Mucosal immunity, respiratory illness, and competitive performance in elite swimmers

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ABSTRACT


Purpose: Exercise and training are known to elicit changes in mucosal humoral immunity, but whether these alterations have any impact on competitive performance remains unclear. This investigation examined relationships between salivary immunoglobulin (Ig) concentration, the incidence of respiratory tract illness (RTI), and competitive performance in elite swimmers.

Methods: Forty-one members of the Australian Swimming Team (21 males and 20 females) aged 15–27 yr were monitored during preparations for the 1998 Commonwealth Games. Twenty-five coaches and staff (19 males and 6 females) aged 32–65 yr, serving as “environmental controls,” were also monitored. Salivary IgA, IgM, and IgG and albumin concentration (mg·L⁻¹) were measured in both groups in May 1998 and again in August 1998, 17 d before competition. Subjects were categorized as “ill” (at least one RTI) or “healthy”.

Results: There were no significant changes in salivary IgA, IgM, or IgG concentration in the swimmers between May and August, nor were there any differences between healthy (N = 23) and ill (N = 18) swimmers. There was a significant positive relationship between IgM and performance in the male swimmers (r = 0.85, P < 0.001) but not for any other parameter. There was no significant difference in performance between ill and healthy swimmers (P = 0.11). Gold medal winners (N = 9) had higher IgM levels than other swimmers (N = 32) in May (P = 0.02) and higher IgG in August (P = 0.02).

Conclusion: These data indicate that a season of training by elite swimmers did not alter salivary immunoglobulin concentrations, and the presence of RTI had no significant impact on competitive performance.

Key Words: ILLNESS, MUCOSAL IMMUNITY, PERFORMANCE, SWIMMING, IMMUNOGLOBULIN

Exercise and training by highly trained athletes are known to elicit changes in mucosal humoral immunity (5,6,10,11,16–18,21,22). The documentation of these changes within the scientific literature raises two pertinent questions. First, do measurable changes in mucosal humoral immunity elicit parallel changes in the incidence of illness; and second, does respiratory tract illness (RTI) have any impact on competitive performance? Although the hypothesis that illness in athletes may have a deleterious impact on performance is an attractive one, it has not yet been tested experimentally. An athlete’s health and well-being may suffer from the symptoms typically associated with RTI, but performance may not be compromised unless moderate or more severe problems are encountered. Clarification of these issues will assist the sporting community in increasing the effectiveness of intervention strategies aimed at reducing the likelihood of illness compromising athletic activity and performance.

Self-limited viral syndromes of the upper respiratory tract are the most common presentation at a typical sports medicine clinic (1). Characteristic symptoms in these viral illnesses may include a sore throat, runny nose, mild fatigue, and headache. Host defense at mucosal surfaces is largely mediated by the family of secretory immunoglobulins (Ig), particularly IgA and IgM (5,11). Salivary IgA acts as a first line of defense against colonization of infectious agents on mucosal surfaces by the exclusion, neutralization, and elimination of viral pathogens (4). Salivary IgM facilitates the early or initial response to infectious challenge, and locally produced IgG antibodies are important in the respiratory and female genital tracts (4). Salivary IgA has been suggested as one of the most promising markers for identifying those athletes more prone to, or “at risk of,” respiratory illness (18,19). Several studies have demonstrated an association between training-induced alterations in mucosal markers and illness in highly trained athletes (7,8,11–13).

Our initial interest in this area was generated by a case report where a swimmer’s training and competitive perfor-
Performance were significantly compromised in association with a year-long hypogammaglobulinemia (3). A subsequent 7-month longitudinal study of mucosal immunity in elite swimmers showed that salivary IgA levels decreased over the course of the season and athletes with lower salivary IgA had an increased risk of upper respiratory tract illness (8). A study of illness in elite female hockey players showed that lower salivary IgA preceded RTI by 48 h (13). Taken together, these studies suggest that lowered salivary IgA concentration is associated with an increased risk of RTI, but the actual impact on competitive performance has not been directly assessed.

In this study, we have examined the relationships between illness, competitive performance, and mucosal humoral immunity in a cohort of elite swimmers undertaking an intensive 18-wk training season in preparation for a major international competition. The aims of the study were to (i) assess changes in the concentration of salivary immunoglobulins during a training season; (ii) determine the incidence of RTI during the taper and competition period; and (iii) identify any relationships between performance, illness, and mucosal immunity in elite swimmers.

METHODS

Subjects. Members of the 1998 Australian National Swimming Team volunteered to participate in this study. Forty-one swimmers (21 males and 20 females) aged 15–27 yr and 25 coaching and support staff (19 males and 6 females) aged 32–65 yr were monitored during preparations for the 1998 Commonwealth Games (CG). The swimmers completed a mean training volume of approximately 700 km during the entire preparation (50 km·wk⁻¹; range, 35–55 km·wk⁻¹ for sprint and distance swimmers). The team staff were selected as “environmental controls” by being exposed to the same environmental conditions, seasonal variations, travel, and potential exposure to pathogens as the swimmers. The staff were involved in regular but moderate exercise up to 4 h·wk⁻¹. As part of regular National Team medical screening, all subjects provided written informed consent before the commencement of the study. All procedures were approved by the Ethics Committee of the Australian Institute of Sport.

Study design. The swimmers and controls were studied during the 5-month period before the 1998 CG held in Kuala Lumpur, Malaysia (Fig. 1). One week after the Australian National Swimming Championships in Melbourne, Australia (May 1998), all team members provided a saliva sample for immunoglobulin assessment. Athletes were training once per day (4000 m or 1.5 h of swimming) in the days before the collection of saliva. All saliva samples were collected at rest, at 2 hours postprandial, and at least 6 hours after prior exercise. After a further 15 wk of training, the swimmers and control subjects were restested 17 d before the commencement of the 1998 CG in August 1998. Episodes of respiratory illness and infection were investigated and recorded by the team physician in the 6-week period before and including the CG swimming competition. In each episode, the severity of symptoms was rated as either “mild” (no modification to training required), “moderate” (training volume and/or intensity was modified), or “severe” (no training permitted). Competitive performance of the swimmers at the 1998 National Championships (May) and the CG (September) was assessed and compared with illness history and salivary immunoglobulin concentrations.

Performance measures. The swimmers’ performance at the two swimming competitions was assessed in two ways. First, the performance of each swimmer’s best event was rated in terms of the International Point Score (IPS), which is recognized by Federation Internationale Natation Amateur (FINA), the world governing body in swimming. This system ascribes a point score to each swim scaled up or down from 1000 points (where 1000 points is equal to the mean time of the eight fastest times in history for that event). The points score system is located on the Internet at http://www.swimnews.com/Rank/Rank.html for use by coaches, athletes, scientists, and swimming officials. Second, the final placing of each swimmer’s best event (first place, second place, third place, or nonmedalist) at the 1998 CG was recorded.

Salivary immunoglobulins and albumin. One milliliter of unstimulated whole mixed saliva was collected directly into a 5-mL plastic collection tube and stored at −20°C until assayed. Salivary IgA, IgM, and IgG were determined by an in-house enzyme-linked immunosorbent assay (ELISA), and albumin by rate nephelometry (Beckman ARRAY). Immunoglobulin concentrations are expressed in absolute values (mg·L⁻¹). The laboratory’s between-run and within-run coefficients of variation (CV) for the assays were all below 10% and 5%, respectively.

Statistical analysis. On the basis of nonnormal distribution of immunoglobulin concentrations, all immune data was log-transformed for statistical analysis and presented as median and range. The Student’s t-test for paired samples was used to compare the change in immunoglobulin concentration over time (May to August) and between groups (healthy [no RTI] and ill [at least one RTI]), and to compare the absolute international point score and change in international point score between the two competitions. Two-list correlational analysis was used to assess the strength of associations between salivary immunoglobulin concentrations (IgA, IgG, and IgM) measured in both May and

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**FIGURE 1**—The experimental design of the study showing the National Championships and the Commonwealth Games in relation to mucosal immune assessments and respiratory illness.
August and competitive performance at the 1998 CG. A $P$ value < 0.05 was considered significant.

**RESULTS**

**Competitive performance.** The Australian Swimming Team won a total of 48 medals (24 gold, 11 silver, 13 bronze) to be the leading nation in the CG swimming competition. A total of one world record, three Commonwealth records, and six national records were set by swimmers in this study at the CG. The mean international point score at the Australian National Championships (April) and the CG (September) were 945 ± 34 points and 947 ± 36 points, respectively.

**Incidence of illness.** The incidence of respiratory illness in the total study population and in each of the different subject categories (all subjects, male swimmers, female swimmers, all swimmers, gold medal winners, non–gold medal winners, coaches, and staff) is presented in Table 1. All subjects who reported illness experienced only one episode in the 6-wk study period. The median duration of illness was 4 d for the swimmers (range, 1–21 d) and 6 d for the coaches and staff (range, 2–14 d). For the severity of symptoms in the 18 episodes of illness in the swimmers, 10 were rated as “mild,” 4 as “moderate,” and 2 as “severe.” Only three swimmers reported illness during the actual competition period (the final week of the 6-week study period). The severity of symptoms was generally mild in nature, and all swimmers were sufficiently healthy to compete in their selected events at the CG.

**Salivary immunoglobulins.** The concentrations of albumin and immunoglobulins for each subject category are presented in Figure 2. There were no significant differences in median salivary IgA concentration between May and August for any subject group. There were small changes in median salivary IgM concentration for male (decreased IgM) and female (increased IgM) swimmers, but these were well within the laboratory’s reference interval for these parameters. Median salivary IgG concentration decreased ($P < 0.05$) in the coaches but not with any other subject group. There were no significant changes in median salivary albumin concentration with any subject group.

**Correlations between salivary immunoglobulin, health status, and competitive performance.** There were no significant differences between healthy ($N = 23$) and ill ($N = 18$) swimmers for albumin and/or salivary immunoglobulins, at the beginning (May) and end of the season (August) (Table 2). In contrast, the same comparison between healthy ($N = 10$) and ill ($N = 15$) coaching and team staff (Table 3) revealed that staff with illness (6.5 mg·L⁻¹) had significantly lower ($P = 0.01$) salivary IgG in May than did healthy staff (22.4 mg·L⁻¹). During the August assessment, staff with illness had a significantly lower median salivary IgA concentration (22.8 mg·L⁻¹), being approximately one third that of healthy staff (67.8 mg·L⁻¹, $P = 0.01$).

Simple correlational analysis was undertaken to determine the extent of relationships between salivary immunoglobulin concentration and international-level competitive performance. There was no evidence of any direct association between salivary immunoglobulin concentrations measured in either May or August and competitive performance at the CG. There was no significant difference in competitive performance at the CG between healthy swimmers (mean International Point Score (IPS) = 955) compared with ill swimmers (mean IPS = 937 points) ($P = 0.11$). Healthy swimmers tended to swim faster at the CG (positive IPS differential) compared with the National Championships (Table 4), whereas ill swimmers tended to swim slower (negative IPS differential).

Although the mean IPS levels of healthy swimmers were only marginally higher than ill swimmers, it was of practical

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![FIGURE 2—Salivary IgA, IgM, IgG and albumin concentration at the beginning (May) and in the taper period (August) of the training season. The laboratory’s reference interval for each parameter is marked by the heavy line adjacent to the y-axis. *$P < 0.05$.](http://www.acsm-msse.org)
interest to assess this difference in terms of the actual competitive results. On the basis of a 5- to 10-point differential between healthy and ill swimmers (Table 4), the equivalent time difference in actual performance was extracted from the IPS charts. The time differentials were then compared with selected results of the 1998 CG (Table 5). A 5-point differential equated to a time difference of between 0.13 and 0.48 s for male and female 100-m and 200-m freestyle (FS) events. Inspection of the competition results at the 1998 CG and the 1998 World Championships showed that this difference would have changed a swimmer’s placing from a medal (first, second, or third) to either a minor medal or a nonmedal finishing position (fourth to eighth). The differences in immunoglobulin concentrations were compared between swimmers (N = 9) who won a gold medal in an individual event compared with those who did not (N = 32) (Table 6). Gold medal winners had a higher median salivary IgM concentration in May (P = 0.02) and a higher median salivary IgG concentration in August (P = 0.02) than swimmers who did not win a gold medal.

DISCUSSION

This study failed to provide significant evidence of an association between respiratory illness and competitive performance in elite swimmers. Although athletes who managed to avoid illness tended to swim faster than their colleagues who experienced an RTI during the 6-week taper and competition period, this difference did not reach significance (P = 0.11). However, the magnitude of the mean difference in performance between healthy and ill swimmers (0.1 to 0.5 s in 100- and 200-m events) was greater than many of the actual time differences between gold, silver, and bronze medal winners, and between medal (first, second, and third) and nonmedal (fourth to eighth) places.

The illnesses diagnosed in this study were essentially mild and self-limited viral syndromes of the upper respiratory tract. This is consistent with previous reports showing respiratory tract problems as the most frequent reason for highly trained athletes to visit a sports medicine clinic (1,2). The median duration of illness in the taper period of 4 d is also similar to that observed in the general community (15). Although these swimmers experience a similar number of RTIs per year as an age- and sex-matched cohort (approximately 2.7 RTI episodes·yr⁻¹) (2), the critical issue is the timing of illness rather than the yearly frequency. It is possible that performance is only affected when moderate to severe illness is experienced.

Despite the intensive training undertaken by the swimmers between May and August, there was no significant change in salivary IgA and IgG concentrations, and only small but statistically significant differences in salivary IgM. These changes are relatively modest and all mean values were within the normal reference range for the laboratory. The stability of salivary IgA over an extended period of training is at odds with previous work showing a significant decrease over a 7-month training period (6,8), but consistent with a recent report indicating a slight increase in salivary IgA in swimmers over a 12-wk training cycle (7). The lower salivary IgA and IgG levels in the coaching and support staff with illness support earlier studies linking low immunoglobulin concentration with an increased risk of RTI in the general population. The failure to observe this association with the swimmers may relate to the timing of a single saliva sample used in the present study. A previous study of illness in athletes showed that lowered

| TABLE 3. Comparison of salivary immunoglobulin and albumin concentrations (mg·L⁻¹) between healthy and ill staff. |
|---|---|---|---|
| III (RTI) | Healthy (No RTI) | P Value |
| | Median | Range | Median | Range | Value |
| May | | | | | |
| Albumin | 33.0 | 14.0–71.0 | 69.3 | 30.6–181.0 | 0.06 |
| IgA | 49.9 | 22.1–92.4 | 122.0 | 35.7–170.0 | 0.08 |
| IgM | 2.5 | 1.7–11.2 | 9.0 | 1.6–27.4 | 0.12 |
| IgG | 6.5 | 2.3–11.5 | 22.4 | 7.7–46.3 | 0.01 |
| August | | | | | |
| Albumin | 50.9 | 50.4–127.0 | 55.3 | 33.5–204.0 | 0.76 |
| IgA | 22.8 | 20.7–31.5 | 67.8 | 32.3–200.0 | 0.01 |
| IgM | 2.4 | 2.1–5.0 | 7.3 | 5.6–25.1 | 0.35 |
| IgG | 8.5 | 6.3–13.7 | 11.0 | 6.5–15.9 | 0.12 |
IgA levels preceded RTI by 48 h (13), which suggests that whereas preseason and intermittent assessment of mucosal immunity may indicate overall risk (18), more frequent assessments are required in the taper period to effectively assess the current risk of RTI.

A key aspect of this study was examining the relationship between illness, mucosal immunity, and competitive performance in elite swimmers. The “healthy” swimmers had performance levels that were in excess of 10 points greater on the IPS system than their counterparts who reported illness. Although this was not significant ($P = 0.11$), the equivalent mean differences in performance time (ranging from 0.1 to 0.5 s in the 100- and 200-m FS events) were greater than the actual differences between winning a gold, silver, or bronze medal, or alternatively between winning a medal or missing a medal altogether. It should be emphasized that at the elite level, a fourth-place finish may well be considered a failure. The major difficulty in this area is determining whether measured or observed differences in the performance of elite athletes are statistically and clinically (real world) significant. Hopkins et al. argue that enhancement of performance as small as 0.3 to 0.4 in the CV could be significant in performance terms.

An unexpected finding was the significantly lower mucosal humoral immunity in control subjects (coaches and support staff) reporting illness. We expected that the highly trained athletes would be more prone to lowered immunity and illness than the relatively sedentary control group. Since the control subjects were limited to a maximum of 4 h of moderate physical activity per week, the incidence of RTI and lowered mucosal immunity suggests the involvement of psychological and lifestyle issues rather than physiological factors in the regulation of effective immunity in this group. Given the age difference between the swimmers and coaches, it is not possible to exclude an age-related alteration in mucosal immunity of coaching and support staff. A number of studies have suggested a link between psychological stress and the incidence of illness (14,20). Coaching at the elite level can be very stressful, and the results of this study suggest that lifestyle and self-management programs should be directed to coaching and team staff as well as the athletes themselves.

In summary, this study has failed to demonstrate a significant relationship between competitive performance and RTI status. However, there was evidence of a modest trend suggesting that swimmers with RTI could experience a performance decrement compared with their counterparts who remain free from illness. Lowered mucosal humoral immunity in the coaches and support staff is suggestive of an association between psychological and lifestyle factors and the risk of illness. Although this study was unable to directly associate lowered salivary immunoglobulin concentration with illness in elite swimmers, the results for the coaching and support staff, and previous studies with this cohort of swimmers, lend support for the routine assessment of mucosal immunity in both athletes and nonathletes during periods of physical and psychological stress to reduce the risk and impact of RTI. Future studies are required to clarify the relationship between illness and competitive performance in elite athletes.

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REFERENCES


TABLE 6. Differences in salivary albumin and immunoglobulin concentrations (mg·L⁻¹) collected in May and August between individual gold medal winners and other swimmers.

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<tr>
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<th>Gold Medal Swimmers (N = 9)</th>
<th>Other Swimmers (N = 32)</th>
<th>P Value</th>
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<td>Median</td>
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<tr>
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