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A Comparison of Motor Delays in Young Children: Autism Spectrum Disorder, Developmental Delay, and Developmental Concerns

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Abstract This study assessed motor delay in young children 21–41 months of age with autism spectrum disorder (ASD), and compared motor scores in children with ASD to those of children without ASD. Fifty-six children (42 boys, 14 girls) were in three groups: children with ASD, children with developmental delay (DD), and children with developmental concerns without motor delay. Descriptive analysis showed all children with ASD had delays in gross motor skills, fine motor skills, or both. Children with ASD and children with DD showed significant impairments in motor development compared to children who had developmental concerns without motor delay. Motor scores of young children with ASD did not differ significantly on motor skill measures when compared to young children with DD.

Keywords Autism · Autism spectrum disorder · Early childhood · Developmental delay · Motor delay · Motor development

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Introduction

Autism or autistic disorder is a developmental disorder characterized by difficulties in social interaction and communication, as well as by repetitive, restricted interests, and behaviors (American Psychiatric Association, 1994). Many of the core characteristics of autism are shared by other diagnoses in the broader category called Pervasive Developmental Disorders (PDD). According to the National Institute of Mental Health, autism spectrum disorders (ASD) is another term for PDD, and includes the classic form of autistic disorder as well as Asperger's Syndrome (AS) and Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS) (National Institute of Mental Health, 2004). Although differences in motor development are not considered primary diagnostic categories for ASD, researchers interested in autism are increasingly considering the importance of motor functioning of children with ASD regarding issues in diagnosis (Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998), influence on behaviors (Leary & Hill, 1996), neuropsychiatric concepts (Mari, Castiello, Marks, Marraffa, & Prior, 2003), and treatment (Baranek, 2002).

Various researchers have noted differences of gross and fine motor skills in school-aged children with ASD. The majority of research conducted on motor skills in the ASD population fall into one of three categories: (a) normative sample comparisons, (b) videotape analysis of home videos, and (c) static group comparisons. The majority of evidence suggesting individuals with ASD have motor delays has centered on findings from normative sample comparisons. Early research found differences in gait in children with autism compared to normal children, including reduced stride lengths and increased stance times (Vilensky, Damasio, & Maurer, 1981). More recently, Green et al., (2002) assessed the motor skills of children between the ages of 6 and 11 years old who had AS, using the Movement Assessment Battery for Children. The Movement Assessment Battery for Children (Henderson & Sugden, 1992) is designed to assess motor skills, including manual dexterity, ball skills, and balance, in children 4–12 years of age. They found that all of the children in their study with AS scored below the 15th percentile on the test, and nine of the children scored below the 5th percentile, indicative of a definite motor problem. Miyahara et al., (1997) reported similar findings of motor incoordination in their AS sample. Other normative data studies have suggested children and adolescents with AS and high functioning autism have delays or disorders in overall motor development, including locomotor and object control (Berkeley, Zittel, Pitney, & Nichols, 2001), manual dexterity, ball skills, and balance (Manjiviona & Prior, 1995), reach to grasp tasks that included movement execution and planning (Mari et al., 2003), bimanual load-lifting differences (Schmitz, Martineau, Barthelem, & Assaiante, 2003), and graphomotor skills (Mayes & Calhoun, 2003). These normative data studies suggest that school-aged children with ASD frequently present with subtle to significant motor delays. More specifically, the studies found 50–73% of children with ASD in their study populations had significant motor delays compared to normative data (Berkeley et al., 2001; Manjiviona & Prior, 1995; Mari et al., 2003; Mayes & Calhoun, 2003).

Differences have also been found in the motor development of younger children with ASD (i.e., younger than the age of 3 years) when researchers have retrospectively examined home videotapes of children later diagnosed with ASD. Baranek, (1999) assessed the home videos of 11 children with autism at 9–12 months of age, and found subtle yet salient sensory-motor deficits in the infants, including excessive mouthing of objects. Two other studies also analyzed home movies of children later diagnosed with autism and found that the infants showed differences from a control group in hypotonia, hypoactivity, and unusual postures (Adrien et al., 1993) as well as disturbances of movement at 4–6 months age and aberrant motor patterns, including persistence of primitive reflexes and delays in head righting reactions (Teitelbaum et al., 1998, 2004). All of the studies examining home videos of children later diagnosed with autism showed a range of motor delay or impairment.

Although standardized motor testing has been used with school-aged children, little has been published about standardized assessment of the fine and gross motor skills of children between infancy and age 3 years. Gillberg et al., (1990) suggested that prior to the age of 3 years children with ASD have a relative motor strength, in comparison to their IQ. Although the exact motor quotients were not given in the article, it was reported that 16 of the 20 children with autistic disorder had an IQ less than 70, with 9 children less than 50; therefore a motor quotient 15 points higher than the IQ would not automatically mean the motor skills of the children were within the normal range. The authors conceded that, although 85% of the children had relatively good motor skills, this was not to say that the children had typical motor development. Although Mayes and Calhoun, (2003) reported that 67% of their sample of 3–15-year-old children with autism had normal motor milestones for walking independently (implying that 33% of the children were delayed in their walking), these milestones were collected by retrospective parent report, rather than by standardized testing.

Some researchers have explored the idea that the motor deficits exhibited by children with ASD can be distinguished from those exhibited by children with other developmental disorders, and differences between groups have been found in some studies and not in others. Baranek's (1999) retrospective video study also assessed the home videos of 10 children with developmental disabilities and 11 typically developing infants to compare them to the videos of the infants with autism for differences in sensory-motor functioning. She found that nine items discriminated the three groups. Infants with autism were more vulnerable to deficits in poor visual orientation/attention, prompted/delayed response to name, excessive mouthing of objects, and social touch aversions, while infants with developmental delay (DD) were more vulnerable to deficits in stereotyped quality to object play, unusual posturing of body parts, diminished looking at camera, visual staring/fixation on objects, and less animated affective expressions. Miyahara et al., (1997) compared motor skills of children with AS with those of children with learning disabilities, and found that both groups had a high incidence of motor delay, although children with AS had better manual dexterity and poorer ball skills. Green et al., (2002) compared the motor skills of school-aged children with AS to those of children whose primary problem was motor, and the researchers felt that the motor impairments were not distinctive in the AS group, with clumsiness looking similar in both groups.

Leary and Hill, (1996) proposed that motor disorder symptoms may have a significant impact on the core characteristics of autism, and that a shift in focus to a movement perspective may provide new insights, which could result in the development of useful tools for future diagnosis and rehabilitation. An important step in shifting focus to a movement perspective is to gather accurate information on the specific motor skills of children with ASD using standardized motor testing. Research using standardized motor testing to assess gross and fine motor skills in children with ASD has focused on school-aged children, however, and little information has been published on standardized assessment of motor skills of younger children with ASD. Given the aforementioned shortcomings in the literature on motor development in ASD, an important next step is to determine the degree of motor disorder in young children with ASD using standardized motor testing. Moreover, the published research is inconclusive about differences in motor skills between children with ASD and children with other developmental problems, and more information is needed on possible differences in motor skills between various groups of young children.

The purpose of this study was to evaluate the motor skills of young children with ASD using standardized motor testing to determine the presence and degree of delay in their motor skills, and to compare their motor development with other children their age who were also demonstrating developmental issues. The questions for this study included: (a) Do young children with ASD show delays in their motor skills as measured on the Bayley Scales of Infant Development (BSID) II Motor Scale and the Peabody Developmental Motor Scales, 2nd Edition (PDMS-2)? (b) Are the motor scores of young children with ASD different from those of young children without ASD who are referred to an early childhood evaluation program for developmental issues? (c) In addition, are the motor scores of young children with ASD different from those of young children with DD including motor delay when the children are matched for chronological age, gender, and mental developmental age?

Method

Participants

Children were recruited from a University Center for Excellence in Developmental Disabilities (UCEDD) to participate in this study. Infants and children were referred to the Early Childhood Evaluation Program at the UCEDD for comprehensive interdisciplinary developmental evaluations because they were at risk for delay or had an established DD, and many of the children had complex neurodevelopmental problems. The interdisciplinary team that saw each child was composed of a cognitive specialist (such as an educational diagnostician or clinical psychologist) who assessed cognitive, adaptive, and social/emotional development, a speech language pathologist who assessed speech and language development, a physical therapist who assessed gross and fine motor development and sensory processing abilities, and a pediatrician who conducted a medical examination. Standardized testing was routinely done to identify DDs and assess the quality of the child's skills in the various areas of development. The motor assessment routinely included the administration of the BSID II Motor Scale (Bayley, 1993) and the PDMS-2 (Folio & Fewell, 2000).

This study was part of a larger research project, and was approved by the University's School of Medicine's Human Research Review Committee. Each child's parent or legal guardian was informed about the study and signed the consent form on the day of the clinic visit.

Fifty-six children participated in this study, and they were divided into three groups: children with ASD (ASD group, $n = 19$), children without ASD who had DD including motor delay (DD group, $n = 19$), and children without ASD who had developmental concerns without motor delay [No Motor Delay (NMD) group, $n = 18$]. Developmental concerns included language and social–emotional issues, and medical risk factors.

The children in the ASD group received a diagnosis of ASD based on the results of their interdisciplinary team evaluations (18 children with a diagnosis of autism, 1 child with a diagnosis of PDD-NOS). The children in the DD group were matched to the children in the ASD group on gender, chronological age within 3 months, and cognitive abilities based on BSID II Mental Scale mental age equivalent within 3 months. The DD group therefore consisted of young children with DD including motor delays. Forty-two boys (15 in the ASD group, 15 in the DD group, and 12 in the NMD group) and 14 girls (4 in the ASD group, 4 in the DD group, and 6 in the NMD group) participated.

The NMD group was matched to the ASD group on chronological age within 3 months. The NMD group consisted of children referred for speech and language delays, social–emotional delays, and other non-motor issues. The NMD group participants' motor scores had to be classified as Within Normal Limits (WNL) on the BSID II Motor Scale or as Average on the PDMS-2 Total Motor Quotient.

Procedures

One of two physical therapists administered the BSID II Motor Scale and the PDMS-2 to each participating child as part of their interdisciplinary developmental evaluation. The two experienced pediatric physical therapists involved in this study have performed developmental testing of young children for over 25 years each. Interrater reliability was established between the two therapists on six children. Three children were videotaped and then scored from the videotape by both researchers. Three children were tested and scored in the clinic setting by one researcher while being observed and scored at the same time by the other researcher. Interrater agreement on the six children averaged 91% for the PDMS-2 (range of 85–98%), and 96% for the BSID II Motor Scale (range of 88–100%).

Instruments

Bayley Scales of Infant Development-2nd Edition

The BSID was revised to become the BSID II in 1993, and renormed on a sample of 1,700 children from birth to 42 months (Bayley, 1993). The BSID II consists of a Mental Scale, a Motor Scale, and a Behavior Rating Scale, and has been reviewed for psychometric strengths and limitations (Koseck, 1999). According to the manual, the Motor Scale assesses degree of control of the body, coordination of the large muscles, finer manipulatory skills of the hands and fingers, dynamic movement, dynamic praxis, postural imitation, and stereognosis. Raw scores on the Motor Scale are converted to developmental age-equivalent scores as well as standard scores called the Psychomotor Development Index (PDI) scores. The mean standard score is 100 and the standard deviation is 15. The BSID II Motor Scale classifies performance based on whole number standard deviations from the mean, into categories of Accelerated, WNL, Mildly Delayed and Significantly Delayed.

Peabody Developmental Motor Scales-2nd Edition

The PDMS was revised to become the PDMS-2 in 2000, and renormed on a sample of 2,003 children (Folio & Fewell, 2000). The PDMS-2 consists of six subscales: Reflexes (for children birth through 11 months), Stationary (ability to sustain control of body within its center of gravity), Locomotion (ability to move from one place to another), Object Manipulation (ability to manipulate balls, for children 12 months and older), Grasping (ability to use hands), and Visual-Motor Integration (ability to use visual perceptual skills to perform complex eye–hand coordination tasks). Raw scores on the PDMS-2 are converted to age-equivalent scores for the subscales, percentiles, subscale standard scores, and composite standard scores called motor quotients. The Reflexes or Object Manipulation, Stationary and Locomotion subscales contribute to the Gross Motor Quotient, while the Grasping and Visual-Motor Integration subscales contribute to the Fine Motor Quotient, and the Total Motor Quotient is formed by a combination of the results of the gross and fine motor subscales. Although the PDMS-2 has a mean motor quotient standard score of 100 and standard deviation of 15, it classifies performance primarily based on 10-point increments (rather than the 15-point standard deviation increments), into categories of Very Superior, Superior, Above Average, Average, Below Average, Poor, and Very Poor.

Data Analysis

In order to examine the question whether children with ASD have significant motor delays compared to children with DDs including motor delays and to children with developmental concerns with NMD, two procedures of Multivariate Analysis of Covariance (MANCOVA) were conducted. The Mental Developmental Index (MDI) from the BSID II was the covariate for the three groups. The first MANCOVA determined if the three groups differed on standard scores of motor development (BSID II PDI, PDMS-2 Gross Motor Quotient, Fine Motor Quotient, and Total Motor Quotient). The second MANCOVA was computed to determine if the groups differed on the standard scores of the subscales of the PDMS-2. For both analyses, the observed covariance matrices were equal across both groups, and skewness and kurtosis were deemed to be acceptable. Although all of the statistical assumptions were met, it is important to note that there is a higher likelihood of a Type I error when using a MANOVA with non-random groups (see Miller & Chapman, 2001 for full discussion). For the MANCOVA's, the Wilk's Lambda test is reported in Sect. 'Results'.

Results

Descriptive Statistics

The ages of the children ranged from 21 to 41 months (M = 30.1 months, SD = 4.7). An ANOVA for differences in age indicated no significant differences among the groups, $F(2, 53) = .10$, $p = .90$ (ASD group M = 30.4 months, SD = 4.6; DD group M = 29.7 months, SD = 4.4; NMD group M = 30.2 months, SD = 5.4). In addition to being matched on mental age equivalents, the ASD group and the DD group did not differ on cognitive abilities based on BSID II MDI standard scores, $t(36) = -.69$, $p = .50$. Descriptive statistics for the MDIs for each of the groups can be found in Table 1. Although the NMD group was not matched exactly to the gender in the other groups, a Kruskal–Wallis test for differences in gender across the three groups indicated there was no significant difference among the groups on gender $\chi^2(2) = .97$, $p = .67$.

Normative data

BSID II Motor Scale Scores

Descriptive statistics for the scores on the motor tests for each of the groups can be found in Table 1. On the BSID II Motor Scale, the mean standard score (PDI) of the children with ASD was 57.1, with a standard deviation of 9.7 and a range from < 50 to 77. Using the classifications based on the standard scores, three children with ASD (16% of the ASD group) were classified as mildly delayed, and 16 children (84% of the children) were classified as significantly delayed (scores at least two SDs below the mean of the test). No child with ASD in this study was classified as WNL on the BSID II Motor Scale.

When using the developmental age-equivalent scores of the BSID II Motor Scale to calculate percentage delayed, 12 children with ASD (63% of the ASD sample) would qualify for early intervention services based on 25% or more delay in their motor skills. Two of those children were more than 50% delayed in their motor skills. In contrast, only seven children with ASD (37% of the ASD group) were less than 25% delayed in their motor skills on the BSID II Motor Scale.

PDMS-2 Scores

On the PDMS-2, the children with ASD had a mean Total Motor Quotient of 76.3, with a standard deviation of 9.2 and a range from 59 to 90. Their mean Gross Motor Quotient was 77.1, with a standard deviation of 9.6 and a range from 59 to 94. Their mean Fine Motor Quotient was 78.8, with a standard deviation of 11.4 and a range from 49 to 94.

Table 2 presents the ASD group classifications of the children's motor quotients on the PDMS-2. One child scored Average in both the gross motor and total motor areas, and another child scored Average in the fine motor area. Most children scored Below Average or lower, with 16–26% scoring at least two SDs below the mean of the test, in the Very Poor category. Table 3 presents the number of children with ASD who were delayed using the developmental age-equivalent scores of the PDMS-2 subscales to calculate

Table 2 Number of children with ASD scoring in the various PDMS-2 Classifications for the Motor Quotients

	Very Poor	Poor	Below Average	Average
Gross Motor Quotients	4	6	8	1
Fine Motor Quotients	3	5	10	1
Total Motor Quotients	5	5	8	1

Table 1 Descriptive statistics for the ASD group, the DD group, and the NMD group on the PDMS-2 and the BSID II Motor Scale Standard Scores

	ASD group (N = 19)		DD group (N = 19)		NMD group (N = 18)	
	M	SD	M	SD	M	SD
PDMS-2						
Stationary[a]	7.6	1.2	7.9	1.0	9.0	.69
Locomotion[a]	5.7	2.4	5.3	2.1	8.8	1.0
Object Manipulation[a]	5.9	1.6	6.4	1.7	9.1	1.1
Grasping[a]	7.8	2.0	8.2	1.8	9.2	.99
Visual-Motor Integration[a]	5.7	1.5	6.1	1.8	9.3	1.3
Gross Motor Quotient[b]	77.1	9.6	77.7	9.4	93.0	4.7
Fine Motor Quotient[b]	78.8	11.4	82.8	9.2	95.4	4.3
Total Motor Quotient[b]	76.3	9.2	77.7	9.6	93.2	3.9
BSID II						
Motor Developmental Index[b]	57.1	9.7	56.7	9.7	87.1	7.5
Mental Developmental Index[b]	54.9	11.1	57.4	10.5	78.2	20.3

[a] Indicates the subscale has a mean of 10 and standard deviation of 3

[b] Indicates the scale has a mean of 100 and a standard deviation of 15

Table 3 Number of children with ASD who were delayed using age-equivalent scores of the PDMS-2 subscales

	0–25% delayed	25–49% delayed	≥50% delayed
Stationary	3	13	3
Locomotion	6	12	1
Object Manipulation	5	12	2
Grasping	4	11	4
Visual-Motor Integration	4	14	1

percentage delayed. At least 13 children with ASD, or 68% of the ASD group, would qualify for early intervention services based on motor skill delays of more than 25%. On the various subscales, 1–4 of those children were more than 50% delayed.

Analysis of Covariance

A MANCOVA indicated the three groups differed on the BSID II Motor Scale PDI scores $F(2, 52) = 46.4$, $p < .001$, and on the PDMS-2 Gross Motor Quotients $F(2, 52) = 11.9$, $p < .001$; PDMS-2 Fine Motor Quotients $F(2, 52) = 8.5$, $p = .001$), and PDMS-2 Total Motor Quotients $F(2, 52) = 13.5$, $p < .001$). The effect sizes (i.e., Eta Squared) were as follows: BSID II PDI (.64), PDMS-2 Gross Motor Quotient (.32), PDMS-2 Fine Motor Quotient (.25), and PDMS-2 Total Motor Quotient (.34). The Bonferroni-corrected post hoc analyses indicated the NMD group significantly differed from the ASD and DD groups on all measures of motor development. However, the ASD group and DD group did not differ on any of the motor tests' standard scores.

A second MANCOVA found that the three groups differed on all five of the PDMS-2 subscales: Stationary $F(2, 52) = 7.8$, $p = .001$; Locomotion $F(2, 52) = 8.0$, $p = .001$; Object Manipulation $F(2, 52) = 11.9$, $p < .001$; Grasping $F(2, 52) = 2.3$, $p < .11$; Visual-Motor Integration $F(2, 52) = 14.8$, $p < .001$. The effect sizes (i.e., Eta Squared) for the Grasping subscale was .08, observed power was .45. The following were the effect sizes for each subscale: Stationary (.94), Locomotion (.94), Object Manipulation (.99), and Visual-Motor Integration (.99). The Bonferroni-corrected post hoc analyses indicated the NMD group significantly differed from the ASD and DD groups on all of the subscales except Grasping. In contrast, the ASD group and DD groups did not differ on any of the subscales.

Discussion

All of the young children with ASD in this study showed some degree of motor delay in at least one area (gross motor skills or fine motor skills) of motor development. Young children are eligible for early intervention services based on delays in development, and in many states, documented delays of 25% or more in one area of development, including the motor area, will qualify a child for early intervention services. Two of the most commonly used standardized tests for assessing motor skills of young children are the BSID II Motor Scale and the PDMS-2, which can document motor delays using age-equivalent scores and/or standard scores. In this study, at least 60% of the young children with ASD qualified for early intervention services based on their motor delays alone, not even considering their delays in other areas of development that are hallmarks of ASD such as communication. In addition, based on standard score classifications, no young child with ASD in this study was classified as having motor skills in the normal/average range on the BSID II Motor Scale and on all areas of the PDMS-2. Only one child with ASD scored average in both the gross motor and total motor areas on the PDMS-2 (but not in the fine motor area), and another child scored average in the fine motor area of the PDMS-2 but not in the gross or total motor areas.

In the current study, the motor scores of young children with ASD did not differ when compared to young children the same age and gender with DDs who had similar mental development. It is important to note the limitations of the current study. The major limitation rises from the use of the MANCOVAs to analyze the group differences. As previously noted, the use of a MANCOVA with static group comparisons increases the likelihood of seeing a Type I error (i.e., observing group differences when they do not exist) (Miller & Chapman, 2001). Such a concern is important to note, however, it does not substantively change the essential findings of the current study (i.e., children with ASD have significant motor delays and these delays can be measured as early as their first diagnostic evaluation).

Our study shows preliminary support for the conclusions of Green et al., (2002), who did not find the motor impairment in children with AS was in any way distinctive when compared to children with motor impairment who did not have AS. However, although the total scores themselves are not significantly different, further research is required to determine whether the patterns of motor skill development are different among and within children with ASD, such as differences in manual dexterity compared with ball-playing skills.

Some researchers have concluded that motor skills in young children with ASD are relatively intact (Gillberg et al., 1990). Such a conclusion appears erroneous because it is frequently based on the parents' report of the child's age at independent walking. Gross motor skills that develop during the preschool years after independent walking are more complex and require a sophisticated use of one's body, such as jumping, going up and down stairs, walking on a beam, balancing on one foot, and throwing and kicking a ball. These complex skills demand a higher level of motor planning abilities and balance, and are often learned through motor imitation. Fine motor activities learned in the preschool years include manipulation and eye–hand coordination skills such as using a crayon, unscrewing lids, snipping with scissors, and stringing beads, and these skills also require higher degrees of motor planning and imitation. Our current findings provide preliminary evidence to refute the assumption that a young child with ASD who walks independently within the normal age range will necessarily acquire preschool motor skills within the typical time period.

Because our study found that all the young children with ASD showed motor impairments, we agree with the findings of Berkeley et al., (2001) that support the need to assess the motor skills of young children with ASD in addition to other developmental skill areas outlined in diagnostic manuals. Much of the play of young preschool children involves motor games (e.g., jumping, playing ball, riding tricycles), and young children learn and practice social skills as they play interactively with each other in these motor activities. It is possible that the success of some of the interactions of young children with ASD with their peers may have a relationship to how well they are able to perform fundamental motor and play skills.

Further Research

Further research needs to be done to clarify the relationship of motor impairments with the social and communication differences seen in children with ASD. Further research also needs to be done to determine whether any particular motor profiles are more prevalent in young children with ASD compared to those of children with DDs without ASD. Total scores on standardized motor tests (including the Movement Assessment Battery for Children and the PDMS-2) are usually calculated from scores from contributing subscales. Although the total scores on the tests may be similar across groups, the relative contributions from the subscales may be different in children with ASD compared with other children, For example, assessing subscale performance in school-aged children, Miyahara et al., (1997) found that children with AS had better manual dexterity and poorer ball skills than children with learning disabilities. Assessment of the motor profiles in younger children would provide important information about specific motor skill development in various motor areas, including the gross motor areas of locomotion, balance, and ball-playing as well as the fine motor areas of Grasping and Visual-Motor Integration.

Conclusion

Our research showed that motor development in young children with ASD is not typical on standardized testing. Although motor skills are not considered primary diagnostic categories for ASD, our study found some degree of motor dysfunction in all of the young children with ASD, with delays in gross motor skills, fine motor skills, or both. The clinical implications of these findings strongly suggest that all young children with ASD should receive complete developmental evaluations that include assessment of their motor functioning. In addition, although children with ASD and children with DD in this study showed significant impairments in motor development compared to children who had developmental concerns without motor delay, the motor scores of young children with ASD did not differ significantly from those of young children with DD.

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