

THE ACUTE EFFECTS OF THE VOLUNTARY PRE-ACTIVITY HYPERVENTILATION ON JUMP AND SPRINT PERFORMANCE IN FEMALE VOLLEYBALL PLAYERS

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ABSTRACT

Objective: The purpose of the present study was to investigate the acute effects of pre-activity brief maximal voluntary hyperventilation (HP) on the jumping and sprint performances. *Methods:* Fourteen young female volleyball players (16.7 ± 1.2 years; 61.1 ± 10.3 kg; 173 ± 8 cm) voluntarily participated in this study. All subjects performed 30s HP protocol followed by 30s passive rest. After the rest period, participants applied jump or sprint performance. All participants practiced HP and normal ventilation (NV) conditions in each test sections and conditions on separate days. Paired sample T-test was used to determine whether there was a significant mean difference between performance values with HP condition compared to NV. *Results:* The results of the analyses showed that there were significant differences in 10-m sprint times between HP and NV ($p < 0.05$). However, no significant differences were determined in countermovement jump, *Conclusion:* The findings of the present study suggested that the pre-activity HP protocol can be effective for 10-m sprint time in moderately trained young female volleyball players.

Key words: respiratory alkalosis, athletic performance, jumping, sprint performance, training

EFECTO AGUDO DE LA HIPERVENTILACIÓN PRE-ACTIVIDAD VOLUNTARIA SOBRE EL RENDIMIENTO EN SALTO Y EN EL SPRINT, EN JUGADORAS FEMENINAS DE VOLEIBOL

RESUMEN

Objetivo: El objetivo del presente estudio fue investigar los efectos agudos de la hiperventilación voluntaria máxima (HP) previa a la actividad en los resultados de salto y sprint. *Método:* Participaron voluntariamente 14 jóvenes jugadoras de voleibol femenino (16.7 ± 1.2 años, 61.1 ± 10.3 kg, 173 ± 8 cm). Todos los sujetos realizaron 30s HP protocolo seguido de 30 segundos de ventilación normal. Después del período de descanso, los participantes aplicaron el salto y el sprint. Todos los participantes practicaron en las mismas condiciones de HP y de ventilación normal (NV) en cada prueba y condiciones, en días separados. Se utilizó una prueba T para determinar si había diferencias significativas entre los valores de rendimiento con la condición de HP en comparación con NV. *Resultados:* Los resultados de los análisis mostraron que hubo diferencias significativas en los tiempos de sprint de 10 m entre HP y NV ($p < 0.05$). Sin embargo, no se determinaron diferencias significativas en salto de contramovimiento. Los resultados del presente estudio sugieren que el protocolo de HP de preactividad puede ser efectivo para el tiempo de sprint de 10 m en jugadoras de voleibol femenino moderadamente entrenadas.

Palabras clave: alcalosis respiratoria, rendimiento atlético, salto, funcionamiento del sprint, entrenamiento

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INTRODUCTION

Hyperventilation can be described as pulmonary ventilation that is deeper and faster than normal respiration, which exceeds oxygen consumption and carbon dioxide removal ratio that the metabolism needs (McArdle, Katch & Katch, 2014). As a result of hyperventilation, carbon dioxide ratio in alveolar decreases and plasma Ph increases while hydrogen concentration decreases (McArdle et al., 2014; Sakamoto, Naito & Chow, 2014; Sakamoto, Naito & Chow, 2015). However, acid-base balance in the body deteriorates (Brown, 1953), dilatation may occur in blood muscle vessels (Clarke, 1952). This disturbance in acid-base balance which is the result of brief hyperventilation is called acute respiratory alkalosis. Respiratory alkalosis decreases metabolic acidosis and increases Ph recovery (Robergs, Hutchinson, Hendee, Madden & Siegler, 2005). During short-term intense exercise, muscle fatigue is related to accumulation of lactate, H⁺ and fall in pH within muscle (Sutton, Jones & Toews, 1981; Sakamoto et al., 2015). Rapid increase in ventilation at the onset of exercise and the level at which ventilation is maintained determines the precision of pH regulation (Stringer, Casaburi & Wasserman, 1992). Pre-exercise increase in blood pH by voluntarily hyperventilation can delay the rapid decrease in blood pH induced by sprint exercise thus fatigue can be delayed and HP can be useful for sprint performance (Jacob, Keyrouz, Bideau, Nicolas, El Hage, Bideau, & Zouhal, 2015).

Alveolar carbon dioxide decreases after hyperventilation therefore the carbon dioxide flow increases from venous blood to alveolar. Redundant carbon dioxide leaves the blood, so the carbon dioxide pressure (Pco₂) decreases. This prolongs the breath holding time and therefore swimmers use hyperventilation before the races (McArdle, Katch & Katch, 2010). It is also indicated that pre-exercise maximal voluntary hyperventilation may increase 50m freestyle swimming performance in well trained swimmers (Jacob et al., 2015). Voluntary hyperventilation little but significantly increases repeated maximal isokinetic knee extension torque values at 60°/s, but not at 300°/s and doesn't attenuate the decrements in EMG amplitude (Sakamoto et al., 2015). On the other hand, respiratory alkalosis with voluntary hyperventilation does not appear to influence on short term (45s) maximal effort performance during cycle ergometer anaerobic test and recovery blood lactate concentrations (Morrow, Fell & Gladden, 1988). Furthermore, there is no significant effect on the maximal anaerobic force after pre-exercise voluntary hyperventilation. However, the fatigue index increases significantly and thus the aerobic participation decreases (Jacob, Moussa, Keyrouz & Zouhal, 2008).

Acute alkalosis may also occur with the consumption of compounds such as basic sodium bicarbonate or sodium citrate which is called metabolic alkalosis (Carr, Hopkins & Gore, 2011). Metabolic alkalosis increases high intensity, short

duration exercise performance by 2% in athletes (Goldfinch, Mc Naughton & Davies, 1988; McArdle, Katch & Katch, 2006; Carr et al., 2011), and also sprint performance (Van Montfoort, Van Dieren, Hopkins & Shearman, 2004).

Volleyball consists of performing many short bouts of high-intensity explosive activities such as jump and sprint during rallies and is interspersed with short rest intervals between rallies and sets (Driss, Vandewalle & Monod, 1998; Gonzalez, Urena Espa, Llop, Garcia, Martin & Navarro, 2005; Sheppard, Gabbett, Reeberg & Stanganelli, 2009). These high-intensity and short duration activities are performed with short intervals throughout the match for 60-90 min and therefore volleyball players need aerobic metabolism (5-10%) to replenish phosphagens that are used to remove lactic acid which might be accumulated during a volleyball play. However, anaerobic metabolic pathways (90-95%) play a more important role than the aerobic metabolism because intensive efforts like jump or short distance multidirectional sprints which are performed during rallies relies on phosphagen metabolism because of the duration and intensity of movement (Cisar & Corbelli, 1989; Kasabalis, Douda & Tokmakidis, 2005). The average time between rallies in volleyball is 11s, during these periods the energy is mainly supplied by resynthesis of phosphocreatine. Also, the average time between rallies is 14s and the aerobic system replenishes the energy stores during these resting periods (Künstlinger, Ludwig & Stegemann, 1987; Sheppard, Gabbett & Riggs, 2013). Besides, lactate concentrations are low throughout volleyball match but relatively greater during the onset of specific volleyball techniques. According to all of this information, it can be said that volleyball players require well-developed anaerobic metabolism, speed, strength and the capacity to perform these repetitive maximal efforts within very short recovery periods throughout a volleyball match (Künstlinger et al., 1987; Chamari, Ahmaidi, Blum, Hue, Temfemo, Hertogh, Mercier, Prefaut. & Mercier, 2001; Sheppard et al., 2013).

Jump, short distance sprint, acceleration and agility are the most important components of athletic performance for all volleyball players and the assessments of these components are important for anaerobic performance measurements in volleyball (Polglaze & Dawson, 1992). Pre-exercise metabolic or respiratory alkalosis has controversial effects on athletic performance during high-intensity exercises and the acute effects of voluntarily hyperventilation on athletic performance have not been investigated in volleyball players. Present study's findings can support that metabolic effects of HP may affect jumping and sprinting performance. Thus players can develop a strategy with HP to enhance performance between rally or sets throughout the game. Therefore, the aim of this study was to investigate the acute ergogenic effects of pre-exercise brief maximal voluntary hyperventilation on the jumping and sprint performances of young female volleyball players. We hypothesized

that pre-exercise hyperventilation induced respiratory alkalosis would provide an acute increase in jump and sprint performance.

METHOD

Participants

Fourteen female volleyball players voluntarily participated in this study (16.7 ± 1.2 years; 61.1 ± 10.3 kg; 173 ± 8 cm; 7.5 ± 1.9 weekly activity hours, 4.5 ± 1.2 weekly training number). The participants' average volleyball training and contest history is 7.7 ± 1.9 and they are healthy individuals with no history of injury. Players with injuries, having health problems or the ones who participate in physical activities other than volleyball were excluded from the study. Each participant has been orally informed about the subject, aim, method and advantages and risks of the study which they will take part. The study protocol was conducted in accordance with accepted ethical standards and with the Declaration of Helsinki. Basic informed consent form of this study was signed in by all the participants.

Procedure

In this study, all of the participants were subjected to two different experimental trials which were hyperventilation (HP) and normal ventilation (NV); also, jumping and sprint tests were implemented on different days and all of the participants participated in the tests 5 times including the adaptation trials. All of the participants were informed about each test and experimental trials, and necessary trials and training were performed one week before the tests in order to let them gain experience. At least 2 days of resting period was given between HP and NV tests. The participants were informed to arrive at the laboratory in a fully rested and hydrated state and to avoid strenuous activity and ingestion of any stimulant substances within the day before each test day. The participants were also asked to avoid caffeine and alcohol for 24 h before each test day.

The participants performed 6-7 min moderate tempo jogging and 5-6 min of various dynamic stretching exercises before the tests. Approximately 3 min after the warm-up session, HP or NV were applied randomly for 30s and the process was monitored with a portable spirometer (MIR Spirolab III, Italy). The participants applied 6 maximal respirations composed of 5s cycle as in the HP protocol; the first 2s of a 5s respiration cycle includes maximal inspiration; last 3s includes maximal expiration (Jacob et al., 2008). Thirty seconds of passive resting period was given between the HP protocol and test; which was followed by jumping or sprint test. During NV, the participants continued normal respiration without hyperventilation about 30s which was followed by 30s passive resting and jumping and sprint tests. The experimental design of the

study is displayed in Figure 1. On each test day; only one HP or NV condition was applied with jumping or sprint tests. Squat and countermovement jump, without arm swing, was measured by the mat (Smartspeed, Fusion sport, Australia). Twenty meters sprint tests were applied as a straight sprint. Sprint test was performed in standing start position and a 1 meter space downward from the starting line without acceleration. Three pairs of photocells (Smartspeed, Fusion sport, Australia) placed on 0, 10 and 20 meters; 10 or 20 meters split time was measured. Each test was applied twice and the higher performance was recorded for the analysis. HP or NV was applied before each athletic performance tests and at least 15 min of recovery periods were allowed between two different test trial. Heart rates (HR) were observed to ensure adequate recovery during these rest periods. As soon as HR recovered to pre-test level (± 10 bpm), the second test trial was performed.

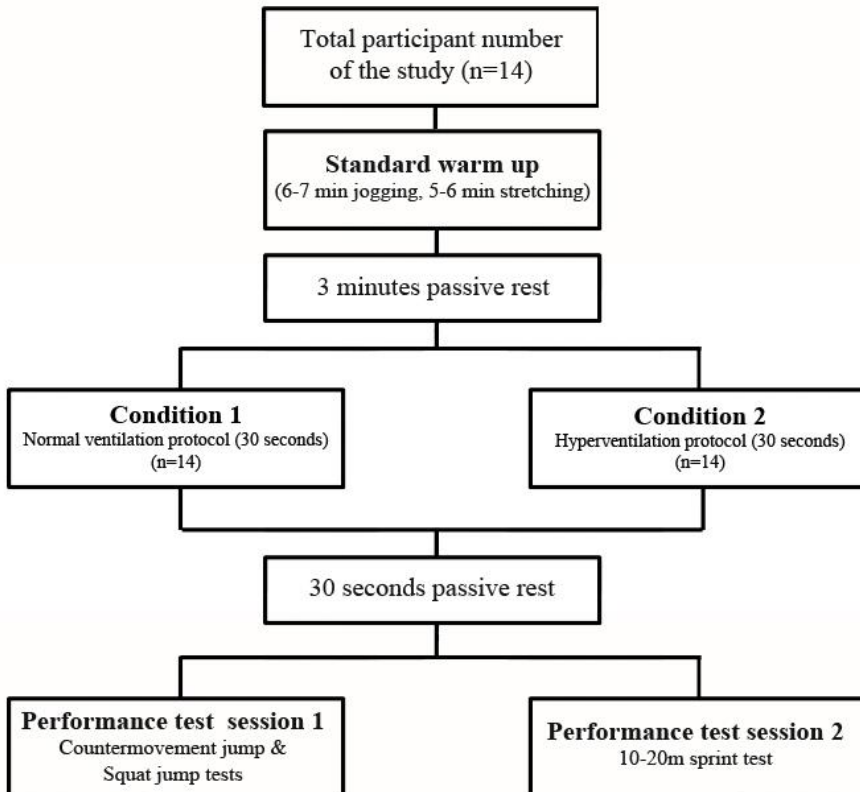


FIGURE 1: Flow chart of the study.

Statistical Analysis

Paired sample T-test was used to determine whether there were significant mean differences between performance values with HP condition compared to

NV. Data are mean \pm standard deviation. The alpha level was set at $p < 0.05$. One outlier was detected that was more than 1.5 box-lengths from the edge of the box in a boxplot. Excluding this outlier didn't change the results and therefore it was kept in the analysis. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > 0.05$). All of the statistical analyses were made with SPSS version 20 software (IBM SPSS Inc., Chicago, IL, USA).

RESULTS

There were no significant differences in CMJ, SJ and 20-m sprint performance between NV and HP protocols except for 10m split time (Table 1). HP elicited a statistically significant increase of $-0.019s$ (95% CI, -0.371 to -0.001) in 10-m sprint times compared to NV. Ten meter sprint time significantly decreased after HP protocol ($1.94 \pm 0.11s$) but this performance enhancement is approximately 1% ($\leq 0.02s$) compared to NV ($1.92 \pm 0.11s$). According to these results it can be said that the pre-exercise brief voluntary hyperventilation didn't increase CMJ, SJ jump and 20-m sprint performance in young female volleyball player but 10-m sprint split time decreased significantly after HP protocol followed by 30s passive resting period.

TABLE 1
The results of Paired Sample T-test in CMJ, SJ, 10-
and 20-m sprint performances ($n = 14$).

Performance Parameters	NV	HP	<i>T</i>	% Change	<i>P</i>	<i>d</i>
Countermovement Jump (cm)	30.7 ± 5.4	30.4 ± 5.1	-0.54	-0.68	0.601	-0.01
Squat Jump (cm)	28.1 ± 5.2	28.1 ± 4.6	0.03	0.04	0.976	0.03
10-m Split time (s)	1.94 ± 0.11	1.92 ± 0.11	-2.33	-1.00	0.037*	-0.62
20-m Sprint time (s)	3.46 ± 0.23	3.45 ± 0.23	-0.68	-0.29	0.515	-0.18

DISCUSSION

In the present study we investigated the acute effects of voluntary hyperventilation of 30s on jump and sprint performance. The main findings of this study were (i) 1% decrease in 10-m sprint time after voluntary brief hyperventilation compared to NV; (ii) CMJ, SJ heights and 20-m sprint time performances were similar in HP and NV. This small but significant enhancement in 10-m sprint performance after HP (Table 2) can be explained by respiratory alkalosis (Jacob et al., 2008), blood pH changes (Sakamoto et al., 2015), breath holding effect of HP (Jacob et al., 2015), compensatory elevation in the anaerobic metabolic rate (Fujii, Tsuchiya, Tsuji, Watanabe, Sasaki, Nishiyasu, 2015) with reduced aerobic metabolic rate (Jacob et al., 2008; Fujii et al., 2015) and these factors may provide some beneficial effects on short distance sprint performances. These findings suggest that HP can have

ergogenic benefits on athletic performance and some previous study support our results (Sakamoto et al., 2015; Jacob et al. 2008; Jacob et al., 2015).

A little but significant performance enhancement of 10-m sprint time showed that HP can affect athletic performance but HP protocol and rest period after the HP is very important for functional athletic performance because the same HP protocol followed by different rest times can produce different outcomes (Jacob et al., 2008; 2015; Kairouz, Jacob, El Hage, Khoury, Moussa, Zouhal, 2013). For example, Kairouz et al. (2013) stated that a brief hyperventilation (6 maximal inspiration/expiration cycles done in 30s) followed by 1 min recovery does not affect performance during the Wingate test. On the contrary, Jacob et al. (2015) found that a pre-exercise maximal voluntary HP followed by 30-s recovery can increase 50-m front crawl swimming performance. Leithäuser, Böning, Hütler, and Beneke (2016) have found that after 15min hyperventilation program, induced respiratory alkalosis can enhance cycling sprint performance. In literature there is no study about effects of HP on sprint performance therefore it is hard to compare the findings of the present study. Nevertheless present finding indicated that HP does not have an ergogenic effect on sprint performance but underlying mechanism is still unknown.

Using HP during recovery period between sets or repetitions decreases performance decrements. Sakamoto et al. (2014) reported that a HP protocol applied during recovery intervals of repeated sprint pedaling attenuate performance decrements in later exercise bouts that were associated with substantial metabolic acidosis. Another study of Sakamoto et al. (2015) showed that HP between repeated maximal isokinetic contractions for 30s have a little ergogenic effect on knee extension torque values at 60°/s but not 300°/s and doesn't attenuate the decrement in muscle activations (EMG). The practical application of HP can have an important role on enhancing training effectiveness and thus may give an advantage on performance outcomes but more research need to be done to investigate the effects of HP on different athletic performances.

Some previous studies stated that HP has an effect on metabolic process but not on athletic performance. For instance, Fujii et al. (2015) suggested that HP before Wingate anaerobic test (30s) decreases the aerobic metabolic rate without effecting exercise performance. They also imply compensatory effect of the anaerobic metabolic rate with decreased aerobic metabolism contribution (Fujii et al., 2015). Jacob et al. (2008) reported that HP doesn't affect maximal power, but seems to reduce aerobic contribution, which may explain the higher fatigue index observed after HP. These research findings HP have some regulatory effect on metabolism without exercise performance. Hilbert, Shushakov & Maassen (2012) stated that HP induced respiratory alkalosis

doesn't improve muscle performance during intermittent high-intensity exercise. According to Morrow et al. (1988) respiratory alkalosis (HP) can be insufficient to affect recovery blood lactate concentrations or to affect intense, short-term exercise performance.

Studies using bicarbonate (NaHCO_3) supplement for metabolic alkalosis reported significant performance enhancement and some others didn't report any significant effects on exercise performance. For example, Siegler, McNaughton, Midgley, Keatley & Hillman (2010) suggested that NaHCO_3 supplementation may improve successive 30-s high intensity sprint performance. On the other hand, Portington, Pascoe, Webster, Anderson, Rutland & Gladden (1998) also reported that NaHCO_3 ingestion failed to improve resistance exercise performance in weight trained male subjects. Furthermore, Thomas, Delfour-Peyrethon, Bishop, Perrey, Leprêtre Dorel & Hanon (2016) suggested that pre-exercise NaHCO_3 ingestion reduces VO_2 decrements at the end of a 70-s supramaximal exercise test as a consequence of the changes in extracellular pH but it doesn't affect functional athletic performance. It seems that metabolic alkalosis induced by NaHCO_3 can affect sprint and explosive type exercise performances but there can be some differences between metabolic and respiratory alkalosis strategies and these differences are likely to be the results from different protocols or underlying metabolic process.

Some studies showed that metabolic alkalosis induced by NaHCO_3 have beneficial effects on on-field physical performance. Siegler and Hirscher (2010) found that NaHCO_3 ingestion (300mg/kg) improves punch efficacy during 4 round of sparring performance in amateur boxers. According to this result, metabolic alkalosis has a beneficial effect on practical application in boxing. According to Siegler and Gleadall-Siddall (2010), NaHCO_3 ingestion (300mg/kg), 2.5 hours before exercise enhances the blood buffering potential and may positively influence swimming performance. Miller, Robinson, Sparks, Bridge Bentley & McNaughton (2016) suggest that NaHCO_3 ingestion improves the total amount of work completed during repeated sprint ability through enhanced blood buffering capacity. Another study showed that NaHCO_3 supplementation could prevent the decline in Loughborough Tennis Skill Test performance after a simulated match (Wu, Shih, Yang, Huang & Chang, 2010). The findings of previous studies have shown that metabolic alkalosis have various effects on athletic performance (Peart, Siegler & Vince, 2012). According to these findings, HP induced respiratory alkalosis can have effects on exercise performance like NaHCO_3 supplementation but there are some differences between them. The reasons of these differences can be due to the probable differences in HP protocols or the resting period followed before the activity and the results of the present study support these findings. Further

studies should investigate whether HP can enhance exercise performance on field or during the game.

These findings may indicate that HP can have acute ergogenic effects on some performance variables and metabolism by induced respiratory alkalosis. HP may have a practical usage as a strategy for training effectiveness but coaches and athletes must take into account the beneficial effects of the present HP protocol on 10-m sprint time which is statistically significant but not very large; however, there are not any acute effects on jumping performance and 20-m sprint time in moderately trained young female volleyball players. Therefore further studies are needed to be done to clarify the underlying mechanism of voluntary HP and to standardize the effects of different HP protocols on different performance parameters also to optimize the rest period after HP for maximum benefits of respiratory alkalosis. Furthermore, future studies should investigate the effects of HP on some other specific athletic performances like repeated sprint ability or running economy in different sports and also should investigate the relationship or differences between metabolic and respiratory alkalosis.

CONCLUSIONS

In conclusion, a small acute effect was observed in 10-m sprint time after a brief HP protocol followed by 30s passive resting period. It can be concluded that the 10-m sprint performance enhancement of HP was probably effective for only elite athletes and it may not be important for young female volleyball players. On the other hand, it hasn't got any effects on CMJ, SJ and 20-m sprint performance after HP protocol compared to NV. The present findings of this study suggest that pre-activity voluntary HP does not provide an ergogenic effect but the underlying mechanism of HP on exercise performance remains unclear.

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