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The Effects of Extra Ventilation after Exercise on Recovery Process

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ABSTRACT This study aims at accomplishing some applicable investigations into the issue of whether any voluntary extra ventilation applies during active recovery process, and also, if an exhausting exercise has any effect on recovery. Seven males participated in the study as volunteers. The volunteers were made to carry out exhausting exercises with incremental running test on treadmill, twice on different days. The active recovery process was traced on the treadmill for a period of 13 minutes, following the application of both exercises. Extra voluntary ventilation for a minute long was applied during the second exercise in addition to the first exercise, at the beginning of the recovery process, and at 4^{th}, 8^{th}, and 12^{th} minutes. The amounts of mean VO_2, VCO_2, respiratory frequencies, oxygen saturation, lactic acid of the volunteers were determined during recovery process. The increase in VCO_2 levels was determined to be significant. The increase at 4-5^{th}, 8-9^{th}, and 12-13^{th} minutes on recovery respiratory frequency after the final testing was also determined to be significant. The decrease reported for the LA levels at 9^{th} minute of recovery which was determined after extra ventilation application was found to be significantly different. There was a significant negative correlation between the LA levels at the 5^{th} minute of the final testing, and respiratory frequency taken immediately after relevant exercises and at 4^{th}, 8^{th}, and 12^{th} minutes. It has been considered that the extra ventilation of 4 phases, each one minute, has put some positive influence on the recovery process, affecting VCO_2 egression and LA removal.

INTRODUCTION

Exhaustion is defined in its simplest form, as the inability to sustain the force or power production during repetitive muscle contractions (Gibson and Edwards 1985). Sustainability of muscle contraction needs to have more metabolic power and therefore, greater rates of ATP use (Rapoport 2010). Exhaustion is directly associated with the inequality between the ATP utilization rate of muscles, and reproduction rate of ATP. Accumulation of metabolites in muscles, oxygen deficiency, the presence of substrate, increased muscle temperature, pH disturbance, increased glycolysis, and reactive oxygen species production leads to fatigue (Grassi et al. 2015). On the other hand, the cardiovascular system which carries the blood with richer oxygen content into the muscles and the amount of lactate accumulation, and content of muscle mitochondria are significant factors which puts restrictions on the performance (Powers and Howley 2014).

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It is clear that the lactic acid accumulation takes its place among the main factors that cause exhaustion (Hausswirth and Mujika 2013). Lactic acid accumulated in the muscle in exercise, incrementally spreads throughout the entire body during exercise and recovery (Yano et al. 2005). Lactate increases during 4-5 min after intensive exercise and then begins to decrease from this duration of recovery (Kowalchuk et al. 1988). During the early period of recovery, CO_2 diffuses from tissue to blood and CO_2 is expired from lungs (Yano et al. 2009). In addition, Lactic acid is buffered by the bicarbonate system. This situation causes a reduction in the level of bicarbonate ions and metabolic acidosis (Beaver et al. 1986). Hyperventilation occurs in order to regulate metabolic acidosis and therefore increase VCO_2 excess in exercise (Yano et al. 2009). Also, some studies found a relationship between an increase CO_2 excess and blood lactate level during exercise (Yunoki et al. 2003; Yano et al. 2002; Yunoki et al. 1999; Hirakoba et al. 1993).

Meanwhile, the oxygen saturation of the hemoglobin is decreased, and the tissue hypoxia is increased during high intensity exercises (Peeling and Andersson 2011). Accordingly, the amount of oxygen in the muscles is decreased during exercises. In such a case, the increase in the amount of oxygen routed to the tissues during recovery period results also in an increase in the regeneration time for the stores of oxygen, phosphogene, and glycogen and the metabolic utilization rate for the lactic acid, speeding up the recovery process (O'Leary and Potts 2006). That the tissues are loaded with more oxygen content during recovery process speeds up the removal of the lactic acid, increasing the rate of lactate to be utilized as substrate by the oxidative metabolism (Chiappa et al. 2008).

In regards to previous data, it is considered that the application of voluntary extra ventilation will be able to cause an increase both in CO_2 egression and in the level of O_2 to be forwarded to the tissues, making a contribution to the removal of lactic acid. No study has been encountered in the literature when strategies to accelerate the recovery process have been investigated in relation with the effects of the voluntary extra ventilation on that process.

Objective of the Study

This study aims at investigating the possibility of having voluntary extra ventilation apply during active recovery period, and also to find out if there is any effect or not on recovery, soon after an exhausting exercise.

METHODOLOGY

Voluntary Group

Seven males who have not been engaged in any active sports branches, with mean age of 21.29 ± 1.49 years, mean height of 176.43 ± 5.02 cm, and with a mean body weight of 75.00 ± 6.83 kg, voluntarily participated in the studies. The volunteers were given necessary information about the study and they signed relevant consent forms prior to the study. The tests applied on them were accomplished in the Performance Measurement Laboratory located at the School of Physical Education and Sports of Nigde University.

Test Protocol

The volunteers were subjected, twice on different days, to exhausting exercises with incremental running test on treadmill. The incremental running test began with an initial speed of 8km.h,$^{-1}$ and increased 1 km.h^{-1} every minute until the volunteers stopped due to volitional exhaustion (Buchheit et al. 2011). As soon as the first exercise application was ended, the speed of treadmill was decreased up to 5.5 km.h^{-1}and active recovery process was monitored on the treadmill for a time period of 13 minutes. The values of average oxygen consumption (VO_2), average carbon dioxide production (VCO_2), and respiratory frequency of the volunteers were determined by means of brand VO2000 portable gas analyzer. The following exercise lactic acid (LA) levels recorded at the 1st, 5th, 9th, and 13th minutes were measured by the lactic acid meter, brand Lactate Plus, and the levels of oxygen saturation (SO_2%) by the pulse oximeter. The heart rates of the volunteers, therefore, were monitored by a telemeter.

Soon after the second exercise application, the speed of treadmill was decreased again to a speed of 5.5 km.h,$^{-1}$ and the active recovery process was monitored for a period of 13 minutes. An extra voluntary ventilation for a minute long was applied in addition to the first exercise application, at the beginning of the recovery process, and the at 4th, 8th, and 12th minutes during the recovery process. The values of VO_2, VCO_2, and respiratory frequency of volunteers were recorded in a similar way to the first exercise practices, by a portable gas analyzer, brand VO2000. The lactic acid (LA) values recorded at the 1st, 5th, 9th, and 13th minutes following the second application of exercises which were measured by the lactic acid meter, brand Lactat Plus, and the level of oxygen saturation (SO_2%) by the pulse oximeter. The heart rates of the volunteers, on the other hand, were monitored by the telemeter.

Statistical Analysis

The statistical evaluation of data obtained was carried out on the SPSS program. A comparison was applied to the same values obtained in two different applications by the Wilcoxon Signed Ranks Test, and the relationship between values was analyzed by the Spearman Brown Sequence Differences Correlation Test.

RESULTS

Figure 1 gives the mean values for VO_2, VCO_2, heart rate, and respiratory frequency during recovery time and after exercises. While the in-

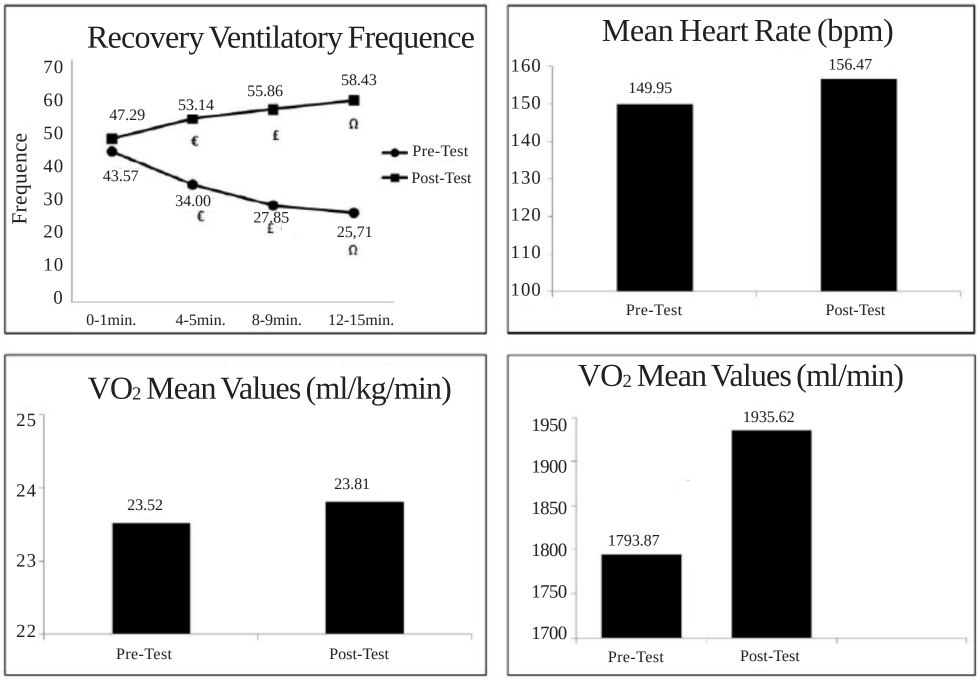

Fig. 1. Levels of Mean Heart Rate, Mean VO2, Mean VCO2, and Recovery Respiratory Rate

creases reported after the final testing for the levels of VO_2 and heart rate were considered statistically insignificant, the increase in the VCO_2 level was determined to be significant ($p<0{,}05$). Additionally, the increase observed at 4-5th, 8-9th, and 12-13th minutes for the recovery respiratory frequency following the final testing was determined to be significant ($p<0.05$).

The lactic acid values obtained during recovery period were given in Figure 2. The decrease recorded for LA levels during 9th minute of recovery after extra ventilation application was

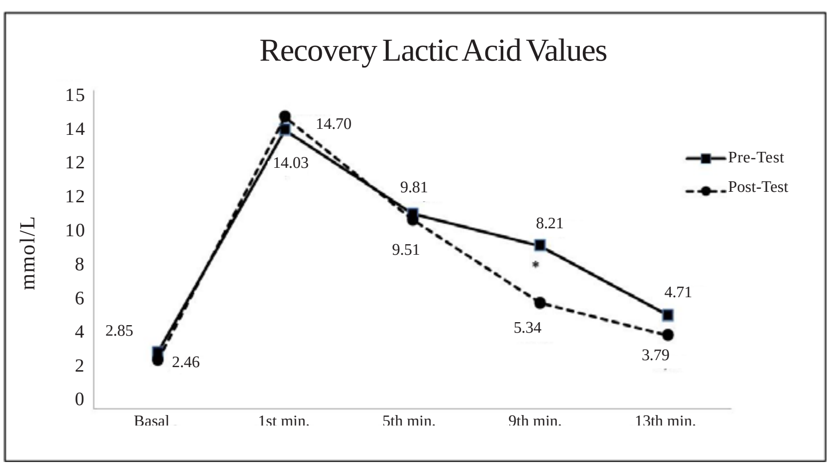

Fig. 2. Recovery Lactic Acid Values

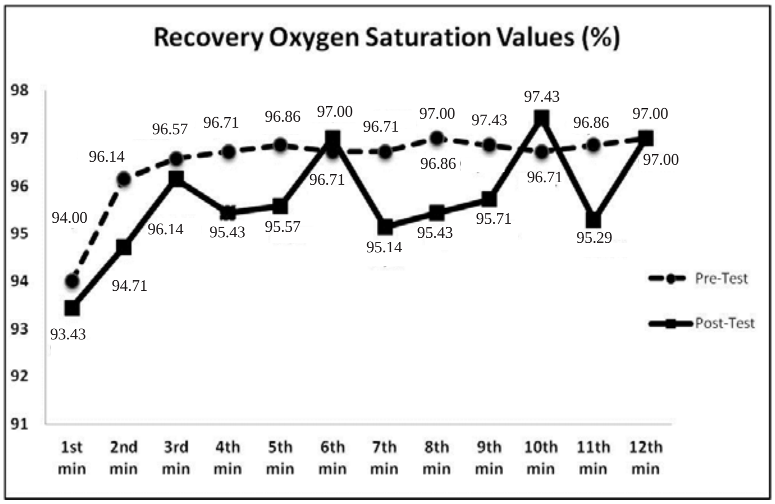

Fig. 3. Recovery Oxygen Saturation Values

found accordingly, to be significantly different ($p<0.05$).

The oxygen saturation values recorded during after exercise recovery period were given in Figure 3. Whereas there were some differences in SO_2 percent levels between pre-test and post-test results, these differences were not statistically significant.

Table 1 gives the relationship between the respiratory frequency and lactic acid values. Accordingly, significant negative correlation was determined between the LA levels obtained at 5th minute of the final testing, and the respiratory frequency measured at immediately after exercise, and the 4th, 8th, and 12th minutes of the final testing.

DISCUSSION

This study reveals an increase in the respiratory rates measured at the 4th, 8th, and 12th minutes respectively, following the voluntary extra ventilation which was significant in comparison to the first testing ($p<0.05$). The average VCO_2 level was therefore eliminated during the recovery period after the second testing process was recorded as significantly higher than the levels obtained for the first testing ($p<0.05$). That the increase in the average levels of VCO_2 egression during recovery period applied in the second measurement has been significant indicates that the extra ventilation applied, has a nature to lead to a significant increase in the average VCO_2. It

Table 1: Correlation between ventilation frequencies and lactic acid values

		Vent freq. 0-1st min	*Vent freq. 4-5th min*	*Vent freq. 8-9th min*	*Vent freq. 12-13th min*
1st min LA	Correlation Coefficient	-.021	.207	.056	.132
	Sig.	.945	.477	.850	.653
5th min LA	Correlation Coefficient	-.588*	-.882**	-.610*	-.542*
	Sig.	.027	.000	.021	.045
9th min LA	Correlation Coefficient	-.428	-.378	.098	-.161
	Sig.	.127	.183	.738	.582
13th min LA	Correlation Coefficient	.131	-.017	.281	-.268
	Sig.	.655	.953	.330	.353

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

is a common finding that the hyperventilation leads to an increase for the CO_2 elimination (Roach et al. 2006). The pressure level of the carbon dioxide in blood determines the amount of carbonic acid concentration. An increase in the carbon dioxide level in blood during exercises results also in some increases in the level of carbonic acid and decreases in the pH level (Katch et al. 2011). Meanwhile, a decrease in the pH levels for both muscle and blood is observed because of the lactic acid production in increased levels during the exercises which were applied at maximal levels. On the other hand, a decrease in pH level and an increase in the amount of lactic acid leads to exhaustion (Powers and Howley 2014). That removal of accumulated lactic acid from relevant area and stabilization of the pH level is extremely important to the recovery rate. Recovery energy expenditure after exercise may also be influenced by training status (Benton et al. 2015). Another study has demonstrated that trained adults rapidly return to resting energy expenditure than untrained adults. This metabolic adaptation results in greater efficiency and diminished energy costs (Borsheim and Bahr 2003). In addition, our study indicates that the voluntary extra ventilation applied in accordance with the findings acquired during recovery period of the second testing in this study, leads to an earlier stabilization in pH level, increasing CO_2 removal.

However, the decrease in the LA level at 9th minute of recovery process during second application of voluntary extra ventilation was determined to be statistically significant, when compared to the first one ($p<0.05$). On the other hand, it was observed that there were significant negative correlation between the LA levels at 5th minute of the second application, and the respiratory frequency taken immediately after the exercises and the 4th, 8th, and 12th minutes ($p<0.05$). Yunoki et al. (2003) claimed, in their study, that the CO_2 egression during recovery period has a relationship with an increase in lactic acid level during recovery. The lactic acid accumulation in the muscles during exercise spreads into the entire body in recovery time. Such a situation leads also to CO_2 elimination (Yano et al. 2005). Since a large part of the accumulated lactic acid is in an ionized form, it is considered that the accumulation of lactic acid during and after an exhausting exercise appears to be a major factor in the formation of metabolic acidosis (decline in pH level). It is well known that the body prevents a decrease in pH level, buffering the lactic acid decomposed from hydrogen ions by bicarbonate ($H^+ + HC0_3^- = H_20 + CO_2$) and that there is no increase in the buffering impact except for the CO_2 to be removed by expiration. Therefore, the expiration of CO_2 is a very important factor in keeping the pH level constant during and after exercises (Yunoki et al. 2003). It is observed in this study that extra voluntary ventilation applied seems to lead to an increase in CO_2 elimination, making a contribution to the removal of lactic acid.

On the other hand, though the increase in VO_2 levels observed during the second measurement was statistically insignificant, a slight increase was determined. Meanwhile, an increase was also observed, though not statistically significant in SO_2 levels, following extra ventilation applied at the second measurement compared to the first measurement. The forwarding of much more oxygen to the tissues during recovery period speeds up the process of lactic acid removal by increasing the rate of utilizing lactate by the oxidative metabolism (Chiappa et al. 2008). In this study, though no statistical increase has been observed for O_2 intake, it has been considered that the partial increase recorded in O_2 intake may have contributed to the cleaning of LA, entering the oxidative phosphorylation process earlier in proportion to the increased amount of O_2 in cells. The levels of blood gases were not observed in the study. If we monitored blood gases levels, we could reach more clear results.

It is known that an increase realized in ventilation results also to an increase in heart rate (Powers and Howley 2014). An increase though not on statistics, was reported in the mean heart rate during the second application compared to the first measurement in this study. The heart muscle is capable of using the LA as a direct energy source by converting it into pyruvic acid (Guyton and Hall 2006). It is considered, meanwhile, that the activities of respiratory muscles and heart muscles, which increase proportionally with extra ventilation during the second application, uses the LA as an energy source and makes a contribution in the removal of it.

CONCLUSION

In conclusion therefore, it is worthy of note that increases which are proportional to extra ventilation lead to earlier stabilization in pH level, increasing CO_2 removal, and that an increased activity of respiratory muscles and heart muscles can contribute to the removal of lactic acid, using this as an energy source to make a contribution in the removal of LA. Extra ventilation implementation during the recovery process has the ability to impact positively on recovery, affecting both the VCO_2 egression and LA removal.

RECOMMENDATIONS

Since the levels of blood gases were not observed in this study, it is hoped that the amount of blood gases being monitored in further studies will lead to more accurate results. Also, further research is required to fully understand the relationship between extra ventilation and recovery.

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