COMMENTARY

Is Sex Hormone the Driving Force of School Violence? The Neurobehavioral Evidence

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"Returning violence for violence multiplies violence, adding deeper darkness to a night already devoid of stars." – Martin Luther King, Jr.

WHEN our students suffer school violence, we often subconsciously focus on the perpetrator's behavior and other external factors related to it, such as family, school, and classmates. Of course, these external reasons are naturally more or less related to the behavior perpetrator's behavior, but are there any internal driving factors that make violence uncontrollable?

The US Department of Justice released the final report on school violence and showed that middle school is the age when violence is high, accounting for more than 70% of all violence cases (**Figure 1A**) (Zweig et al., 2013). After having perpetrated, the probability that the perpetrator will commit violence again will increase significantly (Office of the Surgeon General, et al., 2001). Among all perpetrators, the male to female ratio is 3:1, indicating that boys are more likely to perpetrate violence, but female violence methods and behaviors are more cruel and disgusting (Rivera-Rivera et al., 2007). In the later review of the perpetrators, almost 100% admitted that they were unable to control their violent behavior at that time and seemed to have an invisible impulse to urge them to commit violence, and even when they knew the harm of the violent behavior, they still committed violence without scruples (**Figure 1B**) (Willems et al., 2018). This indicates that among the 30% of middle school students prone to violence, the underlying age-related neuroendocrine changes are most likely to be the driving force leading to violence.

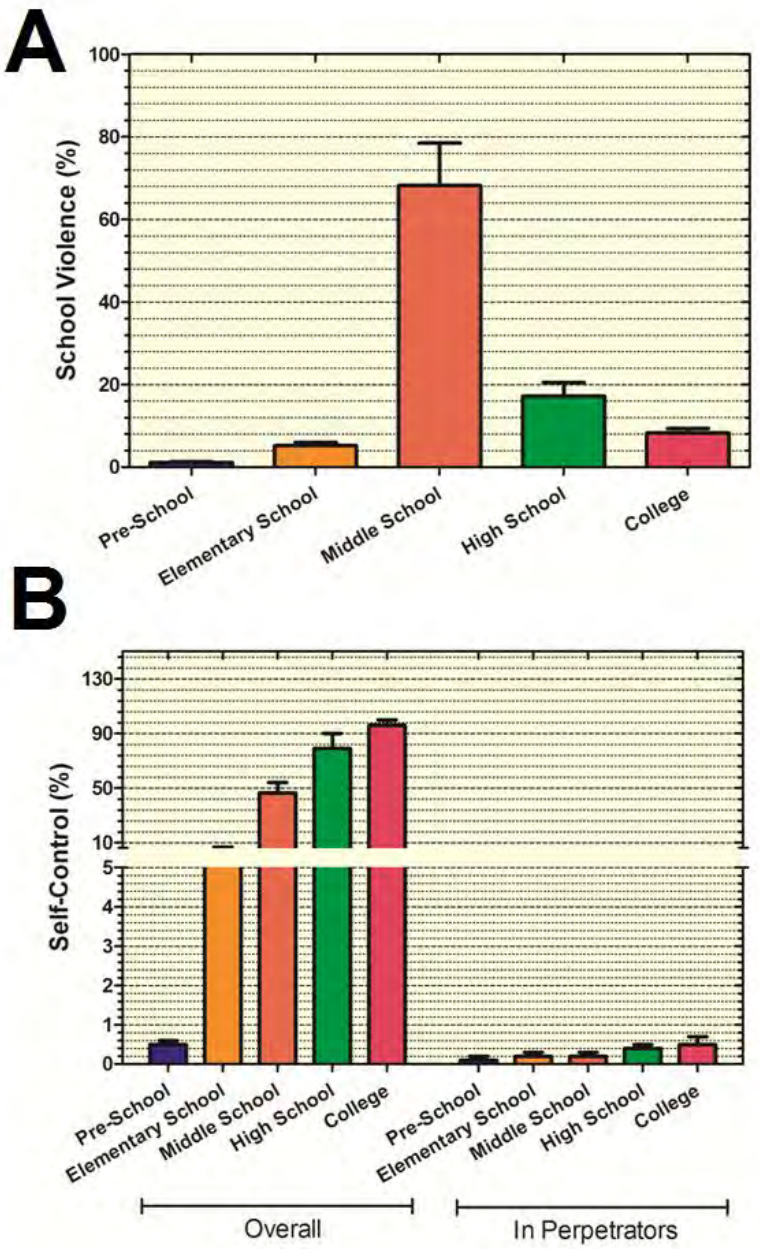

Figure 1. Distribution of School Violence and Self-Control Ability in Students.

(A). Percentage of school violence in different school students. Middle school students have the highest percentage of school violence. (B). Self-control percentage of overall school violence and in perpetrators. The overall self-control increases with students' aging, but for the perpetrators, their self-control is extremely low in all age groups.

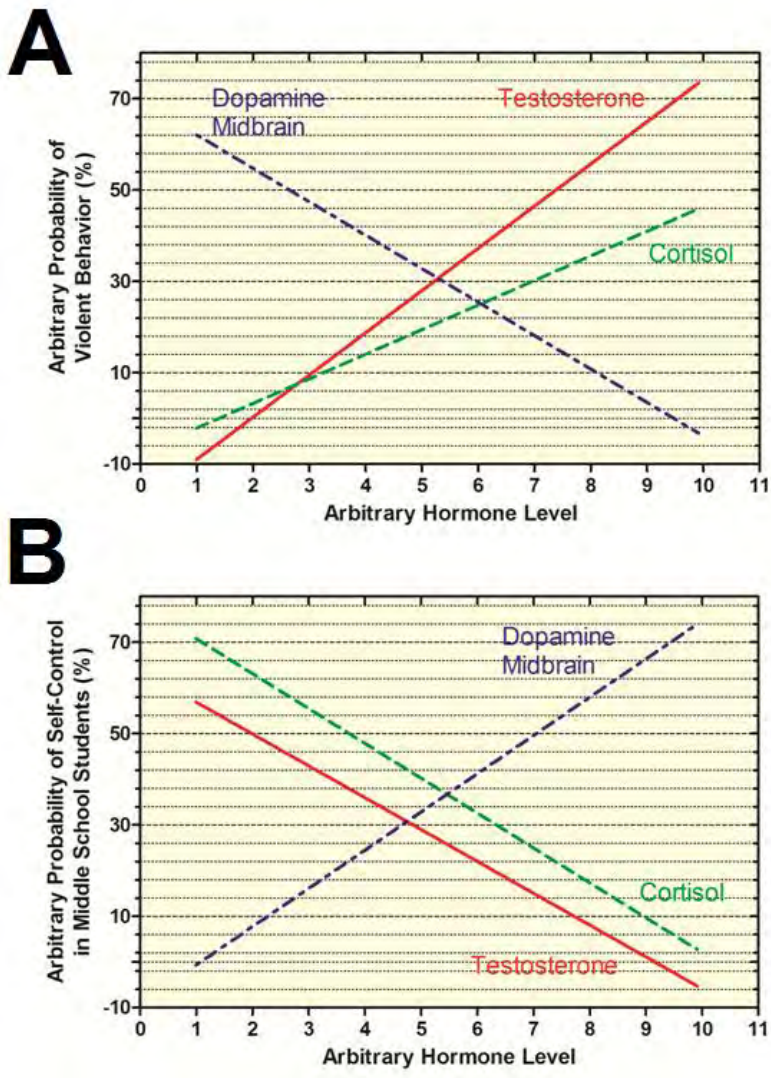

Figure 2. Arbitrary Probability of School Violence and Self-Control in Middle School Students.

(A). The arbitrary probability of school violence with the changes of testosterone, cortisol, and midbrain dopamine. Testosterone and cortisol show a positive correlation with the potential school violence, but dopamine, on the contrary, has a negative correlation with the possible violent behavior in middle school students. (B). The arbitrary probability of student self-control ability and the changes in testosterone, cortisol, and midbrain dopamine. Unlike violent behavior, self-control is negatively correlated with testosterone and cortisol levels but positively with the midbrain dopamine.

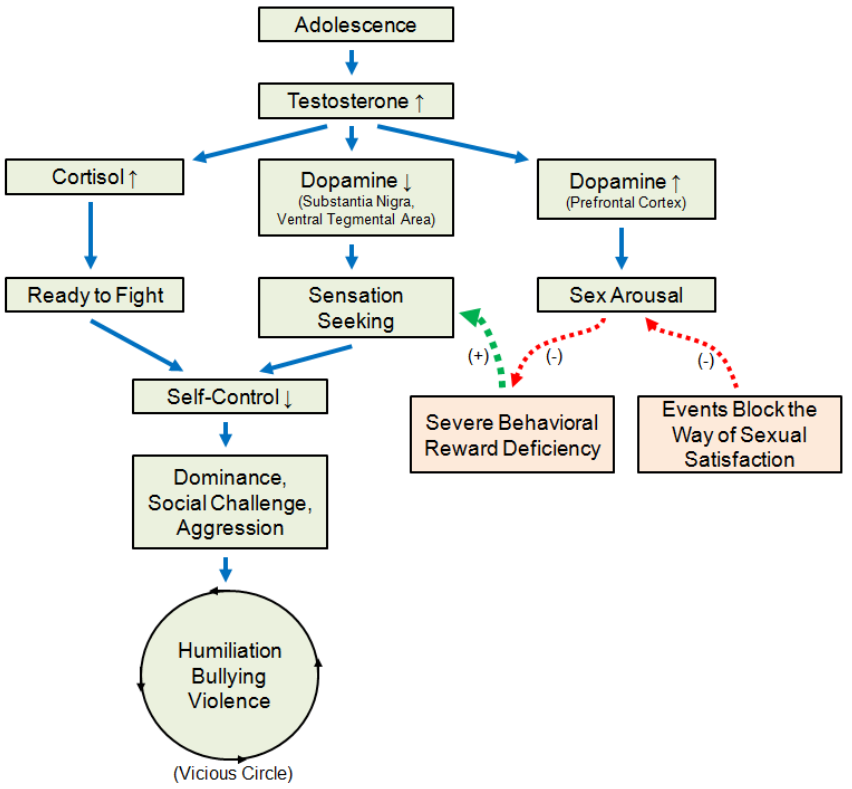

Figure 3. Neurobehavioral Network Regulation of School Violence in Adolescence.

This is the underlying neurobehavioral connection among testosterone, cortisol, and dopamine in adolescence with school violence. A sharp increase in testosterone in adolescence markedly promotes the up-regulation of dopamine in the prefrontal cortex to arouse the sexual drive, but down-regulation of dopamine in the midbrain such as substantia nigra and ventral tegmental area to seek the reward sensation, i.e., sensation seeking. Simultaneously, testosterone significantly increases cortisol to help the student ready for a stressful situation and/or fight. Both these two conditions would substantially reduce students' self-control ability, leading to dominance, social challenge, and aggression under various environments that will eventually get into a vicious cycle expressed as repeated humiliation, bullying, or violence at school. Meanwhile, any events that can block adolescent sexual satisfaction would negatively affect the sexual arousal level regulated by a high level of dopamine in the prefrontal cortex. Subsequently, the student would get into a state of severe behavioral reward deficiency, which would significantly elevate the sensation-seeking behavior that further decreases the self-control level.

With the increase in awareness, in-depth research on middle school students' high violent behavior began to pay attention to the students' potential physiological and brain neurotransmitter changes. Among them, "Reward Deficiency" reasonably emphasizes how the lack of endogenous rewards and positive emotions causes individuals to seek rewards from the external environment through risk-taking behaviors (Blum et al., 2008). The underlying behavioral, molecular mechanism that promotes this is reducing the cerebral striatum and prefrontal cortex dopamine neurons (Blum et al., 2012; Modestino et al., 2015). However, what is more interesting is that the levels of male hormones in adolescent middle school students soared, which caused an increase in dopamine levels in the critical part of sexual arousal of the prefrontal cortex (Calabrò et al., 2019), while the substantia nigra striatum and ventral tegmental area dopamine that regulate rewards were down-regulated (**Figure 2A**) (Purves-Tyson et al., 2014). The direct result of this change is that sexual arousal is high while the sense of reward is low; the imbalance between the two will cause the individual to seek reward after the satisfaction, which will lead to a reduction in their control to achieve dominance, and then take dangerous challenging and even aggressive behavior (Chester et al., 2015). At this time, if any incident in his/her peers that he considers undesirable will arouse his impulse to commit violence, and this impulse will be temporarily terminated with the gratifying reward after his violence (**Figure 2B**) (Jarcho et al., 2013). However, the violence itself does not stop there but repeats like an addiction.

Further research found that testosterone can significantly increase the level of cortisol (Romero-Martínez & Moya-Albiol, 2016; Turan et al., 2015; van der Meij et al., 2019), while cortisol, which is used as a preparation for stress and combat, reduces the level of dopamine in the midbrain (Field et al., 2005; Kudielka et al., 2009). The increased cortisol makes the individual ready to fight, but it still lacks the sense of reward, making the individual's self-control frustrated and entering a state of fighting for rewards. Not only that, the facts may be more severe than this. When an individual's sexual desire cannot be satisfied due to specific events, it will enter a more severe state of lack of behavioral rewards, which will make its impulse to seek rewards more obvious, accompanied by a further decline in self-control, and eventually commit violence to achieve individual rewarding satisfaction. The detailed neurobehavioral network regulation is depicted in **Figure 3**.

In this issue, He (2020) used his experiments and observations and found that more than 90% of his middle school students' violent incidents were caused by conflicts in adolescent men and women's communication behaviors. The reason is the neurobehavioral performance caused by the individual's testosterone level changes. The author found that activities high-intensity training characteristics can satisfy students' lack of behavioral rewards in another way, thus interrupting the vicious circle of school violence. This school approach has achieved the effect of killing two birds with one stone. On the one hand, it reduces school violence; on the other hand, it en-

hances the individual's team consciousness and physical fitness. This is a feasible approach worth promoting.

School violence intervention based on neuroendocrine mechanisms may be more effective than other external factors (Rivara et al., 2016). It is of greater practical significance to use the interactive network formed between testosterone, cortisol, and dopamine at different brain center sites as the target of intervention.

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