The Journal of Sports Medicine and Physical Fitness 2018 mese;58(0):000-000
DOI: 10.23736/S0022-4707.17.07619-8

ORIGINAL ARTICLE

Effects of detraining on breathing pattern and ventilatory efficiency in young soccer players

José R. ALVERO-CRUZ [1] *, Mauro RONCONI [1], Jerónimo GARCIA ROMERO [1], José NARANJO ORELLANA [2]

[1]University of Málaga, Andalucía Tech, Faculty of Medicine, Málaga, Spain; [2]University Pablo de Olavide, Department of Sports and Informatic, Seville, Spain

*Corresponding author: José Ramón Alvero Cruz, López de Peñalver Building, University of Málaga, Campus de Teatinos s/n., 29071 Málaga, Spain.
E-mail: alvero@uma.es

ABSTRACT

BACKGROUND: This study investigated the effects of detraining on breathing pattern. The aim of this study was to evaluate the effect of a six-week detraining period on breathing patterns and ventilatory efficiency.
METHODS: Fourteen young soccer players were evaluated at the end of a competitive season and after a six-week detraining period. Assessment of respiratory efficiency was based on V_E/VCO_2 slope changes below 70% of exercise intensity. All participants underwent twice an incremental graded exercise test up to exhaustion.
RESULTS: No differences in breathing frequency and inspiratory time/ total time ratio (Ti/Ttot) were found after detraining (P>0.05). Differences in tidal volume (V*T*), V*T*/Ti quotient and V_E were significant (P<0.05) at between 40 to 100% of exercise intensity. The V_E/VCO_2 slope did not change (P>0.05) during a postdetraining maximal incremental test.
CONCLUSIONS: A six-week detraining period causes changes in inspiratory flow but does not affect the inspiratory time/total respiratory cycle time ratio. The overall ventilatory efficiency of the respiratory system remains constant and is not affected by detraining.

(*Cite this article as:* Ramón Alvero-Cruz JR, Ronconi M, Garcia Romero J, Naranjo Orellana J. Effects of detraining on breathing pattern and ventilatory efficiency in young soccer players. J Sports Med Phys Fitness 2018;58:000-000. DOI: 10.23736/S0022-4707.17.07619-8)

KEY WORDS: Respiration - Efficiency - Exercise.

Respiratory function in different situations such as physical exercise is frequently analyzed by evaluating changes in ventilation (V_E), tidal volume (V*T*), and respiratory frequency (f_R).[1] The term breathing pattern refers to mechanical changes in breathing and it is measured with parameters such as tidal volume (V*T*), inspiratory and expiratory volume, inspiratory and expiratory flow, respiratory timings, and depends on a number of factors, such as central nervous system (CNS) activity, humoral mechanisms and peripheral receptors.[2] Ventilatory response to incremental physical exercise is characterized by an exercise-mediated increase in V_E. For the purpose of a functional assessment, ventilation mechanisms can be divided into two separate components: central inspiratory activity and the inspiration-expiration alternation mechanism.[3] Many experts agree that the tidal volume/inspiratory time ratio (V*T*/*T*i), also called inspiratory flow or driving component, increases progressively with exercise. This does not apply, however, to inspiratory time/total respiratory cycle time (*T*i/*T*tot), known as the timing component.

Respiratory efficiency is based on the close relationship between CO_2 output and V_E, and is defined as the amounts (liters) of ventilation required to eliminate 1 liter of CO_2. It is measured by analyzing the VE/VCO_2 slope (delta CO_2) below the respiratory compensation point, since above this point VE would increase[4] and $PaCO_2$ would decrease as a result of hyperventilation.

Several studies have analyzed the effect of different situations on the breathing patterns as heart failure patients,[5] obese patients[6] cardiac dysfunction patients,[7] elite cyclists,[8, 9] and in different laboratory-staged incremental exercise tests as cycloergometry or treadmill.[10, 11] All these highlight the importance of parameters such as the V_E/VCO_2 slope as a diagnostic and prognostic marker for different interventions. All these changes and adjustments to the ventilatory response to physical exercise could be affected by training and detraining periods.[12]

Detraining has been defined as the partial or total loss of anatomical and physiological adaptations and performance caused by discontinuity or reduction of physical training stimuli.[12] After cessation of training, heart rate, ventilation, respiratory exchange ratio, and blood lactate levels increased progressively during the first eight weeks of detraining, after which a stabilization occurred.[13] A three-year observational study was analyzed the ventilatory efficiency and breathing pattern in world-class professional cyclists. Also ventilatory efficiency (VE/VCO_2 slope) was analyzed and this was unaffected during the study, independent of training level or performance. In the same way the breathing pattern variables, VT/Ti and Ti/Ttot, did not change significantly over the longitudinal period. These findings suggest that a long period training with changes in cycling performance in a world-class professional cyclists do not modify breathing variables related to the control of ventilatory efficiency.[9]

Therefore it could be hypothesized that after a detraining period, there would be no changes in ventilatory efficiency. The aim of this study was to analyze the effects of a six-week detraining period on the driving and timing components (ventilation control), and other, changes on breathing pattern based on ventilatory efficiency models. Knowing that CNS control and especially, the efficiency are variables that the system tends to keep constants without change with of training level or along the seasons, raising the hypothesis that a detraining period also did not cause changes in respiratory efficiency

Materials and methods

Participants

Fourteen, healthy males, young soccer players (age: 15.35±0.84 years) who underwent four 90-minute training sessions a week followed by 1 day of competition (90-min) a week.

Study protocol

All participants underwent a medical and physical examinations included a test of forced vital capacity. All were found to be healthy and free from acute or chronic diseases, and none was taking any form of medication. Parents, guardians and coaches were given a comprehensive, detailed explanation of the characteristics and objectives of the tests, in accordance with Helsinki declaration protocols. All study procedures were approved by the Independent Ethics Committee of the Faculty of Medicine of Málaga, and all parents or guardians signed an informed consent form explaining in detail all the data gathering instruments and methodology to be used.

Detraining period

The detraining period lasted 6 weeks (42 days) and all participants were warned of not to perform training activities. At the end-of-season physiological tests were carried out during the last week of the competitive period (TRA). Formal training activities started after six weeks (DET), at which time field and laboratory physiological tests were again carried out during the first week. Detraining period was consistent with a decline in certain parameters, such as VO_2max, ventilation, and running speed at aerobic and anaerobic thresholds.[14]

Ergospirometric graded exercise tests

Graded exercise tests were conducted at the end of the season (TRA) and the start of the next, following the rest period (DET), on a PowerJog J series treadmill (UK) connected to a CPX MedGraphics gas analyzer system (Medical Graphics, St Paul, MN, USA) with continuous measurement of VO_2, VCO_2, respiratory quotient, V_E, VT, VT/Ti, $Ti/Ttot$, f_R, $PETO_2$, $PETCO_2$, V_E/VO_2, V_E/VCO_2 through a zirconium O_2 electrode and an infrared CO_2 chamber. Prior to each test the equipment was calibrated according to the manufacturer's settings. The stress test consisted of an 8-10 min warm-up period at a speed of 5 km/h followed by 1 km/min speed increases until maximum effort was reached. The laboratory was kept at an environmental temperature of 22-24 ºC, and 45-60% humidity.

Analysis of breathing pattern

Ventilation was analyzed by means of the driving component, using the VT/Ti quotient, and the inspiration-expiration alternation mechanism, using $Ti/Ttot$. We also analyzed breathing frequency relative to tidal volume (VT): (f_R/VT) and (VT/Ti) relative to V_E with a proposed nomogram.[15] All parameters were analyzed relative to effort intensity from 30 to 100% intensity of maximum oxygen uptake.

Analysis of ventilatory efficiency

Ventilatory efficiency (VE/VCO_2 slope) was calculated from the beginning of exercise test to the second ventilatory threshold (respiratory compensation point) in both moments[11]

Statistical analysis

All variables are expressed as mean±standard deviation. The Shapiro-Wilk Test was used to test normal distribution. A paired sample Student's T-test was performed to compare TRA and DET mean values. Statistical significance was defined as a P<0.05. The data were processed using MedCalc Statistical software version 17.2 (Ostende, Belgium).

Results

The basic anthropometric sample data were age 15.36±0.84 years, weight 64.41±7.3 kg, height 170.91±4.3 cm and BMI 22.05±2.4 kg/m². Neither breathing frequency (f_R) nor *Ti*/*T*tot ratio changed at any effort percentage (P>0.05) after the detraining period, and the same was true of V_E/VCO_2 slopes (P>0.05). Tidal volume (V*T*), V*T*/*T*i quotient, and V_E showed significant changes from 40 to 100% of effort intensity (P<0.01) following the detraining period (Table I).

TABLE I.—*Respiratory variables in training and detraining periods.*

$\%VO_{2max}$	Training (mean±SD)	Detraining (mean±SD)	P
f_R (cycles per min)			
40%	29.786±6.36	30±8.19	0.87
70%	42.5±9.95	42±10.86	0.82
100%	63.071±8.70	60.5±9.61	0.38
Ti/Ttot (s)			
40%	0.409±0.042	0.42±0.03	0.41
70%	0.454±0.036	0.46±0.03	0.45
100%	0.458±0.029	0.47±0.02	0.23
VT/Ti (L/s)			
40%	1608.29±318.18	1380.00±282.94	0.01
70%	2898.50±539.64	2260.79±347.30	0.001
100%	4700.86±550.09	3548.21±707.99	0.001
VT (mL)			
40%	1361±296.16	1217.21±285.37	0.01
70%	1887.6±369.7	1580.64±381.12	0.001
100%	2066.7±343.72	1675.71±373.74	0.001
V̇E (L/min)			
40%	39.13±6.78	34.81±6.92	0.01
70%	78.29±11.15	64.09±6.84	0.001
100%	129.29±17.2	102.59±15.49	0.001

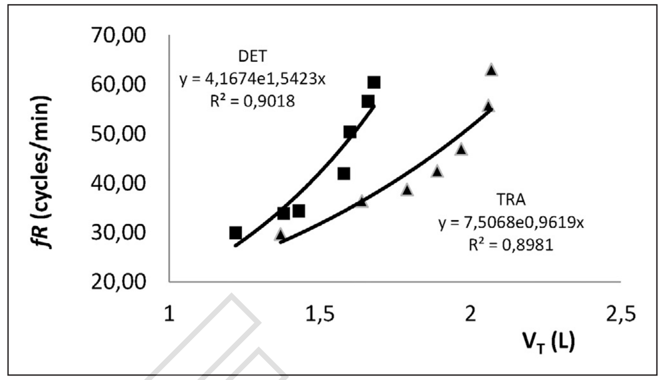

Figure 1.—Correlation between Respiratory frequency (fR) and tidal volume (VT) during training (TRA) and detraining (DET).

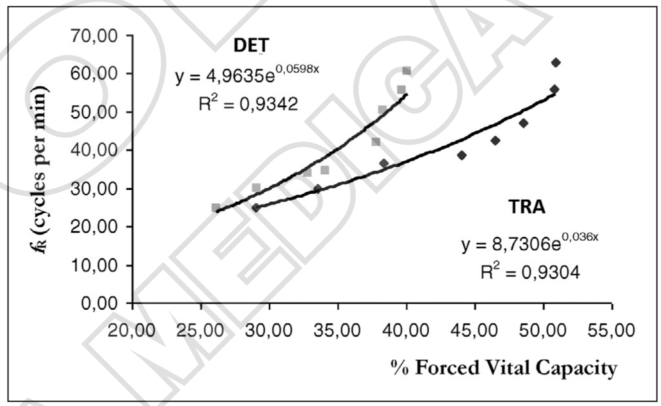

Figure 2.—Respiratory frequency vs. Forced vital capacity during TRA and DET.

An assessment of ventilatory efficiency based on analysis of VE/VCO_2 slopes between TRA and DET showed no significant differences (P=0.46). The correlation between respiratory frequency and tidal volume changed during detraining, showing a left skew that is outside the nomogram for adult subjects (Figure 1).

To rule out differences in lung size, we analyzed a f_R *vs*. percentage of forced vital capacity chart. The results suggest that during DET frequency increase starts earlier (the upward curve starts before 40%) than during training (upward curve occurs at around 50%) (Figure 2).

Discussion

As far as we are aware, this is the first study to evaluate breathing patterns and ventilatory efficiency, and to compare these values in young trained soccer players after a six-week detraining period. The main findings point to a decrease of V*T* and mean inspiratory flow (V*T*/*T*i). The detraining period produced a loss in the ability to generate tidal volume to the same effort intensity, which produced a decline of ventilation but without impairment of ventilatory efficiency.[16] In other studies we have found no differences in the V*T*/*T*i ratio during incremental treadmill and cycloergometry tests with similar V_E levels.[17] Other studies in athletes have shown stable *T*i/*T*tot during exercise, maintaining similar timings during inspiration and expiration. Naranjo *et al.*[15] have shown that this parameter remains constant during treadmill exercise, irrespective of whether a ramp or step exercise protocol is performed. In a simulated laboratory-staged controlled duathlon trial, other investigators analyzed the breathing patterns of specialist athletes without finding differences between V*T*/*T*i or *T*i/*T*tot quotients,[17] or in V_E, in either running or cycling races. This suggested that sustained high intensity activity in excess of 90% of maximum heart rate does not affect the drive component.[18]

Duathlon athletes are well trained and practice both disciplines (running and cycling) regularly, which would probably explain the absence of differences. The fact that no differences were found corroborates the thesis that breathing activity is controlled by central neural mechanisms, and that a change in these breathing strategies could alter pulmonary mechanics.[19] Breathing frequency does not change following the detraining period. Differences in f_R have been found[20] between men and youths and women on the other, and also between men and youths and elderly individuals. As expected, the increase in V_E for each effort level was due to an increase in inspiratory flow (V*T*/*T*i), given that the *T*i/*T*tot ratio remains constant between 60 and 100% of effort. This *T*i/*T*tot relationship remains relatively stable and consistent throughout the exercise following DET, indicating a stable breathing pattern. A reduction in the V*T*/*T*i ratio indicates difficulty to achieve increased air volume compared with the training phase, and therefore less participation of the central inspiratory command at practically all exercise intensities.

These breathing alterations can disrupt mean inspiratory flow for a particular neural respiratory control center.[21] The timing component could be closely related to arterial CO_2 levels, but might also be influenced by neural components, although CO_2 levels in young people seems to have a limited effect on timing component control.[22] Some parameters, such as V*T* and V*T*/*T*i, can vary with age and gender, although the *T*i/*T*tot quotient remains constant with similar values even in young people[23] and professional athletes.[8] The overall efficiency of the respiratory system remains constant, since there is no change in the VE/VCO_2 slope. No changes in breathing pattern and control of the ventilatory efficiency related to training and performance were observed in a longitudinal study in professional cyclists.[9] In the same way that this situation of long training in cyclists did not produce changes on the breathing pattern.

Only in pulmonary patients (pulmonary hypertension, chronic obstructive pulmonary disease or idiopathic fibrosis), respiratory efficiency is restored to normal patterns following a lung transplantation. Analysis of this spirometric variable is relevant in determining the anaerobic threshold resulting from both training and detraining.[14] The breathing frequency response relative to the percentage of vital capacity differs between TRA and DET. Comparing this response to the percentage of vital capacity rules out any possible lung size bias and allows us to conclude that the differences observed in this respiratory function parameter were due to DET. This response suggests that during DET breathing frequency increase starts earlier (the upward curve starts before 40%) than during training (upward curve occurs at around 50%). This means that the ventilatory pattern could be more fatiguing when the subject is detrained, or in other words, the ventilatory pattern "trains itself" to be less fatiguing.

Conclusions

In conclusion, the detraining period causes a mechanical impairment of the ventilation (in tidal volume and respiratory frequency) that is susceptible to improve with the training, but without compromise of the respiratory efficiency and it linear relationship between the ventilation and the central impulse (driving) that, as expected do not show significant changes.

References

1. Hey EN, Lloyd BB, Cunningham DJ, Jukes MG, Bolton DP. Effects of various respiratory stimuli on the depth and frequency of breathing in man. Respir Physiol 1966;1:193–205.

2. Dempsey JA, Harms CA, Ainsworth DM. Respiratory muscle perfusion and energetics during exercise. Med Sci Sports Exerc 1996;28:1123–8.

3. Milic-Emili JG. Drive and timing component of ventilation. Chest 1966;(70):131–3.

4. Arena R, Myers J, Guazzi M. The clinical and research applications of aerobic capacity and ventilatory efficiency in heart failure: an evidence-based review. Heart Fail Rev 2008;13:245–69.

5. Chlif M, Keochkerian D, Choquet D, Vaidie A, Ahmaidi S. Effects of obesity on breathing pattern, ventilatory neural drive and mechanics. Respir Physiol Neurobiol 2009;168:198–202.

6. Arruda AL, Pellikka PA, Olson TP, Johnson BD. Exercise capacity, breathing pattern, and gas exchange during exercise for patients with isolated diastolic dysfunction. J Am Soc Echocardiogr 2007;20:838–46.

7. Lucía A, Carvajal A, Calderón FJ, Alfonso A, Chicharro JL. Breathing pattern in highly competitive cyclists during incremental exercise. Eur J Appl Physiol Occup Physiol 1999;79:512–21.

8. Salazar-Martínez E, Terrados N, Burtscher M, Santalla A, Naranjo Orellana J. Ventilatory efficiency and breathing pattern in world-class cyclists: A three-year observational study. Respir Physiol Neurobiol 2016;229:17–23.

9. Elliott AD, Grace F. An examination of exercise mode on ventilatory patterns during incremental exercise. Eur J Appl Physiol 2010;110:557–62.

10. Sun XG, Hansen JE, Garatachea N, Storer TW, Wasserman K. Ventilatory efficiency during exercise in healthy subjects. Am J Respir Crit Care Med 2002;166:1443–8.

11. Ronconi M, Alvero-Cruz JR. Cambios fisiológicos debidos al desentrenamiento. Apunts Medicina de l'Esport 2008;160:192–8.

12. Habedank D, Reindl I, Vietzke G, Bauer U, Sperfeld A, Gläser S, *et al.* Ventilatory efficiency and exercise tolerance in 101 healthy volunteers. Eur J Appl Physiol Occup Physiol 1998;77:421–6.

13. Coyle EF, Martin WH 3rd, Bloomfield SA, Lowry OH, Holloszy JO. Effects of detraining on responses to submaximal exercise. J Appl Physiol (1985) 1985;59:853–9.

14. Melchiorri G, Ronconi M, Triossi T, Viero V, De Sanctis D, Tancredi V, *et al.* Detraining in young soccer players. J Sports Med Phys Fitness 2014;54:27–33.

15. Naranjo J, Centeno RA, Galiano D, Beaus M. A nomogram for assessment of breathing patterns during treadmill exercise. Br J Sports Med 2005;39:80–3.

16. Gea J, Orozco-Levi M, Martínez-Llorens J. [The breathing pattern, an old friend full of information—but how do we get that information?]. Arch Bronconeumol 2009;45:317–9. Spanish.

17. Ronconi M, Alvero-Cruz JR. Respuesta de la frecuencia cardiaca y consumo de oxígeno de atletas varones de competiciones de duatlón. Apunts Medicina de l'Esport 2011;46:183–8.

18. Neder JA, Dal Corso S, Malaguti C, Reis S, De Fuccio MB, Schmidt H, *et al.* The pattern and timing of breathing during incremental exercise: a normative study. Eur Respir J 2003;21:530–8.

19. Fernández Vázquez R, Alvero-Cruz JR, Ronconi M, Naranjo J. Breathing patterns in a simulated laboratory sprint duathlon. In: Cejuela R, editors. *Proceedings I World Conference of Science in Triathlon.* Alicante: University of Alicante; 2011. p.214-224.

20. Lucía A, Hoyos J, Pardo J, Chicharro JL. Effects of endurance training on the breathing pattern of professional cyclists. Jpn J Physiol 2001;51:133–41.

21. Ondrak KS, McMurray RG. Exercise-induced breathing patterns of youth are related to age and intensity. Eur J Appl Physiol 2006;98:88–96.

22. Gaultier C, Perret L, Boule M, Buvry A, Girard F. Occlusion pressure and breathing pattern in healthy children. Respir Physiol 1981;46:71–80.

23. Habedank D, Ewert R, Hummel M, Dandel M, Habedank F, Knosalla C, *et al.* The effects of bilateral lung transplantation on ventilatory efficiency, oxygen uptake and the right heart: a two-yr follow-up. Clin Transplant 2011;25:E38–45.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Acknowledgements.—We would like to thank Emeritus Prof. Salvador González Barón of the University Málaga for reviewing the manuscript and forwarding his suggestions.

Article first published online: November 17, 2018. - Manuscript accepted: November 8, 2018. - Manuscript revised: October 18, 2018. - Manuscript received: March 29, 2017.