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# Hormonal reactivity during martial arts practice among high-risk youths

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ABSTRACT

Martial arts have become a popular afterschool activity for youths across the globe. Accumulating data suggest that these activities may confer substantial cognitive and psychological benefits, and recent efforts have been made to introduce martial arts training into educational and rehabilitation settings. However, few studies have examined the potential mechanisms that may underlie these benefits. The current study evaluated the reactivity of two hormones, oxytocin (OT) and cortisol (CT), thought to be respectively involved in regulating mammalian social behaviors and responsivity to stress, to a session of intensive martial arts training in samples of at high-risk and low-risk (in regular educational establishments) youths. OT and CT were measured at baseline, during peak training, and following a cool down period. Analyses revealed that high-risk youths had lower OT but similar CT baseline levels, compared to low-risk youths, prior to the martial arts session. A significant group by time interaction indicated that whereas the OT levels among low-risk youths returned to baseline levels following training, OT levels among high-risk youths remained elevated. Finally, unlike low-risk youths for whom CT levels continued to increase throughout the training session, high-risk youths showed no significant CT reactivity. This study suggests that some of the beneficial effects of martial arts may be related to hormonal processes, especially increases in OT levels, and highlights the differing effects that training may have in different populations.

## 1. Introduction

Martial arts are a popular extra-curricular activity for youths in Western countries (Strayhorn and Strayhorn, 2009). They include traditional forms such as judo, jujitsu, karate, Kung Fu, capoeira, and taekwondo, as well as the modern developments, such as Krav Maga and mixed martial arts (MMA). Predominantly designed in the East for combat and to create a warrior who has spiritual, physical, and mental wellbeing, as these combat arts began to permeate the West, they developed to suit the needs of the practitioners, while retaining the basics of Eastern philosophy (Burke et al., 2007). Far from their negative connotations once portrayed by the media (Fuller, 1988), martial arts are now seen in a much more positive light, with both participation and research into their effects now increasing (Harwood et al., 2017; Vertonghen and Theeboom, 2010). In general, it is thought that the traditional martial arts, which include components of honor and respect, are the most authentic and socially beneficial to practitioners (Nosanchuk, 1981).

Martial arts provide an outlet for practitioners to channel energy into a productive and self-enhancing activity (Twemlow & Sacco, 1998), making them a popular choice for both low-risk children (Strayhorn and Strayhorn, 2009), as well and high-risk youths (Sampson, 2015), who are characterized by high levels of externalizing behaviors, which lead to disruption in normal classroom settings and eventually exclusion to non-traditional educational settings (Valdebenito et al., 2019). Indeed, several studies have found martial arts to have a positive effect in reducing aggressive behaviors (Lakes and Hoyt, 2004; Twemlow et al., 2008; Zivin et al., 2001), as well as improving self-esteem (Conant et al., 2008) and executive functions (Lakes et al., 2013; Phung and Goldberg, 2019).

Despite these promising reports, few studies have examined potential mechanisms that may be involved in these behavioral effects. In the current study, we investigated the effects of martial arts on two potential candidates, oxytocin (OT) and cortisol (CT). OT is a peptide hormone that plays an important role in regulating mammalian social behaviors (Carter et al., 1992). In animals, OT has been shown to support the formation of attachment bonds (Insel, 2010) and, in humans, linked to social affiliation in parent-child attachment (Feldman et al., 2010), romantic relationships (Schneiderman et al., 2012), and to the ‘tend and defend’ behaviors witnessed in inter-group situations (De

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Dreu et al., 2010; Levy et al., 2015). OT release both encourages social behavior and is also enhanced following social behavior (Feldman, 2012).

Several animal and human studies have demonstrated increases in OT levels following aerobic activity (de Jong et al., 2015; Torner et al., 2017). We have recently reported OT increases during peak training of martial arts among youths and adults, especially when close-contact grappling was involved (Rassovsky et al., 2019). Given the increase in OT witnessed during caring parental touch (Lebowitz et al., 2017), and the greater increase in OT following human touch as opposed to human administered mechanical touch (Li et al., 2019), this finding was attributed to the increased touch in a positive social environment of martial arts practice. For high-risk youths, there has been limited research with mixed conclusions regarding the role of OT in anti-social behavior. Raised peripheral OT has been reported in adults with a history of childhood maltreatment (Olff et al., 2013) and has been associated with socially deviant behaviors (Mitchell et al., 2013). Conversely, others reported lower diurnal salivary OT among at risk youths (Levy et al., 2015).

In contrast to the limited research on OT reactivity to physical activity, substantial research has been conducted on CT (Ellis, 2014). CT is a glucocorticoid stress hormone involved in regulating responsivity to stress (Young et al., 2012). CT has been demonstrated to increase during physiological stress including exercise and physical exertion (Lautenbach and Laborde, 2015), although CT response is dependent on the intensity, duration, and the competitive nature of the sport (see Gatti & De Palo, 2011 for a review). In Taekwondo, a traditional martial art, CT has been demonstrated to increase during the sparring phase of a competitive bout, and CT reactivity was associated with predicted victory (Lautenbach and Lobinger, 2018). In Judo, CT reactivity has been evidenced in competitive but not practice bouts (Salvador et al., 2003).

As with OT, CT has also been associated with delinquent behaviors. Overall, there seems to be a consensus that people who engage in risky, antisocial, or aggressive behaviors often are less sensitive to stress, reinforcing the theory that an optimal level of stress or arousal is pleasant and generally sought (van Goozen et al., 2007). There is evidence to demonstrate that blunted CT reactivity is correlated with greater antisocial and externalizing behaviors in children (Alink et al., 2008; Fairchild et al., 2008). Similarly, lower diurnal CT levels have been correlated with externalizing behaviors in children (Haltigan et al., 2011) and severly high-risk children (those reported to social services and those in foster care) (Bernard et al., 2010), although several studies failed to find these patterns in adolescent with externalizing (Alink et al., 2008; Fairchild et al., 2008) or antisocial (Feilhauer et al., 2013) behaviors. In addition to externalizing behaviors, lower CT levels have been linked to poorer executive functioning (Conradt et al., 2014), potentially leading these individuals to seek risky, stimulating activities and react less positively to conditioning activities or punishment (van Goozen and Fairchild, 2008).

The current study was an effort to clarify some of these findings by comparing hormonal reactivity (OT and CT) to a martial arts session among high-risk and low-risk youths. It was predicted that high-risk youths would have lower OT and potentially lower CT baseline levels compared to low-risk youths. Based on the aforementioned evidence for lower CT reactivity in high-risk youths, we hypothesized that they would have blunted CT reactivity to the martial arts practice, compared to low-risk youths. Given the limited evidence on OT in this area, no directional hypotheses were made regarding OT reactivity to training.

## 2. Material and methods

### 2.1. Participants

Thirty-one boys from two schools for high-risk youth and 40 boys from an afterschool martial arts club took part in a martial arts session at three separate locations. The high-risk sample, aged 14.8 to 18.5 years (M = 15.85, SD = 0.86), were from schools located in low socioeconomic areas: [removed for masking] and [removed for masking]. [Removed for masking] is an area of high immigration and purpose-built temporary accommodation and [removed for masking] is home to [removed for masking]'s largest prison and one of the highest crime rates in [removed for masking]. All high-risk boys were in regular high school matriculation classes (schools had additional classes for those with significant learning disabilities) but had specific educational needs (ranging from disruptive behavior to nonattendance at previous educational establishments due to behavioral issues). Children are enrolled in these schools as a last attempt to keep them in the general education system. Given the substantial over-representation of boys at these institutions, reflecting the nature of these educational systems in dealing with severe externalizing behavioral problems, only boys were included to avoid potential selection bias. The majority of participants from the high-risk population (66.7%) had no prior experience with martial arts, with average martial arts experience throughout the lifetime being under 5 months (M = 4.96 months, SD = 18.87). All boys took part in sports classes as part of their regular school activity, and about half (54.5%) participated in an additional afterschool sports activity.

The low-risk sample consisted of 40 youths who had been training in afterschool martial arts clubs in central [removed for masking]. This sample was part of a larger study that included both youths and adult participants (Rassovsky et al., 2019). In the present study, low-risk boys were age-matched to the high-risk sample. Boys ranged in age from 14 to 18 years (M = 16.14, SD = 1.17) and comprised of both novices (white belts, N = 19) and experts (black belts, N = 21). Both novices and experts trained twice a week, in addition to regular sports classes at school. In the martial art studied, practitioners progress at an average rate of one belt level per year for lower belts and 1-3 years for higher belts. Thus, at the time of data collection, the white belts had been training under 12 months, and the black belts for at least 7 years. They were sampled during a period of three years during the months of May to June at four sites in the same geographic area. Both novices and experts were included in the analyses, as the original study (Rassovsky et al., 2019) showed no significant differences in acute hormonal reactivity throughout the martial arts session.

All participants received parental informed consent for their participation. The research was approved by the Institutional Review Board at [removed for masking] University and the inclusion of high-risk youth in the research was approved by the Ministry of Education Ethics committee, and the Helsinki Ethics committee of [removed for masking] Hospital in [removed for masking], as required by the Ministry of Health.

### 2.2. Saliva sampling and analysis

Three saliva samples were collected during the first week of training at baseline, immediately after peak training intensity, and following a cool-down period (see Fig. 1). Participants gave saliva by passive drooling into a clean 5 ml tube. If the participant had difficulty producing sufficient saliva, they were instructed to massage their jaw and imagine food on their tongue. Participants were told that they may drink water immediately following saliva production but refrain from drinking until following the next saliva sampling. All samples were then stored at −20 °C.

The concentration of OT was determined by Cayman-OT ELISA kit (Cayman Chemicals, Ann Arbor, Michigan, USA). ELISA (enzyme-linked immunosorbent assay) kits are commonly used for analyzing hormones in saliva. In order to prepare the sample for measurements samples underwent three freeze-thaw cycles, with freeze at −80 °C and thaw at 4 °C to precipitate the mucus. The tubes were subsequently centrifuged at 1500 g (4000 rpm) for 30 minutes. The supernatant was transferred into a clean tube and stored at −20 °C until assayed. Concentration of OT in these samples was determined in duplicates according to the

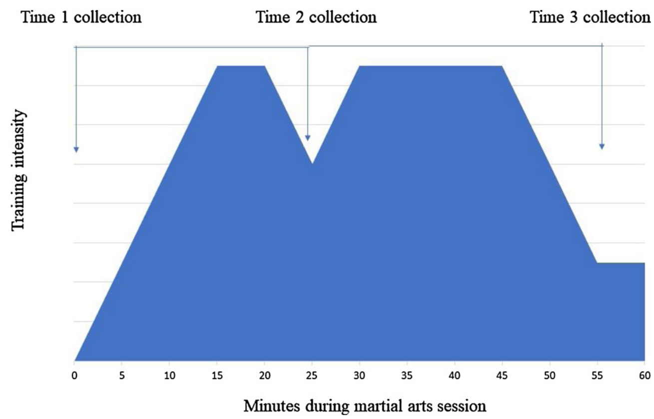


**Fig. 1.** Schematic representation of salivary hormone collection at varying time points of martial arts session.

manufacturer's kit instructions. The inter-assay coefficients of samples and controls were less than 18.7%, which is in the range reported by the manufacturer.

The concentration of CT was also determined by using a commercial ELISA kit (Salimetrics, USA). Measurement were performed according to the kit's instructions. In addition to the manufacture's low and high controls of 1060 + 270, 9700 + 2430 pg/ml, three in-house controls were included in each plate (250, 880, 1330 pg/ml) to correlate between plates measured at different periods. Concentration of CT was calculated according to relevant standard curves. The intra-assay coefficient of variance (CV %) of manufacturer and in-house controls is 7.54%. The inter-assay CV of samples is less than 16.11%.

### 2.3. Procedure

After receiving explanation of the study procedures, participants provided a baseline saliva sample and began the martial arts training session. The martial arts style selected for the study is known as Dennis Survival Jujitsu (DSJJ), developed by Dr. Dennis Hannover over 50 years ago. It is based on traditional Japanese martial art and incorporates elements of karate, judo, and Japanese jujitsu. Beside including the elements common to most traditional martial arts, such as mutual honor and respect, our choice of this type of martial arts was mostly based on practical considerations, as the senior author (YR) is a practitioner and instructor of DSJJ and had access to suitable instructors. Through prior coordination between the researchers and martial arts instructors, the sessions for all three locations were standardized across schools to include the following components: an approximate 10-minute warm-up of mild-moderate intensity (e.g., stretching, squats, sit-ups), 15-minute technique practice (judo throws and falls, "punch-kick" striking, and joint locks), 20-minutes of high-intensity *randori* (semi-competitive sparring), and a 15-minute cool-down period. *Randori* practice included striking and judo throws, while wearing protective shin and arm guards. No face or head striking was allowed. Given the rough interactions during the *randori* component, it was not possible to monitor physiological parameters of physical exercises using standard heart rate (HR) monitors, such as arm bands or chest straps. However, prior simulation of non-contact high-intensity *randori* in the low-risk sample indicated that participants maintained 1-3 min periods at 85%-95% of individual $HR_{max}$, alternating with 30-60 sec periods at 60%-70% of individual $HR_{max}$ (estimated using standard HR zone calculation). This form of physical exercise would be considered high-intensity interval training (HIIT), interspersed with active recovery periods (Lunt et al., 2014). The second saliva sample was obtained immediately following the high-intensity *randori*, and the third sample was taken following the cool-down period.

### 2.4. Data Analysis

Analyses were conducted using Jamovi statistical software (version 1.0.2) (Jamovi, 2019). For the purpose of examining the effect of the intervention on OT and CT responsivity, data were fitted with a Linear Mixed Model (LMM). The advantage of mixed effects models is that they account for variability between subjects and correlations within the data and are superior to Repeated Measures ANOVA in handling missing data (Baayen et al., 2008). As no significant differences between the two high-risk schools were found on any of the measures, the data from both schools were combined for comparison with the low-risk sample. The fixed factors of the fitted models included type of population (high-risk vs. low-risk) and time of saliva collection (baseline, peak-training, cool-down), as well as their interactions. A random intercept for subject was also included in the model. Significant results were followed by post-hoc analyses with Bonferroni correction.

## 3. Results

### 3.1. OT comparison

To examine the OT response between high-risk and low-risk youths during a martial arts session, LMM was conducted, with group (high-risk vs. low-risk), time of saliva collection (baseline, peak-training, cool-down), and their interactions as fixed factors, and an intercept for subject as a random factor. These analyses demonstrated a significant effect of time of saliva collection, [$F(2, 131.5) = 3.88$ $p = 0.02$], with post-hoc comparisons indicating a significant change from baseline to peak-training ($p_{bonferroni} = 0.01$). There was a significant main effect of group, [$F(1, 73.8) = 15.39$, $p < 0.001$], as well as a significant group by time of saliva collection interaction, [$F(2, 131.5) = 3.85$, $p = 0.02$].

Post Hoc comparisons indicated that low-risk youth had significantly higher salivary oxytocin levels compared to high-risk youth at baseline ($p_{bonferroni} < 0.01$) and at peak-training ($p_{bonferroni} < 0.01$). At post-cooldown, whereas salivary OT in low-risk youth dropped significantly ($p_{bonferroni} = 0.03$), OT levels among high-risk youth remained elevated and did not significantly differ from the post-cooldown levels of low-risk youth ($p_{bonferroni} = 1.00$) (see Fig. 2).

### 3.2. CT comparison

The same LMM was then employed to examine potential differences in CT response among the different types of training across time (see Fig. 3). There was a significant main effect of time of saliva collection, [$F(124.8, 2) = 4.63$, $p = 0.01$] and a significant effect of group, [$F(1, 76.2) = 7.01$, $p = 0.01$]. Finally there was an interaction between group and time of saliva collection [$F(2,124.8) = 7.51$, $p < 0.001$].

Post-Hoc comparisons indicated that while low-risk youth

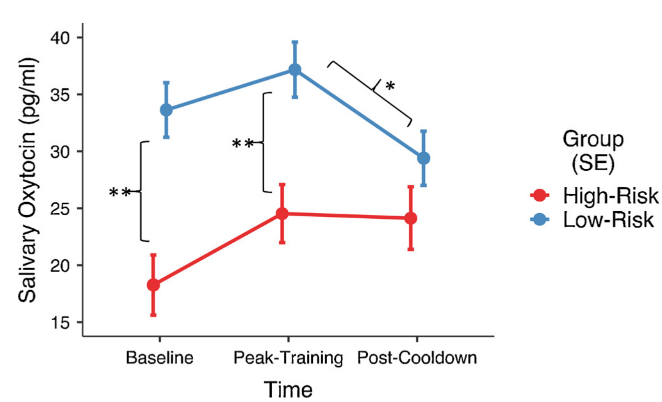


**Fig. 2.** Oxytocin reactivity throughout the martial arts practice session for high-risk and low-risk youth. ** $p < 0.001$, * $p < 0.05$.

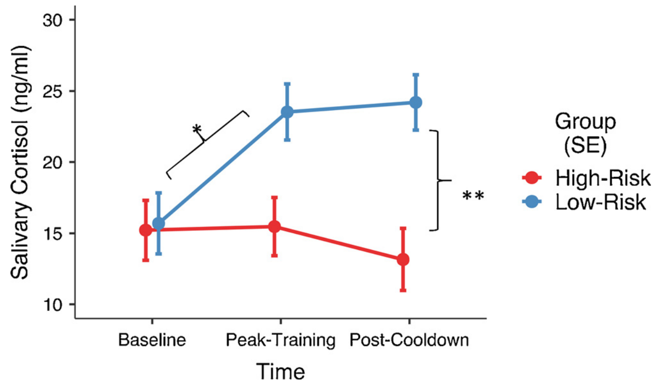


**Fig. 3.** Cortisol reactivity throughout the martial arts practice session for high-risk and low-risk youth. ** p < 0.001, * p < 0.05.

demonstrated a rise in CT from baseline to peak-training ($p_{\text{bonferroni}} = 0.01$) and remained elevated at post-training (baseline-post-training, $p_{\text{bonferroni}} < 0.001$), high-risk youth did not demonstrate any significant increases in CT levels throughout the training period. At post- training, low-risk youth had significantly higher CT levels than at risk ($p_{\text{bonferroni}} < 0.01$) (see Fig. 3).

## 4. Discussion

The present study investigated the hormonal effects of martial arts practice on high-risk youths compared to a low-risk sample. The findings revealed differential hormonal reactivity to martial arts training between the groups. Specifically, low-risk youths had significantly higher salivary oxytocin levels compared to high-risk youths at baseline and at peak-training. Furthermore, whereas salivary OT in low-risk youths demonstrated the typical curve of increase during peak training and dropping post-cooldown, OT levels among high-risk youths remained elevated following the training session. High-risk youths also demonstrated blunted CT reactivity to the martial arts practice. Whereas low-risk youths demonstrated increased CT in response to the intervention, little change was observed for high-risk youths.

Similar findings indicating lower OT levels in high-risk youths have been reported in previous studies (Levy et al., 2015). In cases of poorer attachment, neglect and abuse, attenuated OT levels have been found in salivary, plasma, urinal and CSF samples (Feldman, 2012). Such findings may be consistent with theories suggesting poorer attachment and social relating among offenders (Mitchell & Beech, 2011) and may be reflected in lower OT baseline levels. Despite the overall OT levels among high-risk youths, as compared to controls, the reactivity levels of OT (i.e., change from baseline to peak training) was similar in both groups, supporting the potentially beneficial effects of this intervention.

Based on reviewed literature, we could not identify any studies examining the relationship between reduced or lack of past exposure to human physical contact and hormonal reactivity to experimentally administered positive human touch. There is evidence that lower levels of OT lead humans to seek more touch with their canine companions, thereby raising their plasma OT levels and indicating a subconscious awareness of the need for greater contact (Petersson et al., 2017). Based on this finding, it is possible that high-risk participants who began with lower salivary OT levels sought greater contact and interaction during the session, resulting in greater OT reactivity. Indeed, OT levels among high-risk youths did not show a return to baseline pattern, seen among low-risk youths, but rather remained elevated following the cessation of practice. This might indicate a homeostatic element to OT maintenance at an optimal level. Namely, when baseline OT levels are suboptimal, exposure to interventions that acutely elevate hormonal levels may lead to increased storage, such as observed in fat storage following dietary restriction (Dhurandhar, 2016). Neither of these hypotheses have yet received any research attention and further longitudinal research, not necessarily in the field of martial arts, may prove fruitful in addressing these issues.

These theoretical gaps notwithstanding, the current findings add support to the reported positive experiences of martial arts among participants. Namely, martial arts' triggered increase in OT may be reflected in the greater sense of wellbeing (Grape et al., 2003) and, combined with high levels of mutually agreeable touch occurring during martial arts sessions, may lead to reduced anxiety (Cascio et al., 2019; Yücel et al., 2019). These hypotheses are currently under investigation in our lab.

In contrast to OT reactivity demonstrated in both high-risk and low-risk youths, a different response pattern was found in CT. Specifically, low-risk youths demonstrated increased CT reactivity to the martial arts session whereas high-risk youths showed a blunted response. These findings are consistent with reports showing CT reactivity among low-risk youths found in found in other sports (Lautenbach and Laborde, 2015), yet negate the suggestion that this increase is limited to a competitive sport environment (Salvador et al., 2003). Our finding of blunted CT reactivity is also consistent with prior studies reporting similar effects in high-risk youths (Alink et al., 2008; Fairchild et al., 2008), as well as other studies showing reduced CT reactivity among people who demonstrate higher sensation seeking and risky activities (Frenkel et al., 2018), behaviors often characteristic of high-risk youths enrolled in the current study. The blunted CT reactivity in the current sample may also reflect chronic traumatic stress exposure (Feldman et al., 2013), although this suggestion was not tested in the current study.

A number of limitations to this design need to be acknowledged. Despite efforts to maintain similar settings and session-structures, the martial arts sessions were conducted across three different locations. Although no significant differences were found between the two schools for high-risk youths, as our original study of the low-risk population (Rassovsky et al., 2019) was designed for piloting the physiological data collection procedures, we only collected limited background information on this sample, preventing comprehensive comparisons across samples. Thus, it may be informative to evaluate these measures in the same setting with the same instructor, while controlling for relevant background variables (e.g., prior martial arts exposure or engagement in other sports activities), thereby minimizing potential confounding factors. Additionally, due to the "rough" nature of the physical contact inherent in martial arts training, it was not possible to monitor physiological parameters during the session. However, as indicated above, simulations of non-contact high-intensity randori among low-risk youths indicated that participants maintained heart rate zones comparable with high-intensity interval training (Rassovsky et al., 2019). Nonetheless, it would be informative to adapt physiological measure of exercise intensity levels to be used during martial arts training and to compare this form of training with other types of exercise. This venue of investigation could be useful to disentangle the various parameters that may mediate hormonal reactivity (e.g., aerobic intensity levels, degree of contact, level of competitiveness). Finally, the present cross-sectional analyses were able to detect acute hormonal response to training, rather than track potential changes over time. Notably, these latter types of changes, if found, may reflect a more stable and perhaps long-lasting effect of martial arts practice over the endocrine system. In fact, we originally intended to collect additional saliva samples following subsequent training sessions. Unfortunately, due to inconsistent attendance in our high-risk sample, we were unable to collect sufficient data for meaningful analyses. Thus, future studies following martial arts trainees longitudinally would be informative to examine whether acquisition of expertise in this field may lead to differential hormonal responses.

These limitations notwithstanding, the current study was the first to compare the hormonal responses of low-risk and high-risk youth to a sport intervention, in general, and to martial arts, in particular. A differential pattern of hormonal response to training was found for both OT and CT, suggesting potential explanatory theories for future investigation. Given these findings, it is not surprising that martial arts have become such a popular afterschool activity for both low-risk (Strayhorn and Strayhorn, 2009) and high-risk youths (Meek, 2018; Sampson, 2015). Undoubtedly, prospective studies evaluating the effects of martial arts training in high-risk youths, using endocrinological, behavioral, subjective, and other relevant assessment, are needed to better understand the full value and the underlying mechanisms of this pleasurable, readily available activity.

## Contributors

Anna Harwood-Gross conducted the study and assisted with study conceptualization, data interpretation, and wrote the first draft of the manuscript. Ruth Feldman assisted with study conceptualization, data interpretation, and manuscript preparation. Orna Zagoori-Sharon assisted with data interpretation and manuscript preparation. Yuri Rassovsky conceptualized the study and assisted with data analyses, interpretation, and manuscript preparation.

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## Declaration of Competing Interest

All authors declare that they have no conflicts of interest arising from this manuscript.

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