



## Consequence of mathematical anxiety on students' achievements in mathematics - what does research say?

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### Abstract

*Mathematics anxiety affects students across all abilities and levels. Why is math anxiety related to poor math performance and how can we reduce this linkage? Teachers must learn how to effectively alleviate these problems using the most current research and best practices. This paper focuses on the causes for mathematical anxiety and explores the ways it can be handled at school level. Current behavioural and psycho-physiological research reveals that the math anxiety math performance link is related to both individual (cognitive, affective/physiological, motivational) and environmental (social and contextual) factors. Several interventions have recently been developed to alleviate the relation between math anxiety and math performance. To lower math anxiety and reduce its relation to poor math performance, future interventions may benefit from focusing on both math-anxious individuals themselves and those around them.*

**Keywords:** mathematical, anxiety, mathematics, environmental, interventions

### 1. Introduction

Mathematics gives students the language through which they can interpret, analyse, describe, make predictions, and solve problems in everyday life. It allows them to participate in a wide range of mathematical experiences and relationships both in school and in daily living. All students need higher level math and reasoning skills to be successful in today's technological society. Mathematics anxiety has a negative relationship with mathematics performance and achievement (Green, 1990; Hembree, 1990; Mevarech, Silber & Fine, 1991; Norwood, 1994; Wigfield & Meece, 1988)<sup>[6]</sup>, though it has also been found that a degree of cognitive anxiety (worry or concern) may motivate student to try harder. It is when this worry or concern becomes too strong that it may interfere with performance (Ho, Senturk, Lam, Zimmer, Hong, & Okamoto, 2000; Wigfield & Meece, 1988). A major negative consequence of mathematics anxiety is mathematics avoidance (Hembree, 1990)<sup>[6]</sup>.

### 2. Objectives

This paper focuses on the multi-dimensions of math anxiety, how this anxiety manifests itself in the classroom and to draw a comprehensive picture of what is necessary to teach mathematics to students having mathematical anxiety to engage and inspire all students to innovate, achieve, and succeed in a safe and supportive environment by ensuring high quality instruction in every classroom, every day.

### 3. Methodology

National and international journals, government documents, doctoral theses, and research articles have been used as secondary source of information.

### 4. Findings

#### 4.1 Definition and consequences

In terms of the affective domain, the emotion of anxiety,

specifically mathematics anxiety or math phobia has received by far the most attention in the literature in the past decades, mainly as a result of the fact that recognition has been given to the fact that mathematics anxiety plays an important role in the teaching and the learning of mathematics (Beasley *et al.*, 2001). The exact nature of the role anxiety plays is, however, still tentative and research results are often contradictory. Mathematics anxiety is defined by researcher in various ways, such as:

- One definition of math anxiety is "the panic, helplessness, paralysis, and mental disorganization that arises among some people when they are required to solve a mathematical problem". (Source: Tobias and Weissbrod (1980)).
- An inability by an otherwise intelligent person to cope with quantification and more generally mathematics" (Krantz, 1999).
- An "irrational dread" that 'interferes with manipulation of numbers and solving of mathematical problem (Buckley and Ribordy cited in Furner *et al.*, 2003).
- A "lack of comfort" when required to do mathematics (Wood cited in Ma, 1999).
- An "anxious state" perceived to be "threatening to self-esteem" (Cernen cited in Ma 1999, Hall & Holiday 2000 citing Roundsl Hendel).
- Math anxiety is a serious and pervasive problem, especially in the community-college setting. Students may experience math anxiety in many forms and degrees, from "freezing up" during a math exam, to attempting to avoid anything having to do with numbers. Symptoms may be physical or psychological and may include (but not be limited to) any of the following:

**Physical:** Nausea, shortness-of-breath, sweating, heart palpitations, increased blood pressure.

**Psychological:** Memory loss, paralysis of thought, loss of self-confidence, negative self-talk, math avoidance, isolation (thinking you are the only one who feels this way).

These symptoms and other negative math experiences may lead to a “vicious cycle” in which fear of math interferes with learning math which leads to more negative math experiences. (Source: Preis, Christy; Biggs, Bobbie T. 2001)

All these definition share a common theme, i.e. mathematics anxiety interferes with cognitive process (such as working memory and memory recall) required during problem solving. In this regard Kaja (2002) noted that “mathematics anxiety, like generalized anxiety, hijacks short term or working memory, as intrusive thoughts encroach on the computation at hand”. In addition to interfering with cognitive process mathematics anxiety is also believed to interfere within the affective domain: it is viewed to be both detrimental to the individual into in terms of self-esteem and confidence. This in turn, has a detrimental effect on performance (Cates *et al.*, 2003; Ma, 1999; Maree *et al.*, 2005; Tobias 1991). Math anxiety causes children to fear math. The anxiety hinders a child’s ability to make math a relevant part of their everyday life. According to Sheila Tobias (1993), millions of adults are blocked from professional and personal opportunities because they fear or perform poorly in mathematics for many; these negative experiences remain throughout their adult lives. Baroody and Costlick (1998) suggested that children who develop a math anxiety tend to fall into a self-defeating, self-perpetuating cycle. He further described a math anxiety model which illustrates how unreasonable beliefs can lead to anxiety, anxiety can lead to protective behavior, and the long term disadvantage of protective behavior can reinforce unreasonable beliefs. In this cycle and without the interception of any new techniques, children will continually feed into their anxiety and unreasonable beliefs. This anxiety can come in many forms: worry, fear, high negative emotions, self-deprecatory thoughts, sweaty palms, or a racing heart, Mathematics anxiety is an emotion that is believed to manifest itself in various ways:

- Cognitively in the form of worry (Cates *et al.*, 2003; Ho *et al.*, 2002; Kazelskis *et al.*, 2000; Pajeres & Urda 1996)
- Emotionally in the form of stress or fear (Cates *et al.*, 2003; Ho *et al.*, 2002; Kazelskis *et al.*, 2000; Pajeres, 1996).
- Attitudinally in the form of a negative attitude towards mathematics (Furner *et al.*, 2003, Ma 1999).
- Behaviourally such as avoiding of classes (Ho *et al.*, 2002)
- Physiologically such as in excessive sweating, nail biting or the inability to speak or think clearly, paralysis of thought, heart palpitations and nausea (Krantz 1991, Ma, 1999, Maree *et al.*, 1997, 1999, Perry, 2004).

Math anxiety often results in avoidance of math and math-related situations altogether (Ashcraft MH, Ridley KS, 2005). Its negative consequences may include: poor performance on standardized math tests and general difficulty with math-related problem-solving (Hembree R. 1990) <sup>[6]</sup>; reduced efficiency in solving simple arithmetic problems [Imbo I, Vandierendonck A, 2007]; or difficulties in basic numerical processing [Maloney EA, Ansari D, Fugelsang JA, 2010].

Math-anxious individuals perform poorly on math tasks that rely substantially on working memory, such as addition that involves carrying, but do not show decrements when the problems can be solved via simple fact retrieval [Ashcraft MH, Kirk EP:2001]. Consequently, it is hypothesized that worries and intrusive thoughts associated with math anxiety reduce working memory resources needed for cognitively demanding math tasks.

Mathematics anxiety is believed to be related to other subject specific anxieties such as statistics anxiety (Baloglu, 2004), although the one does not necessarily imply the other (Kazelskis *et al.*, 2000) for example believed that test and mathematical anxiety are induced the same construct but found little empirical support for the notion. Kaja (2002) as well as Ho *et al.*, (2000) expressed the opinion that mathematics anxiety is distinct from test anxiety.

## 4.2 Causes

### 4.2.1 Individual

#### 4.2.1.1. Cognitive

Working memory is a limited short-term memory system that enables one to attend to the relevant task at hand while inhibiting irrelevant information (Miyake A, Shah P, 1999). Accordingly, poor math performance may be due to anxiety-related depletion of cognitive resources, and such effects may dissipate among individuals who, by recruiting brain regions associated with cognitive control, successfully reappraise their negative emotions prior to math performance. It is also important to point out that working memory capacity differs across individuals: some individuals have more capacity and others have less. Higher working memory individuals may be more likely negatively affected by anxiety that co-opts working memory they would otherwise use to carry out difficult math tasks. Indeed, the negative relation between math anxiety and math achievement is the strongest among students with high working memory [Ramirez G, Gunderson EA, Levine SC, Beilock SL, 2013 \_]. Additionally, in children with high working memory capacity, math anxiety negatively relates to math achievement via a reduction in reliance on retrieval-based strategies (considered working-memory-demanding for young children; [Ramirez G, Chang H, Maloney EA, Levine SC, Beilock SL, 2015 \_]), suggesting that anxiety impacts high-working-memory individuals’ use of working-memory-intensive strategies. Increased anxiety-related interruption among those with higher working memory may persist while learning new math knowledge [Vukovic RK, Kieffer MJ, Bailey SP, Harari RR, 2013]

#### 4.2.1.2. Affective/physiological

In general, anxiety is associated with various affective and physiological responses. High levels of math anxiety are known to be associated with increased cardiovascular activity (Faust, PhD thesis, Bowling Green State University, 1992), increased salivary cortisol concentration predicting poor math performance (within high-working-memory individuals; [Mattarella-Micke A, Mateo J, Kozak MN, Foster K, Beilock SL, 2011]), and increased activation in brain regions associated with pain perception [Mattarella-Micke A, Mateo J, Kozak MN, Foster K, Beilock SL, 2012] and negative emotional processing [Young CB, Wu SS, Menon V, 2012].

#### 4.2.1.3. Motivation

Few studies have examined math motivation as a factor that may influence the math anxiety-math performance relation. Wang *et al.* [2015\_] showed that intrinsic math motivation moderates the patterns of relation between math anxiety and math performance. Those with low math motivation show a linear, negative relation between math anxiety and math performance. That is, math anxiety may not uniformly impact math performance across individuals varying in motivation.

#### 4.2.2 Environmental (Social and Contextual)

Social and contextual factors are vital in explaining how math anxiety expands and how it relates to math performance [Wang Z, Lyons IM *et al.* 2014]. Teachers' math anxiety and classroom activities, parental math anxiety, support and expectations, and students' perceived classroom environment [Beilock SL, Gunderson EA, Ramirez G, Levine SC, 2010] are non-negligible social or contextual factors that may affect the math anxiety-math performance relation.

##### 4.2.2.1 Teachers and Parents

Teachers and parents are role models for children — their attitudes toward, and ability to teach, math may indirectly influence the students' levels of math anxiety and their math performance. Among low-income minority second graders, parental home support and expectations influence their child's performance on word problems and algebraic reasoning by reducing the child's math anxiety [Vukovic RK, Roberts SO, Green Wright L, 2013\_] [24]. The benefits of home support may, however, inadvertently backfire if parents are highly math-anxious. First and second grade students' parents' math anxiety is associated with reduced growth in math achievement and increased math anxiety among students across the school year, when their parents report frequently helping with students' math homework [Maloney EA, Ramirez G, Gunderson EA, Levine SC, Beilock SL, 2015\_].

##### 4.2.2.2 Students

Students' perceived classroom environment plays an important role in students' math performance. Fourth to sixth grade students who perceive their classroom as more caring, challenging, and mastery-oriented have higher levels of math self-efficacy, and in turn, higher math performance [LA, Lewis JL, Bryant MJ, Bocian KA, Cardullo RA, Rettig M, Hammond KA, 2013]. Math self-efficacy (the degree to which the student believes he or she is capable of performing on math) is significantly related to math anxiety. For example, in second grade students, lower math self-efficacy predicts higher levels of math anxiety [Jameson MM, 2013\_]. Taken together, various social and contextual factors appear to contribute to the development of math anxiety. Many of these factors also strengthen the relation between math anxiety and math performance.

Ma (1999) asserted that a search for the causes of mathematics

anxiety is elusive while Furner *et al.*, (2003) viewed mathematical anxiety to be caused by:

- Socioeconomic background: including insufficient exposure to everyday applications of mathematical concepts covered in class and parental attitude towards mathematics.
- The educator's own attitude towards mathematics and poor institution by the educator. Expanding on the issue of educator attitude, Yushau *et al.*, (2004) in their report on the conceptions, learning and teaching of mathematics, attributed fears and anxiety of mathematics to the instructional approach of the teaching of mathematics.
- Previous learning experience: Previous poor performances in mathematics result in anxiety (Ho *et al.*, 2000).
- Other causes of mathematics anxiety include belief system (Furner *et al.*, 2003; Yushau *et al.*, 2004) feelings of inadequacy and fear of failure (Perry, 2004) poor test preparation and ineffective study methods (Ho *et al.*, 2000).

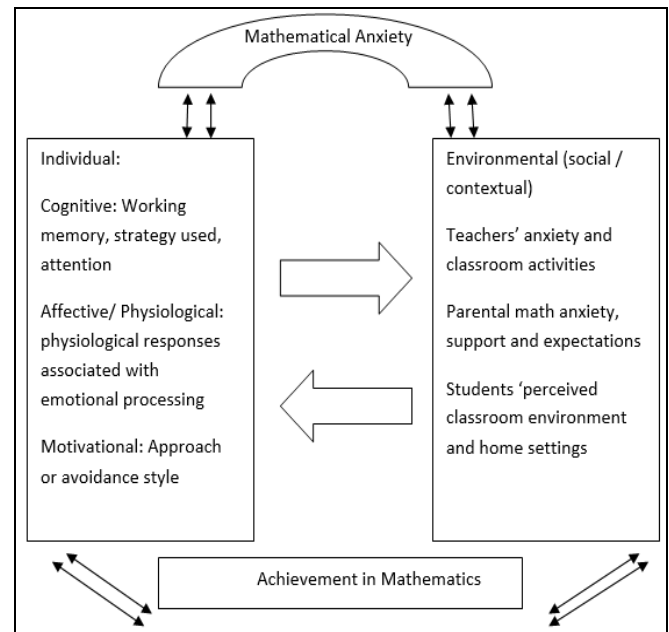
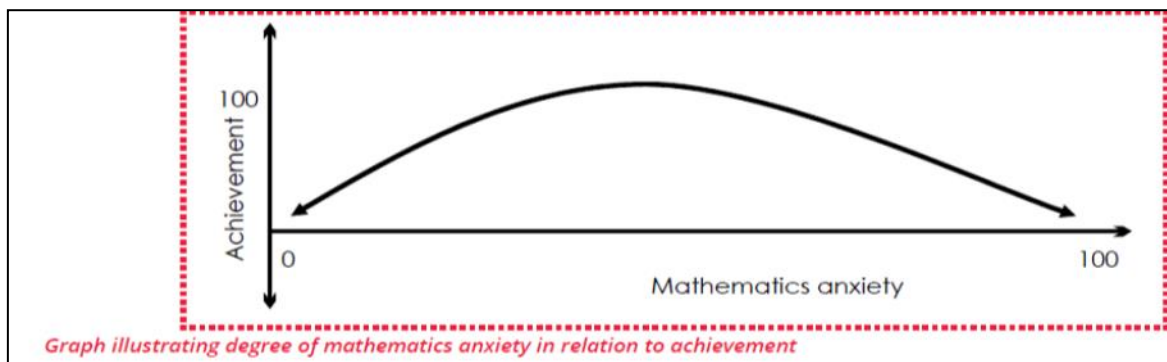


Fig 1: Causes of Mathematics Anxiety

#### 4.3 The Relationship between Mathematics Anxiety and Achievement

As far as empirical evidence of the relationship between mathematics anxiety and achievement is concerned, correlation has been found to be negative (the higher the anxiety, the lower achievement tends to be). In general, reported correlations are small, i.e. in the order of -0.1 to -0.3 (Cates, *et al.* 2003; Ho *et al.*, 2000; Ma (1999); Maree *et al.*, 1997, 1999, 2005).: as math anxiety interferes with math performance [Ashcraft MH, Kirk EP, 2001], poor math performance could in turn increase one's math anxiety [Ma X, Xu J:2004].



(Ref. [www.up.ac.za/juniortukkie](http://www.up.ac.za/juniortukkie))

**Fig 2**

Cates, *et al.* (2003) attempted to unpack the relationship between mathematics achievement and performance when they tried to ascertain with which stage of learning, anxiety correlated. They found empirical evidence that mathematical anxiety is inversely related to the ability to work fast in mathematics. Whereas the form of the relationship between mathematics anxiety and performances in mathematics is commonly viewed to be linear Ma (1999), the relationship has also been hypothesized to be curvilinear (Maree *et al.*, 2003). Anxiety can either debilitate or facilitate learning depending on the magnitude of the emotion; some anxiety can be considered as beneficial, constructive or functional while, if it increases beyond a certain level, mathematical anxiety becomes destructive or dysfunctional.

Whether a reduction in anxiety is associated with an increase in performance but has not been supported empirically. In fact, a single reference is that of Resnick *et al.*, cited in Ma (1999) who found no association between a reduction in anxiety results in increased achievement is debatable (Sloan *et al.*, 2002). Mathematics anxiety has significant negative correlation with mathematics performance but no significant correlation is detected with academic hardiness. It is also found that the gender differences in mathematics anxiety are significant, whereas no significant differences are detected between boys and girls in mathematics performance and academic hardiness. This study has established the fact that the performance of students in mathematics can be perceived by mathematics anxiety and females scored slightly higher on this variable but this relation has not observed with academic hardiness. [Karimi, A and S. Venkatesan, 2009]. Again in 2010, Venkatesh Kumar, G., and Karimi, A. found that Mathematics anxiety significantly has negative correlation with Mathematics performances and overall academic performance. Moreover it was found that there is significant gender difference in Mathematics anxiety, whereas there is no significant difference between boys and girls in Mathematics performances and academic performance. Pourmoslemi, A., Erfani, N., & Firoozfar, I. (2013) showed in their study significant differences between men and women's evaluation anxiety and no significant difference was observed concerning field of study. Also, there is a significant correlation between high level anxiety and low academic performance. Chang, H. & Beilock S. L.(2016) suggested that to lower math anxiety and reduce its relation to poor math performance, future interventions may benefit from focusing on both math-anxious

individuals themselves and those around them.

#### **4.4 Ways to Reduce Math Anxiety and to Enhance the Achievement in Mathematics**

Educators may need to take a more proactive role in encouraging students to become excited about math and see themselves as successful, confident, mathematical problem solvers (Furner & Berman, 2003). Cruikshank and Sheffield (1992) argued that if teachers fail to implement seven important measures they then cause their students to learn math anxious behaviours. These measures include teachers who:

- Show that they like mathematics
- Make mathematics enjoyable
- Show the use of mathematics in careers and everyday life
- Adapt instruction to students' interests
- Establish short-term and attainable goals
- Provide successful activities
- Use meaningful methods of teaching so that math makes sense

Similarly, Woolfolk (1995) believed that in order for teachers to help their students to deal with math anxiety they must:

- Use competition carefully
- Avoid situations in which highly anxious students will have to perform in front of a large group
- Make sure that all instructions are clear
- Avoid unnecessary time pressures
- Remove some of the pressures from major tests and examinations
- Develop alternatives to written tests
- Promote a positive disposition

In addition, Reys, Suydam, and Lindquist (1995) suggested that teachers de-emphasize speed tests or drills and avoid competition among students in order to further reduce the likelihood of creating math anxiety. They also added that communicating about mathematics and reflecting on the mathematics events that occur in the classroom would enhance mathematical power. In order to reduce math anxiety in the classroom, teachers should also focus on the importance of classroom design. Math lessons should be prepared to address a variety of learning styles. Studies have shown that students learn best when they are active rather than passive learners (Spikell, 1993). Marilyn Curtain-Phillips (1999)

identified that students today have a need for practical math. Therefore, math needs to be relevant to their everyday lives. Students enjoy experimenting. To learn mathematics, she stated that, students must be engaged in exploring, conjecturing, and thinking rather than engaged in only rote learning of rules and procedures. It is recommended that all teachers should incorporate technology, cooperative learning, and math manipulatives into their math lessons for all students. Teachers are encouraged to use cooperative learning by placing students in pairs or larger groups where all of the students maintain an equal role. During group activities, it is the teacher's responsibility to promote the groups' successes, by praising even the smallest accomplishments.

#### 4.5 Instruments used

Instruments for the measurement of mathematics anxiety are self-reporting instruments and as such, provide subjective measures of anxiety. These include the Mathematics Anxiety Rating Scale (MARS), Beasley 2001; Kazelskis *et al* 2000; Sloan, Daane & Giesen, 2002; the Mathematics Anxiety Questionnaire MAQ (Ho *et al.*, 2000; Kazelskis *et al* 2000) and the Fennema-Sherman Mathematics Anxiety Scale (MAS) (Cates, *et al.* 2003; Kazelskis *et al* 2000; Pajeres, 1996).

#### 5. Conclusion

In summing up, the current review examined various factors that may account for the math anxiety-math performance relation — at levels of an individual and the environment. The mutually reinforcing relation between math anxiety and math performance highlights the need for reducing this link. Interventions aimed at alleviating math anxiety, training math skills, or remediating other factors that influence this relation — targeting individuals and the environment — have been developed to improve math performance in highly math-anxious individuals.

These suggestions are by no means exhaustive. With this grab bag of strategies, teachers can creatively design their lesson activities to meet students' individual needs. Math anxiety is a complex issue that can manifest itself in a wide variety of ways, and therefore teachers should not adopt just one method for treating it. The more methods a teacher is able to employ, the more likely that they will be successful with the highest percentage of students. Future studies may enhance our understanding of math anxiety-math performance association by identifying various contextual factors that mediate or moderate this relation and may also develop effective interventions by targeting highly math-anxious individuals as well as their parents and teachers.

#### 6. References

- Ashcraft MH, Kirk EP: The relationships among working memory, math anxiety, and performance. *J Exp Psychol Gen.* 2001; 130:224-237.
- Ashcraft MH, Ridley KS. Math anxiety and its cognitive consequences: a tutorial review. In *Handbook of Mathematical Cognition*. Edited by Campbell JID. New York: Psychology Press. 2005, 315-327.
- Beilock SL, Gunderson EA, Ramirez G, Levine SC. Female teachers' math anxiety affects girls' math achievement. *Proc Natl Acad Sci USA.* 2010; 107:1860-1863.
- Chang H, Beilock SL. The math anxiety-math performance link and its relation to individual and environmental factors: a review of current behavioral and psychophysiological research. *Current Opinion in Behavioral Sciences.* 2016; 10:33-38.
- Fast LA, Lewis JL, Bryant MJ, Bocian KA, Cardullo RA, Rettig M, *et al.* Does math self-efficacy mediate the effect of the perceived classroom environment on standardized math test performance? *J Educ Psychol.* 2010; 102:729-740.
- Hembree R. The nature, effects, and relief of mathematics anxiety. *J Res Math Educ.* 1990; 21:33-46.
- Hui FHS, Ed. D. *Teaching Strategies for Students with Learning Disabilities in Mathematics* Nova Southeastern University Cicely Scott, Palm Beach County Schools, 2006.
- Imbo I, Vandierendonck A. Do multiplication and division strategies rely on executive and phonological working memory resources? *Mem Cognit* 2007, 35:1759-1771.
- Jameson MM. Contextual factors related to math anxiety in second-grade children. *J Exp Educ* 2013 <http://dx.doi.org/10.1080/00220973.2013.813367>. Lower math self-concept was the stro
- Joseph MF, Noorchaya Y, Mary LD. *Teach Mathematics: Strategies to Reach All Students Intervention In School And Clinic* 2005; 14(1):16-23.
- Karimi A, Venkatesan S. Mathematics Anxiety, Mathematics Performance and Academic Hardiness in High School Students. *Int J Edu Sci.* 2009; 1(1):33-37. Manasagangothri, Mysore 570 006, Karnataka, India
- Maloney EA, Ansari D, Fugelsang JA: The effect of mathematics anxiety on the processing of numerical magnitude. *Q J Exp Psychol.* 2011; 64:10-16.
- Maloney EA, Ramirez G, Gunderson EA, Levine SC, Beilock SL. Intergenerational effects of parents' math anxiety on children's math achievement and anxiety. *Psychol Sci,* 2015. <http://dx.doi.org/10.1177/0956797615592630>.
- Maloney EA, Risko EF, Ansari D, Fugelsang JA: Mathematics anxiety affects counting but not subitizing during visual enumeration. *Cognition.* 2010; 114:293-297.
- Ma X, Xu J. The causal ordering of mathematics anxiety and mathematics achievement: a longitudinal panel analysis. *J Adolesc.* 2004; 27:165-179.
- Miyake A, Shah P. *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control.* New York: Cambridge University Press, 1999.
- Núñez-Peñalé MI, Suárez-Pellicioni M, Bono R: Effects of math anxiety on student success in higher education. *Int J Educ Res.* 2013; 58:36-43.
- Ramirez G, Gunderson EA, Levine SC, Beilock SL: Math anxiety, working memory, and math achievement in early elementary school. *J Cogn Dev.* 2013; 14:187-202.
- Ramirez G, Chang H, Maloney EA, Levine SC, Beilock SL: On the relationship between math anxiety and math achievement in early elementary school: the role of problem solving strategies. *J Exp Child Psychol.* 2015; 141:83-100.

20. Pourmoslemi A, Erfani N, Firoozfar I. Mathematics Anxiety, Mathematics Performance and Gender differences among Undergraduate Students. *International Journal of Scientific and Research Publications*. 2013; 3(7):2. ISSN 2250-3153.
21. Rossnan S. Overcoming math anxiety. *Mathitudes*. Sarah Rossnan, Palm Beach County Schools. 2006; 1(1).
22. Sian Beilock L, Daniel Willingham T. Math Anxiety: Can Teachers Help Students Reduce It? *American Educator*.
23. Venkatesh Kumar G, Karimi A. Mathematics Anxiety, Mathematics Performance and Overall Academic Performance in High School Students. *Journal of the Indian Academy of Applied Psychology*. 2010; 36:147-150.
24. Vukovic RK, Roberts SO, Green Wright L. From parental involvement to children's mathematical performance: the role of mathematics anxiety. *Early Educ Dev*. 2013; 24:446-467.
25. Vukovic RK, Kieffer MJ, Bailey SP, Harari RR. Mathematics anxiety in young children: concurrent and longitudinal associations with mathematical performance. *Contemp Educ Psychol*. 2013; 38:1-10.
26. Wang Z, Lukowski SL, Hart SA, Lyons IM, Thompson LA, Kovas Y, *et al*. Is math anxiety always bad for math learning? The role of math motivation. *Psychol Sci*, 2015. <http://dx.doi.org/10.1177/0956797615602471>.
27. Wang Z, Hart SA, Kovas Y, Lukowski S, Soden B, Thompson LA, *et al*. Who is afraid of math? Two sources of genetic variance for mathematical anxiety. *J Child Psychol Psychiatry Allied Discip*. 2014; 55:1056-1064.
28. Mattarella-Micke A, Mateo J, Kozak MN, Foster K, Beilock SL. Choke or thrive? The relation between salivary cortisol and math performance depends on individual differences in working memory and math-anxiety. *Emotion*. 2011; 11:1000-1005.
29. Lyons IM, Beilock SL. When math hurts: math anxiety predicts pain network activation in anticipation of doing math. *PLoS ONE*. 2012; 7:e48076.
30. Young CB, Wu SS, Menon V. The neurodevelopmental basis of math anxiety. *Psychol Sci*. 2012; 23:492-501.