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REVIEW

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Exploring 24-h movement behaviors in preschool children with developmental disabilities: a scoping review

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Abstract

Introduction Understanding how 24-h movement behaviors (i.e., physical activity, sedentary behavior, sleep) differ among children with developmental disabilities (e.g., delays, disorders, disabilities) is crucial, with evidence indicating that variations seen in older children may begin to emerge in early childhood. However, reviews have not acknowledged such developmental considerations in young participants. Therefore, a scoping review of the growing body of research focused on preschool-aged children is essential for gaining deeper insights into how these behaviors evolve and differ during this critical period.

Purpose This scoping review aimed to (1) identify 24-h movement behavior levels in preschool-aged children with developmental disabilities, (2) determine whether 24-h movement behaviors differed between children with and without developmental disabilities, and (3) determine if 24-h movement behaviors varied by the domain of developmental difference.

Methods We conducted a systematic search in nine databases. Inclusion criteria were: (1) children between 33 and 72 months, (2) inclusion of children with developmental disabilities in the sample, (3) measures of at least two movement behaviors, (4) written in English, and (5) empirical, original research designs. The date of publication was unrestrained. Title/abstract and full text screening were completed by two independent reviewers. The date of publication was unrestrained.

Results Twenty predominantly cross-sectional articles published between 2004 and 2024 were included. Studies examined movement behaviors across various developmental domains such as autism spectrum disorder, cerebral palsy, and developmental coordination disorder. Findings on sleep, sedentary behavior, and physical activity were mixed, with some studies reporting significant group differences while others found no or inconsistent group differences.

Conclusion This review highlights the variability and gaps in current research on movement behaviors among children with developmental disabilities, underscoring the need for more comprehensive and consistent measurements that consider all 24-h movement behaviors to better inform targeted interventions.

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Keywords Physical activity, Sedentary behavior, Sleep, Disability, Early childhood

Introduction

Early childhood (i.e., under 6 years of age) represents an important developmental window characterized by rapid growth and neuroplasticity, during which foundational health behaviors, cognitive capacities, and socio-emotional skills are established, shaping trajectories for long-term health and well-being [1–3]. Given that early childhood is a pivotal period for establishing lifelong patterns, fostering physical activity, ensuring sufficient sleep, and minimizing sedentary behaviors during these years is essential, as habits formed in this stage tend to track into adolescence and adulthood [4, 5]. In recent research across the lifespan, there has been a transition from investigating the health benefits of individual behaviors in isolation toward adopting an integrative perspective that considers the entire 24-h day [6]. For example, the emerging discipline of time-use epidemiology has introduced the Framework for Viable Integrative Research in Time-Use Epidemiology (VIRTUE framework) as a conceptual guide to facilitate the study of the compositional characteristics of 24-h movement behaviors (i.e., sedentary behavior, physical activity, and sleep), their determinants, associated health outcomes, and potential interventions to inform public health strategies [7].

In support of this 24-h framework, the World Health Organization (WHO) published comprehensive movement guidelines in 2019 for children under five years of age, offering distinct recommendations specifically tailored for infants, toddlers, and preschool-aged children [8]. These guidelines seek to provide a basis for promoting long-term health and well-being by encouraging balanced levels of physical activity, adequate sleep duration, and reduced sedentary behavior within the daily routines of young children. However, a recent review highlighted the alarmingly low adherence to 24-h movement guidelines among preschool-aged children globally [9]. This meta-analysis of 387,437 children from 23 countries determined that only 11.3% of preschool-aged children met the 24-h movement guidelines, while 8.8% did not meet any of the guidelines. Although adherence to guidelines was greater among preschool children compared to preadolescents and adolescents, it remained low overall. Given the increasing recognition of developmental disabilities among children and adolescents [10], it is important that reports on guideline compliance account for these variations to ensure accurate assessment and meaningful comparisons across age groups. Notably, the above meta-analysis did not report on subgroups of children with and without developmental disabilities, limiting the ability to understand how guideline adherence may vary across diverse child populations.

In the present article, developmental disabilities are used to refer to a broad range of diagnosed or suspected developmental disabilities and delays that affect one or more developmental domains during early childhood. Under the US Developmental Disabilities Assistance and Bill of Rights Act of 2000, a developmental disability is a chronic disability due to a mental and/or physical impairment, evident before age 22, that is likely to continue indefinitely, creating limitations across major life domains and requiring ongoing, individualized support services [11]. Examples could include attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), cerebral palsy, and intellectual and learning disabilities. Under the US Individuals with Disabilities Education Act IDEA, developmental delay refers to a state-defined delay in one or more areas of development: physical, cognitive, communication, or and/or social-emotional [12]. National surveillance data indicate that developmental disabilities among US children ages 2 to 17 years have increased over time, rising from 16.2% in 2009–2022 to 17.8% in 2015–2017, with notable increases in ADHD, ASD, and intellectual disabilities [10]. These trends likely reflect improved awareness, earlier identification, and increased access to healthcare and developmental services. Given that developmental disabilities often emerge during the preschool years, it is critical that research and surveillance efforts account for these variations to ensure accurate characterization of developmental needs and inform equitable early childhood intervention strategies.

Children with developmental disabilities may exhibit varying patterns or levels of sleep, physical activity, and sedentary behavior relative to typically developing children. Evidence of such differences has been documented among older children and adolescents and has generally indicated that youth with developmental disabilities are less likely to meet individual [13–18] or comprehensive 24-h movement behavior recommendations [19–21]. Broadly, children and adolescents with neurodevelopmental disorders (e.g., ASD, ADHD, and cerebral palsy) are less likely to meet 24-h movement behavior guidelines, and better adherence to these guidelines has been linked to fewer cognitive and social difficulties [19–21]. For example, systematic reviews have reported that children with autism spectrum disorder (ASD) generally have lower physical activity levels [13] and sleep time [17] than their typically developing peers, with the difference between groups widening with age. Although reviews have begun to highlight the importance of early childhood in promoting 24-h movement behaviors [9, 22, 23], thus far, they have not addressed the developmental makeup of the included participants.

Although research on sleep and developmental outcomes in preschool-aged children (i.e., ages 3 to 5) has grown steadily over multiple decades, there has also been a recent expansion of studies addressing additional movement behaviors. Despite this progress, knowledge regarding 24-h behavioral patterns collectively among preschool children with developmental disabilities remains limited. Consequently, a comprehensive review is warranted to synthesize the existing evidence and enhance understanding of 24-h movement behaviors within the context of developmental disabilities. Therefore, we conducted a scoping review to identify levels of 24-h movement behaviors in preschool-aged children with developmental disabilities. Additionally, our supplemental aims were to determine whether 24-h movement behaviors (1) differed between children with and without developmental disabilities, and (2) varied by the domain of difference or developmental diagnosis.

Methods

Protocol and registration

We pre-registered the protocol for this scoping review with the Open Science Framework [24]. The protocol design and the reporting of this review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Review (PRISMA-ScR) Checklist (Additional File 1) [25].

Eligibility criteria

Criteria for eligible studies were developed with the Patient/Population, Intervention, Comparison, and Outcome (PICO) categories [26]. The literature search was originally conducted as part of a broader review to (1) identify 24-h movement behavior patterns in preschool-aged children with developmental disabilities and (2) to examine the associations and effects of sedentary behavior and physical activity on their health outcomes. Thus, the full search sought studies in early childhood that included at least one 24-h movement behavior. However, for this review focusing on the first aim, a more restrictive eligibility criteria were applied with at least two movement behaviors required. Below, both the full search strategy and the refined criteria used for the present review are detailed to clarify the scope and selection process.

Participants

Studies were included if the participants were between 33 and 72 months old. If samples comprised older children, we only included articles that stratified their results by preschool age. Additionally, the samples must have included children with developmental disabilities. Examples of how we anticipated authors would describe developmental disabilities included a diagnosis of developmental disability, being enrolled in (or eligible for) early intervention, special education services, or being described as having delay(s) in developmental milestones.

Exposure

Articles were eligible for inclusion if, in the full search, they addressed 24-h movement behaviors (i.e., sedentary behavior, physical activity, or sleep, including proxies of these behaviors) or examined potential correlates of these behaviors (e.g., socioeconomic status, gender, home environment). Studies evaluating interventions aimed at promoting one or more 24-h movement behaviors, with outcomes measured in terms of either 24-h movement behaviors or related health indicators, were also included in the initial search. No restrictions were placed on the methods used to assess 24-h movement behaviors (e.g., assessments could be device-based or proxy-reported). For the present review, as the aim was to synthesize research contributing to a 24-h lens, articles needed to report on at least two movement behavior levels (e.g., percent of time spent in behaviors or meeting the recommended guidelines), and therefore, the inclusion of correlates was not required.

Comparison

For observational studies reporting prevalence estimates of one or more movement behaviors, the presence of a comparison group was not required for inclusion. In intervention studies, comparison groups could consist of alternative 24-h movement behavior interventions or programs (e.g., comparisons between two distinct interventions), non-behavioral conditions serving as attention-matched control groups, standard care or practice, or other related forms of control groups. Consistent with the exposure criteria, no restrictions were imposed on the methods used to assess 24-h movement behaviors.

Outcomes

In the full search, studies investigating associations between any 24-h movement behaviors and health outcomes or examining the effects of these behaviors on health outcomes were categorized into one of the following domains: physical health (e.g., overweight/obesity, diabetes risk, fitness, motor skills), psychosocial health (e.g., psychological distress, flourishing, well-being), and brain or cognitive health (e.g., executive function, memory, grey matter volume, cortical thickness). For the present review, studies reporting only prevalence or levels of 24-h movement behaviors with no outcomes were included.

Other inclusion considerations

Additional inclusion criteria required studies to be empirical original research published in peer-reviewed journals and written in English, with no restrictions on publication date. Grey literature, such as non-peer-reviewed preprints, online registries, and conference abstracts, was excluded. Eligible study designs encompassed analytical observational approaches (e.g., cross-sectional and longitudinal studies) as well as experimental designs, including quasi-experimental, within-subjects/crossover, and intervention studies. Case studies and case series were not included. For the present review, intervention studies were only included if baseline prevalence data for the 24-h movement behaviors were presented.

Search and information sources

The search strategy was developed by a librarian serving on behalf of the University of Massachusetts Amherst Libraries' Evidence Synthesis Partnership (ET). The broad scope of inquiry for this review was translated into a database search strategy by separating it into four conceptual elements: 24-h movement behaviors, including physical activity, sleep, sedentary behavior, and screen time (concept 1); preschool-aged children (concept 2); developmental delays, disorders, and disabilities (concept 3); and early childhood intervention (concept 4). After controlled vocabulary and free-text terminology were extensively researched for each of these concepts, they were combined in the initial search strategy for PubMed. A series of systematic reviews conducted to inform the development of the Canadian 24-h movement guidelines was consulted to check that the included terms for each concept were complete, but no published search filters were used [27–29].

The search strategy concepts were combined in two ways. The first combination retrieved articles that matched at least one of the search terms representing each of the 24-h movement behaviors (concept 1), preschool-aged children (concept 2), and developmental delays (concept 3). The second component utilized the early childhood intervention concept as a loose proxy for the preschool-aged children and developmental delays concepts and retrieved records matching the movement behaviors set of terms (concept 1) and the early childhood intervention set of terms (concept 4). References matching either component were retrieved.

A list of eight PubMed-indexed references already known to be relevant, and expected to be retrieved by the PubMed search, was compiled by the team's subject matter experts. PubMed identifiers (PMIDs) for all eight references were used to create a validation set. The validation set was searched against (i.e., ANDed with) the search strategy at different stages of its development to gauge its ability to identify relevant references (sensitivity). If a reference in the validation set was not retrieved, the search strategy was modified to better capture the concepts represented by the missing reference.

Once the terminology and subject headings for each concept had reached a point of saturation and the validation references were all retrieved, the final draft search strategy was presented in detail to the review team to elicit revisions. After the meeting, time was provided for additional commentary from subject matter experts. Revisions were incorporated by the librarian while maintaining optimal tradeoffs between the search strategy's sensitivity and precision. The subject matter expert-revised version of the search strategy was then searched against the validation set to ensure all validation references were still retrieved. Next, a Peer Review of Electronic Search Strategies (PRESS review) was completed by another evidence synthesis librarian (AR). The review resulted in suggested revisions only to PRESS element 2: Boolean and proximity operators regarding the two-component search structure, which were resolved through further discussion with the reviewer and justification of the approach. Validation checks were performed once more before translating the search for all databases, exporting references, and uploading to Covidence, where duplicates were removed automatically (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org).

On November 20th, 2024, the search strategy was executed in PubMed (NCBI), Scopus, Web of Science Core (Web of Science), BIOSIS Citation Index (Web of Science), APA PsycInfo (EBSCOhost), APA PsycArticles (EBSCOhost), SportDiscus (EBSCOhost), CINAHL (EBSCOhost) (Additional File 2). The search strategy was executed on the October Edition of CENTRAL (Wiley Cochrane Library) on November 22nd, 2024. Where available, publication type filters were applied to remove review articles, case reports, and non-empirical articles (e.g., commentaries, letters, etc.), as these would not meet the inclusion criteria. All non-English articles were excluded from the database search results prior to exporting because they could not be read by members of the team. No publication date limiters were applied. Supplemental citation searching was completed by reviewing the cited references of included studies. Authors of included studies were not contacted for the purpose of retrieving additional data. For complete search strategy documentation, please refer to the OSF project files (https://osf.io/r3n8u/files).

Selection of sources of evidence

This review consisted of two screening phases, both conducted in the Covidence program. The initial screening phase began by filtering articles based on their titles and abstracts. Articles that did not meet the inclusion criteria were excluded. Articles that possibly met the inclusion criteria were moved forward to full-text screening. Each article was screened by two independent reviewers, and any discrepancies were reviewed and resolved by one of the primary investigators. During the full text screening, the first reason for exclusion was selected in Covidence for any exclusion decisions. Similar to title and abstract screening, two individual researchers screened the same article, and disagreements were resolved by a primary investigator during full-text screening. One reviewer completed the supplemental screening of the reference list articles, which was cross-checked by a second reviewer.

Data charting and synthesis

We extracted and charted data into summary tables that included the following entities: author(s), year of publication, country of data collection, study design, aims/purpose, population(s) and sample size(s), developmental descriptions and domains, setting, sex and/or gender, intervention (type, duration, description) or 24-h movement behavior exposure(s) (measurements, timing, variables), and results (levels of sedentary, physical activity, and sleep behaviors, summary of evidence) and supplemental information (challenges, barriers, or considerations, funding sources, conflicts of interest, data availability). Prevalence statistics were summarized for 24-h behaviors and stratified by behavior, measure (e.g., percent time in a behavior, or proportion of sample meeting a behavior recommendation), and type of developmental delay domain (if available or applicable).

Results

Characteristics of included articles

Our initial full database search resulted in 19,598 articles. Three additional articles were identified from searching the reference lists of included articles (Fig. 1). After 7,419 duplicates were removed and ineligible articles were excluded (11,297 during title and abstract screening and 652 more during full text screening), 233 articles were further screened for inclusion in the present review (i.e., had two or more movement behaviors with prevalence estimates). Twenty articles were included from the initial search [30–49].

The articles included in the review were published between 2004 and 2024, with sample sizes ranging from 19 to 4936 participants (Table 1). Although each article reported on individual studies, several studies did not identify cohort or data source information, and a potential overlap of participants across studies reviewed cannot be ruled out. All studies employed cross-sectional designs, while two also incorporated longitudinal analyses. Most studies were conducted in Australia (n = 8), with others from the USA (n = 4), Canada (n = 3), China (n = 1), India (n = 1), Japan (n = 1), Singapore (n = 1), and Taiwan (n = 1). Regarding developmental difference domains, the most frequently studied group was children with autism spectrum disorder (ASD; n = 9), followed by those with cerebral palsy (n = 6), developmental coordination disorder (n = 3), unspecified developmental delay (n = 3), ADHD (n = 1), at-risk for conduct problems (n = 1), and speech or language delay (n = 1). Eleven studies included a typically developing or comparison group (i.e., typically developing children or children without the developmental difference being studied). Only one study addressed all three movement behavior categories (physical activity, sedentary behavior, and sleep), while most focused on physical activity and sedentary behavior (n = 15). Three studies examined sedentary behavior and sleep, and one study included physical activity and sleep. Only one study used analytical methods that accounted for the co-dependency of 24-h behaviors (i.e., compositional data analysis) [41].

Sleep

Sleep study characteristics

Five articles published between 2004 and 2023, all utilizing cross-sectional designs, included sleep measures in their studies (Table 2) [30, 32, 34, 38, 42]. Sleep metrics were assessed using daily logs in two studies, the Children's Sleep Habits Questionnaire (CSHQ) in another, and a combination of wearable devices and sleep logs in two studies. The developmental domains examined encompassed ASD (n = 4), children at risk for conduct problems (n = 1), speech or language delay (n = 1), and unspecified developmental delay (n = 2). Two of the articles included typically developing children as part of their samples. While one article solely reported sleep metrics [42], the remaining four studies conducted analyses to assess disabilities in sleep metrics between comparison groups [30, 32, 34, 38].

Comparisons by sleep metric

Among the four studies that included comparative analyses, two reported statistically significant differences across all measured sleep parameters (i.e., sleep duration and restful time) [30, 32], one found no differences [38], and one presented mixed results [34]. Measures of sleep quality varied. Lin et al. [38] found no differences in sleep quality metrics such as sleep efficiency and sleep problems as measured by the CSHQ, whereas Tatsumi et al. [34] observed that autistic children exhibited lower sleep efficiency (percentage of time in bed spent asleep) compared to children without ASD. Similarly, findings for time-based sleep metrics were inconsistent. The CSHQ-measured sleep metrics revealed no differences between autistic children, children with speech and language delays, and children with 'other delays' [38]. However,

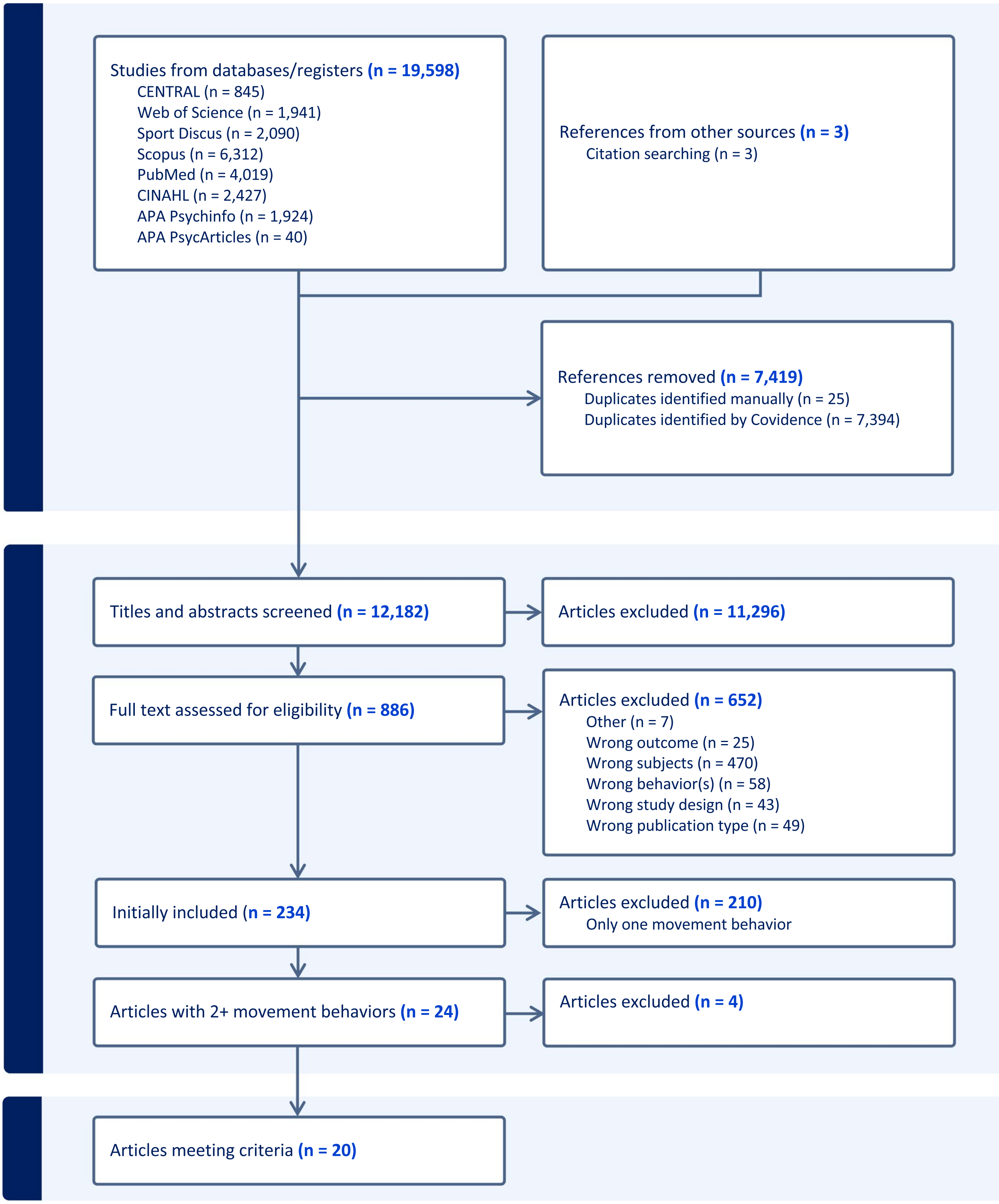

Fig. 1 PRISMA flow diagram

Table 1 Summary of the characteristics in the included articles (n = 20)

Study information				**Sample size**		**Sex/gender**	**Category**
Article	**Country**	**Study design**	**Population(s)**	**Full**	**Subsample(s)**		
Alder 2023	USA	Cross-sectional	Children (2 to 8 years) with ASD (no suspected sleep disorders)	27	N/A	25% female	All
Brown 2021	Canada	Cross-sectional	Children (4 to 5 years) at risk of DCD and TP	589	TD = 301 rDCD = 288	TD = 48.2% boys rDCD = 67.0% boys	SB & PA
Bulten 2020	Canada	Cross-sectional	Children (4 to 5 years) at risk of DCD and TP	507	TD = 274 rDCD = 233	TD = 52.2% girls rDCD = 32.6%	SB & PA
Curzon 2024	USA	Cross-sectional	Children (4 to 7 years) with ADHD & TD	223	ADHD = 127 TD = 96	ADHD = 72.3–7% male TD = 50 to 81.8% male	SB & PA
Keawutan 2017	Australia	Cross-sectional	Children (4 and 5 years) with CP	67	N/A	35.8% females	SB & PA
Keawutan 2017	Australia	Cross-sectional Longitudinal	Children (4 and 5 years) with and without CP (at various functional capacity levels)	Age 4: 63 Age 5: 98	Age 4: GMFCS I–II = 16 GMFCS III–V = 10 TD = 37 Age 5: GMFCS I–II = 42 GMFCS III–V = 18 TD = 38	33% female	SB & PA
Keawutan 2018	Australia	Cross-sectional	Children (4 to 5 years) with CP	67	N/A	Not reported	SB & PA
Ketcheson 2018	USA	Cross-sectional	Children (2 to 5 years) with ASD	53	ASD = 34 TD = 19	ASD = 26.5% female TD = 42.1% female	SB & PA
King-Dowling 2019	Canada	Cross-sectional	Children (4 to 5 years) with rDCD, pDCD, and TD	514	pDCD = 87 rDCD = 149 TD = 278	TD = 48.2% male pDCD = 72.1% male rDCD = 63.8% male	SB & PA
Lin 2019	Singapore	Cross-sectional	Children (2 to 5 years) with NDDs	367	ASD = 39.5% SLD = 36.8% Others = 23.7%	Total = 25.6% female ASD = 20% female SLD = 29.6% female Other DDel = 28.7% female	SLP & SB
Oftedal 2015	Australia	Cross-sectional	Children (2.4 ± 0.5 years) with and without CP (at various functional capacity levels)	78	TD = 20 GMFCS I–II = 32 GMFCS III = 14 GMFCS IV–V = 12	84.5% female	SB & PA
Oftedal 2016	Australia	Cross-sectional Longitudinal	Children born between 2006 and 2009 with CP	175	48 mo = 100 60 mo = 147	48 months = 64% boys 60 months = 61% boys	SB & PA
Oftedal 2017	Australia	Cross-sectional	Children with CP	161	48 months = 82 60 months = 127	61% males	SB & PA
Schenkelberg 2021	USA	Cross-sectional	Preschool students (4.76 ± 0.07 years) with DDel	19	ASD = 15 DDel = 2 DS = 2	68.4% male	SB & PA
Sung 2021	Taiwan	Cross-sectional	Children (48 to 72 months) with and without ASD	53	ASD = 25 TD = 28	ASD = 16.0% female TD = 46.4% female	SB & PA
Tatsumi 2015	Japan	Cross-sectional	Children (48 to 83 months) with and without ASD	47	ASD = 31 No ASD = 16	Control: 62.5% male ASD: 80.6% male	SLP & PA
Thomas 2022	Australia	Cross-sectional	Children (4 to 7 years) with and without ASD	34	ASD = 17 No ASD = 17	ASD = 76.5% male TD = 47.1% male	SB & PA
Venkatesan 2004	India	Cross-sectional	Preschool children with DDel or ASD	140	ASD = 51 DD = 89	Not reported	SLP & SB
Wang 2012	China	Cross-sectional	Children (3 to 6 years) with and without ASD	77	ASD = 41 TD = 36	ASD = 29.3% female TD = 41.7% female	SB & PA
Yu 2012	Australia	Cross-sectional	Children (4 to 5 years) rCoP and not at risk (TD)	4,936	rCoP = 1371 Not rCop = 3565	Full sample = 49% girls rCoP = 44% girls TD = 51% girls	SLP & PA

Key: *ADHD* attention deficit hyperactivity disorder, *CP* cerebral palsy, *DDel* developmental delay or disability, *DS* down syndrome, *GMFCS* Gross Motor Function Classification System, *MC* motor coordination, *MD* motor delay, *NDD* neurodevelopmental disorder, *pDCD* probable developmental coordination disorder, *PA* physical activity, *rCoP* at risk for conduct problem, *rDCD* at risk for developmental coordination disorder, *SB* sedentary behavior, *SLD* speech language disorders, *SLP* sleep, *TD* typical development or typically developing

Table 2 Summary of findings in studies that reported levels of sleep metrics

Article	Measure(s)	Period	Timing	Variable(s)	Difference(s)
Alder 2023	ActiGraph wGT3X-BT (wrist); Sleep diary	5 nights	Once	SE%: 75.2 (6.88) SOL min: 33.85 (28.07) TST min: 475.31 (41.69) WASO min: 125.99 (42.32)	Not analyzed
Lin 2019	CSHQ	N/A	N/A	Total sleep duration (h): ASD = 11.22 (1.16) SL = 11.48 (0.96) Others = 11.32 (1.0 Night sleep duration (h): ASD = 9.55 (0.87) SL = 9.66 (0.74) Others = 9.61 (0.82) Proportion of sleep < 10%: ASD = 14 (11.8%) SL = 8 (7.3%) Others = 7 (10.6%) Total Sleep Problems Score: ASD = 45.90 (6.06) SL = 45.8 (7.21) Others = 46.24 (6.9) Rates of Clinically Elevated Sleep Problems: ASD = 106 (79.1%) SL = 81 (64.3%) Others = 63 (73.3%)	No group differences in sleep
Tatsumi 2015	Actiwatch 2 (non-dominant writs); Daily diary	7 days	Once	Sleep percentage: No ASD = 92.5 ASD = 88.0 Sleep start time (pm): No ASD = 9:36 ASD = 10:02 Sleep end time (am): No ASD = 6:48 ASD = 7:06 Total sleep duration (min): No ASD = 523.5 ASD = 485.0 Snooze duration (min): No ASD = 8.0 ASD = 10.0 Poor sleepers (%): No ASD = 12.5 ASD = 51.7	ASD less sleep % and greater proportion were rated as "poor sleepers" than TD
Venkatesan 2005	Daily activity log	One typical day	Once	Sleep time (h): DDel = 9.62 (1.18) ASD = 9.94 (1.3)	DDel had greater sleep duration than ASD
Yu 2012	Time use diaries	1 weekday, 1 weekend day	Once	Weekday restful time (h/day): rCoP = 10.91 Not rCoP = 11.06 Weekend restful time (h/day): rCoP = 11.07 Not rCoP = 11.11	Children with rCoP had less sleep/rest than TD

Key: CATCH = *ASD* autism spectrum disorder, *CSHQ* child sleep habits questionnaire, *DDel* developmental disability or delay, *rCoP* at risk for behavioral conduct problems, *SE* sleep efficiency, *SL* speech/language disorders, *SOL* sleep onset latency, *TD* typical development or typically developing, *TST* total sleep time, *WASO* wake after sleep onset

Venkatesan et al. [32] reported differences between subgroups of developmental disabilities (i.e., autistic children slept longer than children with other developmental delays), and Yu et al. [30] found that children at risk for behavioral conduct problems had less restful time than typically developing children.

Sedentary behavior

Sedentary behavior study characteristics

Eighteen articles published between 2004 and 2024 examined measures of sedentary behavior, all employing cross-sectional designs, with two additionally incorporating longitudinal data collection (Table 3) [31–33, 35–49]. Sedentary behavior was assessed using various methods, including wearable devices in four studies (n = 4), surveys (n = 1), direct observation (n = 1), and a combination of wearable devices and daily logs (n = 11). Two studies focused on measures of screen time [32, 38], whereas the remaining reported time spent sedentary (in metrics of time or proportion of the waking day). The studies focused on a range of developmental domains, such as ASD (n = 8), cerebral palsy (n = 6), developmental coordination disorder presence or risk (n = 3), general developmental delay (n = 3), ADHD (n = 1), and speech or language delay (n = 1). Of these, two studies provided descriptive information on sedentary behavior within their samples [39, 42], while the remaining sixteen conducted analytic comparisons between participant groups.

Comparisons by sedentary behavior metric

Among the thirteen studies that included comparative analyses, two reported statistically significant differences measured sedentary behavior metrics between typically developing children and those with developmental differences [35, 40], and four reported differences between subgroups of children with developmental disabilities [44–46, 49]. Six reported no differences between typically developing children (or children without the developmental difference of focus) and those with developmental disabilities [20, 31, 33, 37, 47, 48]. The two studies that measured screen time explored differences between children with different developmental disabilities. Venkatesan et al. [32] observed group differences (i.e., autistic children had more screen time than children with 'other' developmental delays), but Lin et al. [38] did not observe any differences between autistic children, those with speech and language delays, or children with 'other' delays.

Physical activity

Physical activity study characteristics

Eighteen articles published between 2012 and 2024 reported on physical activity using primarily cross-sectional designs (n = 18), with two studies also incorporating longitudinal data (Table 4) [30, 31, 33–37, 39–49]. Physical activity was assessed through various methods, including wearable devices (n = 5), surveys (n = 1), direct observation (n = 1), and a combination of wearable devices and daily logs (n = 12). The studies covered a range of developmental domains, including ASD (n = 7), cerebral palsy (n = 6), presence or risk of developmental coordination disorder (n = 3), children at risk for conduct problems (n = 1), ADHD (n = 1), and general developmental delay (n = 1). The most commonly studied physical activity variables across the reviewed studies were light physical activity, moderate-to-vigorous physical activity (MVPA), and total physical activity. Overall, four studies provided descriptive information on physical activity levels, while fourteen also conducted analytic comparisons between participant groups.

Comparisons by physical activity metric

Among the fourteen studies that included comparative analyses, six reported at least some statistically significant differences across all measured physical activity variables between children with and without developmental disabilities [31, 34, 35, 37, 40, 47], and four reported differences between subgroups of children with developmental disabilities [37, 44–46]. Three studies exploring physical activity levels between children with and without developmental differences observed no statistically significant differences [20, 33, 48]. Regarding MVPA, five studies reported group differences in MVPA levels (measured as percent time per day, daily duration, or meeting guidelines) within their samples [31, 35, 40, 43, 47], while three studies found no differences [30, 33, 41]. King-Dowling et al. [47] identified differences when MVPA was parameterized by bout frequency or duration. Among studies examining light physical activity, three observed group differences [31, 35, 40], whereas two did not [41, 47]. For total physical activity, defined as counts per minute or the combined proportion of light activity plus MVPA, five studies reported group differences [34, 43–46], but two studies found no differences [47, 48]. No group differences were reported in steps and energy expenditure [43] or the number of days meeting activity guidelines [37]. In one study that examined exercise, walking, and bike riding, some group differences were noted [30].

Twenty-four movement behavior levels

Substantial heterogeneity in assessment methods, variables, and measurement units across studies produced wide variability in reported 24-hour movement behaviors, making it difficult to identify reliable patterns or trends. Because several developmental-difference groups were represented by only one study each, a quantitative synthesis was not feasible. A descriptive summary of the mean values for variables most consistently reported

Table 3 Summary of findings in studies that reported levels of sedentary behavior

Article	Measure(s)	Period	Timing	Variable(s)	Difference(s)
Alder 2023	ActiGraph wGT3X-BT (wrist); Daily diary	5 days	Once	Sedentary time not reported (but used in MVPA calculation)	Not analyzed
Brown 2021	ActiGraph GT3X + (right hip); Daily diary	7 days	Once	Absolute SB (min/day): TD = 451.69 (44.30) rDCD = 450.78 (46.90) Compositional SB (min/day): TD = 62.47 (5.3) rDCD = 62.19 (5.02)	No differences between TD and rDCD
Bulten 2020	ActiGraph GT3X (hip) + diary	7 days	Once	Sedentary (h/day): TD = 7.54 (0.74) rDCD = 7.51 (0.79)	No differences between TD & rDCD
Curzon 2024	Respironics Actical (waist)	7 days	Once	Sedentary (%): ADHD: 70.26 (5.33) % TD: 69.22 (3.92) %	Not analyzed
Keawutan 2017	ActiGraph GT3X and GT3X + (lower back)	3 days	Once	Sedentary (%): GMFCS levels I–II: 57.6 (8.5) GMFCS level III: 73.6 (12.7) GMFCS levels IV–V: 92.7 (6.4)	Marginally ambulant more sedentary than independent Non-ambulant more sedentary than both other groups
Keawutan 2017	ActiGraph GT3X and GT3X + (lower back); Daily diary	3 days	4 years & 5 years	Age 4 sedentary time (%): GMFCS I–II = 56.2 (9.8) GMFCS III–V = 82.4 (16.6) Age 5 sedentary time (%): GMFCS I–II = 57.7 (8.8) 7 GMFCS III–V = 85.2 (13.4)	Children classified at GMFCS levels I to II had lower sedentary time than those classified at GMFCS levels III to V at both time points
Keawutan 2018	ActiGraph GT3X and GT3X + (lower back); Daily diary	3 days	N/A	Sedentary time (%): GMFCS I = 56.1 (8.7) GMFCS II = 64.3 (6.6) GMFCS III = 72.9 (11.9) GMFCS IV = 85.4 (5.2) GMFCS V = 94.5 (5.4)	No differences between GMFCS I and II Sedentary time higher in GMFCS III–V than GMFCS I
Ketcheson 2018	ActiGraph GT3X + (hip); Daily diary	7 days	Once	SPA (%): ASD = 73.6 (5.96) TD = 80.8 (4.55)	Children with ASD spent less time per day in SPA than TD children
King-Dowling 2019	ActiGraph GT3X (hip); Daily diary	7 days	Once	Sedentary time (min): pDCD = 443.2 (44.2) rDCD = 545.6 (50.6) TD = 452.8 (44.3)	No differences between groups
Lin 2019	Parent questionnaire	N/A	Once	Total Screen Use (hr): ASD = 3.97 (2.34) SL = 3.86 (2.55) Others = 4.16 (2.89)	No differences between groups

Table 3 (continued)

Article	Measure(s)	Period	Timing	Variable(s)	Difference(s)
Oftedal 2015	ActiGraph GT3X (lower back); Daily diary	3 days (2 weekdays, 1 weekend day)	Once	Sedentary (%): TD: 49 (5) GMFCS levels I–II = 52 (7) GMFCS level III = 62 (9) GMFCS levels IV–V = 74 (11)	No difference between TD and ambulatory children with CP Marginally ambulatory children with CP spent more time sedentary than these two groups Non-ambulatory CP group spent more time sedentary than all the other groups
Oftedal 2016	ActiGraph GT3M/GT3x; Daily log	2 weekdays and 1 weekend day	48 months and 60 months	Sedentary time (%): 48 months = 66 (18) 60 months = 66 (16)	Not analyzed
Oftedal 2017	ActiGraph GT3M/GT3x	2 weekdays and 1 weekend day	48 months and 60 months	Sedentary time (%): 48 months = 67 n 60 months = 66 (17)	Not analyzed
Schenkelberg 2021	OSRAC-DD	20-min sessions	8 sessions	Sedentary (% of intervals) = 77.7	Not analyzed
Sung 2021	ActiGraph wGT3X-BT (wrist)	24 h on a weekday	Once	SPA (%): ASD = 78.1 (11.5) TD = 61.4 (9.1)	ASD were more sedentary than TD
Thomas 2022	ActiGraph wGT3X + BT (hip)	8 days	Once	SB (min/day): ASD = 335.17 (95.57) TD = 378.38 (129.90)	No differences between groups
Venkatesan 2005	Daily activity log	One typical day	Once	Screen time (hours): DDel = 1.39 (1.77) ASD = 3.51 (2.90)	ASD greater screen time than DDel
Wang 2024	ActiGraph GT3x (hip)	7 days	Once	SPA (min/day): ASD = 439.70 (78.35) TD = 450.42 (53.67)	No differences between ASD and TD

Key: *ADHD* attention deficit hyperactivity disorder, *ASD* autism spectrum disorder, *CP* cerebral palsy, *DDel* developmental delay or disability, *GMFCS* Gross Motor Function Classification System, *MVPA* moderate to vigorous intensity physical activity, *OSRAC-DD* Observational System for Recording Activity in Children Developmental Disabilities version, *pDCD* probable developmental coordination disorder, *rDCD* at risk for developmental coordination disorder, *SB* sedentary behavior, *SL* speech/language disorders, *SPA* sedentary physical activity, *TD* typical development or typically developing

across studies is presented in Fig. 2. However, these summaries should be interpreted cautiously, given the small samples and inconsistent measurement approaches. Overall, the available evidence suggests that autistic children may obtain less sleep, engage in more sedentary behavior, and participate in less physical activity compared with typically developing peers. No consistent differences were suggested for children with other developmental disabilities based on the limited evidence available.

24-h movement behaviors by developmental domain

Autism spectrum disorder

Nine studies included autistic children in their samples and examined differences in sleep, sedentary behavior, and physical activity between subsamples of participants. When compared to children with other developmental delays, Lin et al. [38] found no differences in sleep or screen time between children with ASD and those with speech or language disorders or other delays, whereas Venkatesan et al. [32] reported shorter sleep duration in children with ASD relative to other developmental delay groups. Regarding sedentary behavior, Venkatesan et al. [32] observed greater screen time in autistic children compared to peers with 'other' developmental disabilities, while Wang et al. [31] found no group differences.

When autistic children were compared to typically developing children (or children without ASD), the findings were mixed across studies. Tatsumi et al. [34] reported that autistic children had lower sleep efficiency, and a higher proportion were rated as poor sleepers compared to children without ASD. Sedentary behavior results were inconsistent. Specifically, Ketcheson et al. [40] found autistic children were less sedentary than

Table 4 Summary of findings in studies that reported levels of physical activity

Article	Measure(s)	Period	Timing	Variable(s)	Difference(s)
Alder 2023	ActiGraph wGT3X-BT (wrist): Daily diary	5 days	Once	MVPA counts/day: 260.11 (6.88) MVPA %/day: 2.80 (1.60) Steps/day: 12,335.24 (2971.98)	Not analyzed
Brown 2021	ActiGraph GT3X + (right hip); Daily diary	7 days	Once	Absolute LPA (min/day): TD = 199.75 (28.38) rDCD = 202.1 (27.25) Absolute MVPA (min/day): TD = 71.97 (20.85) rDCD = 71.63 (18.38) Compositional LPA (min/day): TD = 27.61 (3.54) rDCD = 27.90 (3.26) Compositional MVPA (min/day): TD = 9.94 (2.78) rDCD = 9.90 (2.52)	No differences between RD and rDCD
Bulten 2020	ActiGraph GT3X (hip) + diary	7 days	Once	Total LPA + MVPA (h/day): TD = 4.53 (0.71) rDCD = 4.54 (0.69)	No differences between TD & rDCD
Curzon 2024	Respironics Actical (waist); Family Nutrition and Physical Activity (FNPA) survey	7 days; N/A	Once	ADHD EE (kcal/day): 281.74 (77.21) Steps: 9718.11 (3231.85) MVPA (%): 10.24 (2.88) FNPA: 2.65 (0.58 TD EE (kcal/day): 287.81 (39.20) Steps: 10,314.46 (2410.89) MVPA (%): 10.68 (1.99) FNPA: 3.01 (0.53)	Device-measured steps were higher in ADHD children Regression models to explore interaction of ADHD and sex to predict steps: Sex difference present in TD, but not ADHD children
Keawutan 2017	ActiGraph GT3X and GT3X + (lower back)	3 days	Once	Activity count (counts/min): GMFCS levels I–II: 1324.3 (365.2) GMFCS level III: 814.5 (445.4) GMFCS levels IV–V: 217.7 (184.1)	Independently ambulant were more active than marginally ambulant and non-ambulant Marginally ambulant were more active than non-ambulant
Keawutan 2017	ActiGraph GT3X and GT3X + (lower back); Daily diary	3 days	Relevant to this review: At 4 years & 5 years	HPA (counts/min) at Age 4: GMFCS levels I–II = 1345 (351) GMFCS levels III–V = 510 (494) HPA (counts/min) at Age 5: GMFCS levels I–II = 1319 (379) GMFCS levels III–V = 431 (431)	Children classified at GMFCS levels I to II had higher HPA those classified at GMFCS levels III to V at both time points
Keawutan 2018	ActiGraph GT3X and GT3X + (lower back); Daily diary	3 days	Once	Activity counts (counts/min): GMFCS I = 1388 (367) GMFCS II = 1017 (186) GMFCS III = 838 (422) GMFCS IV = 469 (172) GMFCS V = 154 (144)	Activity counts in children with CP classified as GMFCS II–V were significantly lower than GMFCS I

Table 4 (continued)

Article	Measure(s)	Period	Timing	Variable(s)	Difference(s)
Ketcheson 2018	ActiGraph GT3X + (hip); Daily diary	7 days	Once	LPA (%): ASD = 13.16 (2.17) TD = 10.11 (1.59) MPA (%): ASD = 9.56 (2.46) TD = 6.87 (2.08) MVPA (%): SD = 13.22 (4.52) TD = 9.00 (3.20) VPA (%): ASD = 3.66 (2.44) TD = 2.13 (1.16)	ASD group spent a greater time in in LPA, MPA, MVPA, and VPA than TD
King-Dowling 2019	ActiGraph GT3X (hip); Daily diary	7 days	Once	LPA (min/d): pDCD = 201.9 (28.4) rDCD = 202.2 (27.8) TD = 199.4 (28.5) MPA (min/d): pDCD = 40.0 (9.6) rDCD = 39.9 (8.7) TD = 39.7 (9.3) VPA (min/d): pDCD = 31.2 (10.8) rDCD = 31.5 (11.5) TD = 32.2 (12.2) MVPA (min/d): pDCD = 71.2 (19.4) rDCD = 71.4 (18.7) TD = 72.0 (20.5) Total PA (min/d): pDCD = 273.0 (40.6) rDCD = 273.5 (40.4) TD = 271.4 (42.7) MVPA bout freq. (#/day) pDCD = 712.5 (150.6) rDCD = 702.4 (147.1) TD = 705.8 (159.0) MVPA bout duration (s) pDCD = 5.94 (0.58) rDCD = 6.05 (0.67) TD = 6.06 (0.66)	pDCD accumulated their MVPA in slightly shorter bouts compared to TD
Oftedal 2015	ActiGraph GT3X (lower back); Daily diary	3 days (two weekdays, and one weekend day)	Once	# Days Meeting PA Recommendations (180 + min/d) (n) No days: TD = None GMFCS levels I–II = None GMFCS level III = 2 GMFCS levels IV–V = 7 1 day: TD = None GMFCS levels I–II = None GMFCS level III = 1 GMFCS levels IV–V = 1 2 days: TD = 3 GMFCS levels I–II = 6 GMFCS level III = 4 GMFCS levels IV–V = None 3 days: TD = 17 GMFCS levels I–II = 26 GMFCS level III = 7 GMFCS levels IV–V = 4	TD and GMFCS I–II were more likely to spend 180 min + in active play on all 3 d than GMFCS IV–V

Table 4 (continued)

Article	Measure(s)	Period	Timing	Variable(s)	Difference(s)
Oftedal 2016	ActiGraph GT3M/GT3x; Daily log	weekdays and 1 weekend day	48 months and 60 months	PA (counts/min): 48 months = 1024 (578) 60 months = 1105 (695)	Not analyzed
Oftedal 2017	ActiGraph GT3M/GT3x	weekdays and 1 weekend day	48 months and 60 months	PA (counts/min): 48 months = 1007 (583) 60 months = 1051 (580)	Not analyzed
Schenkelberg 2021	OSRAC-DD	20-min sessions	8 sessions	LPA (% of intervals) = 18.2 MVPA (% of intervals) = 4.0%	Not analyzed
Sung 2021	ActiGraph wGT3X-BT (wrist)	24 h on a weekday	Once	LPA (%): ASD = 13.7 (6.3) TD = 21.0 (4.5) MPA (%): ASD = 8.2 (5.7) TD = 16.0 (5.9) MVPA (%): ASD = 8.2 (5.7) TD = 17.6 (6.1) VPA (%): ASD = 0 TD = 1.6 (3.7)	LPA, MPA, and MVPA was higher in TD children
Tatsumi 2015	Actiwatch 2 (non-dominant writs); Daily diary	7 days	Once	Weekday am (counts/min): No ASD = 8.03.1 ASD = 758.3 Weekday afternoon (counts/min): No ASD = 740.0 ASD = 649.3 Weekday pm (counts/min): No ASD = 577.5 ASD = 541.8 Weekend am (counts/min): No ASD = 746.0 ASD = 630.5 Weekend afternoon (counts/min): No ASD = 789.7 ASD = 789.7 Weekend pm (counts/min) No ASD = 590.5 ASD = 517.0	TD more active on weekend mornings and afternoons than ASD
Thomas 2022	ActiGraph wGT3X + BT (hip); Survey	8 days	Once	MVPA (min/day): ASD = 87.03 (38.28) TD = 82.10 (40.45) Meets MVPA guidelines (n/%): ASD = 12 (70.6%) TD = 11 (64.7%) Participate in organized sport weekly (n/%): ASD = 15 (88%) TD = 15 (88%)	No differences between groups

Table 4 (continued)

Article	Measure(s)	Period	Timing	Variable(s)	Difference(s)
Wang 2024	ActiGraph GT3x (hip)	7 days	Once	LPA (min/day): ASD = 263.96 (43.17) TD = 242.32 (37.91) MPA (min/day): ASD = 34.99 (14.23) TD = 36.38 (12.85) VPA (min/day): ASD = 11.63 (6.53) TD = 11.09 (7.0) MVPA (min/day): ASD = 46.62 (18.93) TD = 47.47 (18.26) Meeting MVPA Guidelines (n/%): ASD = 10 (24.4) TD = 9 (75.0)	ASD more light PA than TD
Yu 2012	Time use diaries (parent reported)	1 weekday, 1 weekend day	Once	Weekday MVPA (hours/day): rCoP = 1.08 No rCoP = 1.07 Weekend MVPA (hours/day): rCoP = 1.66 No rCoP = 1.62 Weekday Walk (hours/day): rCoP = 0.18 No rCoP = 0.18 Weekend Walk (hours/day): rCoP = 0.20 No rCoP = 0.23 Weekday Bike (hours/day): ACoP = 0.25 No rCoP = 0.23 Weekend Bike (hours/day): rCoP = 0.34 No rCoP = 0.31 Weekday Exercise (hours/day): rCoP = 0.66 No rCoP = 0.69 Weekend Exercise (hours/day): rCoP = 1.13 No rCoP = 1.08	No differences for weekdays and weekends separately When combined, rCoP more time riding bikes than TD

Key: *ADHD* attention deficit hyperactivity disorder, *ASD* autism spectrum disorder, *CP* cerebral palsy, *EE* energy expenditure, *FNPA* Family Nutrition and Physical Activity questionnaire, *GMFCS* Gross Motor Function Classification System, *HPA* habitual physical activity, *LPA* light intensity physical activity, *MPA* moderate intensity physical activity, *MVPA* moderate to vigorous intensity physical activity, *OSRAC-DD* Observational System for Recording Activity in Children Developmental Disabilities version, *PA* physical activity, *pDCD* probable developmental coordination disorder, *rCoP* risk of conduct problems, *rDCD* at risk for developmental coordination disorder, *SL* speech/language disorders, *TD* typical development or typically developing, *VPA* vigorous intensity physical activity

typically developing peers, while Sung et al. [35] reported more sedentary time in autistic children, and two other studies observed no differences in sedentary behavior between groups [31, 33]. Ketcheson et al. [40] found autistic children to be more active than typically developing children, whereas Sung et al. [35] found the opposite. In Tatsumi et al. [34], autistic children were less active, specifically on weekend mornings and afternoons, compared to typically developing children, while Wang et al. [31] reported more light physical activity in autistic children but no differences in MVPA.

Lin et al. [38] reported no differences in sleep metrics or screen use between autistic children and those with speech and language delays or 'other' development delays and Thomas et al. [33] found no differences in overall activity levels.5

Cerebral palsy

Among the six articles that included children with cerebral palsy, four studies explored group differences and reported generally consistent findings. Three studies by Keawutan et al. [44–46] compared subgroups of children with cerebral palsy and found that children who were more independent or ambulant tended to be less sedentary and more physically active than those who were less ambulant. Similarly, Oftedal et al. [37] observed comparable patterns when examining ambulatory groups of children with cerebral palsy alongside typically

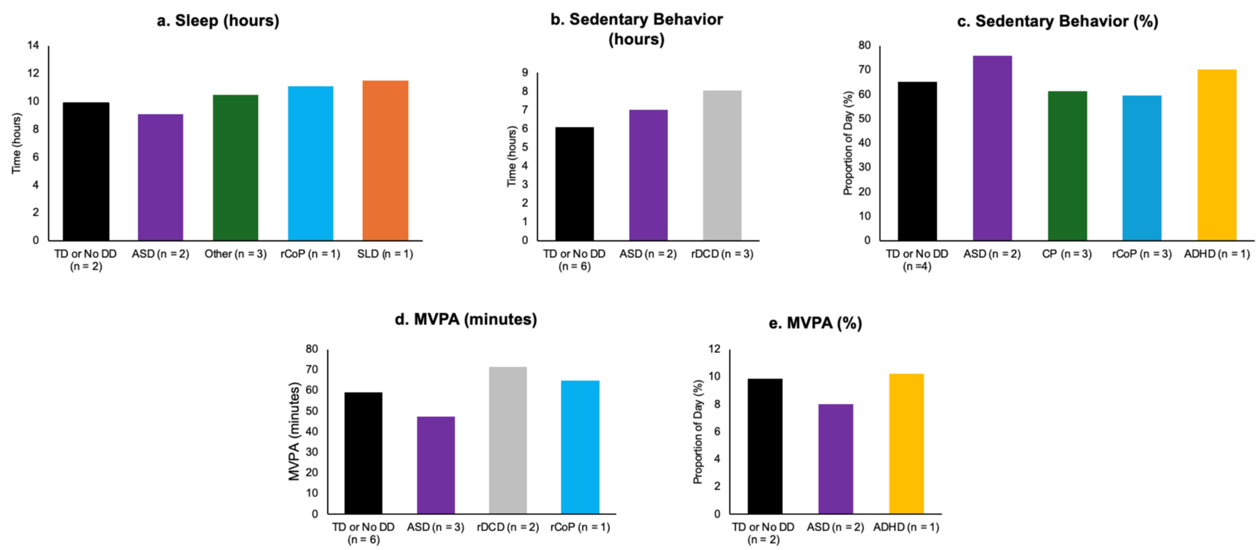

Fig. 2. 24-h movement behaviors of commonly reported variables among studies. Note: Among all studies contributing to this figure, five reported sleep time in hours [30, 32, 34, 38, 42], six reported sedentary time in hours [20, 30, 31, 33, 47, 48], nine reported sedentary time as a percentage [35–37, 40, 43–46, 49], six reported MVPA time in minutes [20, 30, 31, 33, 35, 47], and three reported MVPA as a percentage [40, 42, 43]. Key: ADHD = attention deficit hyperactivity disorder; ASD = autism spectrum disorder; CP = cerebral palsy; DD = developmental difference; MVPA = moderate to vigorous intensity physical activity; other = non-defined developmental difference or developmental delay; rCoP = at risk for conduct problem; rDCD = at risk of developmental coordination disorder; SLD = speech or language disorder; TD typical development or typically developing

developing children, noting that both typically developing children and children with cerebral palsy who had greater ambulatory ability were more likely to engage in higher levels of physical activity than children with cerebral palsy who were less ambulatory.

Developmental coordination disorder

The three included studies investigating children at risk for or with probable developmental coordination disorder all performed analyses to identify potential group differences. Notably, none of the studies incorporated sleep measures. Both Brown et al. [20] (2021) and Bulten et al. [48] found no differences in sedentary behavior or physical activity metrics between children at risk for or with probable developmental coordination disorder compared to typically developing peers. Similarly, King-Dowling et al. [47] reported no significant differences in most physical activity variables, except for shorter duration of MVPA bouts in the developmental coordination disorder group compared to typically developing children.

Other domains

The remaining developmental domains were less frequently studied across the included research. Yu et al. [30] examined sleep and physical activity in children at risk for conduct problems, finding that these children had less restful time (i.e., sleep and rest) on both weekdays and weekends compared to peers who were not at risk for conduct problems. Among several physical activity metrics, the only significant difference was increased bike riding time in children at risk for conduct problems when weekday and weekend data were combined.

Regarding ADHD, Curzon et al. [43] found that children with ADHD took more steps than typically developing children, though no differences emerged in other physical activity measures. Sedentary behavior was measured, but group comparisons were not examined.

Lin et al. [38] studied a subsample of children with speech and/or language delays and found no differences in sleep or screen use compared to autistic children or other developmental disabilities. Physical activity was not assessed in this study.

Finally, three additional studies included children with various or unspecified developmental disabilities [32, 38, 39]. Lin et al. [38] reported no differences in sleep or screen use across developmental domains. Venkatesan et al. [32] found that children with 'other' (non-ASD) developmental delays had longer sleep duration and less screen time than autistic children. Schenkelberg et al. [39] measured sedentary behavior and physical activity in children with Down syndrome, ASD, and other developmental delays, but did not compare these behaviors between groups.

Discussion

This scoping review provides a synthesis of the current evidence on 24-h movement behavior levels in preschool-aged children with developmental disabilities. Through the twenty studies resulting from the search, we summarized levels and identified potential disparities in these behaviors across various developmental domains, including ASD, cerebral palsy, developmental coordination disorder, and other less frequently studied subgroups. Overall, the findings highlight some variability in movement behaviors among young children with developmental disabilities. Notably, most of the included research focused on physical activity and sedentary behavior, with relatively few studies including sleep or fully integrating all three behavior categories.

Physical activity and sedentary behavior have been more extensively studied in older children with developmental disabilities, revealing clearer patterns of disparity compared to typically developing peers [13, 14]. Research in older autistic children and children with other developmental disabilities frequently documents lower MVPA and higher sedentary time compared to typically developing peers, in contrast to the mixed differences among the preschool studies in the present review. Notably, ambulatory ability consistently emerges as a critical factor influencing activity levels in children with cerebral palsy across age groups [18]. This pattern aligns with our findings in preschoolers, suggesting that mobility constraints play an important role in shaping physical activity and sedentary behavior from early childhood through later developmental stages.

The heterogeneity in findings across the included studies may, in part, also reflect fundamental differences in how distinct functional limitations shape movement behaviors [50, 51]. For example, while mobility constraints in cerebral palsy could directly limit physical activity capacity, sensory processing differences in autism may affect activity participation through mechanisms related to environmental tolerance and social engagement. Similarly, children with developmental coordination disorder may experience reduced physical activity not due to inability, but due to motor inefficiency and related motivational factors. These different mechanistic pathways contribute to the complexity of interpreting movement behavior differences across diagnostic groups.

Sleep has been more extensively studied across various age groups in children with developmental disabilities, although independently of physical activity and sedentary behavior [15–17]. The literature in older children consistently shows poorer sleep quality and shorter sleep duration among those with developmental disabilities such as ASD and ADHD. In contrast, findings for preschool-aged children were less consistent in the current review, which may be due to variability in measurement methods or smaller sample sizes. The 24-h movement behavior framework, which integrates physical activity, sedentary behavior, and sleep, originated primarily from physical activity research and has only recently begun to include sleep as a focus [7]. This evolving integration may contribute to the limited number of studies examining both sleep and daytime movement behaviors together in young children with developmental disabilities. Notably, across age groups, many studies apply exclusion criteria that omit children with developmental differences, often without providing a rationale or justification, which may further limit the evidence base in young children [52]. These gaps highlight the importance of further standardized and comprehensive research on sleep within the full 24-h behavior paradigm in preschool populations.

Studies in older children with developmental disabilities highlight that disparities in physical activity often stem from environmental and systemic barriers rather than intrinsic child deficits [53–56]. For example, inaccessible physical environments, lack of adaptive equipment, and insufficient inclusive community and school programming limit opportunities for physical activity [55, 56]. Social factors such as stigma, low expectations, and inadequate support may further reduce participation. System-level challenges, including fragmented services, limited integration of movement goals in individualized education plans (IEPs), and socioeconomic disparities, also appear to contribute to unequal access and engagement in healthy physical activity levels [55]. These findings suggest that similar barriers may influence movement behaviors in preschool-aged children, yet research at this developmental stage rarely acknowledges accessibility or inclusion explicitly [9].

Although sleep disorders or disturbances are commonly present among children with developmental disabilities, similar to physical activity, external barriers to healthy sleep promotion and development may also play significant roles. Specifically, factors such as limited access to specialized care, time and cost constraints, and challenges in parental implementation of child sleep interventions are barriers to adequate sleep management in children with developmental disabilities [57–59]. These findings suggest it is important to explore similar barriers in preschool-aged children to better tailor early sleep support and interventions. Future studies should prioritize investigating how environmental, social, and policy factors affect 24-h behaviors in preschoolers with developmental disabilities to inform early inclusive interventions and reduce disparities that may develop over time.

Notably, in the present review, only one study included all three 24-h movement behaviors simultaneously, highlighting a prominent gap. In contrast, research involving older children has more frequently utilized integrated analytical approaches, such as compositional data analysis, which are recommended within the 24-h behavioral paradigm to account for the co-dependency of these behaviors [6, 7]. These integrated methods may offer valuable insights into how time spent in one behavior influences others and help identify effective intervention targets by revealing behavior trade-offs. Applying such analyses in preschool populations may be an important opportunity for future research to enhance understanding and guide holistic, developmentally appropriate interventions at earlier stages of development.

Considerations for future research

Future research in preschool children with developmental disabilities should prioritize the use of comprehensive and standardized measurement approaches that encompass all three core movement behaviors. Notably, few of the included studies discussed compliance considerations related to measurement devices when they were used. Critically, these approaches should be tailored to the specific functional profiles being studied. Wearable device compliance can be challenging across the preschool age range in general [60], but developmental disabilities may introduce additional barriers, such as sensory sensitivities, behavioral inflexibility, or difficulty tolerating certain materials or placements. To address measurement limitations identified in this review, future studies should consider: (1) alternative nearable (e.g., non-contact devices placed near the individual to estimate sleep patterns such as mattress sensors) or wearable devices such as inclinometers to capture postural information and body position transitions (particularly relevant for children with postural or motor control differences); (2) parent-reported measures (activity logs, structured questionnaires) as complements to or alternatives from device-based measurement, especially for children unable to tolerate wearables, and to capture contextual information about sedentary behavior quality (e.g., active learning engagement vs. passive screen time); and (3) explicit guideline compliance reporting with disability-specific stratification to enable meaningful comparison with typically developing peers and assessment of whether current WHO guidelines require modification for different profiles. Greater attention to these factors (e.g., measurement approach selection, device type and placement, materials, participant burden, and guideline-referenced outcomes) would help guide more inclusive and developmentally appropriate assessment strategies that advance our understanding of 24-h movement behaviors across the diversity of functional profiles in early childhood disabilities.

Expanding the scope beyond commonly studied groups such as ASD and cerebral palsy to include a broader range of developmental domains will enhance the generalizability and relevance of findings for intervention. Additionally, employing integrated 24-h behavior analytic methods can better capture the complex interplay between movement behaviors, providing more nuanced insights into how changes in one behavior impact others. Finally, research should account for contextual factors (e.g., environmental settings, family dynamics, and sociocultural influences) that are especially pertinent during early childhood.

Limitations of the current evidence base and review

The current evidence on 24-h movement behaviors in preschool children with developmental disabilities is subject to several important limitations. Among the included studies, there was substantial heterogeneity in measurement tools and inconsistent operational definitions of physical activity, sedentary behavior, and sleep. These factors complicate direct comparisons and meta-analytic synthesis across studies. This heterogeneity could be compounded by the diverse functional profiles of children with developmental disabilities [50, 51]. Standard accelerometer cut-points derived from typically developing children may systematically misclassify movement intensity in children with different functional capabilities [61]. Furthermore, most studies did not explicitly report guideline compliance rates, limiting comparisons with typically developing peers or assessment against WHO recommendations. Additionally, research is heavily concentrated in higher-income countries, further limiting the generalizability of findings. Most developmental domains were underrepresented. Further, the predominance of cross-sectional study designs restricts causal interpretations regarding how these behaviors develop over time or impact child outcomes.

Additionally, there are potential limitations related to the review methodology. The search strategy might have overlooked relevant articles published in non-indexed journals or in languages other than English, thereby narrowing the scope of included evidence. Additionally, some data extraction and study categorization decisions were constrained by incomplete or inconsistent reporting within the primary studies. For example, in some cases, details of measurement were not reported or described inconsistently across studies. As a result, the reviewers were sometimes required to make interpretive decisions about how to classify studies. Further, the use of "typically developing" to refer to subsamples without a particular developmental difference may not have been an accurate assumption or categorization in each study. Addressing these methodological considerations in future reviews will help strengthen the robustness and inclusivity of synthesized evidence on movement behaviors in this population.

Conclusions

This scoping review highlights the complexity of 24-h movement behavior patterns in preschool children with developmental disabilities and emphasizes the need for more holistic, integrated, and methodologically robust research. In particular, there is a gap in incorporating sleep alongside physical activity and sedentary behaviors within the same studies, as well as a need for more thorough and consistent reporting of the developmental profiles of preschool participants to better contextualize findings. Such comprehensive approaches, which consider all movement behaviors collectively within diverse developmental contexts, are essential for advancing our understanding of health trajectories and informing tailored interventions to promote optimal outcomes from the earliest years.

Supplementary Information

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Additional File 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist.

Additional File 2. Search terms and strategies.

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Authors' contributions
SC and CWS developed the initial conception of this review. The review protocol was developed and designed by SC, SB, ET, MH, AW, KK, and CWS. Abstract/title screening, full text screening, and data charting were performed by SC, SB, KK, MF, EJ, GS, LR, SF, MF, and CWS. Data were synthesized and interpreted by SC and CWS. SC and CWS drafted the manuscript, with revisions and feedback provided by all other authors.

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Data availability

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

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Brown TT, Jernigan TL. Brain development during the preschool years. Neuropsychol Rev. 2012;22(4):313–33. https://doi.org/10.1007/s11065-012-9214-1.
2. Goldman-Rakic PS. Development of cortical circuitry and cognitive function. Child Dev. 1987;58(3):601–22.
3. Gathercole SE. The development of memory. J Child Psychol Psychiatry. 1998;39(1):3–27. https://doi.org/10.1017/S0021963097001753.
4. Tham EKH, Xu HY, Fu X, Schneider N, Goh DYT, Lek N, et al. Variations in longitudinal sleep duration trajectories from infancy to early childhood. Sleep Health. 2021;7(1):56–64. https://doi.org/10.1016/j.sleh.2020.06.007.
5. Telama R. Tracking of physical activity from childhood to adulthood: a review. Obes Facts. 2009;2(3):187–95. https://doi.org/10.1159/000222244.
6. Rosenberger ME, Fulton JE, Buman MP, Troiano RP, Grandner MA, Buchner DM, et al. The 24-hour activity cycle: a new paradigm for physical activity. Med Sci Sports Exerc. 2019;51(3):454–64. https://doi.org/10.1249/MSS.0000000000001811.
7. Pedišić Ž, Dumuid D, Olds TS. Integrating sleep, sedentary behaviour, and physical activity research in the emerging field of time-use epidemiology: definitions, concepts, statistical methods, theoretical framework, and future directions. Kinesiology. 2017;49(2):252–69.
8. Willumsen J, Bull F. Development of WHO guidelines on physical activity, sedentary behavior, and sleep for children less than 5 years of age. J Phys Act Health. 2020;17(1):96–100. https://doi.org/10.1123/jpah.2019-0457.
9. Tapia-Serrano MA, Sevil-Serrano J, Sánchez-Miguel PA, López-Gil JF, Tremblay MS, García-Hermoso A. Prevalence of meeting 24-hour movement guidelines from pre-school to adolescence: a systematic review and meta-analysis including 387,437 participants and 23 countries. J Sport Health Sci. 2022. https://doi.org/10.1016/j.jshs.2022.01.005.
10. Zablotsky B, Black LI, Maenner MJ, Schieve LA, Danielson ML, Bitsko RH, et al. Prevalence and Trends of Developmental Disabilities among Children in the United States: 2009–2017. Pediatrics. 2019;133(4):e20190811.
11. United States Congress. Developmental Disabilities Assistance and Bill of Rights Act of 2000. 2000.
12. Individuals with Disabilities Education Act. US Congress; 2004.
13. Rech JP, Irwin JM, Rosen AB, Baldwin J, Schenkelberg M. Comparison of physical activity between children with and without autism spectrum disorder: a systematic review and meta-analysis. Adapt Phys Activ Q. 2022. https://doi.org/10.1123/apaq.2021-0152.
14. Jones RA, Downing K, Rinehart NJ, Barnett LM, May T, McGillivray JA, et al. Physical activity, sedentary behavior and their correlates in children with autism spectrum disorder: a systematic review. PLoS ONE. 2017. https://doi.org/10.1371/journal.pone.0172482.
15. Lok R, Deshpande N, Nair S, Andrillon T, Gatera G, Hill CM, et al. The sleep–circadian connection: pathways to understanding and supporting autistic children and adolescents and those with attention-deficit hyperactivity disorder. Lancet Child Adolesc Health. 2025. https://doi.org/10.1016/S2352-4642(25)00211-1.
16. Hollway JA, Aman MG. Sleep correlates of pervasive developmental disorders: a review of the literature. Res Dev Disabil. 2011;32(5):1399–421. https://doi.org/10.1016/j.ridd.2011.04.001.
17. Cortesi F, Giannotti F, Ivanenko A, Johnson K. Sleep in children with autistic spectrum disorder. Sleep Med. 2010;11(7):659–64. https://doi.org/10.1016/j.sleep.2010.01.010.
18. Koldoff EA, Holtzclaw BJ. Physical activity among adolescents with cerebral palsy: an integrative review. J Pediatr Nurs. 2015;30(5):e105–17. https://doi.org/10.1016/j.pedn.2015.05.027.
19. Taylor A, Kong C, Zhang Z, Herold F, Ludyga S, Healy S, et al. Associations of meeting 24-h movement behavior guidelines with cognitive difficulty and social relationships in children and adolescents with attention deficit/hyperactive disorder. Child Adolesc Psychiatry Ment Health. 2023. https://doi.org/10.1186/s13034-023-00588-w.
20. Brown DMY, McPhee PG, Kwan MY, Timmons BW. Implications of disability severity on 24-hour movement guideline adherence among children with neurodevelopmental disorders in the United States. J Phys Act Health. 2021;18(11):1325–31. https://doi.org/10.1123/jpah.2021-0282.
21. Healy S, Aigner CJ, Haegele JA, Patterson F. Meeting the 24-hr movement guidelines: an update on US youth with autism spectrum disorder from the

2016 National Survey of Children's Health. Autism Res. 2016;12(6):941–51. https://doi.org/10.1002/aur.2095.
22. Feng J, Zheng C, Sit CHP, Reilly JJ, Huang WY. Associations between meeting 24-hour movement guidelines and health in the early years: a systematic review and meta-analysis. J Sports Sci. 2021;39(22):2545–57. https://doi.org/10.1080/02640414.2021.1945183.
23. Rollo S, Antsygina O, Tremblay MS. The whole day matters: Understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. J Sport Health Sci. 2020;9(6):493–510.
24. St. Laurent C, Cacciola S, Burkart S, Toole E, Woodman A, Kiely K, et al. Exploring 24-Hour Movement Behaviors in Preschool Children with and without Developmental Delays, Disabilities, or Disorders: A Scoping Review. [Internet]. [cited 2025 Sep 25]. Available from: https://osf.io/r3n8u/
25. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467–73. https://doi.org/10.7326/M18-0850.
26. Eriksen MB, Frandsen TF. The impact of patient, intervention, comparison, outcome (PICO) as a search strategy tool on literature search quality: a systematic review. J Med Lib Assoc. 2018. https://doi.org/10.5195/jmla.2018.345.
27. Tremblay MS, Chaput JP, Adamo KB, Aubert S, Barnes JD, Choquette L, et al. Canadian 24-hour movement guidelines for the early years (0–4 years): an integration of physical activity, sedentary behaviour, and sleep. BMC Public Health. 2017;17(Suppl 5):874–905. https://doi.org/10.1186/s12889-017-4859-6.
28. Poitras VJ, Gray CE, Janssen X, Aubert S, Carson V, Faulkner G, et al. Systematic review of the relationships between sedentary behaviour and health indicators in the early years (0-4 years). BMC Public Health. 2017. https://doi.org/10.1186/s12889-017-4849-8.
29. Carson V, Lee EY, Hewitt L, Jennings C, Hunter S, Kuzik N, et al. Systematic review of the relationships between physical activity and health indicators in the early years (0–4 years). BMC Public Health. 2017. https://doi.org/10.1186/s12889-017-4860-0.
30. Yu ML, Ziviani J, Baxter J, Haynes M. Time use differences in activity participation among children 4–5 years old with and without the risk of developing conduct problems. Res Dev Disabil. 2012;33(2):490–8. https://doi.org/10.1016/j.ridd.2011.10.013.
31. Wang J, Yao J, He Y. A comparison of the physical activity levels of 3-to-6-year-old children with autism spectrum disorder and children with typical development. Front Psychol. 2024;4:15. https://doi.org/10.3389/fpsyg.2024.1432389.
32. Venkatesan S. Activity log of preschool children with developmental disabilities and autism spectrum disorders. Asia Pac Disabil Rehabil J. 2004;15(2):58–66.
33. Thomas S, Barnett LM, Papadopoulos N, Lander N, McGillivray J, Rinehart N. How do physical activity and sedentary behaviour affect motor competence in children with autism spectrum disorder compared to typically developing children: a pilot study. J Autism Dev Disord. 2022;52(8):3443–55. https://doi.org/10.1007/s10803-021-05205-3.
34. Tatsumi Y, Mohri I, Shimizu S, Tachibana M, Ohno Y, Taniike M. Daytime physical activity and sleep in pre-schoolers with developmental disorders. J Paediatr Child Health. 2015;51(4):396–402. https://doi.org/10.1111/jpc.12725.
35. Sung YS, Loh SC, Lin LY. Physical activity and motor performance: a comparison between young children with and without autism spectrum disorder. Neuropsychiatr Dis Treat. 2021;17:3743–51. https://doi.org/10.2147/NDT.S343552.
36. Oftedal S, Davies PSW, Boyd RN, Stevenson RD, Ware RS, Keawutan P, et al. Longitudinal growth, diet, and physical activity in young children with cerebral palsy. Pediatrics. 2016;138(4):e20161321–e20161321. https://doi.org/10.1542/peds.2016-1321.
37. Oftedal S, Bell KL, Davies PSW, Waterl RS, Boyd RN. Sedentary and active time in toddlers with and without cerebral palsy. Med Sci Sports Exerc. 2015;47(10):2076–83. https://doi.org/10.1249/MSS.0000000000000653.
38. Lin J, Magiati I, Chiong SHR, Singhal S, Riard N, Ng IHX, et al. The relationship among screen use, sleep, and emotional/behavioral difficulties in preschool children with neurodevelopmental disorders. J Dev Behav Pediatr. 2019;40(7):519–29. https://doi.org/10.1097/DBP.0000000000000683.
39. Schenkelberg MA, Brown WH, McIver KL, Pate RR. An observation system to assess physical activity of children with developmental disabilities and delays in preschool. Disabil Health J. 2021. https://doi.org/10.1016/j.dhjo.2020.101008.
40. Ketcheson L, Hauck JL, Ulrich D. The levels of physical activity and motor skills in young children with and without autism spectrum disorder, aged 2–5 years. Autism. 2018;22(4):414–23. https://doi.org/10.1177/1362361316683889.
41. Brown DMY, Kwan MYW, King-Dowling S, Cairney J. Cross-sectional associations between wake-time movement compositions and mental health in preschool children with and without motor coordination problems. Front Pediatr. 2021;30:9. https://doi.org/10.3389/fped.2021.752333.
42. Alder ML, Johnson CR, Zauszniewski JA, Malow BA, Burant CJ, Scahill L. Feasibility of actigraphy for evaluating sleep and daytime physical activity in children with autism spectrum disorder. J Autism Dev Disord. 2023;53(9):3670–82. https://doi.org/10.1007/s10803-022-05661-5.
43. Curzon MM, Dick AS, Coccia C, Graziano PA. Exploring differences in physical health in young children with and without ADHD. J Pediatr Psychol. 2024;49(2):120–30. https://doi.org/10.1093/jpepsy/jsad090.
44. Keawutan P, Bell KL, Oftedal S, Davies PSW, Ware RS, Boyd RN. Habitual physical activity in children with cerebral palsy aged 4 to 5 years across all functional abilities. Pediatr Phys Ther. 2017;29(1):8–14. https://doi.org/10.1097/PEP.0000000000000327.
45. Keawutan P, Bell KL, Oftedal S, Davies PSW, Ware RS, Boyd RN. Relationship between habitual physical activity, motor capacity, and capability in children with cerebral palsy aged 4–5 years across all functional abilities. Disabil Health J. 2018;11(4):632–6. https://doi.org/10.1016/j.dhjo.2018.03.006.
46. Keawutan P, Bell KL, Oftedal S, Ware RS, Stevenson RD, Davies PSW, et al. Longitudinal physical activity and sedentary behaviour in preschool-aged children with cerebral palsy across all functional levels. Dev Med Child Neurol. 2017;59(8):852–7. https://doi.org/10.1111/dmcn.13439.
47. King-Dowling S, Kwan MYW, Rodriguez C, Missiuna C, Timmons BW, Cairney J. Physical activity in young children at risk for developmental coordination disorder. Dev Med Child Neurol. 2019;61(11):1302–8. https://doi.org/10.1111/dmcn.14237.
48. Bulten R, Brown D, Rodriguez C, Cairney J. Association of sedentary behaviour on internalizing problems in children with and without motor coordination problems. Ment Health Phys Act. 2020;18:100325. https://doi.org/10.1016/j.mhpa.2020.100325.
49. Oftedal S, Davies PS, Boyd RN, Stevenson RD, Ware RS, Keawutan P, et al. Body composition, diet, and physical activity: a longitudinal cohort study in preschoolers with cerebral palsy. Am J Clin Nutr. 2017;105(2):369–78. https://doi.org/10.3945/ajcn.116.137810.
50. Eguia KF, Ng SSM, Capio CM, Wong TWL. Applications of motor learning strategies in children with neurodevelopmental disorders: a scoping review. Rev J Autism Dev Disorders. 2025. https://doi.org/10.1007/s40489-025-00500-6.
51. Verbecque E, Johnson C, Scaccabarozzi G, Molteni M, Klingels K, Crippa A. Motor difficulties in children with neurodevelopmental conditions: a report from a cross-national study in Belgian and Italian children. Eur J Pediatr. 2025. https://doi.org/10.1007/s00431-025-06009-8.
52. Camanni G, Ciccone O, Lepri A, Tinarelli C, Bedetti C, Cicuttin S, et al. 'Being disabled' as an exclusion criterion for clinical trials: a scoping review. BMJ Glob Health. 2023;8(11):e013473. https://doi.org/10.1136/bmjgh-2023-013473.
53. Verschuren O, Peterson MD, Balemans ACJ, Hurvitz EA. Exercise and physical activity recommendations for people with cerebral palsy. Dev Med Child Neurol. 2016;58(8):798–808. https://doi.org/10.1111/dmcn.13053.
54. Rimmer JH, Riley B, Wang E, Rauworth A, Jurkowski J. Physical activity participation among persons with disabilities. Am J Prev Med. 2004;26(5):419–25. https://doi.org/10.1016/j.amepre.2004.02.002.
55. Shields N, Synnot AJ, Barr M. Perceived barriers and facilitators to physical activity for children with disability: a systematic review. Br J Sports Med. 2012;46(14):989–97. https://doi.org/10.1136/bjsports-2011-090236.
56. Wright A, Roberts R, Bowman G, Crettenden A. Barriers and facilitators to physical activity participation for children with physical disability: comparing and contrasting the views of children, young people, and their clinicians. Disabil Rehabil. 2019;41(13):1499–507. https://doi.org/10.1080/09638288.2018.1432702.
57. Tan-MacNeill KM, Smith IM, Jemcov A, Keeler L, Chorney J, Johnson S, et al. Barriers and facilitators to treating insomnia in children with autism spectrum disorder and other neurodevelopmental disorders: parent and health care professional perspectives. Res Dev Disabil. 2020. https://doi.org/10.1016/j.ridd.2020.103792.
58. Sutton JE, Huws JC, Burton CR. Experiences of sleep hygiene education as an intervention for sleep problems in children with developmental disabilities: findings from an exploratory study. Br J Learn Disabil. 2019;47(3):165–73. https://doi.org/10.1111/bld.12270.
59. Berenguer C, Baixauli I, Rosa E, De Stasio S. Sleep problems in children with autism spectrum disorder and attention-deficit/hyperactivity disorder:

a comparative study and effects on communication skills. Autism Res. 2024;17(2):355–65. https://doi.org/10.1002/aur.3077.

60. Cliff DP, Reilly JJ, Okely AD. Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0-5 years. J Sci Med Sport. 2009;12(5):557–67. https://doi.org/10.1016/j.jsams.2008.10.008.

61. White L, Volfson Z, Faulkner G, Arbour-Nicitopoulos K. Reliability and validity of physical activity instruments used in children and youth with physical disabilities: a systematic review. Pediatr Exerc Sci. 2016;28(2):240–63. https://doi.org/10.1123/pes.2015-0123.

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