Science Letters ISSN 2345-5463 DOI: https://doi.org/10.47262/SL/11.3.132023910

Data analysis
2023 | Volume 11 | Issue 3 | Pages 96-104

ARTICLE INFO

Received
July 15, 2023
Revised
September 04, 2023
Accepted
September 06, 2023
Published
October 09, 2023

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Keywords
Dyslexia
Learning disability
Mathematics
Phonological processing
Prevalence

How to Cite
Kunwar R. Investigation of the impact of dyslexia on mathematics achievements among secondary level students in Nepal. Science Letters 2023; 11(3):96-104

Open Access

Investigation of the Impact of Dyslexia on Mathematics Achievements Among Secondary Level Students in Nepal

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Abstract

Dyslexia, a specific learning difficulty, has a profound impact on reading skills, language processing and mathematical abilities. It hampers word recognition, spelling, comprehension and decoding skills. The objective of this study was to ascertain the occurrence of dyslexia and its influence on mathematics achievement among secondary school students in Nepal. A mixed-method research design was employed for this purpose. The sample included 904 students from grade IX selected randomly. To identify dyslexic students, quantitative data was collected using adapted assessment tools such as the dyslexic student's checklist for teachers (DSCT), dyslexic students' checklist for parents (DSCP) and dyslexia identification self-assessment questionnaire (DISQ). These tools were utilized to screen for dyslexia. Qualitative data was gathered through an observation checklist and semi-structured interviews with selected students to verify the presence of dyslexia. The findings of the study revealed a prevalence rate of 5.53% for dyslexic students at the secondary level, with a slightly higher prevalence among male students (5.94%) compared to female students (5.22%). Moreover, the research demonstrated that dyslexic students exhibited significantly lower achievement scores in mathematics when compared to their non-dyslexic peers.

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Introduction

Dyslexia, classified as a specific learning difficulty (SpLD), is a condition that is believed to be inherent and has long-lasting effects. It is crucial to recognize that learning difficulties do not reflect an individual's intelligence but rather stem from diverse information processing methods in the brain, which can vary significantly from person to person. Dyslexia primarily impacts the acquisition of language and literacy skills, and individuals with dyslexia may face significant hurdles in areas such as phonological processing, working memory and processing speed [1]. This difficulty in language processing extends to reading, writing, and spelling [2]. Students with dyslexia often encounter challenges with phonemic awareness, decoding, fluent word recognition and spelling [3], which can lead to difficulties in reading comprehension and reduced reading speed. Dyslexia is a recognized learning disability that impacts a student's reading, writing, and speaking abilities. It is classified as a specific learning disability and has a neurobiological basis [4]. Historically referred to as "reading blindness," dyslexia has been associated with reading difficulties rooted in neurological factors [5]. The term "dyslexia" is derived from the Greek words "dys," meaning impaired, and "lexis," meaning words or language. Consequently, dyslexia is characterized by challenges in speech, phonemic awareness, word decoding, and difficulties in rapid naming or recalling of familiar objects, such as colors, symbols, and numbers [5, 6]. However, the current understanding of dyslexia extends beyond reading difficulties alone [5]. It encompasses difficulties in acquiring reading and writing skills, cognitive processes and inconsistencies in academic performance [7, 8]. Dyslexia is a lifelong condition that can persist into adulthood [5]. The experiences of individuals with dyslexia can vary based on the severity of the condition [9, 10]. Some children may struggle with speech and vocabulary, while others may have difficulties with recognizing symbols and sounds. Similarly, some children may face challenges in number processing [8, 11].

According to Forrester et al. [8], dyslexia is a learning disability that primarily affects language skills, particularly reading and spelling. It specifically impacts the ability to read words accurately and fluently, as well as the skill of spelling words correctly [1, 11]. Dyslexia is characterized by difficulties in accurately recognizing and decoding words, often accompanied by poor spelling abilities [5]. It is not uncommon for individuals with dyslexia to also experience co-occurring challenges in attention, math and oral language, with approximately 50% of children with dyslexia showing symptoms of another learning disorder [11, 12].

Dyslexia encompasses two key aspects of specific learning difficulties: difficulties in speech processing when language or cognitive function relies on speech-based coding and challenges with reading [9, 13]. The development of dyslexia is influenced by a complex interplay of neurobiological, genetic and environmental factors [9, 14]. Dyslexia can lead to various behavioral problems, including anxiety, aggression, low self-esteem and social withdrawal from peers, parents, and teachers [15]. The severity of dyslexia directly impacts the formation of negative attitudes toward language and mathematics learning [5, 16]. These negative attitudes and concerns often hinder a child's ongoing education. Insufficient understanding of basic math facts, formulas, and symbols can hinder learning and problem-solving in other math-related subjects [16]. Moreover, it prevents students from acquiring logical reasoning skills applicable in diverse fields, not limited to mathematics alone [17]. Dyslexia primarily affects reading skills, but its impact can extend to other academic areas as well. Research conducted by Chinn and Ashcroft [18] suggests that dyslexic children often experience difficulties with short-term memory, which can affect their overall learning. Additionally, dyslexic students may take approximately 50% more time to complete arithmetic-related tasks compared to their non-dyslexic peers, indicating challenges with number recognition, calculation, and slower performance [19, 20]. In the context of mathematics, specific skills are required, including recognizing numbers and understanding symbols, mathematical rules, formulas, and their relationships. These challenges can make learning mathematics particularly challenging for dyslexic students [20]. However, dyslexic children can still retain basic number facts, especially through rote learning programs [18]. The difficulties dyslexic students face can hinder their comprehension of mathematical language and related concepts [21], making them more prone to struggling with solving verbal math problems compared to their non-dyslexic peers. The occurrence of dyslexia exhibits considerable variation across different countries. In the United States, estimates suggest that dyslexia affects approximately 5% to 17% of children, while

in the United Kingdom, the prevalence ranges from 3% to 6% [22]. In Europe, dyslexia or similar learning disorders can be prevalent in as much as 15% of the population [23]. Non-English-speaking countries like China also witness varying prevalence rates, ranging from 3.0% to 12.6% among school-aged children [24]. These differences in prevalence rates can be attributed to the distinct writing systems employed across different cultures [25].

Research on learning disabilities, including dyscalculia and dyslexia, is limited in Nepal. Additionally, there is a lack of official diagnosis and specific studies dedicated to students facing these learning difficulties [8, 26]. The phonological and written language difficulties associated with dyslexia can have implications for mathematics as well, given the reliance on language and reading skills in mathematical tasks. Despite an increase in awareness of hidden learning disabilities in Nepal over the past two decades, the country still lacks strategic initiatives for early identification, intervention, and support of students with dyslexia [8, 26]. Moreover, students with dyslexia face a higher likelihood of encountering challenges in mathematics, especially in areas such as word problems, logic and abstract reasoning [27]. This study aimed to determine the prevalence of dyslexia among basic-level school students and its impact on mathematics achievement. By understanding the frequency of dyslexia in this student population, the researchers sought insights into its implications for education. They also examined how dyslexia affects students' performance in mathematics, uncovering potential challenges. The study aimed to provide valuable insights into the influence of dyslexia on academic achievement in basic-level mathematics education.

Methods and Materials

A mixed-method research design was employed in this study, utilizing both quantitative and qualitative approaches. The quantitative approach was utilized to screen for dyslexic students, while the qualitative approach was used to verify the diagnosis. In the quantitative phase, several survey tools were employed to identify potential dyslexic students, while the qualitative phase involved observation and semi-structured interviews for confirmation. The study focused on students enrolled in grade IX of institutional schools located in Kathmandu Valley. A simple random sampling technique was then used to select six institutional schools from each of the three districts Kathmandu, Lalitpur and Bhaktapur. The study sample consisted of a total of 904 students randomly selected from 18 different schools. Among the participants, 517 were female students, while 387 were male students. The age range of the students included in the study was between 13 and 16 years.

The tool Dyslexic Students' Checklist for Teachers (DSCT) was adapted from the Luke Waites Center for Dyslexia and Learning Disorders at the Scottish Rite for Children, Teacher Questionnaires 2020, USA. It consists of 35 items that cover seven dyslexic factors. Similarly, the Dyslexic Students Checklist for Parents (DSCP) was adapted from the Swindon Dyslexia Centre in the United Kingdom, comprising 15 items that address dyslexic factors such as reading, spelling, writing, memory, and mathematics. Both the DSCT and DSCP tools were used in the screening approach to identify dyslexic students based on the presence of a majority of the listed behaviors marked or accepted in the tool. The Dyslexia Identification Self-Assessment Questionnaire (DISQ) tool was adapted from the British Dyslexia Association for Dyslexia Diagnosis. It consists of 15 Likert-type items on a four-point scale, ranging from "rarely" to "mostly" for items 1-10, and "easy" to "very difficult" for items 11-15. The DISQ primarily focuses on the characteristics of dyslexic learners, although many of the questions can also apply to non-dyslexic learners. Various tools were used to identify dyslexic learners, and the DISQ assigns a specific score to each scale based on dyslexic attributes. Dyslexia is defined based on the obtained score, with individuals scoring less than 45 considered probably non-dyslexic, those scoring 40-60 classified as mildly dyslexic, and those scoring above 60 categorized as severely dyslexic.

To ensure linguistic accuracy, all checklists and questionnaires were translated into Nepali and reviewed by a language expert. They were then piloted in a non-sampled school in the schools of Kathmandu Valley to assess their practicality and standardize them. Subsequently, a student observation checklist and semi-structured interview were used to verify dyslexic learners. The observation checklist involved evaluating students based on their writing, homework and classwork, recent progress reports, math test results, loud reading observations, and overall student activity. Similarly, the semi-structured interview focused on cognitive abilities related to the students and their family's difficulty in processing speech and sound, developmental delays in literacy skills, variations in

languages including pronunciations, alphabets, and scripts, as well as emotional problems. Students displaying dyslexic characteristics based on the DSCT, DSCP, and DISQ were observed by the researcher on school premises using an observation checklist. Semi-structured interviews were conducted with the identified students to eliminate biases and subjectivity and further verify the dyslexic students identified through the quantitative survey. Furthermore, the researcher examined the final Grade Point Average (GPA) of the doubtful dyslexic students in their previous mathematics grades at their respective schools to assess the impact of dyslexia on mathematics achievement.

Results

Results obtained from quantitative tools

The data collected through the DSCT, DSCP, and DISQ quantitative survey tools for students displaying potential dyslexic characteristics were compiled and organized in tabular format. The organization was based on districts, schools, and gender. The results obtained from the three tools generally showed consistency in identifying dyslexic characteristics among students, with only a few cases of overlapping characteristics. Table 1 presents the students who were identified as doubtful through the three different tools. Table 1 provides evidence supporting the validity and effectiveness of the dyslexia screening tools used to identify dyslexic students. The results from the three tools show a high level of agreement, indicating their reliability in identifying dyslexic characteristics. Although there were a few cases where student characteristics were unclear or showed inconsistencies, overall, the results obtained from the DSCT and DSCP tools align reasonably well with the findings from the DISQ tool. These findings reinforce the confidence in the accuracy of the screening process and the identification of dyslexic students.

Results obtained from qualitative tools

As part of this study, qualitative data was collected through student observation, which served as a valuable tool for validating the findings obtained from the three quantitative assessment tools. Student observation involved directly observing students in their natural environment, offering a more authentic, reliable, accurate, and effective means of gathering robust data. Due to time limitations, only students who were identified as potentially dyslexic were selected for observation, while those identified as dyslexic in all three tools were not included. The primary focus was on observing students who

Table 1 The results obtained from the tools (DSCT, DSCP and DISQ) about Dyslexic students.

District-wise schools	No. of dyslexic students verified by observation checklist and interview							
	Students gender		DSCT		DSCP		DISQ	
	Female	Male	Female	Male	Female	Male	Female	Male
Kathmandu								
Ks_1	27	19	3	1	2	1	2	1
Ks_2	31	22	2	1	1	1	1	2
Ks_3	34	27	2	2	2	2	2	2
Ks_4	33	24	2	1	2	1	2	1
Ks_5	32	23	2	1	3	1	2	2
Ks_6	28	21	1	1	2	1	1	1
Lalitpur								
Ls_1	24	21	1	1	1	1	1	1
Ls_2	28	22	1	2	1	2	1	2
Ls_3	29	22	2	2	2	1	2	1
Ls_4	27	21	3	1	1	2	1	1
Ls_5	29	23	2	1	2	2	2	2
Ls_6	26	18	2	1	2	1	1	1
Bhaktapur								
Bs_1	31	17	3	1	2	1	2	1
Bs_2	26	21	1	1	1	1	1	1
Bs_3	25	21	2	1	1	2	1	1
Bs_4	27	20	3	2	3	2	2	2
Bs_5	29	23	1	1	2	1	1	1
Bs_6	31	22	2	2	2	2	1	2

DSCT: Dyslexic students' checklist for teachers, DSCP: Dyslexic students' checklist for parents, DISQ: Dyslexia identification self-assessment questionnaire
Ks: School of Kathmandu district, Ls: School of Lalitpur district, Bs: School of Bhaktapur district

showed dyslexic indications in one or both of the tools, with the aim of confirming their dyslexic status. Based on the reports generated from the observation process, the students who were initially doubtful were classified as either dyslexic or non-dyslexic. The verified dyslexic students were then organized by gender and are presented in Table 2 for reference. The report generated from student observation and the insights gathered through semi-structured interviews played a critical role in validating the dyslexic characteristics and behaviors of the initially identified doubtful students. Table 2 presents intriguing findings where the results obtained from the observation and interviews sometimes conflicted with the initial identification of students as dyslexic or non-dyslexic. For example, there was a male student who was not initially identified as dyslexic according to the DSCP tool, but through observation, it was later confirmed that he exhibited dyslexic traits. Conversely, in some cases, the observation and interview processes aligned with the results obtained from the quantitative tools. For instance, a male student who was identified as dyslexic using both the DSCT and DSCP tools was further verified as a dyslexic student through the observation and interview processes. These findings emphasize the importance of employing multiple assessment methods to gain a comprehensive understanding of the dyslexic characteristics and behaviors displayed by students. The observation and interview processes served to either support or challenge the initial identification, shedding light on the dynamic nature of dyslexia assessment and the need for a holistic approach.

Gender and district-wise distribution of dyslexia

Table 3 presents the distribution of dyslexic students based on gender. Out of the total sample size of 904 students, 50 students were diagnosed with dyslexia, resulting in a dyslexia prevalence rate of 5.53%. The prevalence rate of dyslexia was slightly higher among boys compared to girls. However, a statistical analysis using a significance level of $p < 0.001$ revealed no significant difference in the prevalence rates between boys and girls. Specifically, 5.22% of the female students were identified as dyslexic, while 5.94% of the male students were identified as dyslexic. This indicates a slightly higher prevalence rate of dyslexia among male students. Moreover, when comparing the dyslexia prevalence rates across districts, it was found that the rates were relatively similar in Kathmandu and Lalitpur districts. However, the

Table 2 Observation and interview results of the suspicious students**.**

District-wise schools	No. of dyslexic students verified by observation checklist and interview							
	Students gender		DSCT		DSCP		DISQ	
	Female	Male	Female	Male	Female	Male	Female	Male
Kathmandu								
Ks_1	27	19	3-1=❷	1☑	2☑	1☑	2☑	1☑
Ks_2	31	22	2-1=❶	1☑	1☑	1☑	1☑	2-1=❶
Ks_3	34	27	2☑	2☑	2☑	2☑	2☑	2☑
Ks_4	33	24	2☑	1☑	2☑	1☑	2☑	1☑
Ks_5	32	23	2☑	2-1=❶	3-1=❷	1☑	2☑	1☑
Ks_6	28	21	1☑	1☑	2-1=❶	1☑	1☑	1☑
Lalitpur								
Ls_1	24	21	1☑	1☑	1☑	1☑	1☑	1☑
Ls_2	28	22	1☑	2☑	1☑	2☑	1☑	2☑
Ls_3	29	22	2☑	2-1=❶	2☑	1☑	2☑	1☑
Ls_4	27	21	3-2=❶	1☑	1☑	2-1=❶	1☑	1☑
Ls_5	29	23	2☑	1+1=❷	2☑	2☑	2☑	2☑
Ls_6	26	18	2-1=❶	1☑	2-1=❶	1☑	1☑	1☑
Bhaktapur								
Bs_1	31	17	3-1=❷	1☑	2☑	1☑	2☑	1☑
Bs_2	26	21	1☑	1☑	1☑	1☑	1☑	1☑
Bs_3	25	21	2-1=❶	1☑	1☑	2-1=❶	1☑	1☑
Bs_4	27	20	3-1=❷	2☑	3-1=❷	2☑	2☑	2☑
Bs_5	29	23	1☑	1☑	2-1=❶	1☑	1☑	1☑
Bs_6	31	22	2☑	2☑	2☑	2☑	1+1=❷	2☑

● The black circled letters denote the actual number of dyslexic students after observation.
☑ Check square boxes in Table 2 denote the verified dyslexic students
DSCT: Dyslexic students' checklist for teachers, DSCP: Dyslexic students' checklist for parents, DISQ: Dyslexia identification self-assessment questionnaire
Ks: School of Kathmandu district, Ls: School of Lalitpur district, Bs: School of Bhaktapur district

prevalence rate in Bhaktapur district was slightly higher compared to the other two districts. Overall, the study found that 5.53% of students aged between 14 and 16 years were identified as dyslexic, highlighting the presence of dyslexia within this age group.

Mathematics achievement level of the dyslexic learner

The study collected district-level final test scores in mathematics for grade VIII students from the school records of the sampled participants. These scores were categorized based on the approved range of categories for the school grade point average, as determined by the curriculum development center in Nepal. However, the first category, labeled as "not-graded," had a broad range. To provide a more detailed analysis, this category was further subdivided into two sub-ranges: 0-19 and 20-34. Upon analyzing the students' achievement scores, it was observed that a significant number of dyslexic students either failed to pass or obtained low scores in mathematics. However, it is crucial to note that there were also a considerable number of non-dyslexic students who obtained very low scores in mathematics. Table 4 presents the test scores of both dyslexic and non-dyslexic students in mathematics, enabling a comparison between the two groups. This analysis allows for a deeper understanding of the performance disparities between dyslexic and non-dyslexic students in the subject of mathematics.

Discussion

Dyslexia, a specific learning disorder, can have a profound impact on various aspects of learning, including mathematics. The symptoms and manifestations of dyslexia can vary greatly from person to person, but common indicators include word skipping, difficulties with letter recognition, spelling challenges, and impaired reading comprehension [11]. These symptoms often become apparent in early childhood, and children with dyslexia may struggle with learning the alphabet, identifying rhyming patterns, and pronouncing familiar words [28]. Dyslexia not only affects reading and writing abilities but also impacts other areas such as short-term memory, attention deficits, and motor skills [11]. These difficulties hinder students' ability to effectively handle tasks involving reading, writing, and mathematics, thereby affecting their overall academic achievements [29]. The development of dyslexia is influenced by various factors, including neurological and genetic factors, cognitive factors, environmental factors, and cultural differences [30]. The screening and identification process for dyslexia can be challenging due to its complex nature. However,

Table 3 Gender-wise prevalence of dyslexic students at the basic level.

Characteristics	Dyslexia (N = 50)	No dyslexia (N = 854)	Prevalence rate (%)	χ^2 $p<0.001$
Female	27	517	5.22	2.887
Male	23	387	5.94	
Districts				
Kathmandu	17	304	5.59	
Lalitpur	16	274	5.83	
Bhaktapur	17	276	6.15	
Total	50	904	5.53	

Table 4 Mathematics test scores of the students.

Range of scores	Dyslexic students		Non-dyslexic student		Letter grade	Performance	GPA
	Male	Female	Male	Female			
0-19	14	11	3	2	NG	Not graded	-
20-34	10	9	10	6	NG	Not graded	-
35-39	2	2	26	32	D	Basic	1.6
40-49	1	1	93	122	C	Acceptable	2.0
50-59	-	-	109	130	C+	Satisfactory	2.4
60-69	-	-	72	86	B	Good	2.8
70-79	-	-	36	81	B+	Very good	3.2
80-89	-	-	9	13	A	Excellent	3.6
90-100	-	-	6	8	A+	Outstanding	4.0
Total	27	23	364	480			

GPA: Grade point average

researchers and experts widely agree that dyslexia primarily stems from neurological irregularities within the brain, rather than being solely caused by factors like lack of motivation, sensory impairments, or emotional issues [31]. Efforts have been made in educational research to identify and address the challenges faced by individuals with dyslexia. Cognitive and achievement tests serve as fundamental tools for diagnosing dyslexia [32]. However, dyslexic children continue to face ongoing challenges, often due to a lack of teacher awareness about dyslexia and inadequate screening [33].

The prevalence of dyslexia varies across different countries and populations, and accurate measurements can be challenging. Estimates indicate that dyslexia affects approximately 5-10% of the population, with variations in prevalence rates observed in different countries. For example, the prevalence of dyslexic students among school-age children in the United States is estimated to be as high as 17%, while in the United Kingdom, it ranges from 3% to 6% [30]. In India, the estimated frequency of dyslexic students among school-age children is between 5% to 17%, with a prevalence of 6% among primary school children [15]. The prevalence of dyslexia can also differ based on languages, diagnostic tools, and criteria. For instance, the prevalence rate of dyslexia among school-age children in the Chinese language ranges from 3.0% to 12.6%, while approximately 17.5% of native English-speaking students are identified as having dyslexia [24, 34]. These variations highlight the influence of language and cultural factors on dyslexia prevalence. Dyslexia can significantly impact students' performance in mathematics. Despite mathematics being a subject that involves numbers and symbols, dyslexic students may struggle with reading and understanding mathematical instructions and word problems, which are essential for solving mathematical tasks [35]. Difficulties in decoding, comprehension, auditory processing, visual processing, organizational skills, and attention can all hinder dyslexic students' mathematical learning [21, 35]. The cognitive deficits associated with dyslexia, such as phonological processing difficulties, can adversely affect students' literacy skills and mathematical performance [11, 28]. As a result, dyslexic students often achieve lower scores in mathematics compared to non-dyslexic students [36]. These challenges can have long-term consequences, as individuals with dyslexia are at a higher risk of experiencing depression, low self-esteem, reduced social activity, and higher rates of unemployment in adulthood [37]. In conclusion, dyslexia is a complex learning disorder that affects various aspects of learning, including mathematics. The prevalence of dyslexia varies across countries and populations, and accurate diagnosis and effective treatment are crucial for addressing the challenges faced by individuals with dyslexia. Dyslexic students often experience difficulties in phonological processing, reading comprehension, and retaining knowledge, which impact their mathematical performance. The cognitive deficits associated with dyslexia contribute to their lower scores in mathematics compared to non-dyslexic students. Addressing these challenges and providing appropriate support and accommodations are essential to help dyslexic students succeed in mathematics and other academic areas.

Conclusions

Dyslexia is a specific learning disability characterized by difficulties in reading and writing skills. It has a significant impact on information processing, literacy acquisition, organizational skills, and mathematical abilities. Dyslexia specifically affects short-term memory, processing speed, sequencing, quantitative reasoning, reading, and comprehension. In this study, the prevalence of dyslexia was determined by assessing cognitive and linguistic aspects for screening and diagnosis. While cognitive assessments may not offer the same level of precision as neuroimaging or clinical techniques [38], they play a valuable role in helping evaluators understand the "what," "how well," and "why" of dyslexia [39]. Cognitive assessments provide valuable insights into individual differences among learners, enabling the selection of targeted and personalized interventions [40]. They also raise awareness about the impact of dyslexia in various domains such as mathematics, science, and language. Therefore, it is crucial to emphasize and increase knowledge regarding the prevalence of dyslexia and its impact. The findings of this study offer valuable insights into the influence of dyslexia on the mathematics achievement of elementary-level students in Nepal. It is noteworthy that a significant number of children identified as having dyslexia in the study did not receive any specialized educational services, as reported by both parents and schools. This highlights the ongoing need to enhance awareness of this disorder and its consequences within research and educational

environments. By increasing awareness, teachers and relevant authorities in schools can better identify dyslexic students and implement intervention programs to improve outcomes and prevent the condition from worsening.

Acknowledgments

The investigator would like to extend sincere gratitude to the dedicated school staff, students and parents for their invaluable support and cooperation throughout the research project. Their unwavering commitment and participation were instrumental in ensuring the successful completion of the study within the specified timeframe. Their willingness to contribute their time and efforts is greatly appreciated and has significantly enriched the findings of this research. I would also like to acknowledge the financial support provided by the University Grants Commission (UGC) Nepal for funding this research project. The funding played a crucial role in the successful completion of the research.

Conflict of interest

The authors declare no conflict of interest.

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