbach's α = 0.62-0.95) and test-

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retest reliability (ICCs = 0.52-0.84), supporting its applicability in Taiwanese young children.

3.3.2 Autistic Traits Severity: Modified Checklist for Autism in Toddlers, Revised with Follow-up (M-CHAT-R/F) and Social Responsiveness Scale, Second Edition (SRS-2)

The M-CHAT-R/F is an ASD screening tool suitable for children aged 16 to 30 months. It has been translated into Chinese and adapted for use in Taiwan. The M-CHAT-R/F is a two-stage questionnaire. In the first stage, primary caregivers complete 20 yes/no questions. Based on the number of at-risk responses, children are classified into three risk categories: low risk (0-2 items), medium risk (3-7 items), and high risk (8-20 items). In the present study, risk categories were used as indicators of autistic trait severity. In Taiwan, it has demonstrated acceptable predictive validity for ASD diagnosis made at 36 months of age, with a sensitivity of 0.86 and a specificity of 0.96 (Tsai et al., 2019).

The SRS-2 is a caregiver- or teacher-report questionnaire designed to evaluate the social functioning of children and adolescents aged 2.5 to 18 years, and is widely used for assessing individuals with ASD and other conditions involving social impairments (Bruni, 2014). The instrument is organized into

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five treatment clusters (social awareness, social cognition, social communication, social motivation, and restricted interests and repetitive behavior), two composite subscales are aligned with the DSM-5 diagnostic framework (social communication and interaction and restricted interests and repetitive behavior), and total score. Each form contains 65 items rated on a 4-point Likert scale, ranging from 1 (“not true”) to 4 (“almost always true”), with raw scores converted to standardized T-scores. In the present study, categories based on the total score were used as indicators of autistic trait severity. A validated Chinese version of the SRS is also available in Taiwan, demonstrating good internal consistency (Cronbach’s α = 0.94-0.95) and acceptable test-retest reliability (ICC = 0.75-0.85), supporting its reliability for use in the Chinese population (Gau, Liu, Wu, Chiu, & Tsai, 2013).

3.3.3 Cognitive Level: Mullen Scales of Early Learning-Taiwan Version (MSEL-T)

The MESL-T is a developmental test that widely applied in children who with limited response capacities like children with ASD or with special needs (Mullen, 1995). It contains the following domains: the visual reception, expressive language, receptive language, gross motor, and fine motor. The total raw scores in each subscale can be transformed into T-scores to compare the

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results from normative sample. The early learning composite score represents overall cognitive function combing the T-scores of four subscales excluded gross motor. We used it to represent cognitive level in the present study. The MSEL had translated into Taiwan version and revealed acceptable convergent and discriminative validity for developmental assessments in a Taiwanese sample. All subscale scores of MSEL-T showed moderate to high correlations with VABS (r = 0.4-0.83), and high correlations in motor subscales scores (r = 0.78-0.8) with PDMS-2 (Cheong et al., 2022; Wang Y-C, 2019).

3.3.4 Motor Development: Peabody Developmental Motor Scales, Second Edition (PDMS-2) and Movement Assessment Battery for Children, Second Edition (MABC-2)

The PDMS-2 is a norm-referenced assessment designed to evaluate multiple domains of motor development in children from birth to 72 months of age (Folio & Fewell, 2000). It comprises six subscales: Reflexes (for newborns to 11 months), Stationary, Locomotion, Object Manipulation, Grasping, and Visual-Motor Integration. Each item is scored on a 3-point scale, and raw scores are converted to standardized scores based on American and Canadian normative data. Composite quotients are derived as follows: the Gross Motor Quotient (GMQ) from the Stationary, Locomotion, and Object Manipulation subscales;

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the Fine Motor Quotient (FMQ) from the Grasping and Visual-Motor Integration subscales; and the Total Motor Quotient (TMQ) from the GMQ and FMQ combined. The PDMS-2 demonstrates excellent inter-rater reliability (ICCs = 0.96–0.99) (Folio & Fewell, 2000), test-retest reliability (ICC = 0.97) (Griffiths, Toovey, Morgan, & Spittle, 2018), and strong concurrent validity with the Bayley Scales of Infant Development-2 ($r = 0.67–0.97$, $p < 0.001$) in children with developmental delay (Provost et al., 2004).

The MABC-2 is an assessment tool for evaluating motor coordination in children aged 3 to 16 years (Henderson, Sugden, & Barnett, 1992). It consists of eight tasks divided into three domains: Manual Dexterity, Aiming and Catching, and Balance. Raw scores are converted into standard scores and percentiles based on normative data. Scores above the 15th percentile indicate typical motor development, scores between the 6th and 15th percentile suggest a risk for motor difficulties, and scores at or below the 5th percentile denote significant movement difficulties. The MABC-2 has demonstrated good test-retest reliability ($r = 0.80$) (Henderson et al., 1992) and excellent inter-rater reliability (ICC = 0.892-0.996) (Hua, Gu, Meng, & Wu, 2013). Correlations between the MABC-2 Manual Dexterity subscale and the PDMS-2 fine motor subtests were high (Spearman's $\rho = 0.75$) (Hua et al., 2013), while correlations between other

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MABC-2 components and the PDMS-2 ranged from moderate to weak (Spearman's ρ = 0.011–0.743) (Hua et al., 2013).

3.4 Statistical Analyses

3.4.1 Demographic Variables Analyses

Demographic variables of the young children and their primary caregivers were compared between the ASD and non-ASD groups using SPSS (version 29). The demographic variables included the age, gender and autistic traits severity, and cognition level of the young children, as well as the education levels and socioeconomic status of the primary caregivers and their families. The age and cognition level were treated as a continuous variable and analyzed using independent samples t-tests. The other variables were categorical and analyzed using Chi-square tests. Missing data were examined descriptively to determine the proportion and distribution of missingness. Because all missing values occurred in categorical variables and the proportion of missingness was below 5-10%, single imputation using mode substitution was applied.

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3.4.2 Comparing Behavioral Problems and Motor Development between Young Children with ASD and non-ASD

The subscale scores of the CBCL/1.5-5, PDMS-2 and MABC-2 were compared between young children with ASD and non-ASD using multivariate analysis of covariance (MANCOVA). The models will control for covariates that differed significantly between groups, such as age, gender, cognitive level, and the education and socioeconomic status of the primary caregivers and their families (A. Bhat, 2023; Hedgecock et al., 2018). Effect sizes were interpreted using Cohen's criteria: $\eta^2 = 0.01$ was considered a small effect, $\eta^2 = 0.06$ a medium effect, and $\eta^2 \geq 0.14$ a large effect.

3.4.3 Associations between Behavioral Problems and Motor Development

Multiple linear regression analyses were conducted in SPSS (version 29) to examine whether the T-scores of syndromes and broadband scales of the CBCL/1.5-5 were associated with motor development outcomes from the PDMS-2 and MABC-2 in the ASD and non-ASD groups. Multicollinearity among predictors was assessed using variance inflation factors (VIF). VIF values greater than 10 were considered indicative of problematic multicollinearity (Hair, 2010). When collinearity was identified, redundant predictors were removed or examined in separate models to ensure model

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stability and interpretability. Motor development scores were treated as dependent variables, and behavioral problems were treated as independent variables.

Given differences in sample size across groups, different analytical strategies were applied. For the full ASD and non-ASD samples, in which sample sizes were sufficient to support multivariable modeling, sex, age, cognitive level, and parental occupation were included as covariates to reduce potential confounding influences on behavioral-motor associations (A. Bhat, 2023; Hedgecock et al., 2018). Cognitive level was entered as a continuous covariate based on standardized assessment scores. Although autistic trait severity has also been linked to motor outcomes, cognitive level cognitive level and autistic trait severity both were covariates with motor development, they were highly correlated in the present study. We chose cognitive level as the primary covariate to minimize multicollinearity, given its well-established role in motor development across neurodevelopmental populations (Licari et al., 2020; van der Fels et al., 2015). Parental occupation was selected as an indicator of family socioeconomic resources because it demonstrated stronger associations with motor outcomes than parental education level in the present dataset.

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For age-stratified subgroups, the sample sizes were small. To avoid loss of statistical power, Spearman correlation analyses were first conducted to identify background variables significantly associated with motor development. Only covariates that showed significant correlations with the corresponding motor domain were subsequently included in the regression models. A hierarchical modeling approach was adopted to examine the contributions of behavioral problems. Two separate regression models were conducted. In the first model, covariates and Total Problems were entered to examine the overall association between behavioral problems and motor development. In the second model, covariates together with Internalizing Problems and Externalizing Problems were entered to assess their contributions to motor development.

3.5 Statistical Power

Post hoc power analyses were conducted using G*Power 3.1 to evaluate the achieved statistical power of the main analyses. For group comparisons of behavioral problems and motor development, power was estimated based on MANCOVA models with an alpha level of 0.05. Effect sizes were derived from the observed partial eta squared values in the present study. To provide conservative estimates, the smallest observed effect sizes were used for power calculations. The achieved power for behavioral problem and motor

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development comparisons was approximately 0.99, indicating adequate sensitivity to detect group-level differences. For the multiple linear regression analyses examining associations between behavioral problems and motor development, post hoc power estimates ranged from 0.48 to 0.72, depending on the specific model. Given the inclusion of multiple covariates and the exploratory nature of these models, these powers levels are considered acceptable for developmental clinical research. The identification of statistically significant predictors despite moderate power further supports the robustness of the observed associations.

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Chapter 4 Results

4.1 Comparison of Behavioral Problems between ASD and non-ASD Groups

With respect to the proportion of children reaching the borderline and clinical range, all syndrome scales and broadband scales of the CBCL/1.5-5 showed significant group differences (Table 2). For the broadband scales, 46.0% to 67.7% of children with ASD met borderline and clinical criteria, compared with 14.6% to 16.3% of children in the non-ASD group. Among the syndrome scales, the percentage of children in the ASD group scoring in the borderline and clinical range ranged from 13.7% to 71.0%, whereas the corresponding proportions in the non-ASD group ranged from only 1.6% to 7.3%. Adjusted group comparisons of CBCL/1.5-5 T-scores between the ASD and non-ASD groups are also presented in Table 2. After adjusting for age, sex, parental occupation, cognitive level, and autistic trait severity, children with ASD exhibited significantly higher T-score of behavioral problem across multiple domains. Within the broadband scales, higher scores were observed for Internalizing Problems (partial $\eta^2 = 0.10$, $p < 0.001$) and Total Problems (partial $\eta^2 = 0.05$, $p < 0.001$). Within the syndrome scales, the ASD group showed elevated scores on Emotionally Reactive (partial $\eta^2 = 0.04$, $p = 0.002$),

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Anxious/Depressed (partial $\eta^2 = 0.06$, $p < 0.001$), Somatic Complaints (partial $\eta^2 = 0.04$, $p = 0.005$), Withdrawn (partial $\eta^2 = 0.19$, $p < 0.001$), and Attention Problems (partial $\eta^2 = 0.03$, $p = 0.007$).

Age-specific analyses in children younger than 3 years revealed significant group differences across the CBCL/1.5–5 syndrome and broadband scales, with the exception of Sleep Problems and Aggressive Problems (Table 3). At the broadband level, 44.7% to 60.5% of children with ASD met borderline and clinical criteria, compared with 18.2% to 19.7% of children in the non-ASD group. At the syndrome scale level, the percentage of children in the ASD group scoring in the borderline and clinical range ranged from 7.9% to 60.5%, whereas the corresponding proportions in the non-ASD group ranged from only 3.0% to 9.1%. After adjustment for sex, autistic traits severity and cognition level, no significant group differences were observed on the broadband scales in this younger subgroup (Table 3). However, at the syndrome scale level, the ASD group showed significantly higher scores than the non-ASD group on Anxious/Depressed (partial $\eta^2 = 0.05$, $p = 0.033$) and Withdrawn (partial $\eta^2 = 0.14$, $p < 0.001$).

Among children aged 3 years and older, significant group differences were observed across the CBCL/1.5–5 syndrome and broadband scales (Table 4). The

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proportion of children meeting borderline and clinical criteria on the broadband scales was significantly higher in the ASD (46.5%-70.9%) group than in the non-ASD group (8.8%-14%). A similar pattern was observed for the syndrome scales, with 14%-75.6% of children with ASD meeting borderline and clinical range compared with 0%-7% of children in the non-ASD group. This pattern was further supported by the adjusted T-score analyses. After adjusting for sex, parental occupation, autistic traits severity and cognition level, the ASD group showed significantly higher scores on Internalizing Problems (partial $\eta^2 = 0.20$, $p < 0.001$), Externalizing Problems (partial $\eta^2 = 0.05$, $p = 0.011$), and Total Problems scales (partial $\eta^2 = 0.13$, $p < 0.001$). Significant group differences were also found for Emotionally Reactive (partial $\eta^2 = 0.13$, $p < 0.001$), Anxious/Depressed (partial $\eta^2 = 0.09$, $p < 0.001$), Somatic Complaints (partial $\eta^2 = 0.06$, $p = 0.006$), Withdrawn (partial $\eta^2 = 0.30$, $p < 0.001$), and Attention Problems (partial $\eta^2 = 0.10$, $p < 0.001$).

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4.2 Comparison of Motor Development between ASD and non-ASD Groups

The proportions of children classified in the borderline or delayed range for motor development are presented in Table 5. In the ASD group, the proportion of children meeting criteria for borderline or delayed motor performance on the overall motor quotients ranged from 57.7% to 75.7%, and from 35.1% to 71.2% across the gross and fine motor subtests, whereas the corresponding proportions in the non-ASD group were 0% for the motor quotients and ranged from 0% to 5.6% across the gross and fine motor subdomains. Consistent with these findings, children with ASD showed significantly lower scores than non-ASD children across all PDMS-2 composite quotients and subtests. Significant group differences were observed for GMQ (partial $\eta^2 = 0.10$, $p < 0.001$), FMQ (partial $\eta^2 = 0.06$, $p = 0.001$), and TMQ (partial $\eta^2 = 0.09$, $p < 0.001$). At the subtest level, significant group differences were found for Stationary (partial $\eta^2 = 0.03$, $p = 0.025$), Locomotion (partial $\eta^2 = 0.08$, $p < 0.001$), Object Manipulation (partial $\eta^2 = 0.08$, $p < 0.001$), Grasping (partial $\eta^2 = 0.03$, $p = 0.020$), and Visual-Motor Integration (partial $\eta^2 = 0.04$, $p = 0.014$).

In children younger than 3 years, the proportions of children classified in the borderline or delayed range for motor development were significantly higher in the ASD group than in the non-ASD group (Table 6). At the composite

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quotient level, 52.9% to 79.4% of children with ASD met criteria for borderline or delayed motor performance, whereas none of the children in the non-ASD group met these criteria. At the subtest level, significantly higher proportions of children with ASD were classified in the borderline or delayed range on Locomotion, Object Manipulation, and Visual-Motor Integration (58.8%-73.5%), compared with only 0%-2.9% in the non-ASD group. These findings were further supported by the adjusted score analyses. After adjustment for sex, autistic trait severity, and cognitive level, significant group differences were observed for GMQ (partial $\eta^2 = 0.16$, $p = 0.001$) and TMQ (partial $\eta^2 = 0.16$, $p = 0.001$), whereas the difference in FMQ did not reach statistical significance (partial $\eta^2 = 0.03$, $p = 0.152$). At the subtest level, children with ASD showed significantly lower scores than non-ASD children on Locomotion (partial $\eta^2 = 0.07$, $p = 0.036$) and Object Manipulation (partial $\eta^2 = 0.20$, $p < 0.001$).

Among children aged 3 years and older, the proportions of children classified in the borderline or delayed range for motor development were consistently higher in the ASD group than in the non-ASD group (Table 7). At the composite quotient level, 59.7% to 74.0% of children with ASD met criteria for borderline or delayed motor performance, whereas none of the children in the non-ASD group met these criteria. At the subtest level, 42.9% to 70.1% of

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children with ASD were classified in the borderline or delayed range across the PDMS-2 subtests, compared with 0% to 10.8% in the non-ASD group. Similarly, on the MABC-2, 44.4% of children with ASD fell below the normal range on the Total Percentile, whereas no children in the non-ASD group fell into the below range. Elevated proportions were also observed for percentile scores for Manual Dexterity, Aiming and Catching, and Balance in the ASD group (26.7%-53.3%), compared with only 0%-3.8% in the TD group. These findings were further supported by the score-based analyses. The ASD group showed significantly lower scores on the composite quotients GMQ (partial $\eta^2 = 0.09$, $p = 0.003$), FMQ (partial $\eta^2 = 0.05$, $p = 0.026$), and TMQ (partial $\eta^2 = 0.08$, $p = 0.007$). At the subtest level, group differences were observed for Stationary (partial $\eta^2 = 0.08$, $p = 0.006$), Locomotion (partial $\eta^2 = 0.04$, $p = 0.049$), and Object Manipulation (partial $\eta^2 = 0.06$, $p = 0.019$). Similar group differences were found on the MABC-2 for the Total Percentile (partial $\eta^2 = 0.08$, $p = 0.032$) and Aiming and Catching (partial $\eta^2 = 0.19$, $p < 0.001$).

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4.3 Associations between Behavioral Problems and Motor Development

Across all cases (Table 8), significant associations between T-scores of behavioral problems and quotients of motor development were observed in the ASD group but not in the non-ASD group after adjusting for age, sex, cognitive level, and parental occupation. For ASD group, the inclusion of Internalizing and Externalizing Problems in the models resulted in significant increases in explained variance (ΔR^2) for TMQ, GMQ, and FMQ, indicating incremental contributions beyond the covariates. T-score of Internalizing Problems were negatively associated with motor development across all three motor quotients, including TMQ ($\beta = -0.3$, $p = 0.003$), GMQ ($\beta = -0.3$, $p = 0.003$), and FMQ ($\beta = -0.3$, $p = 0.004$). In contrast, T-score of Externalizing Problems were positively associated with motor quotients, including TMQ ($\beta = 0.3$, $p = 0.003$), GMQ ($\beta = 0.3$, $p = 0.005$), and FMQ ($\beta = 0.3$, $p = 0.007$). Total Problems were not significantly associated with any motor quotients in the ASD group. In the non-ASD group, no significant associations were found between T-scores of behavioral problems and motor quotients across TMQ, GMQ, or FMQ.

In children younger than 3 years (Table 9), the associations between T-scores of behavioral problems and motor development quotients were limited and inconsistent after adjustment for cognitive level in the ASD group. The only

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association was observed between Total Problems and FMQ (β = −0.2, p = 0.028). In the non-ASD group, T-score of Internalizing Problems were negatively associated with TMQ (β = −0.6, p = 0.014) after adjustment, whereas no other significant associations were observed between behavioral problems and motor quotients.

Among children aged 3 years and older (Table 10), consistent associations between behavioral problems and motor development emerged in the ASD group after covariate adjustment. In children with ASD, the inclusion of Internalizing and Externalizing Problems in the models resulted in significant increases in explained variance (ΔR^2) for both TMQ and GMQ, indicating incremental contributions beyond the covariates. T-score of Internalizing Problems were negatively associated with motor performance across TMQ (β = −0.3, p = 0.006; adjusted for sex, age, cognitive level, and parental occupation), GMQ (β = −0.4, p = 0.004; adjusted for sex, age, cognitive level, and parental occupation), and FMQ (β = −0.3, p = 0.021; adjusted for age, cognitive level, and parental occupation). T-score of Externalizing Problems were positively associated with TMQ (β = 0.3, p = 0.022) and GMQ (β = 0.3, p = 0.012), but not with FMQ (β = 0.2, p = 0.103).There were not significant associations between behavioral problems and percentile of

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total coordination scores of MABC-2. In the non-ASD group, there were also not significant associations between behavioral problem and motor quotients.

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Chapter 5 Discussion

5.1 Comparison of Behavioral Problems between ASD and non-ASD Groups

Children with ASD showed markedly higher proportions of clinically significant behavioral problems across the Total, Internalizing, and Externalizing domains of the CBCL/1.5-5. In addition, T-score comparisons demonstrated significantly higher mean scores for Total Problems and Internalizing Problems in the ASD group after controlling for age, sex, parental occupation, cognitive level, and autistic trait severity, with Internalizing Problems reaching a large effect size. In contrast, although the proportion of children meeting borderline and clinical criteria for Externalizing Problems was significantly higher in the ASD group, the mean T-score difference did not reach statistical significance. This pattern suggests that externalizing behaviors may be more heterogeneous in young children with ASD, with substantial variability in severity across individuals. This finding is consistent with previous literature indicating that internalizing symptoms, including anxiety, emotional reactivity, somatic complaints, and social withdrawal, are highly prevalent and often prominent in young children with ASD (Chericoni et al., 2021; Davis et al., 2010; Li, Bos, Stockmann, & Rieffe, 2020; Quinnett, Drafton, Wilson, Geib, & O'Connor, 2025; L. Rescorla et al., 2015; L. A. Rescorla et al., 2019; Tseng, Fu, Cermak, Lu, & Shieh, 2011; Yang et al., 2019). In contrast,

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externalizing behaviors such as aggression, hyperactivity, and disruptive behaviors have been reported less consistently across studies, with some reporting elevated levels, (L. Rescorla et al., 2015; L. A. Rescorla et al., 2019; Yang et al., 2019) whereas others have found no significant differences (Chericoni et al., 2021; Morales-Hidalgo, Voltas-Moreso, Hernandez-Martinez, & Canals-Sans, 2023).

At the syndrome scale level, all domains showed significantly higher proportions of children in the borderline and clinical range in the ASD group, indicating elevated behavioral risk. Among these, Withdrawn exhibited a large effect size, highlighting its prominence in distinguishing children with ASD from their non-ASD peers. However, when examining mean T-scores after adjustment, Sleep Problems and Aggressive Problems did not show significant group differences. Although sleep problems and aggressive behaviors are frequently reported in children with ASD (L. Rescorla et al., 2015; L. A. Rescorla et al., 2019; Yang et al., 2019), it is noteworthy that most evidence regarding sleep problems is derived from studies using dedicated sleep-specific measurements (Hirata et al., 2016; Reynolds et al., 2019), which may be more sensitive to sleep-related problems. In contrast, findings regarding aggressive behaviors have been mixed, with some studies reporting no significant group differences between children with ASD and their non-ASD peers (Chericoni et al., 2021). The absence of significant

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mean differences in Sleep Problems and Aggressive Problems in the present study therefore likely reflects both phenotypic heterogeneity in these domains and methodological differences in measurement sensitivity.

Age-stratified analyses further revealed distinct developmental patterns in behavioral profiles between children younger than 3 years and those aged 3 years and older. In the younger group, significant group differences at the categorical levels were observed for Total Problems, Internalizing Problems and Externalizing Problems, and all syndrome scales except for Sleep Problems and Aggressive Problems. However, children with ASD differed from their TD peers only on the adjusted T-scores of the Anxious/Depressed and Withdrawn syndromes. This pattern is consistent with previous studies focusing on children under three years of age, which also reported no significant group differences in Sleep Problems and Aggressive Problems, despite observing differences at the broadband scale level (Chericoni et al., 2021). It should be noted that the prior literatures in this age group remains limited and is often based on relatively small samples. These findings suggest that behavioral problems in ASD are most evident in emotional and social withdrawal domains in early toddlerhood, rather than in overt disruptive or regulatory behaviors.

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In contrast, among children aged 3 years and older, group differences extended to a broader range of domains. At both the categorical and T-score levels, significant differences were observed across all broadband and syndrome scales, with the exception of T-scores of Sleep Problems and Aggressive Problems. This pattern indicates that behavioral problems become more differentiated and encompass a wider range of emotional, attentional, and behavioral regulation domains as children with ASD grow older. The expanding divergence between ASD and non-ASD groups with increasing age is consistent with longitudinal evidence indicating that some children with ASD exhibit minimal or near-typical symptomatology in early toddlerhood, with more pronounced behavioral and developmental features emerging over time (Ozonoff et al., 2018). Notably, Withdrawn consistently demonstrated large effect sizes across different age groups, indicating that social withdrawal is a stable and prominent behavioral characteristic of ASD from early toddlerhood onward. In addition, Anxious/Depressed symptoms emerged as a significant differentiating feature primarily before the age of 3, suggesting that early emotional distress and internalizing tendencies may serve as early behavioral markers of ASD risk. As children grow older, behavioral differences between ASD and non-ASD groups may become evident across a

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wider range of domains, including attention problems, somatic complaints, and broader internalizing and externalizing problems.

5.2 Comparison of Motor Defficulties between ASD and non-ASD Groups

A high proportion of children with ASD demonstrated motor difficulties, with motor quotients falling in the borderline or delayed range for 75.7% in gross motor, 57.7% in fine motor, and 66.7% in total motor development in the present study. Moreover, children with ASD showed significantly lower motor development scores than their non-ASD peers across all PDMS-2 subtests. This finding aligns with the evidences indicating that motor difficulties are highly prevalent in ASD throughout early childhood (Licari et al., 2020; Ting Liu & Breslin, 2013b; Mohd Nordin et al., 2021). Notably, Locomotion and Object Manipulation exhibited large effect sizes in the ASD and non-ASD comparison, representing the most pronounced group differences among all subtests. These skills place high demands on hand-eye coordination, and rely heavily on the integration of sensory input, motor planning, and adaptive control. In addition, these skills are often learned through observation, imitation, and social engagement, children with ASD may be particularly vulnerable in these domains (Provost et al., 2007). Consistent with this interpretation, meta-analytic findings

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have shown that object control is among the most severely affected motor domains in ASD (Wang et al., 2022).

Age-stratified analyses further revealed that motor difficulties were already evident in children younger than 3 years. At this early stage, children with ASD showed significantly lower motor scores than non-ASD group in GMQ and TMQ after adjusted for sex, autistic traits severity, and cognitive level. And at the subtest level, group differences were showed in standard scores of Locomotion and Object Manipulation after adjusted for the same covariates. The results highlighting early vulnerabilities in gross motor skills involving jumping, walking stairs, running coordination, and ball-handling skills. Moreover, motor difficulties became more widespread in children aged 3 years and older, with significant group differences observed across GMQ, FMQ, and TMQ after adjusted for covariates. At the subtest level, all gross motor domains showed significant group differences, whereas fine motor subtests did not reach statistical significance. Motor difficulties in two age groups indicated that early motor difficulties in ASD affected some gross motor domain, GMQ and TMQ, and extended to other motor domains including static balance and FMQ in the older group with increasing task demands (Mohd Nordin et al., 2021). There was significant difference at the FMQ level but not any fine motor subtests, this pattern suggests that fine motor difficulties in ASD may be

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more diffusely distributed across tasks rather than concentrated in specific skill areas.

The MABC-2 findings provide converging evidence that motor coordination difficulties are prominent in children with ASD aged 3-6 years, consistent with previous studies reporting coordination difficulties in older children with ASD (Ting Liu & Breslin, 2013b; Piccolo et al., 2025). Children with ASD in the present study showed lower percentile of total motor coordination scores than non-ASD group after adjusting for covariates. And the Aiming and Catching skills emerging as the most affected domain. These skills are essential for playground play, sports, and peer interaction, and their difficulties may further restrict social participation (Ketcheson et al., 2023; Wang et al., 2022). Accordingly, the absence of significant motor difficulties before 3 years of age does not rule out later-emerging difficulties and underscores the need for ongoing, domain-specific monitoring of motor development in children with ASD beyond early childhood.

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5.3 Associations between Behavioral Problems and Motor development

The primary finding of this study is the associations between behavioral problems and motor development specifically within the ASD population. Prior research has primarily focused on associations between ASD core symptoms and motor development, typically reporting modest to moderate correlations (Hedgecock et al., 2018; Holloway et al., 2018; Ohara et al., 2019; Shiri, Hosseini, & Pishyareh, 2024; Wang et al., 2022). These findings enhance our understanding of how overall behavioral problems are linked to motor development, rather than restricting the discussion to ASD core symptoms. Specifically, the joint inclusion of Internalizing and Externalizing Problems accounted for significant incremental variance in motor quotients for the ASD group even after adjusting for covariates. In contrast, behavioral problems in the non-ASD group generally did not show significant associations with motor development. In the absence of early neurodevelopmental vulnerabilities for non-ASD children, behavioral-motor associations in non-ASD children may be more plausibly shaped by psychosocial mechanisms, including experience-dependent learning and environmental exposure (Erskine et al., 2024; Houwen et al., 2017). Such influences likely accumulate gradually over time, and therefore may not be readily observable in early childhood The only association in non-ASD group was found between the

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Internalizing Problems and TMQ in younger than 3 years. Consequently, the lack of significant associations in non-ASD groups may partly reflect limited statistical power and restriction of variance, as 100% of the non-ASD cohort performed within the normal range. In children with ASD, Internalizing Problems were positively associated with motor development, whereas Externalizing Problems were negatively associated with motor development. The negative associations for Internalizing Problems are consistent with developmental accounts suggesting that social withdrawal and related affective difficulties may reduce children's opportunities for motor exploration, participation, and imitation-based learning during early childhood (A. N. Bhat, Boulton, & Tulsky, 2022; Holloway, Long, & Biasini, 2021; Wang et al., 2022). These findings also align with prior evidence reporting internalizing-related features were associated with motor development in children with ASD (Hedgecock et al., 2018). Conversely, children with poorer motor development may experience reduced perceived competence and confidence, which may further discourage participation and social engagement, and exacerbating withdrawn and internalizing behaviors (Erskine et al., 2024).

Externalizing Problems were found positively associated with motor development in the present study. One possible explanation for this association is that higher externalizing behaviors may represent higher levels of physical activity.

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Prior research has shown that children with ASD who exhibit aggressive outbursts tend to display higher levels of hyperactivity and physical activity. This pattern suggests that children with Externalizing Problems may engage in more physical activity, which in turn support better basic motor skill development during early childhood (Hill et al., 2014). However, this association should not be interpreted as beneficial in the long term. Much of the physical activity in children with externalizing behaviors is unstructured and driven by poor inhibitory control rather than intentional engagement in skill-building tasks. This advantage may diminish as they grow older and face increasingly complex motor tasks that require coordination, planning, and executive functioning. Research in school-aged children with ASD has shown that externalizing behaviors are associated with impaired executive function and motor difficulties (T. Liu, Tongish, Li, & Okuda, 2023; Nauman & Ingersoll, 2023). Therefore, it is essential to continuously monitor the motor development of young children with ASD who exhibit externalizing problems, and to actively provide structured physical activity programs that not only support motor development but may also help reduce externalizing behaviors (Bremer, Crozier, & Lloyd, 2016). Notably, no significant associations were observed for the MABC-2 total percentiles in either the ASD or non-ASD groups. This finding may be attributable to cognitive demands of the

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MABC-2, which requires children to comprehend and follow explicit instructions, comply with structured rules, and execute movements under time constraints (Ting Liu & Breslin, 2013a). Motor coordination performance may be more strongly associated with cognitive capacity, as reflected by the significant proportion of variance in total coordination percentile scores explained by linear regression models including both cognitive level and sex.

Age-stratified analyses further revealed that the only associations observable in children with ASD younger than 3 years of age was Internalizing Problems and FMQ. And the associations became robust in the older group. This age group differences consistent with the patterns discussed earlier, suggests that increasing environmental demands with age may amplify underlying developmental difficulties more apparent. Given the small sample size of this subgroup, these findings should be interpreted as preliminary trends, and further longitudinal research is needed. Although motor difficulties are often overlooked in clinical practice (Hedgecock et al., 2018), they are highly prevalent in young children with ASD. The observed associations between behavioral problems and motor development may therefore provide valuable clinical indicators for identifying children at risk for motor difficulties and for guiding more comprehensive assessment and intervention planning.

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5.4 Clinical Implications and Future Directions

The present findings have important clinical implications for the assessment and intervention of young children with ASD. The identification of distinct behavioral and motor profiles supports the need for routine, integrated assessments, with regular follow-up across early childhood. In addition, specific behavioral problems may provide early clinical cues for identifying children at risk for motor difficulties. In particular, internalizing problems were negatively associated with motor development and may serve as early warning signs. Although externalizing problems showed positive associations with motor performance in young children with ASD, these findings should be interpreted cautiously and may reflect the influence of factors such as physical activity level.

From a clinical perspective, young children with ASD show a high prevalence of motor difficulties, and the observed associations between behavioral problems and motor difficulties highlight the critical role of physical therapy in the early identification and management of motor difficulties in this population. Early physical therapy that focuses on motor development integrated with behavioral support may facilitate broader functional outcomes in young children with ASD. Future longitudinal studies using more representative Taiwanese samples from

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both clinical and community-based settings are needed to clarify developmental trajectories and strengthen generalizability.

5.5 Limitation

Several limitations should be considered when interpreting the present findings. First, this research utilized a cross-sectional design and secondary analysis of data derived from prior projects. The cross-sectional design limits the ability to explain developmental trends directly, and the retrospective data could not involve several potentially relevant variables including detailed intervention history, physical activity levels, parenting style and medical comorbidities. Second, the ASD and non-ASD groups differed significantly in some covariates, specifically age and cognitive level. While these variables were statistically controlled in our study, residual confounding remains a possibility. Furthermore, the broad age range might blur meaningful developmental shifts occurring within narrower age bands during early childhood. Future studies with prospectively matched samples and narrower age bands are needed to better describe age-specific patterns. Third, the sample size for specific age-stratified analyses was relatively small, particularly for the non-ASD cohort under three years of age. This small subgroup size means that the identified associations in younger non-ASD children should be viewed as preliminary trends rather than definitive conclusions. Finally,

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participants were recruited primarily from medical centers in northern Taiwan, which may limit the generalizability of the findings to community-based samples or to other regions. Children referred to tertiary medical settings may present with more pronounced developmental concerns, and families may differ in socioeconomic or healthcare access characteristics. Population-based samples are necessary to determine whether these findings can be generalized to the broader population of young children with ASD in Taiwan.

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Chapter 6 Conclusion

Children with ASD showed distinct profiles of behavioral problems and motor development compared with non-ASD children. These profiles were observable before 3 years of age and involved a broader range of domains in children aged older than 3 years. ASD-specific associations were identified in which Internalizing Problems were negatively associated with motor development, whereas Externalizing Problems showed positive associations. Although group differences and behavior-motor associations were more pronounced after 3 years of age, meaningful behavioral and motor profiles were already observable before age 3, supporting the value of early developmental surveillance. These findings emphasize the importance of early behavioral and motor assessments, providing culturally specific evidence to optimize clinical evaluation and intervention for Taiwanese children with ASD. Future longitudinal studies with more representative Taiwanese samples are needed to clarify developmental trajectories and strengthen generalizability.

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Tables

Table 1 Demographic Characteristics of the ASD and non-ASD Groups

	All cases			< 3 y			≥ 3 y		
	ASD (n=124)	non-ASD (n=123)	*P* value[a]	ASD (n=38)	non-ASD (n=66)	*P* value[a]	ASD (n=86)	non-ASD (n=57)	*P* value[a]
Age, mean (SE), months	44.3 (13.8)	37.8 (12.1)	<0.001***	30.3 (2.7)	29.8 (2.7)	0.309	50.5 (12.0)	47.2 (12.2)	0.110
Sex, n (%)			<0.001***			0.006**			0.001**
Boys	103 (83.1)	70 (56.9)		31 (81.6)	36 (64.4)		72 (83.7)	34 (59.6)	
Girls	21 (16.9)	53 (43.1)		7 (18.4)	30 (35.6)		14 (16.3)	23 (40.4)	
Parental education, n (%)			0.672			0.663			0.475
Below high school,	5 (4.0)	4 (3.2)		2 (5.3)	4 (6)		3 (3.5)	0 (0.0)	
High school	12 (9.7)	16 (13.0)		6 (15.8)	16 (15.4)		6 (7.0)	6 (10.5)	
College or university	89 (71.8)	88 (71.5)		21 (55.3)	64 (61.5)		68 (79.1)	45 (78.9)	
Above master program	18 (14.5)	15 (12.2)		9 (23.7)	18 (17.3)		9 (10.5)	6 (10.5)	
Parental occupation, n (%)			0.002**			0.790			<0.001***
Manual labor	5 (4.0)	10 (8.1)		2 (5.3)	3 (4.5)		3 (3.5)	7 (12.3)	
White-collar workers	66 (53.2)	86 (69.9)		24 (63.2)	46 (69.7)		42 (48.8)	40 (70.2)	
Professionals	53 (42.7)	27 (22.0)		12 (31.6)	17 (25.8)		41 (47.7)	10 (17.5)	
Autistic trait severity[b], n (%)			<0.001***			<0.001***			<0.001***
Mild	30 (24.2)	117 (95.1)		7 (18.4)	62 (93.9)		23 (26.7)	55 (96.5)	
Moderate	53 (42.7)	6 (4.9)		16 (42.1)	4 (6.1)		37 (43.0)	2 (3.5)	
Severe	41 (33.1)	0 (0.0)		15 (39.5)	0 (0.0)		26 (30.2)	0 (0.0)	
Cognition[c], mean (SE)	76.1 (25.8)	116.2 (15.8)	<0.001***	72.4 (19.3)	113.9 (16.3)	<0.001***	77.7 (28.1)	118.8 (15.0)	<0.001***

Note. [a] Age (continuous variables) was analyzed by t test, and other variables (categorical variables) were using χ^2 test. [b] Autistic trait severity was classified based on the combined T-scores of the SRS-2 and the M-CHAT. [c] Cognitive ability was classified based on the Early Learning Composite score of the MSEL. SE: standard errors. *p < .05, **p < .01, ***p < .001.

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Table 2 Comparison of behavioral problems between ASD and non-ASD groups (all cases)

Behavioral problems	Proportions, n (%)			T-scores, mean (SE)			
	ASD (n=124)	non-ASD (n=123)	P value	ASD (n=124)	non-ASD (n=123)	P value	partial η^2
Emotionally Reactive	54 (43.5)	8 (6.5)	<0.001***	60.6 (1.1)	54.6 (1.5)	0.002**	0.04
Anxious/Depressed	39 (31.5)	9 (7.3)	<0.001***	60.3 (1.0)	53.6 (1.4)	<0.001***	0.06
Somatic Complaints	22 (17.7)	5 (4.1)	<0.001***	56.3 (0.8)	52.2 (1.1)	0.005**	0.04
Withdrawn	88 (71.0)	9 (7.3)	<0.001***	70.5 (1.1)	55.8 (1.5)	<0.001***	0.19
Sleep Problems	17 (13.7)	2 (1.6)	<0.001***	56.6 (1.0)	53.6 (1.3)	0.082	0.01
Attention Problems	56 (45.2)	5 (4.1)	<0.001***	59.8 (1.0)	55.3 (1.3)	0.007**	0.03
Aggressive Problems	20 (16.1)	8 (6.5)	0.017*	57.9 (1.2)	54.6 (1.6)	0.109	0.01
Internalizing problems	84 (67.7)	20 (16.3)	<0.001***	62.9 (1.3)	51.5 (1.8)	<0.001***	0.10
Externalizing problems	57 (46.0)	18 (14.6)	<0.001***	55.9 (1.5)	52.0 (2.0)	0.137	0.01
Total problems	77 (62.1)	19 (15.4)	<0.001***	60.8 (1.4)	52.1 (2.0)	<0.001***	0.05

Note. Proportions: values are presented as n (%) for children in the borderline or clinical range. T-scores: values are presented as adjusted mean T-scores with standard errors (SE) for CBCL/1.5–5 scales. Group differences in proportions were examined using chi-square tests. Group differences in T-scores were examined using MANCOVA, controlling for age, sex, parental occupation, autistic traits severity, and cognitive level. The overall MANCOVA model: Wilks' Lambda = 0.777, F(10, 212) = 6.099, p<0.001, partial $\eta^2 = 0.223$. *p < .05, **p < .01, ***p < .001.

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Table 3 Comparison of behavioral problems between ASD and non-ASD groups (< 3 y)

Behavioral problems	Proportions, n (%)			T-scores, mean (SE)			
	ASD (n=38)	non-ASD (n=66)	P value	ASD (n=38)	non-ASD (n=66)	P value	partial η^2
Emotionally Reactive	15 (39.5)	5 (7.6)	<0.001***	60.7 (2.0)	56.0 (2.1)	0.111	0.03
Anxious/Depressed	9 (23.7)	5 (7.6)	0.020*	59.2 (1.9)	53.2 (1.9)	0.033*	0.05
Somatic Complaints	10 (26.3)	3 (4.5)	0.001**	54.2 (1.6)	53.8 (1.6)	0.865	0.00
Withdrawn	23 (60.5)	6 (9.1)	<0.001***	68.9 (2.0)	57.3 (2.1)	<0.001***	0.14
Sleep Problems	4 (10.5)	2 (3.0)	0.114	55.7 (1.9)	54.3 (1.9)	0.626	0.00
Attention Problems	15 (39.5)	4 (6.1)	<0.001***	57.6 (1.8)	57.7 (1.8)	0.966	0.00
Aggressive Problems	3 (7.9)	6 (9.1)	0.835	56.6 (2.2)	55.4 (2.3)	0.725	0.00
Internalizing problems	23 (60.5)	12 (18.2)	<0.001***	60.0 (2.6)	53.7 (2.7)	0.100	0.03
Externalizing problems	17 (44.7)	13 (19.7)	0.007**	52.6 (3.1)	54.5 (3.2)	0.675	0.00
Total problems	21 (55.3)	13 (19.7)	<0.001***	56.4 (3.0)	54.6 (3.1)	0.690	0.00

Note. Proportions: values are presented as *n* (%) for children in the borderline or clinical range. T-scores: values are presented as adjusted mean T-scores with standard errors (SE) for CBCL/1.5–5 scales. Group differences in proportions were examined using chi-square tests. Group differences in T-scores were examined using MANCOVA, controlling for sex, autistic traits severity, and cognitive level. The overall MANCOVA model: Wilks' Lambda = 0.735, F(10, 84) = 3.025, p=0.003, partial $\eta^2 = 0.265$. *p < .05, **p < .01, ***p < .001.

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Table 4 Comparison of behavioral problems between ASD and non-ASD groups (≥ 3 y)

Behavioral problems	Proportions, n (%)			T-scores, mean (SE)			
	ASD (n=86)	non-ASD (n=57)	P value	ASD (n=86)	non-ASD (n=57)	P value	partial η^2
Emotionally Reactive	39 (45.3)	3 (5.3)	<0.001***	62.1 (1.3)	52.1 (1.9)	<0.001***	0.13
Anxious/Depressed	30 (34.9)	4 (7.0)	<0.001***	61.7 (1.1)	54.0 (1.7)	<0.001***	0.09
Somatic Complaints	12 (14.0)	2 (3.5)	0.040*	57.1 (0.9)	52.5 (1.3)	0.006**	0.06
Withdrawn	65 (75.6)	3 (5.3)	<0.001***	72.1 (1.3)	54.7 (1.9)	<0.001***	0.30
Sleep Problems	13 (15.1)	0 (0.0)	0.002**	57.1 (1.0)	53.7 (1.6)	0.093	0.02
Attention Problems	41 (47.7)	1 (1.8)	<0.001***	61.1 (1.1)	53.6 (1.6)	<0.001***	0.10
Aggressive Problems	17 (19.8)	2 (3.5)	0.005**	58.8 (1.3)	54.5 (1.9)	0.071	0.03
Internalizing problems	61 (70.9)	8 (14.0)	<0.001***	64.7 (1.4)	50.2 (2.1)	<0.001***	0.20
Externalizing problems	40 (46.5)	5 (8.8)	<0.001***	57.9 (1.6)	50.2 (2.4)	0.011*	0.05
Total problems	56 (65.1)	6 (10.5)	<0.001***	63.5 (1.5)	50.4 (2.3)	<0.001***	0.13

Note. Proportions: values are presented as n (%) for children in the borderline or clinical range. T-scores: values are presented as adjusted mean T-scores with standard errors (SE) for CBCL/1.5–5 scales. Group differences in proportions were examined using chi-square tests. Group differences in T-scores were examined using MANCOVA, controlling for sex, parental occupation, autistic traits severity, and cognitive level. The overall MANCOVA model: Wilks' Lambda = 0.659, F(10, 113) = 5.842, p<0.001, partial $\eta^2 = 0.341$. *p < .05, **p < .01, ***p < .001.

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Table 5 Comparison of motor development between ASD and non-ASD groups (all cases)

Motor development	Proportions, n (%)			Standard Scores, mean (SE)			
	ASD (n=111)	non-ASD (n=72)	P value	ASD (n=111)	non-ASD (n=72)	P value	partial η^2
Stationary	39 (35.1)	3 (4.2)	<0.001***	8.38 (0.25)	9.31 (0.30)	0.025*	0.03
Locomotion	66 (59.5)	2 (2.8)	<0.001***	7.69 (0.25)	9.29 (0.30)	<0.001***	0.08
Object Manipulation	79 (71.2)	4 (5.6)	<0.001***	7.11 (0.26)	8.72 (0.32)	<0.001***	0.08
Grasping	48 (43.2)	4 (5.6)	<0.001***	8.34 (0.31)	9.54 (0.37)	0.020*	0.03
Visual-Motor Integration	53 (47.7)	1 (1.4)	<0.001***	9.37 (0.27)	10.46 (0.32)	0.014*	0.04
					Quotients, mean (SE)		
GMQ	84 (75.7)	0 (0.0)	<0.001***	85.33 (1.25)	94.27 (1.52)	<0.001***	0.10
FMQ	64 (57.7)	0 (0.0)	<0.001***	91.98 (1.50)	100.08(1.82)	0.001**	0.06
TMQ	74 (66.7)	0 (0.0)	<0.001***	87.30 (1.35)	95.98 (1.64)	<0.001***	0.09

Note. Proportions: values are presented as n (%) for children in the borderline or motor delay. Standard scores: values are presented as adjusted mean standard scores or quotients with standard errors (SE) for PDMS-2 scales. Group differences in proportions were examined using chi-square tests. Group differences in T-scores were examined using MANCOVA, controlling for sex, age, parental occupation, autistic traits, and cognitive level. GMQ: gross motor quotient. FMQ: fine motor quotient. TMQ: total motor quotient. The overall MANCOVA model: Wilks' Lambda = 0.872, F(8, 154) = 2.820, p=0.006, partial $\eta^2 = 0.128$. *p < .05, **p < .01, ***p < .001.

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Table 6 Comparison of motor development between ASD and non-ASD groups (< 3 y)

Motor development	Proportions, n (%)			Standard Scores, mean (SE)			
	ASD (n=34)	non-ASD (n=35)	*P* value	ASD (n=34)	non-ASD (n=35)	*P* value	partial η^2
Stationary	2 (5.9)	0 (0.0)	0.145	9.2 (0.3)	9.6 (0.3)	0.384	0.01
Locomotion	23 (67.6)	1 (2.9)	<0.001***	7.7 (0.4)	9.1 (0.4)	0.036*	0.07
Object Manipulation	25(73.5)	1 (2.9)	<0.001***	7.0 (0.4)	9.6 (0.4)	<0.001***	0.20
Grasping	3 (8.8)	0 (0.0)	0.072	9.4 (0.3)	9.6 (0.2)	0.608	0.00
				Quotients, mean (SE)			
Visual-Motor Integration	20 (58.8)	1 (2.9)	<0.001***	8.3 (0.4)	9.4 (0.4)	0.073	0.05
GMQ	27 (79.4)	0 (0.0)	<0.001***	86.9 (1.8)	96.5 (1.6)	0.001**	0.16
FMQ	18 (52.9)	0 (0.0)	<0.001***	92.9 (1.6)	96.5 (1.4)	0.152	0.03
TMQ	25 (73.5)	0 (0.0)	<0.001***	88.2 (1.6)	96.3 (1.4)	0.001**	0.16

Note. Proportions: values are presented as n (%) for children in the borderline or motor delay. Standard scores: values are presented as adjusted mean standard scores or quotients with standard errors (SE) for PDMS-2 scales. Group differences in proportions were examined using chi-square tests. Group differences in T-scores were examined using MANCOVA, controlling for sex, autistic traits severity, and cognitive level. GMQ: gross motor quotient. FMQ: fine motor quotient. TMQ: total motor quotient. The overall MANCOVA model: Wilks' Lambda = 0.710, F(8, 55) = 2.802, p=0.011, partial $\eta^2 = 0.290$. *p < .05, **p < .01, ***p < .001.

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Table 7 Comparison of motor development between ASD and non-ASD groups (≥ 3 y)

Motor development	Proportions, n (%)			Standard Scores, mean (SE)			
	ASD (n=77)	non-ASD (n=37)	*P* value	ASD (n=77)	non-ASD (n=37)	*P* value	partial η^2
Stationary	37(48.1)	3 (8.1)	<0.001***	7.9 (0.3)	9.3 (0.4)	0.006**	0.08
Locomotion	43 (55.8)	1 (2.7)	<0.001***	8.1 (0.3)	9.2 (0.4)	0.049*	0.04
Object Manipulation	54 (70.1)	3 (8.1)	<0.001***	7.2 (0.3)	8.4 (0.4)	0.019*	0.06
Grasping	45 (58.4)	4 (10.8)	<0.001***	8.0 (0.4)	9.1 (0.5)	0.099	0.03
Visual-Motor Integration	33 (42.9)	0 (0.0)	<0.001***	10.4 (0.4)	11.2 (0.6)	0.263	0.01
					Quotients, mean (SE)		
GMQ	57 (74.0)	0 (0.0)	<0.001***	85.4 (1.4)	93.3 (2.1)	0.003**	0.09
FMQ	46 (59.7)	0 (0.0)	<0.001***	93.4 (2.0)	101.7 (2.9)	0.026*	0.05
TMQ	49 (63.6)	0 (0.0)	<0.001***	87.4 (1.7)	95.8 (2.4)	0.007**	0.08
MABC-2	ASD (n=45)	non-ASD (n=26)		ASD (n=45)	non-ASD (n=26)		
					Percentile, mean (SE)		
MDP	22 (48.9)	0 (0.0)	<0.001***	37.06 (5.58)	44.22 (7.38)	0.476	0.01
ACP	24 (53.3)	1 (3.8)	<0.001***	19.61 (4.86)	51.45 (6.42)	<0.001***	0.19
BP	12 (26.7)	0 (0.0)	0.004**	50.43 (5.35)	60.76 (7.07)	0.284	0.02
TP	20 (44.4)	0 (0.0)	<0.001***	34.47 (5.13)	54.59 (6.78)	0.032*	0.08

Note. Proportions: values are presented as n (%) for children in the borderline or motor delay. Standard scores: values are presented as adjusted mean standard scores, quotients with standard errors (SE) for PDMS-2 scales and percentile with standard errors (SE) for MABC-2. Group differences in proportions were examined using chi-square tests. Group differences in T-scores were examined using MANCOVA, controlling for sex, parental occupation, autistic traits, and cognitive level. GMQ: gross motor quotient. FMQ: fine motor quotient. TMQ: total motor quotient. The overall MANCOVA model (PDMS-2): Wilks' Lambda = 0.836, F(8, 88) = 2.151, p=0.039, partial $\eta^2 = 0.164$ (PDMS-2). The overall MANCOVA model (MABC-2): Wilks' Lambda = 0.794, F(4, 56) = 3.643, p=0.010, partial $\eta^2 = 0.206$. *$p < .05$, **$p < .01$, ***$p < .001$.

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Table 8 Association between behavioral problem and motor development (all cases)

Dependent variables	Independent variables	Children with ASD (N = 111)			non-ASD Children (N = 72)		
		R^2 (ΔR^2)	β (t)	*P* value	R^2 (ΔR^2)	B (SE)	*P* value
TMQ	Total Problems	0.54***(0.00)	0 (-0.2)	0.827	0.30*** (0.04)	-0.2 (-2.0)	0.05
	Internalizing Problems	0.58***(0.04**)	-0.3 (-3.1)	0.003**	0.30*** (0.04)	-0.2 (-0.9)	0.36
	Externalizing Problems		0.3 (3.0)	0.003**		-0.1 (-0.5)	0.62
GMQ	Total Problems	0.45*** (0.00)	0 (-0.3)	0.763	0.17* (0.05)	-0.2 (-2.0)	0.05
	Internalizing Problems	0.50*** (0.05**)	-0.3 (-3.0)	0.003**	0.16 (0.04)	-0.1 (-0.7)	0.51
	Externalizing Problems		0.3 (2.9)	0.005**		-0.1 (-0.7)	0.51
FMQ	Total Problems	0.56*** (0.00)	0 (-0.4)	0.674	0.54*** (0.00)	-0.1 (-1.0)	0.34
	Internalizing Problems	0.59*** (0.04*)	-0.3 (-3.0)	0.004**	0.55*** (0.01)	-0.1 (-0.6)	0.52
	Externalizing Problems		0.3 (2.7)	0.007**		-0.2 (-0.9)	0.86

Note. R^2 = coefficient of determination. ΔR^2 = change in R^2. Values are presented as standardized regression coefficients (β) with t-statistics in parentheses. All regression models were adjusted for age, sex, cognitive level, and parental occupation. GMQ: gross motor quotient. FMQ: fine motor quotient. TMQ: total motor quotient. *p < .05, **p < .01, ***p < .001.

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Table 9 Association between behavioral problem and motor development (< 3 y)

Dependent variables	Independent variables	Children with ASD (N = 34)			non-ASD Children (N = 35)		
		R^2 (ΔR^2)	β (t)	*P* value	R^2 (ΔR^2)	B (SE)	*P* value
TMQ	Total Problems	0.60*** (0.03)	-0.2 (-1.6)	0.114	0.15 (0.10)	-0.3 (-1.9)	0.062
	Internalizing Problems		-0.3 (-1.5)	0.144		-0.6 (-2.6)	0.014*
	Externalizing Problems	0.61*** (0.04)	0.1 (0.4)	0.701	0.25* (0.21*)	0.3 (1.1)	0.267
GMQ	Total Problems	0.57*** (0.05)	-0.3 (-1.8)	0.060	0.17 (0.03)	-0.2 (-1.1)	0.271
	Internalizing Problems		-0.3 (-1.3)	0.222		-0.5 (-1.7)	0.099
	Externalizing Problems	0.57*** (0.05)	0 (-0.02)	0.903	0.22 (0.09)	0.2 (0.9)	0.376
FMQ	Total Problems	0.54*** (0.02)	-0.2 (-1.3)	0.212	0.30 (0.02)	-0.1 (-0.9)	0.395
	Internalizing Problems		-0.5 (-2.3)	0.028*		-0.2 (-0.8)	0.411
	Externalizing Problems	0.55*** (0.07)	0.3 (1.5)	0.134	0.31 (0.03)	0 (0.1)	0.912

Note. R^2 = coefficient of determination. ΔR^2 = change in R^2. Values are presented as standardized regression coefficients (β) with t-statistics in parentheses. For the ASD group, all regression models were adjusted for cognitive level. For the non-ASD group, TMQ models were adjusted for age, GMQ models were adjusted for sex, and FMQ models were adjusted for age and cognitive level. GMQ: gross motor quotient. FMQ: fine motor quotient. TMQ: total motor quotient. *p < .05, **p < .01, ***p < .001.

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Table 10 Association between behavioral problem and motor development (≥ 3 y)

Dependent variables	Independent variables	Children with ASD (N = 77)			non-ASD Children (N = 37)		
		R^2 (ΔR^2)	β(t)	*P* value	R^2 (ΔR^2)	B (SE)	*P* value
TMQ	Total Problems	0.64*** (0.00)	0 (-0.6)	0.569	0.10 (0.03)	-0.2 (1.1)	0.299
	Internalizing Problems		-0.3 (-2.8)	0.006**		0.1 (0.5)	0.647
	Externalizing Problems	0.68*** (0.04*)	0.3 (2.3)	0.022*	0.19 (0.05)	-0.3 (-1.3)	0.220
GMQ	Total Problems	0.52*** (0.00)	0 (-0.4)	0.660	0.04	-0.2 (-1.1)	0.270
	Internalizing Problems		-0.4 (-3.0)	0.004**		0 (0.2)	0.837
	Externalizing Problems	0.57*** (0.06*)	0.3 (2.6)	0.012*	0.04	-0.2 (-1.0)	0.344
FMQ	Total Problems	0.64 (0.00)	-0.1 (-0.9)	0.373	0.29** (0.01)	-0.1 (-0.8)	0.453
	Internalizing Problems		-0.3 (-2.4)	0.021*		0.1 (0.4)	0.679
	Externalizing Problems	0.66 (0.03)	0.2 (1.7)	0.103	0.31* (0.03)	-0.2 (-1.1)	0.279
TP	Total Problems	0.38*** (0.01)	0.1 (0.6)	0.558	0.02	-0.2 (-0.8)	0.565
	Internalizing Problems		0.1 (0.6)	0.561		-0.4 (-1.5)	0.182
	Externalizing Problems	0.38*** (0.01)	-0.1 (-0.4)	0.693	0.11	0.1 (0.3)	0.752

Note. R^2 = coefficient of determination. ΔR^2 = change in R^2. Values are presented as standardized regression coefficients (β) with t-statistics in parentheses. For the ASD group, TMQ models were adjusted for sex, age, cognition level, and parental occupation; GMQ models were adjusted for sex, age, cognition level, and parental occupation; FMQ models were adjusted for age, cognition level, and parental occupation; TP models were adjusted for age and cognition level. For the non-ASD group, TMQ models were adjusted for age and parental occupation; GMQ and TP models were unadjusted; and FMQ models were adjusted for age and parental occupation. GMQ: gross motor quotient. FMQ: fine motor quotient. TMQ: total motor quotient. TP: total percentile. *p < .05, **p < .01, ***p < .001

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