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Relationship between fundamental motor skills and physical fitness in children with global developmental delay

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ABSTRACT

Importance: Understanding the significance of motor skills in promoting physical fitness (PF) can offer valuable insights for devising comprehensive intervention and clinical rehabilitation programs for children with global developmental delay (GDD). However, it remains unclear whether fundamental motor skills (FMS) can improve the PF of children with GDD.

Objective: To investigate the correlation between FMS and PF in children with GDD.

Methods: A total of 180 children with GDD and 180 typically developing (TD) children aged 3–5 years were selected. All participants completed the Gesell Developmental Schedule, FMS, and PF tests at Beijing Children's Hospital between September 2022 and August 2023. Partial correlation and regression analyses were performed to examine the relationship between FMS and PF.

Results: Children with GDD had significantly lower FMS and PF scores compared to TD children ($P < 0.05$). No significant differences were found between males and females with GDD in FMS and PF score ($P > 0.05$). A more severe developmental delay was associated with lower FMS and PF scores. The correlation coefficients between individual FMS items and individual PF items, as well as the total PF score, ranged from 0.20 to 0.56. Regression analysis indicated that manual dexterity ($\beta = 0.241$, $P = 0.029$) and body balance ($\beta = 0.399$, $P = 0.001$) significantly predicted the total PF score.

Interpretation: In children with GDD, both FMS and PF are underdeveloped. Focusing on motor skills development is vital for promoting their PF.

KEYWORDS

Children, Global developmental delay, Fundamental motor skills, Physical fitness

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INTRODUCTION

Early childhood is a stage of rapid growth and development for the human body. This stage also serves as an important period for establishing a solid foundation of physical health throughout life. The motor abilities and physical fitness (PF) level at this stage can influence future health, habits, and psychological well-being. Children encountering developmental delays do not acquire these essential skills at the same pace as their typically developing peers. Consequently, they are at a greater risk of impaired health and subsequent social, emotional, and cognitive development delays throughout their lives.[1,2] Global developmental delay (GDD) is a type of neurodevelopmental disorder that poses a serious threat to physical and mental health.[3] Current research indicates that among children under 5 years old, the prevalence of GDD is approximately 1%–3%.[3,4] Despite continuous endeavors in diagnosing, treating, and preventing GDD over the years, no effective cure for children with GDD has yet been found. This persistent issue is primarily due to unclear pathogenesis, strong heterogeneity of clinical phenotypes, and the complex etiology and symptoms varying among patients.[5]

Motor development in early childhood typically refers to the evolution of fundamental motor skills (FMS), which include body control skills, movement abilities, and object control skills.[6] Such FMS involve non-naturally occurring basic motor learning models,[7] and serve as a foundation for children and adolescents' future participation in physical activities and sports.[8] These skills play a significant role in individual health and cognitive, emotional, and social development.[9] However, research indicates that children's proficiency levels in FMS worldwide are low,[10] with those in China experiencing a particular delay in development.[11] Children with neurodevelopmental disorders demonstrate a more pronounced delay and impairment in FMS proficiency compared to typically developing (TD) children.[12] Studies have found that children with developmental delays lack the motor capacity to perform FMS and risk subpar physical, social, and emotional functioning later in life.[2]

The development of motor skills and PF is a lifelong process. Children aged 3–6 years old experience not only a rapid increase in PF but also a golden period for the development of FMS.[13] Motor ability does not exist independently; it is closely tied to the physical condition of the individual. Individuals with superior motor abilities typically also have a healthy physical state, which is crucial for the development of children's and adolescents' motor abilities.[14,15] PF is an essential index for evaluating an individual's health level. This term usually refers to the basic capability of human muscle activity, signifying the response of various organ systems during muscle work. PF mainly alludes to "strength, speed, endurance, sensitivity, flexibility, coordination, balance, and other abilities".[16] In 2018, an analysis of PF monitoring data for 300 000 children aged 3–6 years across 130 cities and regions in China revealed troubling insights into the overall PF status of young children.[17] A comparison of the National Fitness Monitoring Reports from 2010, 2014, and 2020 indicates a downward trend in the PF of young children in China, including their muscle strength, balance, flexibility, and agility.[18] Enhancing PF is vital for boosting the overall health of children. Current studies have identified the functional relationship between FMS and PF in TD children, with motor skills shown to have a predictive effect on PF.[13,19,20] However, the link between FMS and PF in children with GDD is not well-defined. It remains unclear whether motor skills can improve the PF of children with GDD. Accordingly, this study underscores children with GDD, intending to evaluate their levels of FMS and PF and analyze the correlation between these two aspects. Understanding the significance of motor skills in promoting PF can offer valuable insights for devising comprehensive intervention and clinical rehabilitation programs for children with GDD.

METHODS

Ethical approval

This study was approved by the Ethics Committee of Beijing Children's Hospital, Capital Medical University (No: 2022E138Y). Informed consent was obtained from the parents or guardians of all participants who volunteered for the study.

Participants

Children with GDD

A total of 180 children diagnosed with GDD were selected from the Children's Health Care Clinic of Beijing Children's Hospital, Capital Medical University, from September 2022 to August 2023.

Inclusion criteria include: 1) Meeting the diagnostic criteria for GDD as outlined in the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (DSM-5)[21]; 2) The Development Quotient from the Gesell Developmental Schedule (GDS) being less than 75 in at least two domains of five indicators such as gross or fine motor skills, language, personal-social behaviors, and adaptive behavior; 3) The age is from 3 to 5 years old; 4) The children must complete the FMS and PF test assessments.

Exclusion Criteria: 1) participants with any genetic metabolic diseases, severe physical disorders, or hearing impairments. 2) Any other neurodevelopmental disorders apart from GDD.

Control group

Children aged 3–5 years, who were TD, were selected as the control group during routine physical examinations at the Children's Health Care Clinic of Beijing Children's Hospital, from September 2022 to August 2023.

Measures

Gesell developmental schedule

The Chinese version of the GDS, revised by Beijing Children's Hospital,[22] was utilized to assess the developmental level of children with GDD. The GDS encompasses five functional areas: gross motor, fine motor, language, individual-social, and adaptive behavior. The severity of GDD was determined by the total developmental quotient based on the results of the GDS: a quotient of 55–75 indicates mild developmental retardation, 40–54 shows moderate developmental retardation, 25–39 suggests severe developmental retardation, and a quotient less than 25 is considered extremely severe developmental retardation.

Due to the extreme developmental delays, children were unable to complete the FMS and PF test assessments. Therefore, only children with mild, moderate, and severe grades of developmental retardation were included in this study.

Physical fitness

The Standard Manual of National Physical Fitness Measurement's Physical Fitness test indexes (infant portion) were utilized,[23] encompassing six components: 10-meter shuttle run, standing long jump, tennis ball throw, continuous jumping with both feet, balance beam walk, and sit-and-reach. Individual test outcomes were determined using the standard age group tables, and the standard score was 5 points, allowing for a total score of 30 points (File S1).

Fundamental motor skills

The Movement Assessment Battery for Children, Version Two (MABC-2) was used to evaluate FMS. The tool encompasses three dimensions: manual dexterity, aiming and catching, and body balance ability. It features eight test items, namely: posting coins, threading beads, drawing trails, catching a beanbag, throwing a beanbag onto a mat, walking with raised heels, balancing on one leg, and jumping on mats. The norms for this assessment tool have been established in China and can be effectively applied to Chinese children (Table S1).[24]

The test team consisted of five test personnel, comprising scientific researchers and healthcare doctors. All test personnel underwent relevant theoretical and practical training before the commencement of the study.

Statistical analysis

The statistical analysis of the data was conducted using SPSS 26.0. The Kolmogorov-Smirnov test (K-S test) was implemented to examine the normal distribution of the data. The Mann-Whitney U test, Kruskal-Wallis test, and independent samples t-test were deployed to analyze the FMS and PF characteristics of children with GDD. Bonferroni correction was utilized for pairwise comparisons. We performed a partial correlation analysis to unearth the correlation between FMS and PF in children with GDD. Additionally, we conducted a regression analysis of these factors. The benchmark for statistical significance of difference was set at $P < 0.05$.

RESULTS

The basic characteristics of the participants

A total of 360 participants were included in the study, including 180 in the GDD group and 180 in the TD group. There were no significant differences in age, height, and weight between the two groups ($P > 0.05$) (Table S2).

FMS and PF scores by sex

The manual dexterity, aiming and catching, and body balance abilities of children with GDD were compared by sex with those of TD children. Both female and male children with GDD scored significantly lower in these skills than TD children ($P < 0.05$). Among GDD children, no significant differences in motor skill scores were found between males and females ($P > 0.05$) (Table 1).

The scores of the six individual items and the overall PF score for children with GDD, stratified by sex, were compared with those of TD children. Both the individual scores and the total scores for GDD children, regardless of sex, were lower than those of TD children ($P < 0.05$). However, within the GDD group, there was no significant difference between the PF scores of males and females ($P > 0.05$) (Table 1).

FMS and PF scores in GDD children with different levels of disorder

The Kruskal-Wallis test revealed significant differences in FMS among children with varying degrees of developmental delay (Table 2). Children with GDD had significantly lower skill scores compared to TD children ($P < 0.05$). The scores for manual dexterity and aim and catching were lower in the severe group compared to the mild group.

TABLE 1 Comparison of fundamental motor skills and physical fitness scores in the participants with different sexes

	Female			Male		
Variables	**GDD ($n = 54$)**	**TD ($n = 54$)**	***P***	**GDD ($n = 126$)**	**TD ($n = 126$)**	***P***
Fundamental motor skills						
Manual dexterity	6.0 (3.0, 9.0)	11.0 (9.0, 13.0)	0.001	6.0 (3.0, 7.0)	9.0 (8.0, 12.0)	0.001
Aiming and catching	5.0 (3.0, 7.0)	10.0 (8.0, 12.0)	0.001	5.0 (4.0, 8.0)	10.0 (8.0, 12.0)	0.001
Body balance ability	7.0 (5.0, 9.0)	13.0 (11.0, 15.0)	0.001	6.0 (5.0, 9.0)	11.0 (9.0, 16.0)	0.001
Physical fitness						
10-meter shuttle run	2.0 (1.0, 2.0)	3.0 (2.0, 4.0)	0.001	2.0 (1.0, 2.0)	3.0 (2.0, 4.0)	0.001
Standing long jump	3.0 (1.0, 4.0)	4.0 (4.0, 5.0)	0.001	2.0 (2.0, 3.0)	4.0 (3.0, 5.0)	0.001
Tennis ball throw	2.0 (1.0, 3.0)	3.0 (2.0, 4.0)	0.001	2.0 (1.0, 3.0)	3.0 (2.0, 4.0)	0.001
Continuous jumping with both feet	2.0 (1.0, 3.0)	4.0 (3.0, 5.0)	0.001	2.0 (1.0, 3.0)	4.0 (3.0, 5.0)	0.001
Sit-and-reach	2.0 (1.0, 3.0)	3.5 (2.0, 5.0)	0.001	2.0 (1.0, 3.0)	3.0 (2.0, 4.0)	0.001
Balance beam walk	1.0 (1.0, 2.0)	4.0 (3.0, 5.0)	0.001	1.0 (1.0, 2.0)	3.0 (2.0, 4.0)	0.001
Total score	12.0 (11.0, 15.0)	20.5 (18.0, 25.0)	0.001	13.0 (10.0, 15.0)	19.0 (15.0, 24.0)	0.001

Data are shown as median (Q1, Q3).
Abbreviations: GDD, global developmental delay; TD, typically developing.

TABLE 2 Comparison of fundamental motor skills and physical fitness scores in the participants with different disorder levels

	GDD				
Variables	**Mild ($n = 114$)**	**Moderate ($n = 46$)**	**Severe ($n = 20$)**	**TD ($n = 180$)**	***P***
Fundamental motor skills					
Manual dexterity	6.0 (5.0, 8.0)†,‡	4.5 (2.0, 6.0)†	3.0 (2.0, 5.0)†	10.0 (9.0, 13.0)	0.001
Aiming and catching	6.0 (5.0, 8.0)†,‡	4.5 (2.0, 7.0)†	2.0 (2.0, 5.0)†	10.0 (8.0, 12.0)	0.001
Body balance ability	6.0 (5.0, 9.0)†	5.0 (3.0, 8.0)†	4.0 (2.0, 6.0)†	12.0 (10.0, 16.0)	0.001
Physical fitness					
10-meter shuttle run	2.0 (1.0, 2.0)†,‡	2.0 (1.0, 2.0)†	1.0 (1.0, 1.0)†	3.0 (2.0, 4.0)	0.001
Standing long jump	3.0 (2.0, 4.0)†,‡	2.0 (1.0, 3.0)†	1.0 (1.0, 2.0)†	4.0 (3.0, 5.0)	0.001
Tennis ball throw	2.0 (2.0, 3.0)†,‡	2.0 (1.0, 3.0)†	1.0 (1.0, 2.0)†	3.0 (2.0, 4.0)	0.001
Continuous jumping with both feet	2.0 (1.0, 3.0)†	2.0 (1.0, 3.0)†	1.0 (1.0, 2.0)†	4.0 (3.0, 5.0)	0.001
Sit-and-reach	2.0 (1.0, 3.0)†	2.0 (1.0, 4.0)†	1.0 (1.0, 3.0)†	3.0 (2.0, 4.0)	0.001
Balance beam walk	1.0 (1.0, 2.0)†	1.0 (1.0, 2.0)†	1.0 (1.0, 1.0)†	3.0 (2.0, 4.0)	0.001
Total score	13.0 (11.0, 16.0)†,‡	12.5 (10.0, 15.0)†,‡	9.0 (8.0, 11.5)†	20.0 (16.0, 25.0)	0.001

Data are shown as median (Q1, Q3).
$^{\dagger}P < 0.008$ compared with TD group;
$^{\ddagger}P < 0.008$ compared with the severe group.
Abbreviations: GDD, global developmental delay; TD, typically developing.

However, no significant difference was found in body balance ability among children with different levels of GDD severity.

The six individual PF scores and the total PF scores of GDD children with varying disorder levels were compared with those of TD children. Across all disorder levels, GDD children had significantly lower individual and total PF scores compared to TD children ($P < 0.05$). The scores for the 10-meter shuttle run, standing long jump, and tennis ball throw were lower in the severe group compared to the mild group. However, the other three skills—sit-and-reach, continuous

TABLE 3 Comparison of fundamental motor skills and physical fitness scores in children with global developmental delay of different years

Variables	3–<3.5 years (n = 28)	3.5–<4 years (n = 37)	4–<4.5 years (n = 53)	4.5–<5 years (n = 62)	P
Fundamental motor skills					
Manual dexterity	6.0 (3.5, 8.0)†	6.0 (4.0, 9.0)†	6.0 (5.0, 8.0)†	4.0 (2.0, 6.0)	0.001
Aiming and catching	6.0 (5.0, 7.0)	5.0 (2.0, 8.0)	5.0 (4.0, 7.5)	5.0 (3.0, 8.0)	0.404
Body balance ability	7.5 (5.0, 10.0)	8.0 (5.0, 9.0)	6.0 (5.0, 9.0)	6.0 (4.0, 7.5)	0.060
Physical fitness					
10-meter shuttle run	2.0 (1.0, 2.0)	2.0 (1.0, 2.0)	2.0 (1.0, 2.0)	1.0 (1.0, 2.0)	0.131
Standing long jump	3.0 (1.8, 4.0)	2.0 (1.0, 4.0)	2.0 (2.0, 3.0)	3.0 (2.0, 3.0)	0.711
Tennis ball throw	2.0 (2.0, 3.0)	2.0 (1.0, 3.0)	2.0 (1.0, 3.0)	2.0 (1.0, 3.0)	0.789
Continuous jumping with both feet	3.0 (2.0, 4.0)	2.0 (1.0, 3.0)	2.0 (1.0, 3.0)	2.0 (1.0, 3.0)	0.128
Sit-and-reach	3.0 (1.3, 4.0)	2.0 (1.0, 3.0)	2.0 (1.0, 3.0)	2.0 (1.0, 3.0)	0.105
Balance beam walk	1.0 (1.0, 3.0)	1.0 (1.0, 2.0)	1.0 (1.0, 2.0)	1.0 (1.0, 2.0)	0.932
Total score	14.0 (11.0, 18.5)	12.0 (10.0, 15.0)	12.0 (10.0, 14.0)	12.0 (9.0, 16.0)	0.084

Data are shown as median (Q1, Q3).
†$P < 0.008$ compared with 4.5–<5 years old group.

jumping with both feet, and balance beam performance—did not show any difference across GDD severity levels ($P > 0.05$) (Table 2).

FMS and PF scores in participants across different ages

Children aged 3–5 years old experience rapid stages of growth and development. To explore age-related differences in FMS, we grouped children by 0.5-year increments. We compared the manual dexterity, aiming catching, and body balance abilities of children with GDD to those of TD children (Figure S1). Across all age groups, children with GDD scored significantly lower in these skills compared to TD children ($P < 0.05$). However, except for manual dexterity, the FMS scores within the GDD group were consistent across different age groups. The manual dexterity scores were lowest in the 4.5–5-year-old group compared to the other age groups (Table 3).

We also compared the six individual items and the overall PF scores amongst GDD children of various ages to those of TD children. As shown in Figure S2, GDD children consistently scored lower than TD children across all age groups. However, age did not have a statistically significant effect on PF scores within the GDD group ($P > 0.05$) (Table 3).

Partial correlation between FMS and PF in GDD children

After controlling for factors such as age, sex, and severity level, the correlation coefficient between individual FMS indices and the total score, as well as individual PF indices, ranged from 0.20 to 0.56 ($P < 0.05$) (Table 4).

TABLE 4 Partial correlation analysis of fundamental motor skills and physical fitness scores of children with global developmental delay

Variable	Manual dexterity	Aiming and catching	Body balance ability
10-meter shuttle run	0.32*	0.27*	0.20*
Standing long jump	0.34*	0.31*	0.56*
Tennis ball throw	0.15	0.27*	0.39*
Continuous jumping with both feet	0.37*	0.24	0.17*
Sit-and-reach	0.10	0.03	0.14
Balance beam walk	0.15	0.12	0.38*
Physical fitness total score	0.41*	0.30*	0.49*

*$P < 0.05$.

Regression analysis of FMS and PF in GDD children

The total score for PF is utilized as the dependent variable, with age, sex, and disorder level used as control variables. The independent variables comprise the standard score of manual dexterity, aiming and catching, and body balance ability. The regression model accounts for 33.6% of the variations in PF among GDD children. After controlling the independent variables, both manual dexterity ($\beta = 0.241$, $P = 0.029$) and body balance ability ($\beta = 0.399$, $P = 0.001$) significantly predict the total score for PF (Table 5).

TABLE 5 Regression analysis of fundamental motor skills and physical fitness of children with global developmental delay

Independent variable	*B*	SE	Beta	*t*	*P*
(Constant)	13.537	1.887	/	7.173	0.001
Age	−0.041	0.318	−0.011	−0.129	0.272
Sex	−0.474	0.713	−0.054	−0.665	0.392
Level	0.045	0.516	0.007	0.087	0.258
Manual dexterity	0.360	0.119	0.241	2.261	0.029
Aiming and catching	0.245	0.141	0.144	0.386	0.420
Body balance ability	0.527	0.124	0.399	3.218	0.001

DISCUSSION

This study investigated the FMS and PF levels in children diagnosed with GDD, focusing on differences and relationships between these factors. The study yielded the following findings: (1) Children with GDD have significantly less developed motor skills and PF levels compared to TD children, and this discrepancy broadens with age. (2) Sex differences do not affect FMS or PF levels in children with GDD. (3) The severity of GDD negatively impacts both FMS and PF levels. (4) A positive correlation exists between FMS and PF levels in children with GDD.

This study illustrates variations in FMS among children with varying degrees of developmental delay. A more severe degree of developmental delay correlates with a lower score of FMS, with the most pronounced disparity between children with severe impairment and TD children. This finding aligns with previous research on FMS in children with other neurodevelopmental disorders.[25] The development of FMS is critical for children to comprehend the world and engage with their environment.[1] These skills also play a significant role in executing physical activities and accomplishing basic life functions. Movement development enhances not only PF but also influences a child's intellectual, cognitive, emotional, and social growth. Studies have demonstrated that the development of various domains of energy in children follows specific patterns and rules, with these domains being closely interrelated and interacting with one another.[26] Numerous studies have shown a strong connection between movement and social interaction, adaptation, and language development.[27,28] Impairments in language and cognition can lead to developmental issues in motor skills.[29] Early motor behaviors are crucial for acquiring and practicing certain perceptual or cognitive skills. Disorders in motor development can impede the further development of these perceptual or cognitive skills, potentially resulting in cognitive development issues in young children.[9,30]

According to the International Classification of Functioning, Disability, and Health for Children and Youth, an individual's physical and motor functions depend on both environmental and personal factors. The individual restriction factor mainly indicates that a more severe disorder degree results in a lower developmental level, reduced adaptive capacity, and difficulty in understanding and performing complex skills. The external environment also significantly impacts children with GDD. Early motor development is closely linked to the maturation of the nervous system, a process that can be enhanced by individual motor experiences.[7] In the context of a child's nervous system development, gross motor movements are regarded as a foundational stage.[31] FMS should be taught and practiced via a suitable approach, encouragement, feedback, and guidance to ensure successful development.[32] TD children can develop basic skills through everyday life and kindergarten teaching activities. However, children with GDD frequently face challenges due to their lagging cognitive development and low levels of social adaptation. This can lead to limited engagement in everyday life and kindergarten activities, resulting in inadequate motor learning experiences and delayed motor skill development.

In this study, we discovered that children with GDD had a lower PF level compared to TD children. The golden age for a child's growth and development is between 3–6 years old. PF and FMS, two distinct but interrelated developmental areas, are crucial during this stage.[13] In TD children, children with low sports proficiency often exhibit poor PF.[33] Moreover, FMS has been revealed as an essential predictor of PF, implying that individuals with low exercise capacity are more predisposed to health-related issues.[33]

Furthermore, insufficient physical activity can lead to a decline in the PF of children and adolescents, with motor skills being a potential influencer of such activity.[15] Children who are less athletically inclined might choose a less active lifestyle to avoid motor difficulties.[7] This scenario can trigger a vicious cycle of ongoing inactivity, reduced physical activity, low athletic ability and fitness levels, and poorer health.

Currently, most scholars primarily focus on the relationship between FMS and PF in TD individuals, neglecting to explore this relationship in children with comprehensive developmental delays. In this study, we conducted a linear regression analysis on the scores of three motor skill dimensions and the PF scores of children with developmental delays. The results revealed a strong correlation between fine motor hand movements, body balance abilities, and the PF of these children. This finding aligns with research conducted on FMS and PF of TD individuals.[20]

Hand dexterity not only indicates the developmental stage of children's small muscle groups but is also closely related to their cognitive level.[33] Moreover, PF testing necessitates a certain degree of athletic ability, along with cognitive, sensory processing, planning, and other elements. Therefore, the fine motor level can influence the PF test scores of children with GDD.

Balance ability is crucial for children's healthy growth and forms the basis for engaging in sports and physical activities.[34] In TD individuals, balance ability represents muscle strength, body coordination, the speed of the central nervous system's information processing, and the functionality and sensitivity of various sensory organs. It serves as a comprehensive reflection of a person's physical condition.[35] Hence, body balance ability significantly influences the overall development of children's PF.

TD children demonstrated certain sex differences in PF and FMS.[20] However, the current study found no difference in PF and FMS for children with GDD across different sexes. Several factors may contribute to this phenomenon: 1) There might be subject bias as the selected subjects are children who visit the hospital for treatment; 2) Children with GDD exhibit characteristics of delayed development to a certain degree. Compared to children with normal development levels, their FMS and PF are deficient; hence, no differences are discernible between males and females.

In summary, children with GDD exhibit significantly lower levels of FMS and PF compared to their TD peers. The level of FMS in children with GDD effectively mirrors their PF levels, indicating that improving PF in children with GDD necessitates a focus on the enhancement of their motor skills. Intervention programs for children with GDD should not simply mimic those created for TD children. A deep understanding of the distinct aspects of motor skill development in children with GDD is imperative for developing personalized intervention strategies. Moreover, as children with GDD consistently trail behind their TD counterparts in motor skills and PF over time, the importance of early intervention for improved outcomes becomes increasingly evident.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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