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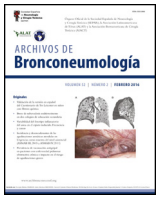

Original Article

Changes in Ventilatory Response to Exercise in Trained Athletes: Respiratory Physiological Benefits Beyond Cardiovascular Performance☆

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ABSTRACT

Introduction: The beneficial impact of an 8-month competitive season on the ventilatory profile response to exercise in soccer players has never been evaluated.
Material and methods: Ventilatory profile (evaluated by determining individual tidal volume [V_T] relative to minute ventilation [V_E] inflection points during exercise) and metabolic responses to incremental exercise were evaluated in 2 professional soccer teams before and after an 8-month competitive season.
Results: No differences between teams in anthropometric characteristics or in resting cardiopulmonary variables, included oxygen uptake (VO_2) and heart rate (HR), before and during the competitive season were found. At iso-speed, there were overall improvements in carbon dioxide output (VCO_2), V_E/VO_2, V_E/VCO_2, V_E and respiratory frequency (fR) during the season. The V_T/V_E inflection points 1 and 2 occurred with greater exercise time, HR, VO_2, VCO_2, V_E and V_T during the competitive season.
Conclusions: Despite very high baseline performance and a negligible improvement in VO_2, an 8-month competitive season improved ventilatory profile response to exercise in elite athletes.

Cambios en la respuesta ventilatoria al esfuerzo en deportistas entrenados: efectos beneficiosos sobre la fisiología respiratoria más allá del rendimiento cardiovascular

Palabras clave:
Perfil ventilatorio
Esfuerzo
Patrón respiratorio
Jugadores de fútbol

RESUMEN

Introducción: El efecto beneficioso de una temporada de competición de 8 meses sobre el perfil ventilatorio en respuesta al esfuerzo no se ha evaluado en jugadores de fútbol.
Material y métodos: Se evaluó el perfil ventilatorio (analizando los puntos de inflexión específicos de la razón entre el volumen corriente [V_T] y la ventilación [V_E] durante el esfuerzo) y la respuesta metabólica al esfuerzo gradual en 2 equipos de fútbol profesional, antes y después de una temporada de competición de 8 meses.
Resultados: No se observaron diferencias entre equipos en las características antropométricas ni en las variables cardiopulmonares en reposo, incluidos el consumo de oxígeno (VO_2) y la frecuencia

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cardíaca (FC). Durante la temporada de competición, a velocidad estándar (iso), se observaron mejorías globales en la producción de dióxido de carbono (VCO_2), las razones V_E/VO_2 y V_E/VCO_2, la V_E y la frecuencia respiratoria (FR). Los puntos de inflexión 1 y 2 de la razón V_T/V_E se observaron tras un mayor tiempo de ejercicio y mayores FC, VO_2, VCO_2, V_E y V_T durante la temporada de competición.
Conclusiones: A pesar del elevado rendimiento inicial y de la escasa mejoría del VO_2, la temporada de competición de 8 meses mejoró el perfil ventilatorio en respuesta al esfuerzo de estos deportistas de élite.

Introduction

Training programs that include exercising the leg muscles with walking, stationary cycling, or treadmill exercise are commonly used in sedentary populations[1] and patients suffering from chronic obstructive pulmonary disease (COPD), chronic heart failure (CHF) and pulmonary arterial hypertension (PAH) to improve exercise performance, reduce symptom perception (shortness of breath and leg discomfort) and improve quality of life.[1–3]

The effects of training on the cardiovascular, metabolic and ventilatory adaptation/response to exercise are largely known in these populations[3–5] and also in sport elite athletes.[1,6,7]

The ventilatory response to exercise can be evaluated in terms of ventilatory demand, ventilatory efficiency and ventilatory profile. Ventilatory demand can be assessed as the relative contribution of tidal volume (V_T) and respiratory frequency (fR) to total ventilation (V_E), ventilatory efficiency as the rate of increase of V_E with respect to carbon dioxide production (VCO_2) (i.e., the V_E/VCO_2 slope and ratio), and ventilatory response profile as the V_T to V_E inflection points during exercise, which are usually determined by examining individual Hey plots.[8] In healthy subjects, 1 and sometimes 2 inflection points (V_T/V_E inflection 1 and 2) can be observed.[8] In addition, the V_T/V_E inflection point corresponds to the attainment of critical constraints on V_T expansion, and marks the point where both dyspnea intensity and selection of perceived unsatisfied inspiration escalate sharply in asthma and COPD patients.[9–11]

Little is known of the effects of training on the ventilatory profile during exercise, and whether this may affect exercise performance in elite athletes. The aim of this study, therefore, was to evaluate the effects of 8 months of training and competition on the ventilatory profile response to treadmill exercise in elite athletes from the Italian soccer "Serie A" league.

We hypothesized that 8 months of training and competition would have a beneficial impact (reduction) on the ventilatory response to exercise in these athletes by postponing the occurrence of V_T/V_E inflection 1 and 2, thus ameliorating the ventilatory profile. This, in turn, would likely help improve exercise performance under these circumstances.

Material and Methods

Study Design and Subjects

This is an exploratory, observational, follow-up study of 14 professional male soccer players, aged between 21 and 33 years, belonging to 2 Italian "Serie A" league soccer teams. The population was examined before the start of the championship (July 2014) and after 8 months of competition during the championship (March 2015) according to a standardized protocol consisting of clinical and functional assessment parameters. The clinical assessment included history of risk behavior and physical examination, and the functional assessment included spirometry and ergospirometry. After receiving the description of the procedures and potential risks, all subjects gave their written informed consent. The study was approved by the Internal Institutional Review Boards of both teams. All procedures performed in the study complied with the ethical standards of the Internal Institutional Review Board Committee and with the 1964 Helsinki declaration and its subsequent amendments or with comparable ethical standards.

Spirometry and Ergospirometry

A pneumotachograph was used to measure dynamic volume indices such as forced vital capacity (FVC) and indices derived from it such as the forced expiratory volume in 1 s (FEV_1) and its correlation with FVC (FEV_1/FVC ratio). The observed values were expressed as a percentage of the predicted values based on the American Thoracic Society/European Respiratory Society reference values.[12] For heart rate (HR) monitoring, a polar heart rate monitor was used (Polar, Kempele, Finland).

For the ergospirometric test (Vmax Encore, Yorba Linda, CA, USA), a "ramp" protocol at a constant treadmill incline (1%) (starting at 8 km/h and increasing speed by 1 km/h every 60 s) was used. Using "breath by breath" analysis of the flows and concentrations of respiratory inhaled and exhaled gases (VO_2 and VCO_2) obtained via mass flow and fast-responding gas analyzers (fuel cell and infrared analyzers), the following variables were obtained: oxygen uptake (VO_2) and its relationship to heart rate (oxygen pulse or VO_2/HR), the derived ventilatory variables (V_E and V_T) and the ventilatory equivalents for O_2 and CO_2 (V_E/VO_2, V_E/VCO_2). The anaerobic threshold (AT or ventilatory threshold) was evaluated using non-invasive measurements of respiratory variables derived from the VCO_2/VO_2 slope method[13] and verified against the increase in V_E/VO_2 without change in V_E/VCO_2 during exercise.[14]

The VO_2 test was rigorously performed to verify the attainment of maximal VO_2 ($V'O_2max$), accordingly to established procedures.[15]

The breathing respiratory reserve (BRR) was expressed as the difference in liters between the maximum voluntary ventilation (MVV) of each athlete and ventilation achieved at peak exercise (V_E peak), where the predicted MVV was defined as $FEV_1 \times 40$. Exercise tolerance was expressed as the maximum speed reached (maximal exercise velocity: MEV), adjusted according to a modified Kuiper's equation (Eq. (1)):

$$\mathrm{MEV} = v_l + \left(\frac{n}{60}\right) \quad (1)$$

where v_l represents the speed achieved on the last exercise step, and n the number of seconds attained during the last stage.

The V_T inflection point of each subject was manually identified on the V_T/V_E graph.

All functional measurements were performed before and after 8 months of competition during the championship. Specialized sports physicians individualized the training regimens for each player. Both soccer clubs specifically requested that investigators be blinded to their physical training programs to prevent any disclosure of these regimens. All measurements were performed according to standardized criteria of the American Thoracic Society and American College of Chest Physicians (ATS/ACCP).[16]