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Effect of Reinfusion of Autologous Blood on Exercise Performance in Cross-country Skiers

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Abstract

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The effect of reinfusion of autologous blood (1350 ml) on exercise time over a specified distance (approx. 15 km) 4 weeks after phlebotomy ("blood doping") were investigated in six well-trained cross-country skiers. An additional control group of six well-trained skiers was included in the study. Test races were performed before phlebotomy, 3 h after, and 14 days after reinfusion of blood. In each test race, the mean time of the control group was set to 100 % and the time of the blood-doped subjects expressed in percentage of the control group mean time. In the first control race, the mean time of the subjects who were later "blood doped" was 99.4 % of the control group. However, both 3 h and 14 days after the reinfusion of autologous blood, the mean time of the blood-doped subjects was significantly lower (94.1 %; $P < 0.05$; 96.3 %, $P < 0.05$, respectively) than the control group. In conclusion, reinfusion of autologous blood stored in a refrigerator for 4 weeks after phlebotomy significantly increased performance expressed as race time in cross-country skiers. The significantly increased performance was observed both 3 h and 14 days after reinfusion.

Key words: physical exercise, blood storage, blood doping, blood boosting

Introduction

Physical performance in endurance events is closely related to maximal oxygen uptake, which in turn is mainly limited by maximal oxygen transport capacity times the oxygen content of arterial blood (1). Several laboratory studies (4, 5, 8) have demonstrated that increased oxygen content of the arterial blood through increased hemoglobin concentration by means of reinfused autologous blood increases the maximal aerobic power. The mass media has termed this procedure "blood doping."

The possibility, and magnitude, of enhanced performance by blood doping in actual endurance events has been studied very little (9). Therefore, the aim of the present investigation was to evaluate the magnitude, if any, of enhanced physical performance expressed as a decrease in exercise time over a specific distance in cross-country skiers both immediately and 2 weeks after single-blind reinfusion of autologous blood.

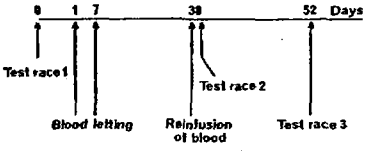

Fig. 1 Design of study

Material and Methods

Test Subjects

Eleven males and one female, all well-trained cross-country skiers between the age of 19 and 35 years, participated in the study. Their training time was approx. 500 h/year. Six of the males were blood doped and the remaining subjects served as controls. The skiers consumed the same type of mixed diet, and there was no change in physical training throughout the study.

Blood Letting and Reinfusion

Six of the subjects let blood on two occasions separated by 1 week. The total amount was 1350 ml (3 units) (Fig. 1). This blood was stored in a blood bank until reinfusion 4 weeks after the last letting. The other six subjects (the control group) took part in a "blind" procedure with blood letting with immediate reinfusion on the first two occasions and a slow infusion of physiologic saline on the third occasion. For both groups, all above procedures were performed with blindfolds, thus making the study "single-blind" and minimizing the influence of psychological factors.

Test Race

Three test races were performed on a 15-km racing course before blood letting, 4 weeks later (after reinfusion of blood, i.e., blood doping), and 14 days after the reinfusion (Fig. 1). The first race was a control race only. In the second and third races, 50 % of the participants were blood doped and the remaining subjects served as a control group. All participants were instructed to perform their maximum in all races.

Calculations

To minimize the influence of weather and snow condi-

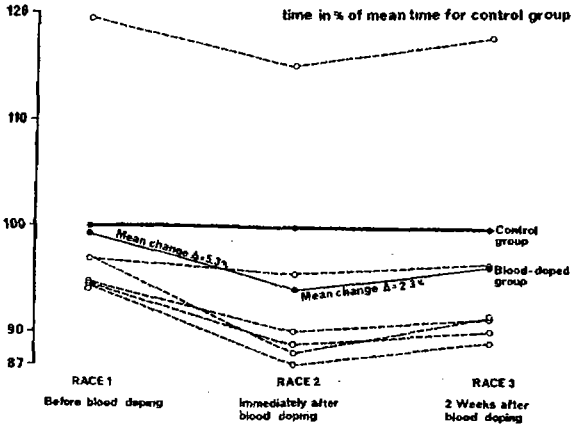

Fig. 2 Race time in each of the blood-doped subjects (dotted lines) as well as race mean times for the entire blood-doped group (thin solid line) expressed as percentage of mean time for the control group (wide solid line) before phlebotomy, immediately after, and 2 weeks after reinfusion of 1350 ml autologous blood

tions, a normalization procedure was performed. In each race for each subject in the blood-doped group, the race time was expressed in percent of mean control group race time of that specific race. The differences between the first control race and the races after blood doping could thus be calculated pursuant to a method previously outlined (2).

Ethical Considerations

This study is part of an investigation on the possibility of detecting blood doping. All participants were fully and fairly informed volunteers who did not take part in ski races during the period of the project. The study was approved by the Ethical Committee of the Karolinska Institute as well as by the International Ski Federation (FIS).

Statistical Methods

Student's paired t test was used for comparison.

Results

In the first test race, the mean time of the control group was 45 min 18 s, whereas the group to be blood-doped had a mean time of 45 min 1 s, which is 99.4% of the control group (Fig. 2).

In the second test race, the mean time of the control group was 51 min 28 s and the mean time of the blood-doped subjects was 48 min 25 s, which is 94.1% of the control group. Thus, the difference in mean exercise time (expressed as percent of mean control group exercise time) between the race before and immediately after blood doping for the blood-doped group was 5.3% ($P < 0.05$) (Fig. 2).

In the third race performed 14 days after blood doping, the mean time of the control group was 50 min 6 s as compared to 48 min 14 s in the blood-doped group (96.3% of the control group). Thus, the difference between the race before blood doping and 14 days after blood doping was 3.1% ($P < 0.05$). For the blood-doped group, the increase in race time (2.2%) between the second and third races was significant ($P < 0.05$) (Fig. 2).

There was no significant difference in Hb levels between the group to be blood-doped and the controls at the time of the first test race (147.0 ± 7.6 and 148.4 ± 5.1 g/l, mean ± SD, respectively)

Three hours after blood doping, the Hb levels were 153.2 ± 5.3 g/l in the blood-doped group and 145.8 ± 6.7 g/l in the control group. Two weeks after blood doping, the Hb levels were 150.4 ± 9.7 g/l and 143.3 ± 4.8 g/l, respectively.

Discussion

The present study indicates that autologous reinfusion of 1350 ml blood 4 weeks after phlebotomy (blood doping) increases the physical performance of cross-country skiers 3 h after reinfusion. The magnitude of improvement in the race time over 15 km was approximately 5% in comparison with a control group. In addition, this improvement seemed to be long-lasting, and even 2 weeks later the race time in the blood-doped group was approximately 3% less than the control group. The participants in our study were highly motivated, familiar with physical performance until exhaustion, and also instructed to perform their best in all races.

In a study with a design like ours one cannot fully exclude a training effect. However, the period between the test races was fairly short (2 weeks) and both the controls and the blood-doped subjects performed the same type of training throughout the study. Furthermore, the test races were performed toward the end of the season and not during the pre-season training period. Therefore, it seems reasonable to believe that the results 2 weeks after blood doping should be attributed mainly to the reinfusion of blood rather than to alteration in training effect.

That adequate reinfusion volumes, in combination with proper storing and a sufficient time between phlebotomy and reinfusion, increases maximal oxygen uptake and thereby performance in endurance events has been suggested by many investigators. For review, see Gledhill (7). Therefore, it is not surprising that our blood-doped subjects decreased their racing time significantly. The increased performance was not a placebo effect since psychological influence was minimized by our blind technique, thereby supporting earlier studies (4, 9).

The physiologic background was somewhat different in the second and third races. In the second race, the blood-doped subjects had *both* supranormal erythrocyte concentration and hypervolemia. However, a previous study (6) suggested that maximal cardiac output is unaltered after blood volume expansion and therefore it seems likely that the main contribution to increased performance in the second race comes from increased O_2 transport due to the hypererythrocytemia.

Due to extreme cold, no further race could be performed until 2 weeks after the first one. Since hypervolemia returns to normal within approximately 24 h (6), the third race was performed during hypererythrocytemia only. It is therefore likely that the increased performance by the blood-doped group in this race was mainly a result of the latter factor.

Assuming normovolemia, Hb concentration is a good measure of total hemoglobin mass; it is thus a good measure of

O_2 transport capacity. In the present study, the increase in Hb as compared to prephlebotomy values was 4.2% 3 h and 2.3% 2 weeks after reinfusion. These data seem to correspond well to the increase in performance capacity expressed as a reduction of racing time (5.3% and 3.1%, respectively). For more hematologic data, see ref. (3). Our data therefore suggest that the performance capacity followes the Hb mass and thereby O_2 transport capacity. Since full normalization of Hb after blood doping was not achieved within 2 weeks, we cannot make any statements concerning how long increased performance capacity can be expected. However, data by Buick et al. (4) suggest increased $\dot{V}O_{2max}$ up to 16 weeks, whereas (on the other hand) they found increased running time to exhaustion only during the 1st week.

The reduction in racing time after blood doping is considerable, approximately 2.5 min over 15 km within a few hours after reinfusion and approximately 1.5 min over the same distance 2 weeks after the reinfusion. In the 1985 world championships, these time differences would have meant the difference between first and tenth and first and fifth places, respectively, thus emphasizing the immense impact of blood doping on performance in endurance events. It is therefore with satisfaction that we note that the International Olympic Committee (IOC) has followed FIS and banned the procedure.

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