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The effect of blood infusion upon endurance capacity and ratings of perceived exertion

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ABSTRACT. The purpose of this investigation was to study the effect of blood infusion upon maximal endurance capacity and ratings of perceived exertion (RPE). Sixteen long-distance runners, 13 of whom were marathoners, undertook four trials (T1-T4) of a treadmill run to exhaustion over a five week period. Criterion measures were time to exhaustion (TE) and RPE during each T. Data on Hb, Hct and RBCs were collected prior to each trial. Based on TE at T1, Ss were matched and assigned to either the experimental (E) or control (C) group. One week after T1, all Ss had 460 ml blood withdrawn. T2 was undertaken 2 weeks postwithdrawal. One week after T2, or 21 days postwithdrawal, the E group was infused with their own RBCs while the C group received 460 ml normal saline. T3 was taken 2 hours postinfusion and T4 one week later. The results of the factorial repeated measures ANOVA revealed no significant differences ($p < .05$) between groups for either TE or RPE, even though the Hb level for the E group was significantly higher ($P < .01$) than the C group at T3 and T4.

RBCS, HEMATOCRIT, EXERTION, HEART RATE, ERGOGENIC AIDS, DOPING

At the 1976 Montreal Olympics, the technique of blood doping, or the infusion of blood into an athlete, received international attention when some sports commentators suggested the technique was being utilized by an Olympic champion. The theory underlying blood doping is based upon possible increases in the oxygen carrying capacity of the blood due to increased volume and/or RBCs and hemoglobin (Hb), which may help increase $\dot{V}O_2$ max. Of the various physiological factors which govern $\dot{V}O_2$ max, Shephard (19) indicated that it is normally limited by physiological rather than biochemical processes and concluded that overall conductance of oxygen can be augmented by an increase in blood Hb concentrations or increased cardiac output.

The reported research relative to the effects of blood infusion upon endurance performance is limited and conflicting. Studies by Pace and others (16) and Gullbring and his colleagues (8), using submaximal exercise heart rates as criterion measures, reported beneficial effects of blood infusion. Ekblom and his associates (3,5) reported similar beneficial effects during maximal exercise. On the other hand, reports by Williams and others (21) and Frye and Ruhling (6) provided evidence that blood infusion had no significant effect upon maximal and submaximal exercise performance.

Previous research relative to the effect of blood infusion upon endurance performance may have been confounded by one of several factors, including the nature of the criterion workload task, a training effect on untrained subjects, a failure to measure selected blood variables such as Hb, absence of a double-blind protocol, and volume of blood infused. The purpose of this investigation was to study the effect of blood infusion on endurance capacity with these confounding variables eliminated to a major degree. A subproblem was to investigate the effects of blood infusion upon ratings of perceived exertion (RPE).

METHODS

Sixteen males, experienced distance runners associated with a local amateur running club, the Tidewater Striders, volunteered as subjects; 13 were marathon runners and nine completed the famous Boston Marathon (Table 1). Subjects were informed of the nature of the experiment, including the potential risks of blood infusion and the maximal run to exhaustion. A physician was present to answer any questions of a medical nature. Informed consent was obtained from each subject prior to the start of testing. The research proposal has been approved by the University Review Committee for the Protection of Human Subjects. Each subject received a full medical examination both prior to and following the experiment. Based upon performance times on the prewithdrawal treadmill test, subjects were ranked, matched, and randomly assigned to either the experimental or control group by a hematologist not directly involved in the experimental testing. Both groups followed identical protocol throughout the experiment. Although informed consent was obtained, the design and conduct of the experiment assured adherence to the principles underlying double-blind experimentation.

A standardized maximal treadmill test was used to administer the workload. The work was continuous with the initial speed of 9.6 kmh^{-1} (6 MPH) increasing to 11.2 kmh^{-1} (7 MPH) after 5 minutes; additional increases were 0.8 kmh^{-1} (0.5 MPH) every 5 minutes until the subject

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TABLE 1. Description of subjects.

SUBJECT	AGE	HT (CM)	WT (KG)	YEARS RUNNING	AVERAGE MILES/WEEK	** DISTANCE	** TIME
BLOOD GROUP							
1.	32	177	72.7	7	25	6.0	0:40
2.*	32	185	86.4	16	40	26.2	2:54
3.*	33	177	67.7	14	50	10.0	1:00
4.*	34	177	63.7	11	60	26.2	3:06
5.*	39	180	75.0	20	60	26.2	2:51
6.*	26	178	75.0	13	25	26.2	3:14
7.*	50	175	69.5	7	40	26.2	3:26
8.*	37	177	79.5	10	40	26.2	3:24
$\bar{X}$	35.4	178.2	73.7	12.2	42.5		
SD	7.1	3.1	7.1	4.5	13.6		
SALINE GROUP							
1.	22	176	73.6	8	20	6.0	0:39
2.*	33	188	81.8	16	60	26.2	3:03
3.*	25	175	77.3	5	45	26.2	2:59
4.*	28	175	69.1	6	40	10.0	1:09
5.*	29	188	71.8	4	90	26.2	2:49
6.*	40	172	62.3	10	70	26.2	2:59
7.	24	177	65.9	3	40	6.0	0:34
8.*	20	175	63.6	3	60	10.0	0:58
$\bar{X}$	27.6	178.2	70.7	6.9	53.1		
SD	6.5	6.2	6.8	4.4	21.5		

*Marathon Runners
**Best Distance/Time in 6-month period preceding study. Distance in miles; time in hours and minutes.

reached exhaustion. The main criterion of interest was time to exhaustion (TE) to the nearest second. Timing started when the subject released his grip on the supportive handrail and stopped when he used the handrail for support at exhaustion.

A second criterion measure was rating of perceived exertion (RPE). The RPE scale of 1-20 described by Morgan (15) was utilized, and RPE were recorded for local stress (legs), cardiovascular-respiratory stress (breathing), and general overall stress. A chart with the RPE scale was in view directly in front of the treadmill. The RPEs were reported verbally by each subject during the first, third and fifth minute of each five minute workload, and the average of these three scores represents the RPE for each workload.

Supportive data included measures of Hb, hematocrit (Hct), and RBCs. Prior to each trial, approximately 7 ml of blood was withdrawn from the antecubital vein which was analyzed later via a Coulter Counter. Heart rate (HR) was monitored continuously.

All blood withdrawal, storage and infusion procedures were conducted at and under the aegis of the Tidewater branch of the American Red Cross (ARC). One unit of blood (460 ml) was withdrawn and stored as frozen RBCs according to standard ARC procedures. For the infusion stage, the appropriate units were deglycerolized and thawed per ARC procedure. Each subject in the experimental group received his RBCs diluted with normal saline to a volume of 460 ml while the control group received 460 ml normal saline. None of the subjects were able to discern which of the solutions they received.

The experiment was conducted over a five-week period in May-June, 1977. Prior to the initiation of testing all subjects were directed to maintain their current level of training and to prepare for each treadmill test as if preparing for a 6-10 mile race, including little or no training the day before the test and a light diet several hours before testing. All treadmill tests were administered in the Human Performance laboratory at Old Dominion University. Room temperature was maintained at a constant 20°-21°C (68-70°F). For those subjects who had never run on a treadmill, a learning trial was given to each. The treadmill test was administered during four trials (T1, T2, T3, T4) over the experimental period. T1 was the prewithdrawal test and was also used as a matching test. Approximately one week after T1 the blood was withdrawn from each subject. T2 was taken two weeks following withdrawal and represents the postwithdrawal test. T3 was administered one week later, approximately two hours following infusion. T4 was taken one week after T3. Subjects were instructed to run to exhaustion with no encouragement from the two investigators present.

For every trial subsequent to T1 each subject was informed of their previous best time and the current record time. A Cramer Universal timer was visable and was started when the subject initiated his run. Thus, for T2-T4, feedback relative to his time provided motivation to better his performance.

The primary statistical tool for the main criterion measure, TE, was a 2X4 factorial repeated measures ANOVA. The same analysis was used for Hb, Hct and RBCs. In addition, analyses of covariance (ANOCOVA) were utilized to help clarify the interpretation of the data where necessary. A 2X4X8 factorial ANOVA, with repeated measures on two factors, was utilized to analyze the RPE data. Analyses were done by computer, using both SPSS and BMDP programs.

RESULTS

Time to Exhaustion (TE) and Maximal Heart Rate (HRmax). The means and standard deviations for TE are presented in Table 2 for the experimental and control group across trials. The range of total miles completed in the treadmill run was 4.16-8.49, with $\bar{X} = 6.08$ and SD = 1.05. The results of the factorial repeated measures ANOVA revealed no significant differences between groups ($F = 0.59$), among trials ($F = 0.15$), or interaction effects between groups and trials ($F = 0.56$). Moreover, a repeated measures ANOCOVA using T1 as the covariate supported the repeated measures ANOVA findings of no significant difference between groups.

HRmax data are presented in Table 2. Individual replication of HRmax was consistent. Statistical analysis by a factorial repeated measures ANOVA revealed no significant difference between groups or trials for HRmax, thus insuring that subjects were working at similar levels during each workload, at least as measured by this physiological variable.

TABLE 2. Means and standard deviations for experimental groups across trials.

GROUP	EXPERIMENTAL GROUP				CONTROL GROUP			
TRIAL	T1	T2	T3	T4	T1	T2	T3	T4
Time to exhaustion (seconds)	2547 (391)	2595 (340)	2676 (387)	2656 (453)	2466 (323)	2561 (273)	2514 (324)	2550 (372)
Maximal Heart Rate	189 (11)	188 (13)	190 (11)	189 (10)	191 (12)	189 (9)	189 (9)	190 (9)
Hemoglobin (g)	15.1 (0.5)	14.7 (0.7)	15.5 (0.8)	15.6 (0.9)	14.8 (0.5)	13.9 (0.8)	14.0 (0.6)	14.4 (0.7)
Hematocrit (%)	42.5 (1.6)	43.0 (2.1)	44.8 (2.4)	44.4 (2.3)	41.6 (1.6)	40.4 (2.6)	41.1 (2.5)	41.0 (1.7)
RBC (10^6)	4.84 (0.15)	4 68 (0.23)	4.85 (0.29)	4.89 (0.28)	4.85 (0.26)	4.54 (0.31)	4.60 (0.28)	4.63 (0.29)

T1—Pre-Withdrawal T3—2-Hour Post-Infusion
T2—2-Week Post-Withdrawal T4—1-Week Post-Infusion

Analysis of the simple effects by the Neuman-Keuls procedure produced identical results for hemoglobin and hematocrit with the RBC differences paralleling, but not exactly matching, these results Between group differences revealed the experimental group (E) was significantly higher than the control group (C) at T2 ($P<.05$) and T3 and T4 ($P<.01$). Across trial differences revealed E to be higher at T3 and T4 than at T2 ($P<.01$), while C had higher values at T1 compared to T2 and T3 ($P<.01$).

Hemoglobin (Hb). Means and standard deviations for Hb, Hct, and RBCs are presented in Table 2 for the experimental and control groups across triasls. A correlation matrix between Hb, Hct and RBCs for each group at each trial revealed a high degree of common variance among the three variables. Hence, the results and related discussion are restricted to Hb changes, keeping in mind that the Hct and RBC changes were similar within each group across trials.

The results of the repeated measures ANOVA for Hb revealed a significant F ratio for differences between groups ($F = 9.34$; $p = .009$), between trials ($F = 9.34$; $p = .001$), and interaction between groups and trials ($F = 5.99$; $p = .002$). The significant interaction effect necessitated analysis of the simple effects rather than the main effects. The procedure is described in Winer (22). For differences between groups at each trial the simple effects ANOVA revealed that there was no significant difference for T1. At T2 the experimental group had a significantly higher Hb level ($P< .05$). The differences between groups was more pronounced following blood infusion with the experimental group having significantly greater Hb levels ($P < .01$) at T3 and T4. The mean difference on the day of infusion favored the experimental group by almost 1.5g/100 ml.

Significant F ratios were found also for both the experimental group ($F = 8.09$; $p < .01$) and the control group ($F = 7.24$; $p < .01$) across trials. The significant F ratios necessitated further analyses to ascertain which mean Hb levels were significantly different for each group across trials. For the experimental group the mean Hb level dropped from a T1 value of 15.11 to 14.71 at T2, a decrease which barely missed statistical signifiance. The Hb levels following infusion were 15.53 and 15.58 for T3 and T4 respectively. Both of these values are significantly higher than T2 ($P < .01$). For the control group, the T1 Hb level was significantly greater ($P < .01$) than both T2 and T3, but not T4. No other significant differences were noted.

Ratings of Perceived Exertion (RPE). Mean values for local, cardiovascular-respiratory (CVR), and general RPE are presented in Table 3 for both experimental and control groups across trials for 7 submaximal workloads and the maximal workload. Since all subjects completed the first 7 workloads, only these were selected for the submaximal analysis. A 2X4X8 factorial ANOVA with repeated measures on two variables was utilized to evaluate the data. There was a high degree of interrelationship between the three measures of RPE and the ANOVA is in total agreement for each measure. There was no significant difference between the experimental and control group, nor was there any significant interaction effect between groups and trials or groups and workloads.

There was a significant difference among trials for all three measures of RPE ($P<.001$). Further analysis via the Newman-Keuls procedure revealed that T1 was significantly higher than T2, T3 and T4 for all three measures of RPE. No significant differences were noted between T2, T3 and T4.

As was expected, there was a highly significant difference between workloads ($P< .001$), as subjects rated each subsequent workload higher. There was also a significant interaction effect between trials and workloads ($P < .001$). However, these differences were not explored further as they were expected and the analysis for the main effect across trials provides the essential information of interest for the trials and workloads interaction.

DISCUSSION

Several investigators (2,19) have proposed that $\dot{V}O_{2max}$ and endurance capacity may be limited by oxygen transport mechanisms. The infusion of blood into an athlete might confer two advantages in this respect, i.e. hypervolemia and increased Hb content.

TABLE 3. Mean local, cardiovascular-respiratory (CVR) and general RPE values for experimental and control groups across trials for 7 submaximal (1-7) and maximal workloads (8).

	T1*		T2		T3		T4	
WORKLOAD	EXPERIMENTAL	CONTROL	EXPERIMENTAL	CONTROL	EXPERIMENTAL	CONTROL	EXPERIMENTAL	CONTROL
1-Local	4.58	6.19	3.66	4.12	3.50	2.95	4.12	2.80
1-CVR	4.95	6.05	3.68	4.04	3.46	2.86	4.05	2.68
1-General	5.08	5.94	3.71	3.96	3.46	2.86	4.09	2.70
2-Local	8.79	9.32	6.24	6.58	5.62	5.21	5.96	4.96
2-CVR	8.34	9.29	6.08	6.82	5.71	5.46	5.91	4.82
2-General	8.46	9.25	6.18	6.54	5.66	5.30	5.86	5.04
3-Local	11.39	10.95	8.91	8.91	8.01	7.61	8.64	7.38
3-CVR	10.49	11.11	9.01	9.04	8.16	7.96	8.32	7.29
3-General	10.68	10.99	9.09	9.00	8.00	7.59	8.49	7.45
4-Local	12.68	12.00	11.16	10.50	11.05	10.22	10.70	9.72
4-CVR	12.22	11.82	11.12	10.66	11.00	10.15	10.58	9.60
4-General	12.22	11.75	11.00	10.62	11.04	10.10	10.75	9.62
5-Local	13.64	12.71	12.75	11.84	12.70	11.92	12.76	11.29
5-CVR	13.26	12.45	12.62	12.05	12.84	11.62	12.92	11.16
5-General	13.35	12.46	12.71	11.92	12.84	11.64	12.92	11.16
6-Local	15.09	13.70	14.30	13.11	14.42	13.45	14.40	12.95
6-CVR	14.80	13.62	14.32	13.12	14.21	13.32	14.44	12.96
6-General	14.88	13.49	14.32	13.24	14.39	13.45	14.52	12.95
7-Local	16.25	14.72	15.96	14.34	15.74	15.25	15.60	14.89
7-CVR	16.25	15.01	15.96	14.58	15.70	15.30	15.80	14.81
7-General	16.38	14.94	16.00	14.50	15.66	15.38	15.76	15.06
8-Local	19.00	17.25	19.18	17.78	19.75	17.81	18.91	18.29
8-CVR	19.15	17.62	19.20	18.15	19.75	17.94	19.04	18.29
8-General	19.12	17.46	19.18	18.09	19.75	17.94	19.09	18.41

T1—Pre-withdrawal T2—2-Week post-withdrawal T3—2-Hour post-infusion T4—1-Week post-infusion

*T1>T2-4, $P<.001$

Theoretically, induced hypervolemia could prove to be beneficial during an aerobic work task as the increased blood volume could increase the capacity for greater cardiac output. However, Guyton (9) stated that the increased cardiac output caused by an acute increase in blood volume, as through transfusion, lasts only a few minutes. The increased cardiac output increases the capillary pressure so that the fluid begins to transude out of the capillaries into the tissues, therby returning blood volume to normal. He indicated the cardiac output would gradually return to normal in about 40 minutes.

Gregersen and Chien (7) noted that the plasma component of transfused blood underwent rapid reduction in comparison to cell volume. Calculations by Williams and others (21), extrapolating data from Berne and Levy (1) and Mollison (14), have indicated that most of the infused plasma would transude from the vascular system within one hour of transfusion. Thus, infusion of 460 ml whole blood, or packed RBCs in normal saline to an equivalent 460 ml, would result primarily in an elevated Hb concentration, RBC count and Hct with little change in total blood volume. Leavell and Thorup (13) noted that the use of packed RBCs allows an increase in oxygen carrying capacity of the blood with as small an increment in blood volume as possible.

Theoretically, the increased Hb concentration resulting from infusion of RBCs could increase endurance capacity. Shephard (19) has indicated that $\dot{V}o_2$ max is normally limited by physiological rather than biochemical processes and concluded that overall conductance of 0_2 can be augmented by an increase in blood Hb concentration. Ekblom and his associates (4) provided some very relevant data to support this viewpoint. Comparing the effects of room air (control), a 50 percent 0_2 mixture (hyperoxia), and a carbon monoxide gas mixture (hypoxia) upon $\dot{V}o_2$ max and physical performance, they noted that physical performance changed in parallel with $\dot{V}o_2$ max. A correlation was found between $\dot{V}o_2$ max and transported 0_2, i.e. $\dot{Q}$ max and arterial oxygen content (Ca_{0_2}), thus suggesting that central circulation is an important limiting factor for human maximal aerobic power. They further noted that of the 12.5 percent increase in $\dot{V}o_2$ max, Ca_{0_2} could account for 7.4 percent of the increase with the remainder accounted for by an increase in peripheral utilization of the offered 0_2, suggesting that the muscle can use the extra 0_2 offered during maximal exercise.

On the other hand, RBC infusion could be a possible disadvantage to increasing physical performance if a marked polycythemia occurs. Due to increases in blood viscosity the infusion of RBCs has been reported to decrease cardiac output (20), blood flow velocity (10, 12), and peripheral 0_2 content (17, 20). It should be noted, however, that in these studies a high degree of polycythemia was created, well above a Hct of 50 percent. In most studies investigating the effect of blood infusion upon physical performance in humans, including the present study, the hematocrit has

not exceeded 50 percent. Hence, the polycythemia created by infusion of 500-1000 ml of blood may not increase the blood viscosity significantly enough to retard oxygen transport.

Several investigators have reported significant effects of blood infusion upon $\dot{V}o_2$ max and/or maximal endurance capacity. In one of the first major reports, Ekblom and his associates (5) studied the effects of blood loss and subsequent reinfusion (800-1200 ml) on the physical working capacity (PWC) of seven nonathletic subjects. With a few exceptions, the increased blood volume caused a significant increase in $\dot{V}o_2$ max, Hb and maximal work time. Although it was a highly sophisticated study, the data may have been confounded by a training effect and lack of a control group; in addition, no indication of a double-blind design was noted. In a subsequent investigation, Ekblom, Wilson and Astrand (3) studied five well-trained subjects under three conditions: control, after venesection of 800 ml whole blood, and after reinfusion of 360 ml packed RBCs (110 g Hb) about 30-35 days after venesection. The preinfusion control trial was given 30 days post venesection. Within 2-5 days after the control trial, the packed RBCs were infused and the performance tests were conducted one day later. Comparing the control and postinfusion trials, there was 4.5 percent increase in hemoglobin during the maximal exercise period, which was only about one-third of that expected theoretically. There was a significant increase in $\dot{V}o_2$ max during the postinfusion trial which the authors attributed to an increase in Ca_{O_2} (Hb concentration) and a lowering of $C\bar{v}_{O_2}$. There were no changes in maximal values for HR, SV and $\dot{Q}$. It should be noted, however, that the report did not indicate whether or not there was an increase in physical performance capacity even though the $\dot{V}o_2$ max increased by approximately 6 percent. In addition, there was no mention of a control group. In a related study, Horstman and others(11) studied the effect of an extended sojourn at high altitude (HA) and the specific role of HA-induced polycythemia upon sea level work capacity. Nine subjects were divided into two groups and underwent $\dot{V}o_2$ max and endurance time to exhaustion tests prior to four weeks at altitude. One week prior to return to sea level five subjects had 450 ml blood withdrawn while the other four subjects were exposed to a sham withdrawal. Upon return to sea level the performance tests were retaken. There was no significant difference in $\dot{V}o_2$ max and endurance time for the blood donor group, but the sham group increased significantly in both. Since the Hct of the sham group was significantly higher during the second trial as compared to the first and the blood donor group experienced no significant difference, the authors postulated that the increased work capacity was a function of the increased 0_2 transport afforded by the HA-induced polycythemia.

On the other hand, evidence presented by other investigators reveals no significant influence of blood infusion upon $\dot{V}o_2$ max and/or endurance capacity. Robinson and his associates (18) reported that the infusion of 1000-1200 ml of autologous blood into six subjects had no effect upon $\dot{V}o_2$ max during treadmill exercise. In a double-blind study with a control group, Williams and his colleagues (21) evaluated the effects of reinjected hematological components on the endurance capacity and HR max of twenty male athletes, mostly distance runners. The autologous components infused into the three experimental groups included whole blood (500 ml), packed RBCs (275 ml), and plasma (225 ml). Twentyone days following withdrawal the hematological components were infused into the appropriate groups. A maximal test was readministered approximately two hours postinfusion, two days postinfusion, and six days postinfusion. A two-way ANOVA revealed no significant effects due to treatments and the authors concluded the infusion of whole blood, packed RBCs, or plasma, at least in the quantities utilized in their study, had no differential effect upon endurance capacity. Frye and Ruhling (6), using a single blind design, randomly assigned 16 male and female volunteers to four groups following a modified Balke protocol pretest. The four groups were control, exercise, RBC infusion, and exercise and RBC infusion. All subjects experienced venipuncture with the latter two groups having 500 ml withdrawn. During the next two weeks the exercise groups trained five days/week. Seventeen days after the initial withdrawal all subjects experienced venipuncture again with the first two groups receiving normal saline and the infusion groups receiving their own packed RBCs. Analysis of the data revealed no significant differences between groups relative to peak $\dot{V}o_2$.

In the present investigation blood infusion did not increase endurance capacity as measured by a treadmill run to exhaustion. In addition, subjective evaluation of the severity of the work task as measured by RPE revealed no significant psychological effect of the infusion.

A possible criticism of this investigation was the amount of RBCs infused, being only approximately 200 ml in about 260 ml normal saline. In their most recent study, Ekblom and others (3) infused 360 ml packed RBCs. With this amount they noted a 4.5 percent rise in Hb concentration, less than expected, prior to the maximal test. In our investigation the experimental group increased their Hb concentration 5.6 percent between T2 and T3 while the control group only increased 1.1 percent. Thus, the percentage increases in Hb between our investigation and others (3) following infusion were similar. As Ekblom and others (3) reported increased Ca_{O_2} with a Hb increase of 4.5 percent, it could be assumed Ca_{O_2} was increased in our study although it was not actually measured.

The results of the present investigation support the viewpoint that the infusion of autologous RBCs does not increase maximal endurance capacity as reflected by a run to exhaustion on a motor driven treadmill. This finding is in sharp contrast to the previously cited reports (3,5,11) of increased $\dot{V}o_2$ max and/or endurance capacity following

RBC infusion or altitude induced polycythemia. One of the major criticisms of these latter studies (3,5) is the apparent lack of a control group and a double-blind procedure. When the data from the present investigation was analyzed via a one-way repeated measures ANOVA for the experimental group alone, a significant F ratio was obtained, indicative of a significant difference between the four trials. A Neuman-Keuls analysis then revealed that performance on T3 and T4 was significantly ($P < .05$) better than T1. However, there were no other significant comparisons, indicating that the blood infusion did not improve performance over T2. Thus, depending upon how one desired to interpret this data without a control group, it could be concluded that blood infusion did increase performance capacity. However, it would be an improper conclusion as it would not include comparisons with the control group. In any experimentation with theoretical ergogenic aids designed to increase physical performance capacity, it is essential that double blind protocol with control groups be utilized in order to account for a possible psychological placebo effect. These conditions, which prevailed in the present investigation, may help to explain our negative findings in comparison to other investigations (3,5) which did not employ them.

CONCLUSION

Within the limitations of the present investigation the following conclusion appears to be warranted. The infusion of approximately 200 ml RBC, combined with normal saline to a volume of 460 ml, has no significant effect upon either maximal endurance capacity or perceived measures of exertion (RPE) during an exhaustive treadmill run.

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