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Field versus race pace conditions to provoke exercise-induced bronchoconstriction in elite swimmers: Influence of training background

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A R T I C L E I N F O

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A B S T R A C T

Background: Diagnosing Airway hyper-responsiveness (AHR) requires bronchial provocation tests that are performed at rest and after exercise or hyperventilation in either a lab or field setting. Presently, it is unclear whether the proposed AHR field test for swimming induces sufficient provocation due to lack of intensity. Thus we aimed to examine how the 8 minute field swim test compared to all out racing and a lower intensity practice exposure affected AHR. We hypothesized that the race would affect AHR the most thereby highlighting the importance of maximal effort in swim AHR.

Methods: 10 female and 15 male swimmers completed three conditions (sanctioned race of different distances, 8 min field swim challenge and swim practice). Forced vital capacity (FVC), forced expired volume in 1 second (FEV_1) and forced expiratory flow ($FEF_{25\text{-}75}$) were measured at rest and after each exercise condition (at 6 and 10 min) in accordance with standard protocols. AHR was defined as a decrease in FEV_1 of $\geq$10% post exercise.

Results: A significant increase in FEV_1 and $FEF_{25\text{-}75}$ was observed for both post swim field test and post-race. The practice condition reduced FEV_1 in 44% of swimmers although the magnitude of change was small. There was a wide variability in the individual responses to the 3 conditions and AHR was diagnosed in one swimmer (race condition).

Conclusion: All conditions have poor sensitivity to diagnose EIB and total accumulated ventilation (distance swum) did not influence AHR. These results also indicate that elite swimmers, despite many risk factors, are not limited by respiratory function in race conditions. It is proposed that the swim field test not be used for AHR assessment in swimmers due to too high relative humidity.

1. Introduction

Airway dysfunction is the most prevalent chronic medical condition facing athletes (8% of all Olympic athletes)[1] and the incidence increases (up to 76%) in what is described as high-risk sports such as swimming.[2] Airway hyper-responsiveness (AHR) is a specific type of airway dysfunction in which the airways respond "too much and too easily to stimuli".[3]

Elite swimmers undergo high volume and high intensity training in a chlorinated pool environment on most days of the week for several hours, sometimes accompanied by high levels of fatigue from inadequate sleep, illness symptoms, and other life stressors.[4] Additionally, their pool training is rather unfavourable to overall lung health[5] and can result in AHR. AHR is most often associated with acute airway narrowing post intense exercise[6] and has been defined as exercise induced bronchoconstriction (EIB).[7] For swimmers the high prevalence of EIB is likely due to a combination of ventilatory demand and airborne chlorine derivatives[8] which have been shown to damage or cause remodeling in the airway epithelium.[5] Swimmers have a higher prevalence of EIB and maximal decrease in FEV_1 compared to other "high ventilation"

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athletes despite having larger forced vital capacities (FVC).[9,10]

EIB can be assessed with bronchial provocation tests, which are both lab based[11] and field tests[12] that have been identified as both direct[13] and indirect[14] challenges to the airway. Ultimately, both direct and indirect challenges lead to constriction of the airways from either direct contraction of smooth muscle or indirect via inflammation leading to smooth muscle constriction.[15] In swimmers the majority of research has focused on indirect laboratory challenges to determine EIB; however an eight minute field swim test as an indirect bronchial provocation test for swimmers[10] has been proposed.

In general, sport specific field tests are sensitive and specific similar to lab based (exercise and non-exercise) bronchial provocation tests in identifying EIB.[16] More importantly sport specific field tests replicate the degree of EIB that occurs in high ventilation training and racing situations (prolonged periods of heavy ventilation) providing direct insight on how EIB influences performance.[12] Furthermore, given the unique environment that swimmers train and compete in heightens the importance of validating a swim specific field test. Yet only one swimming specific field test has been reported in the literature where it was found to be a poor surrogate for EIB compared to a lab based test.[10] In this study, the degree of hyperpnoea was discussed as potentially inadequate limiting the magnitude of airway provocation because the prescribed intensity was not all out race pace. This speculation may be true because post-race EIB in youth swimmers provided similar EIB prevalence and magnitude of EIB to lab based challenges.[17] Thus the role of intensity and the degree of hyperpnoea associated with a specific intensity requires further examination in the manifestation of EIB in swimmers.

Thus, our main aim was to examine the influence of swim specific intensity on EIB in elite swimmers. To answer this question we replicated the 8 min field swim challenge test which is high intensity and purported to induce sufficient hyperpnoea to provoke airways. These results were compared to all out intensity from a race and from a practice where the intensity was lower but of longer duration. Finally, to understand whether cumulative training volume influenced responsiveness to these specific intensities we grouped swimmers into sprint, middle and long distance. It was hypothesized that greater prevalence and magnitude of EIB would occur in the race condition compared to the field swim challenge test and that the field swim challenge test would induce more EIB than a normal practice. We hypothesized that the distance swimmers would have greater prevalence of EIB and the magnitude of the response would be greater compared to middle distance or sprint swimmers.

2. Methods

2.1. Study population

Twenty five varsity swimmers with 10 years or more of competitive swimming experience were recruited (10 female and 15 males). All swimmers were preparing for the National University Swimming Championships and were recruited to the program from high performance clubs. All were currently training and free from any diagnosed illness, respiratory infection or injury which prohibited them from their normal training program. Their training program for the 3 months prior to testing included 7-9 swim sessions, 2 dryland sessions, and one day off per week (Sunday). All participants had normal baseline FEV_1 and FVC values for their age, height and gender (ATS/ERS task force: Standardization of lung function testing).[18] Swimmers with a history of asthma or respiratory symptoms associated with exercise were not excluded. Based on expected prevalence from previous research on field or lab EIB testing we could conservatively estimate 10 percent prevalence with a precision of 5% and 95% level of confidence the sample size estimate would be 6.9 participants.

2.2. Experimental design

Participants were assessed at three different time points over a 4 week period. The order of testing was practice, swim field challenge, race. First swimmers were measured before and after swim practice in the pool environment. The swimmers were exposed to the pool environment for approximately 10 minutes before pre-practice spirometry was taken. Practice was approximately 90 minutes long and included some low intensity/kick sets as well as some "hard intensity intervals (duration between 30 seconds and 1 minute)". Three days after practice intensity spirometry was completed swimmers completed the 8 min swim field test using the recommended protocol[10] in an indoor 25 m pool. On the day of the 8 min swim field test participants had not completed any training or strenuous exercise a minimum 24 hours prior to their arrival at the pool. Swimmers were allowed to warm up for 400 m before starting their swim field challenge test. The participants were asked to "swim as far as possible in 8 minutes" and they all employed an even pace strategy based on their own assessment of fitness. To explain the swimmers decided upon a target 100 m pace they wanted to hold to achieve their farthest distance possible in the 8 minutes. Once 8 minutes had been surpassed swimmers were notified by placing a kick board in the water as they were about to complete their next flip turn. At that time the swimmer exited the pool and completed their post field test spirometry. Participants were asked on a scale of 0 -10 how hard they swam in the field test. This question was asked post spirometry to reduce the chance of immediate acute fatigue from biasing their perspective on how hard the entire 8 min swim was. Participants were asked to refrain from medications that might influence lung function (24 hours for short acting $\beta 2$ agonists and 72 hours for inhaled corticosteroids) and abstain from caffeine 6 hours prior to their test.

The race condition spirometry was measured at a National level meet that was the key qualifier for the University Championships. Swimmers were measured after their "best/strongest race" which was decided a priori by the swimmers, the head coach and the research staff. The distance ranged from 50 m to 1500 m and the races were spread over a 2 day period. Given the range of distances raced swimmers were grouped into sprint (50, 100 m), middle (200, 400 m) and long distance (800, 1500 m) groups to determine influence of distance raced on EIB. The pool environment conditions were similar for both the practice and 8 min swim field challenge testing (28°C and 75 % relative humidity). The race condition ambient conditions were 30°C and 90 % relative humidity. The study received Institutional Research Ethics Board approval and all participants provided informed consent for all tests and procedures prior to starting the study.

2.3. Spirometry measures

Spirometry measures were performed on a portable spirometer (Spirolab III, Medical International Research, Rome, Italy) using recommended manufacturer guidelines. Participants completed baseline spirometry assessments of FEV_1 and FVC to determine lung function according to "ATS/ERS Task Force: Standardisation of Lung Function Testing guidelines".[19] FEF_{25-75} was also recorded to provide an estimation of small airway function in athletes.[20] Post condition spirometry was completed as follows. FEV1 was measured in duplicate at 6 and 10 minutes post condition in accordance with standard protocols.[21] Minimum post-exercise FEV1 was the lowest recorded value post exercise regardless of