

EFFECTS OF DIFFERENT BREATHING PATTERNS ON BIOCHEMICAL, CARDIORESPIRATORY AND PERFORMANCE VARIABLES IN YOUNG TENNIS PLAYERS

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ABSTRACT

Aim: To investigate the effect of different breathing patterns (spontaneous breathing as a control, hyperventilation and forced exhalation) on biochemical, cardiorespiratory and performance variables following a specific tennis test. Methods: Thirteen trained nationally ranked male tennis participated in this study. In three different sessions the players performed a passing-shot drill test, only modifying the breathing pattern (hyperventilation, forced exhalation or spontaneous breathing) during the recovery periods in randomized and counterbalance manner. Results: No differences were found between the three tests in biochemical variables (pH: $F_{2,12}=0.118$, $P=0.890$; pCO_2 : $F_{2,24}=1.24$, $P=0.307$; $[HCO_3^-]$: $F_{2,24}=3.257$, $P=0.056$; $[La^-]$ $F_{2,24}=0.179$, $P=0.838$) except for the base excess (BE; $F_{2,24}=4.339$, $P=0.025$). On the other hand, ventilation and breathing frequency were different among the test (VE: $F_{2,24}=23.134$, $P<0.001$; BF: $F_{2,24}=74.633$, $P<0.001$, respectively), while VO_2 and heart rate were similar (VO_2 : $F_{2,24}=0.031$, $P=0.9691$; HR: $F_{2,24}=1.213$, $P=0.315$, respectively). Finally, no relevant differences were observed for the performance variables, being the mean speed stroke, maximum speed stroke and precision stroke similar between the three tests ($F_{2,36}=0.043$, $P=0.958$; $F_{2,36}=0.007$, $P=0.993$; $F_{2,36}=0.435$, $P=0.651$, respectively). Conclusion: It seems that the performance during a submaximal specific tennis drill is not influenced by the breathing pattern used during recoveries. Therefore, altering breathing pattern does not seem a good strategy to modify the acid-base status or performance during a tennis trial.

Key words: hyperventilation, tennis performance, acid-base status, stroke speed, stroke precision

EFFECTOS DE LOS DIFERENTES PATRONES RESPIRATORIOS SOBRE VARIABLES BIOQUÍMICAS, CARDIORRESPIRATORIAS Y DE RENDIMIENTO EN JÓVENES TENISTAS

RESUMEN

Objetivo: Investigar el efecto de los diferentes patrones respiratorios (respiración espontánea como control, hiperventilación y espiración forzada) sobre variables bioquímicas, cardiorrespiratorias y de rendimiento tras una prueba específica de tenis. Métodos: Trece tenistas, varones, bien entrenados y clasificados a nivel nacional participaron en este estudio. En tres sesiones diferentes, los jugadores realizaron un simulacro de entrenamiento de carrera lateral, modificando únicamente el patrón respiratorio (hiperventilación, espiración forzada o respiración espontánea) durante los períodos de recuperación de forma aleatoria y contrabalanceada. Resultados: No se encontraron diferencias entre las tres pruebas en variables bioquímicas (pH: $F_{2,12}=0.118$, $P=0.890$; pCO_2 : $F_{2,24}=1.24$, $P=0.307$; $[HCO_3^-]$: $F_{2,24}=3.257$, $P=0.056$; $[La^-]$ $F_{2,24}=0.179$, $P=0.838$) excepto para el exceso de base (BE; $F_{2,24}=4.339$, $P=0.025$). Por otra parte, la ventilación y la frecuencia respiratoria fueron diferentes entre las pruebas (VE: $F_{2,24}=23.134$, $P<0.001$; BF: $F_{2,24}=74.633$, $P<0.001$, respectivamente), mientras que VO_2 y frecuencia cardíaca fueron similares (VO_2 : $F_{2,24}=0.031$, $P=0.9691$; HR: $F_{2,24}=1.213$, $P=0.315$, respectivamente). Finalmente, no se observaron diferencias relevantes para las variables de rendimiento, siendo la carrera media, la carrera

máxima y la carrera de precisión similares entre las tres pruebas ($F_{2,36}=0.043$, $P=0.958$; $F_{2,36}=0.007$, $P=0.993$; $F_{2,36}=0.435$, $P=0.651$, respectivamente). Conclusión: Parece que el rendimiento durante un entrenamiento de tenis submáximo específico no se ve influenciado por el patrón de respiración utilizado durante las recuperaciones. Por lo tanto, alterar el patrón de respiración no parece una buena estrategia para modificar el estado ácido-base durante la práctica del tenis.

Palabras clave: hiperventilación, rendimiento de tenis, estado ácido-base, velocidad del golpeo, precisión del golpeo

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INTRODUCTION

Tennis is an intermittent sport alternating high intensity exercise periods (4-10 sec) with short (10-20 sec) and long recoveries (60-120 sec) (Fernandez, Mendez-Villanueva, & Pluim, 2006). The rallies demand glycolytic metabolism with a subsequent increase in muscle and blood lactate (Wu, Shih, Yang, Huang, & Chang, 2010). Mean lactate levels observed during a singles tennis match are about 2-4 mmol/L (Fernandez, et al., 2006; Wu, et al., 2010), although these levels could increase up to 6-8 mmol/L (Christmass, Richmond, Cable, Arthur, & Hartmann, 1998; Mendez-Villanueva, Fernandez-Fernandez, Bishop, Fernandez-Garcia, & Terrados, 2007). These higher concentrations could determine the final result of the matches, since the athlete's physical status might be a decisive factor for winning or losing points (Fernandez, et al., 2006). In fact, a decline in some tennis skills such as the groundstroke or the service hitting accuracy have been reported during high intensity circumstances (Davey, Thorpe, & Williams, 2002; Lyons, Al-Nakeeb, Hankey, & Nevill, 2013).

Over the past decades, numerous studies have demonstrated that increases in the extracellular buffer capacity through alkalinizing agents may enhance human exercise performance (Forbes, Raymer, Kowalchuk, & Marsh, 2005; Linderman & Fahey, 1991; McNaughton, Ford, & Newbold, 1997; Requena, Zabala, Padial, & Feriche, 2005; Sostaric et al., 2006; Stephens, McKenna, Canny, Snow, & McConell, 2002) even in the specific case of tennis (Wu, et al., 2010). However, these agents are usually provided via the oral ingestion of an alkaline solution, making difficult for tennis players to benefit from these aids among points. Nevertheless, changes in breathing pattern such as hyperventilation have been reported to induce alkalosis and to enhance intermittent sprint performance (Sakamoto, Naito, & Chow, 2014). These strategies seem to be much easier to accomplish for players, especially after long and intense rallies where the acid-induced fatigue could compromise their performance.

Thus, this study aims to investigate the effect of different breathing patterns (spontaneous breathing as a control, hyperventilation and forced exhalation) on biochemical, cardiorespiratory and performance variables, following a specific tennis test. It was hypothesized that hyperventilation would attenuate decreases in biochemical and performance parameters in male tennis players.

METHOD

Participants

Thirteen trained healthy and nationally ranked male tennis players (age 16 ± 1.2 years, height 1.78 ± 0.06 m, body mass 64.9 ± 7.5 kg) who were all regularly competing in Spanish national level competitions participated in this study. All of them trained at least 5 hr/week of on-court and conditioning

training, respectively and had been playing tennis for 3 years or more. All participants were given written information concerning the nature and purpose of the study and signed an informed consent. The protocol was approved by the institutional ethics committee of the Universidad Politécnica de Madrid (UPM) and was in accordance with the Declaration of Helsinki for Human Research.

Procedure

Participants carried out four experimental sessions with minimum and maximum intervals of 48 hours and 72 hours, respectively. Evaluation of body composition by Dual-energy x-ray absorptiometry (DXA) was determined within the first experimental session. Furthermore during this session, players carried out a maximum effort test following the “Hit & Turn Tennis Test” protocol (Ferrauti, Kinner, & Fernandez-Fernandez, 2011). In the second, third and fourth experimental sessions players performed an on-court intermittent test (passing-shot drill test) following the protocol previously described (Ferrauti, Pluim, & Weber, 2001), modifying the breathing pattern during the recovery periods. Hyperventilation, forced exhalation and spontaneous breathing (as control) were used in the recovery periods within each passing-shot drill test to see their effect on biochemical, cardiorespiratory and performance variables. During the tests, the players were allowed to drink water ad libitum. The environmental conditions and ambient temperature were similar on each test day.

Body composition

Dual-energy X-ray Absorptiometry (DXA) was used to measure the percentage of total fat mass (TFM%) and the lean mass (kg) using a GE Lunar Prodigy apparatus (GE Healthcare, Madison, Wisconsin, USA). All DXA scan analyses were performed using the GE Encore 2002 software v6.10.029.

Hit & Turn Tennis Test

This test is an acoustically controlled and progressive test for tennis players, and was implemented following the instructions suggested by Ferrauti et al. (2011). All the on-court tests were conducted on an indoor hard court where participants had to move for as long as possible along an 11-m line following the rhythm of the sound emitted by a DVD specifically recorded for the test (Ferrauti, 2008). Each participant was instructed to use his own racket and technique when simulating the strokes. At the time the acoustic signal was issued, the players had to run along the baseline and hit a ball with their forehand or backhand simultaneously to the sound signals. The test had 20 stages, each lasting approximately 55 seconds, and the recoveries between

stages lasted from 10 to 20 seconds. On level one the span of time between forehand and backhand strokes lasted five seconds and was reduced by 0.1 seconds on each subsequent level until three seconds at level 20. The maximal oxygen consumption (VO_{2max}) was measured by indirect calorimetry (breath by breath), using a mobile gas analyzer (Erich Jaeger, Viasys Healthcare, Germany). Similar to the study of Ferrauti et al. (2011) exhaustion was determined when participants were unable to reach a predetermined area of 1.5 m for two consecutive sound signals or when we observed a plateau in oxygen uptake or the players were not capable of executing the prescribed footwork patterns and strokes with acceptable technique according to an experienced tennis coach.

Passing-shot drill test

All the players completed the passing-shot drill test on three different days, separated at least by 48 hours. In this study, we used the protocol described by Ferrauti et al. (2001) adding different breathing patterns during the first 30 sec of each recovery between sets: 1) Spontaneous breathing: The participant breathes as he does normally, not forcing inspiration or expiration; 2) Hyperventilation: The participant breathes vigorously and more often; 3) Forced expiration: The participant tries to force expiration but not inspiration. The order of these tests were randomized and counterbalanced. Participants were familiarized and instructed in the test protocol and the breathing patterns before the beginning of the tests. The tennis balls used were the same in all the on-court trials (Dunlop Fort, Hanau, Germany). In each testing session, the players performed a standardized warm-up that involved 5 min of aerobic run at 60% of HRR. Immediately after the warm-up, players performed five maximal sprints (initial sprints) along the baseline of the court (9.5 m) recording the running speed by means of infrared photoelectric cells (MuscleLab, Ergotest Technology as, Norway). After 1 min of recovery, the players performed another 30 times the same 9.5 m run, but at 80% of the maximum running speed recorded in the initial sprints, and hit a forehand passing-shot from the outer sideline. These 30 passing-shots and sprints were subdivided into 6 sets of 5 repetitions with a 1 min rest between sets, performing the selected breathing pattern during the first 30 sec of each recovery. Finally, after the sixth set of passing-shots, five maximal sprints (final sprints) were performed again along the baseline of the court. The recovery duration between each stroke-and-sprint lasted 10 seconds, with the aim of reaching higher lactate levels by the players (Ferrauti, et al., 2001). The standardization of the test (resting periods between strokes and speed of the pitched ball) was guaranteed by the use of the machine "Elite Grand IV" (North Hollywood, California, USA). The flight time of the ball was individually adjusted by varying the angle and the speed of the balls that were thrown to the

players. During the tests oxygen uptake (VO_2), carbon dioxide production (VCO_2), breathing frequency (BF) and ventilation (VE) were recorded using the Oxycon Mobile portable metabolic system (Erich Jaeger, Viasys Healthcare, Germany). These measurements allowed controlling the correct execution of each breathing pattern. The Oxycon Mobile system was calibrated prior to each test. Heart rate was also recorded using a heart rate monitor (Polar Electro Oy, Kempele, Finland) functioning alongside the gas analyser. On the other hand, capillary blood samples (~2 mL) were collected from a fingertip for the assessment of blood lactate concentration ($[\text{La}^-]$) by enzymatic method using the YSI 1500 (Yellow Springs Instruments Co., Yellow Springs, USA). Blood samples were drawn prior to the test, immediately after the warm-up, after the initial and final sprints and after each 5-passing-shots set. The samples were higher (~4mL) after aerobic warm up, after the sixth set of passing-shots and after the final sprints, with the purpose of measuring carbon dioxide partial pressure (pCO_2), bicarbonate concentration ($[\text{HCO}_3^-]$), pH and base excess (BE) using a blood gas analyser ABL77 (Radiometer, Copenhagen, Denmark). As performance variables, we recorded the stroke speed of each passing-shot using the "Speed track radar" (EMG Companies. Inc., Wisconsin, USA), and the stroke precision recording errors and target hits at the opponent's backhand corner, which was subdivided into three areas reflecting this precision (Most precise = 1.37×1.83 m, Medium precise = 2.74×3.66 m, Least precise = 4.12×5.49 m).

Statistical analyses

Statistical tests were performed using PASW Statistics version 18.0 for Windows (SPSS Inc., Chicago, IL, USA). A two-way ANOVA (time X breathing pattern) with repeated-measures was used to compare the biochemical and cardiorespiratory variables. A one-way ANOVA was used to study the differences between breathing patterns on performance variables. Compound symmetry, or sphericity, was verified by the Mauchly test. When the assumption of sphericity was not met, the significance of F ratios was adjusted according to the Huynh-Feldt procedure. Multiple comparisons were made with the Bonferroni post hoc test. The P-values that were equal to or less than 0.05 were considered statistically significant, and all values are presented as mean \pm SD.

RESULTS

The mean age of the thirteen players who participated in the study was 16 ± 1.2 years. Anthropometric characteristics were 64.9 ± 7.5 kg and 1.78 ± 0.06 m for weight and height respectively, $10.6 \pm 3.7\%$ of fat mass and 55.6 ± 6.1 kg

of fat free mass. Their vital capacity was 5.0 ± 0.7 L, maximum voluntary ventilation 142.9 ± 24.9 L·m and VO_{2max} 55.4 ± 7.0 mL·kg·min.

Biochemical variables

A significant interaction was found for the variables BE ($F_{2,27}=7.692$, $P=0.001$) and $[HCO_3^-]$ ($F_{2,26}=14.582$, $P<0.001$). The two-way repeated-measures ANOVA showed that all the biochemical variables were modified (pH: $F_{2,12}=9.945$, $P=0.003$; pCO_2 : $F_{2,24}=34.931$, $P<0.001$; BE: $F_{2,24}=28.507$, $P<0.001$; $[HCO_3^-]$: $F_{2,24}=24.851$, $P<0.001$; $[La^-]$: $F_{2,24}=27.963$, $P<0.001$) between the different measuring times. On the other hand, no differences were found between the breathing patterns (pH: $F_{2,12}=0.118$, $P=0.890$; pCO_2 : $F_{2,24}=1.24$, $P=0.307$; $[HCO_3^-]$: $F_{2,24}=3.257$, $P=0.056$; $[La^-]$ $F_{2,24}=0.179$, $P=0.838$) except for the base excess (BE) ($F_{2,24}=4.339$, $P=0.025$). The pair-wise comparisons can be studied in Table 1 and Figure 1.

TABLE 1
Biochemical variables. Presented as mean \pm standard deviation.

	Spontaneous breathing	Hyperventilation	Forced exhalation
pH _{rest}	7.38 ± 0.04	7.36 ± 0.02	7.37 ± 0.04
pH _{passing-shot}	7.32 ± 0.09	7.34 ± 0.07	7.30 ± 0.07^a
pH _{final sprints}	7.32 ± 0.04^a	7.35 ± 0.06	7.36 ± 0.05
pCO_2 _{rest} (mmHg)	37.99 ± 3.63	$42.75 \pm 1.60^*$	$38.67 \pm 1.67^{\#}$
pCO_2 _{passing-shot}	38.20 ± 4.72	35.15 ± 4.20^a	35.56 ± 3.06^a
pCO_2 _{final sprints}	34.84 ± 1.48^a	35.15 ± 2.15^a	34.78 ± 2.85^a
BE _{rest} (mmol·L ⁻¹)	-2.07 ± 1.46	-1.41 ± 1.16	-2.60 ± 1.90
BE _{passing-shot} (mmol·L ⁻¹)	-4.57 ± 4.61	-3.61 ± 3.69	$-7.90 \pm 2.84^{*\#}$
BE _{final sprints} (mmol·L ⁻¹)	-8.38 ± 2.50^{ab}	-5.25 ± 0.56^a	$-5.95 \pm 2.59^{ab*}$
$[HCO_3^-]$ _{rest} (mmol·L ⁻¹)	21.99 ± 1.25	23.98 ± 2.06	21.79 ± 3.22
$[HCO_3^-]$ _{passing-shot} (mmol·L ⁻¹)	20.09 ± 5.11	18.83 ± 3.40^a	$17.07 \pm 2.44^{a*}$
$[HCO_3^-]$ _{final sprints} (mmol·L ⁻¹)	17.95 ± 3.69^a	19.18 ± 0.60^{ab}	19.21 ± 2.85^b

* Different from spontaneous breathing ($p<0.05$)

Different from hyperventilation ($p<0.05$)

^a Different from rest ($p<0.05$)

^b Different from passing-shot test ($p<0.05$)

pCO_2 , carbon dioxide partial pressure; BE, base excess; $[HCO_3^-]$, bicarbonate.

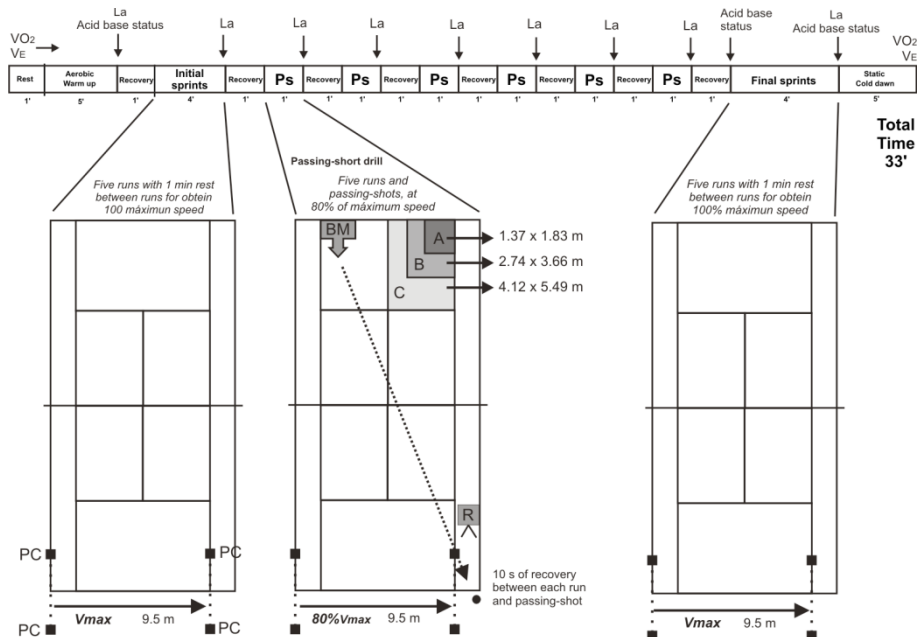


FIGURE 1. Mean (\pm standard deviation) blood lactate concentrations evolution during the passing-shot tests (Ps, Passing-shot).

Cardiorespiratory variables

A significant interaction was found for the variables VE ($F_{2,11}=18.756$, $P<0.001$) and BF ($F_{1,15}=62.603$, $P<0.001$). VO_2 and HR were different between the different measuring times (VO_2 : $F_{1,12}=184.57$, $P<0.001$; HR: $F_{1,12}=290.802$, $P<0.001$), while VE and BF remained similar (VE: $F_{1,12}=0.867$, $P=0.37$; BF: $F_{1,12}=1.062$, $P=0.323$). Nevertheless, VE and BF showed differences between the different breathing patterns (VE: $F_{2,24}=23.134$, $P<0.001$; BF: $F_{2,24}=74.633$, $P<0.001$, respectively), while VO_2 and HR were similar (VO_2 : $F_{2,24}=0.031$, $P=0.9691$; HR: $F_{2,24}=1.213$, $P=0.315$, respectively). The pair-wise comparisons can be studied in Figure 2.

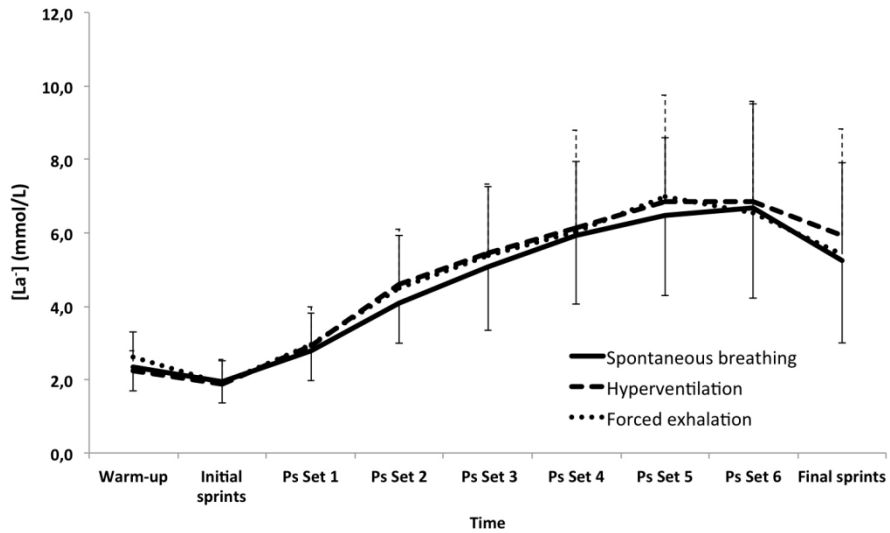


FIGURE 2. Mean values (\pm standard deviation) of oxygen consumption (VO_2 ; A), ventilation (VE; B), heart rate (HR; C) and breathing frequency (BF; D) during the active phases (black columns) and the recoveries (white columns) of the passing-shot tests. * Different from control ($p < 0.05$); # Different from hyperventilation ($p < 0.05$); ^a Different from passing-shot tests ($p < 0.05$).

Performance variables

No relevant differences were observed for the performance variables. Running speed in the initial sprints was similar between the three breathing patterns ($F_{2,36}=0.415$, $P=0.664$), as well as in final sprints ($F_{2,36}=0.776$, $P=0.468$). In addition, mean speed stroke, maximum speed stroke and precision were similar between the three tests ($F_{2,36}=0.043$, $P=0.958$; $F_{2,36}=0.007$, $P=0.993$; $F_{2,36}=0.435$, $P=0.651$, respectively). The values of these variables are presented in Figure 3.

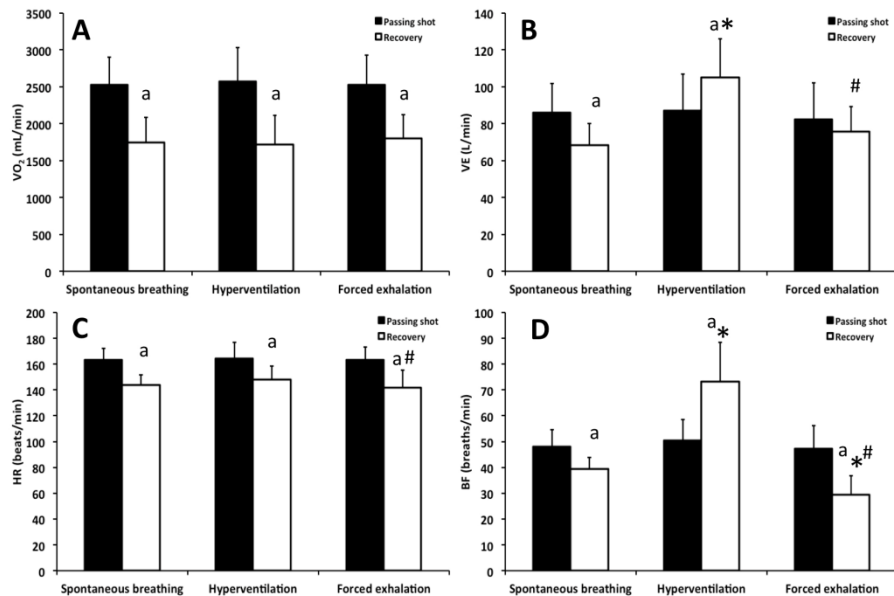


FIGURE 3. Running speed during initial and final sprints (A), speed stroke (B), and precision stroke (C) for the spontaneous breathing (black columns), hyperventilation (white columns) and forced exhalation (striped columns) groups.

DISCUSSION AND CONCLUSIONS

The objective of the present study was to analyze the effect of different breathing patterns on several biochemical, cardiorespiratory and performance variables during a specific tennis test. The obtained results suggest that altering breathing pattern is not an effective way to modify the acid-base status during a specific tennis trial, and has influence on performance.

The induced blood alkalosis may improve H⁺ efflux out of the muscle cell and thereby limiting the effects of the reduced intracellular pH determined by strenuous exercise (Bishop, Edge, Davis, & Goodman, 2004; Linderman & Fahey, 1991; Requena, et al., 2005; Street, Nielsen, Bangsbo, & Juel, 2005). It is generally accepted that a decreasing intracellular pH during exercise induces allosteric inhibition of the rate-limiting enzymes phosphofructokinase and glycogen phosphorylase, decreases release of calcium from the sarcoplasmic reticulum, and reduces the number and force of muscle cross-bridge activations (Linderman & Fahey, 1991). Anaerobic glycolysis is associated with the intracellular accumulation of H⁺, which have been implicated as a cause of muscular fatigue (Spriet, Matsos, Peters, Heigenhauser, & Jones, 1985) and previous results report that administration of alkalotic agents may improve performance during high-intensity exercise by reducing the decline in pH (Hollidge-Horvat, Parolin, Wong, Jones, & Heigenhauser, 2000).

On the other hand, tennis is a sport where the players have access to ergogenic aids only at specific moments defined by official rules. Therefore, the benefits from the intake of alkaline agents reported by previous studies (Wu, et al., 2010) would be available only at certain times of the event. However different breathing patterns as hyperventilation, which has proved their positive effects on performance (Sakamoto, et al., 2014), could be a good option available for every recovery. However, the results of the present study are not in agreement with previous investigations reporting performance improvements in tennis with bicarbonate intake (Wu, et al., 2010) or in other sports with hyperventilation pattern (Sakamoto, et al., 2014). In our study, we did not find any change in the acid-base status despite using different breathing patterns. This could be due to the fact that the pH values remained close to 7.4 and it was not observed even a mild metabolic acidosis. Furthermore, despite the moderate increase in lactate levels due to the passing-shot tennis drills, no differences appeared among breathing patterns. Therefore, our data show that none of the two breathing pattern used led to significant changes in lactate neither hydrogen ion concentration compared to spontaneous breathing. These results disagree with those reported by Sakamoto et al. (2014) who found that the pH decrease was attenuated by hyperventilation manoeuvres during all-out sprints of 10 seconds. This lack of effect in our study could be due to the fact that intensity was not high enough to reach lower pH levels and greater muscle lactate production to need an alkaline treatment. In this regard, our pH data are not increased during hyperventilation pattern, reflecting this absence of effect since other studies have reported that blood pH has to be above 7.5 to affect intracellular muscle pH (Bishop, et al., 2004). Therefore, despite we did not measure intracellular parameters, our data suggest no influence in intracellular metabolism, although futures studies are needed to confirm this.

During a tennis game several authors have reported mean lactate values around 2-4 mmol/L (Christmass, et al., 1998; Fernandez, et al., 2006; Mendez-Villanueva, et al., 2007; Wu, et al., 2010), although values of 6-8 mmol/L have been also observed (Christmass, et al., 1998; Mendez-Villanueva, et al., 2007). Nevertheless, most of the measurements were done during the larger recoveries (60-90 seconds) instead of immediately after the longest and most intense points, where lactate could reach peak values of 8 mmol/L (Fernandez, et al., 2006). Therefore with the aim of simulating a real tennis match we chose the protocol described by Ferrauti et al. (2001) with recoveries of 10 seconds, in which the $[La^-]$ reached similar levels as these peak values.

Regarding the cardiorespiratory variables, our results show how VO_2 was not higher for the hyperventilation pattern as it was expected due to a greater work performed by the respiratory and trunk muscles. Our results are similar to those reported by Sakamoto et al. (2014) who hypothesize that this absence

of differences could be explained by the reduced work of breathing resulting from bronchodilation and decreased airflow resistance with the sympathetic activation and catecholamine secretion during exercise (Coast et al., 1993; Walsh et al., 2006). All these mechanisms would compensate each other so the mean VO_2 would be equal to those for spontaneous breathing. We found a significant lower heart rate during the recoveries of the forced exhalation passing-shot drill test, compared to hyperventilation. As we said above, ventilation was also lower during forced exhalation recoveries, since the participants were required to do so. Therefore, the differences seen in heart rate may be caused by the cardiorespiratory coupling, encompassing term describing the well-recognized influences of respiration on heart rate and blood pressure (Dick et al., 2014).

On the other hand, considering the performance variables measured, they do not seem to be affected by the different breathing patterns. These patterns do not influence speed and precision stroke or running speed during sprints, although previous studies showed a decline in some tennis skills during high intensity circumstances (Davey, et al., 2002; Lyons, et al., 2013). Baiget et al. (2013) found that the technical effectiveness decrease seen during a specific progressive tennis drill was associated with VO_2 values higher than 5000 mL/min (2013). In our study VO_2 reached 2500 mL/min, far from the values reported to decline performance, suggesting that intensity drills could have been not enough.

Finally, although our participants correctly performed the hyperventilation pattern since the ventilation and breathing frequency values were significantly higher, the forced exhalation pattern did not show significant differences with control breathing. Thus, futures studies are encouraged to set more restrictive values of breathing frequency and ventilation for the forced exhalation.

Therefore, it seems that shorts bouts of hyperventilation during a tennis drill at submaximal intensity do not affect the performance. Nevertheless, with the data available, we cannot conclude if this lack of differences is due to an insufficient intensity, to the protocol followed (more strokes would imply more active muscle and therefore would increase the intensity), or because it is possible that time spent performing each breathing patterns might have been too short.

In conclusion, breathing pattern does not influence the performance during a submaximal tennis drill since none of the measured variables were influenced by the respiratory manoeuvres used in this study. Therefore, altering breathing pattern does not seem a good strategy to modify the acid-base status or performance during a tennis trial, and oral ingestion of alkaline solutions, available only during recoveries between games, remains the primary means of increase the extracellular buffer capacity in tennis. More studies are needed to

clarify if any breathing pattern is effective for maintaining the performance during higher intensities or higher durations tennis drills.

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