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Letter to editor

Salivary Parameters of Competitive Swimmers at Gas-Chlorinated Swimming-Pools

Dear Editor-in-Chief

Earlier reports have demonstrated that prolonged exposure to a gas-chlorinated swimming-pool was associated with enamel erosion, particularly in competitive swimmers (Centerwall et al., 1986). A few additional reports have confirmed these findings (Buczkowska-Radlińska et al., 2012; Gabai et al., 1988; Geursten, 2000). Although the regulation may vary according to each state jurisdiction (as is the case for the US), a frequently recommended chlorine level for a typical swimming pool is between 1.0 to 1.5 mg·L^{-1}. When using cyanic acid (stabilizer) minimum and maximum values are set to respectively 2.0 and 5.0 mg·L^{-1}. The expected pH range for swimming pools is between 7.2 and 8.0. However, if a gas-chlorinated pool becomes inadequately buffered, the pH may decrease rapidly to tooth decalcifying levels as low as 3.

While swimmers may not be sensitive to the low pH, it may lead to tooth demineralization. The dental literature suggests that pool water with a low pH can cause very rapid and extensive dental erosion (Centerwall et al. 1986; Dawes and Boroditsky, 2008; Geursten, 2000). Thus, habitual swimming may be considered a contributory factor when diagnosing dental erosion in competitive swimmers.

The purpose of this study was therefore to determine the salivary parameters of competitive swimmers at a gas-chlorinated swimming-pool, before and after a 2-hour swimming practice. We hypothesized that intensive exercising may alter significantly the salivary flow rate and balance of calcium (Ca), phosphorus (P) and fluoride (F) salivary levels for competitive swimmers while in training at gas-chlorinated swimming-pools.

Competitive swimmers from the University of Michigan Swimming Team 18-23 years old (males only) participated in the study. Consent was obtained from all participants approved by an institutional review board (University of Michigan, School of Dentistry IRB). Participants were asked to fill a semi-structured questionnaire concerning aspects of their diet, medicine intake, self-determined tooth color appearance and tooth-brushing habits and frequency. Thus, a total of twenty-two athletes participated in this study.

Unstimulated whole saliva of swimmers was collected before and immediately after their training session, which took an average of two hours (between 10 am and 12 pm). The saliva collection was performed with the athletes seated, head slightly down and they were asked not to swallow or move the tongue or lips during the collection period. During a period of 3 minutes they were asked to spit the accumulated saliva into a pre-weighed tube (kept on ice). The tubes containing saliva were weighted on a precision balance. The rate of saliva secretion was then determined gravimetrically (mL·min^{-1}).

Salivary parameters were analyzed by different assays before and after swimming that included salivary pH, P, F, Ca salivary levels. Saliva aliquots used for the assays were as follows: 50 µL, 6 µL, 500 µL and 500 µL, respectively. Salivary pH was derived from colorimetric assays (Hydrion, Micro Essential Lab., Brooklyn, NY, USA). P salivary levels were obtained by the ammonium molybdate method using an ultraviolet spectrophotometer at a wavelength of 690 nm. P salivary levels were expressed in mmol·L^{-1}. F salivary levels were analyzed by means of an F ion-specific electrode (Orion Model 96-09, Orion, Helsinki, Finland). The concentration of Ca in saliva was determined using an atomic absorption spectrometer with a deuterium background corrector (Perkin-Elmer 3030 B, Waltham, MA, USA). Ca and F salivary concentrations were computed and expressed in mmol·L^{-1}. Paired *t*-tests were employed to estimate differences between each one of the measured parameters before and after swimming using the statistical software package housed in Minitab 16 (Minitab Inc., State College, PA, USA).

The average salivary parameters of the 22 competitive swimmers before and after swimming in the gas-chlorinated swimming-pool are depicted in the Figure A-D. A significant decrease in the rate of saliva secretion was observed after a swimming session ($p < 0.05$) (Figure 1A). A statistically significant increase of Ca ($p < 0.05$) and F ($p < 0.05$) levels in saliva, was observed (Figure 1B and 1D). The P salivary levels were significantly decreased after the swimming session ($p < 0.05$) (Figure 1C). There was a tendency for a decrease in average salivary pH after the swimming session, varying from 6.8 ± 1.1 (before swimming) to 6.5 ± 0.9 (after swimming). This decrease was not statistically significant ($p > 0.05$). The water pH and levels of ions in the gas-chlorinated pools at University of Michigan were monitored daily. On the day and time period we performed our study sampling, the pH of the water fluctuated between 7.0 and 8.0, with an average pH of 7.5. Chlorine and F levels were 1.5 mg·L^{-1} and 0.8 mg·L^{-1}, respectively.

The present results show that competitive swimmers who swam at a gas-chlorinated swimming-pool experienced a significant alteration of their salivary parameters, such as salivary flow rate and concentration of Ca, P and F and, therefore are consistent with our initial hypothesis. As indicated in previous studies (Centerwall et al. 1986; Gabai et al., 1988), competitive swimming led to the development of severe dental erosion in inadequately maintained gas-chlorinated swimming-pools. Our study suggests that even in properly maintained

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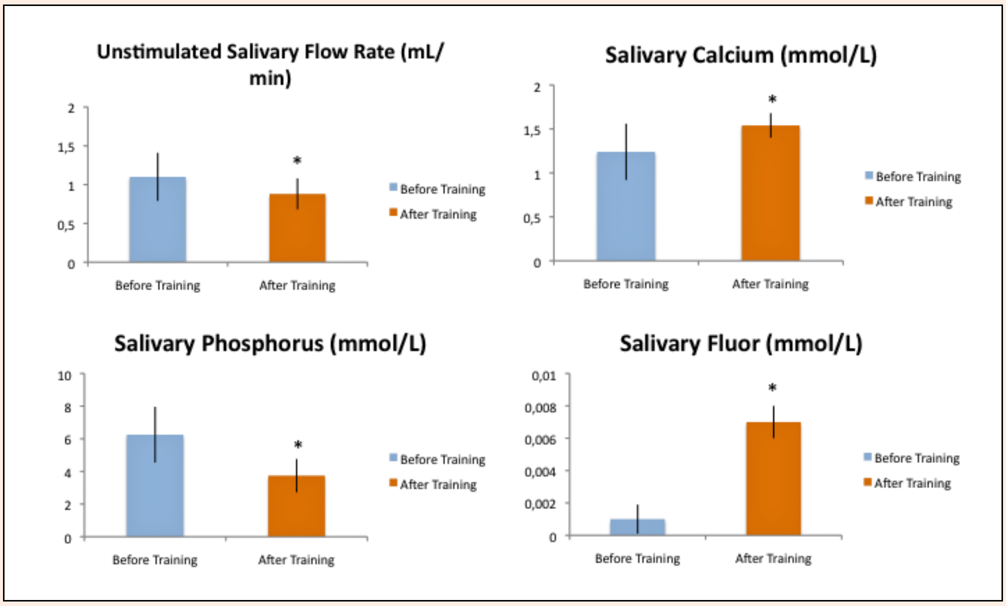

Figure 1. Salivary parameters of competitive swimmers measured before and after a swimming session. Mean ± SD (n = 22). Statistical differences between groups by paired-*t*-test are designated with an asterisk (*).

gas-chlorinated swimming-pools (i.e. average pH 7.5, calcium chloride = 1.5 mg·L^{-1}), parameters (decrease in saliva output and increase in Ca an F salivary levels) contributing to enamel dissolution of competitive swimmers who swim on a regular basis may be affected. This study per se does not establish a direct causal relationship between competitive swimming and dental erosion, but it suggests that additional longitudinal studies merit evaluation on this topic.

We did not measure dental erosion of the swimmers, but the athletes are well aware of the risk for erosion when swimming in gas-chlorinated pools. In fact, many of the athletes in this study reported being aware of their "yellow teeth" (loss of enamel) due to swimming. Consistent with these anecdotal self-reports, the literature describes the detection of unusual yellowish brown staining on tooth surfaces of competitive swimmers (Escartin et al., 2000; Rose and Carey, 1995). These adverse events can be minimized if athletes who engage in competitive swimming at an early age are educated about the potential risk for developing staining and dental erosion. This would entail the supervised use of fluorides (i.e. mouthrinses, gels, varnishes) in order to prevent loss of the tooth mineral content while swimming in gas-chlorinated swimming-pools and regular attendance for periodic dental check-ups.

The possible consequences of enamel dissolution due to frequent swimming are therefore of considerable diagnostic and therapeutic significance for competitive swimmers and regular swimmers of the general public. This fact also underscores the significance of regular pH monitoring of the water of gas-chlorinated swimming-pools.

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