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SHORT REPORT

Effect of post-exercise sauna bathing on the endurance performance of competitive male runners

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Summary The physiological adaptations to sauna bathing could enhance endurance performance. We have therefore performed a cross-over study in which six male distance runners completed 3 wk of post-training sauna bathing and 3 wk of control training, with a 3 wk washout. During the sauna period, subjects sat in a humid sauna at 89.9 ± 2.0 °C (mean ± standard deviation) immediately post-exercise for 31 ± 5 min on 12.7 ± 2.1 occasions. The performance test was a ~15 min treadmill run to exhaustion at the runner's current best speed over 5 km. The test was performed on the 1st and 2nd day following completion of the sauna and control periods, and the times were averaged. Plasma, red-cell and total blood volume were measured via Evans blue dye dilution immediately prior to the first run to exhaustion for each period. Relative to control, sauna bathing increased run time to exhaustion by 32% (90% confidence limits 21—43%), which is equivalent to an enhancement of ~1.9% (1.3—2.4%) in an endurance time trial. Plasma and red-cell volumes increased by 7.1% (5.6—8.7%) and 3.5% (−0.8% to 8.1%) respectively, after sauna relative to control. Change in performance had high correlations with change in plasma volume (0.96, 0.76—0.99) and total blood volume (0.94, 0.66—0.99), but the correlation with change in red cell volume was unclear (0.48, −0.40 to 0.90). We conclude that 3 wk of post-exercise sauna bathing produced a worthwhile enhancement of endurance running performance, probably by increasing blood volume.

Introduction

The heat stress of a single session of sauna bathing produces hemodilution via an increase in plasma volume.[1] With repeated exposures the hemodilution subsides, but it is not clear whether this

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adaptation is due to restoration of normal plasma volume or an increase in red-cell volume.[2] A reduction in renal blood flow during sauna bathing or the hemodilution resulting from the plasma volume expansion could provide the stimulus to produce more red cells via release of erythropoietin.[3] The resulting increase in total blood volume could enhance high-intensity endurance performance by delivering more oxygen to muscles.[4]

Notwithstanding the possibility that sauna bathing could enhance performance, there appears to be only one published study of the effects of sauna bathing on athletes, an investigation showing only that the acute physiological responses to the heat were augmented when the sauna followed exercise.[5] In the present study we therefore investigated endurance performance of athletes following a period of adaptation to sauna bathing undertaken immediately after training sessions. We included measurement of plasma and red-cell volumes to investigate their possible contribution to any enhancement of performance.

Methods

Subjects were six male competitive distance runners and triathletes. They gave informed consent in accordance with the requirements of the institutional human ethics committee. They had the following characteristics (mean ± S.D.): age, 23 ± 3 yr; body mass, 81 ± 5 kg; current best 5 km run time within the previous year, 17.5 ± 1.6 min (17.1 ± 1.6 km h^{-1}). The study was performed during their winter competitive season. They were randomized into two groups of three (two runners and one triathlete) for a crossover study of 3 wk of normal or sauna training, separated by a 3 wk washout. They recorded their training duration and subjective intensity (four levels) during the 2 wk before starting the first treatment and were instructed to attempt to repeat this training throughout the study. Blood volumes were measured and a run to exhaustion was performed the day after completion of the sauna and control periods. To increase the precision of the estimate of performance, subjects performed a second run to exhaustion the next day. The subjects did not take iron supplements during the study.

Sauna bathing was performed immediately after endurance training sessions by including the run to the sauna facility as part of their training. They were expected to stay in the sauna for about 30 min, which produced tolerable discomfort in preliminary trials. They sat in an upright position in the sauna. Fluid intake was ad libitum. Heart rate was recorded before entering, and every 5 min while in the sauna, using a Polar PE 4000 heart rate monitor (Polar Electro, Kemplele, Finland). Blood pressure was also recorded before entering and every 5 min while in the sauna, using a mercury sphygmomanometer and stethoscope. Systolic and diastolic pressures were defined by the appearance and disappearance of the Korotkoff sounds. Sauna temperature was recorded every 5 min with a mercury thermometer fixed ~1.8 m from the floor. Nude body mass accurate to 0.01 kg was measured immediately before and after each session (Wedderburn Scales, Teraoka Seiko, Tokyo, Japan). Subjects were instructed to drink fluid equivalent to any difference in pre- and post-sauna mass within 2 h of leaving the sauna.

The performance test was a run to exhaustion performed at constant speed and zero slope on a treadmill (Quinton Q65, Seattle, Washington). On the first visit to the laboratory during the 2 wk period before the first treatment, each subject performed a familiarization run to determine the treadmill speed that would elicit fatigue within 12—15 min. The treadmill speed was set initially to correspond to the runner's current best 5 km time. Four runners required a second familiarization run on another day. For subsequent visits the speed was set to the speed determined during the familiarisation run. Subjects reproduced a 10 min self-paced warm-up before starting the test. They were not told their run time during or after each test.

Blood volumes were measured using a dye dilution method.[6] Briefly, a 20-gauge catheter was inserted into an antecubital vein, and after 20 min of supine rest, Evans blue dye (New World Trading, DeBary, Florida) was injected and saline flushed by a medical practitioner. The volume (~15 ml) was determined by weighing the syringe (PG503, Watson Victor, Australia) to within 0.001 g. Blood was withdrawn before and 10, 15, 20 and 25 min later, timed using the mid-point of withdrawal and following a 2 ml discard. Absorbencies of dye in the sera were read at 620 nm with a spectrophotometer (model 80-2088-64, Pharmacia, LKB Biochrom, England) and converted to dye concentrations via a curve of absorbencies of dye diluted with saline, following subtraction of the absorbency from each participant's pre-infusion sample. Linear regression of the log concentration of dye against time following injection was used to estimate blood concentration at the time of injection. Plasma volume was calculated as (dye concentration)/(volume of dye injected); red cell and total blood volumes were calculated from plasma volume and venous hematocrit (not adjusted to whole-body hematocrit).

Data analysis

The effects of sauna on performance and blood volumes were estimated with mixed modeling using Proc Mixed in the Statistical Analysis System (Version 8.2, SAS Institute, Cary, NC). For blood volumes and body mass the fixed effects in the statistical model were treatment (sauna, control), order of treatment (first test, second test), and their interaction. The random effects were the subject identity and the residual (the standard error of measurement in the experiment). The model for performance included a random effect representing extra within-subject variance for the sauna condition. All variables were log-transformed before analysis to reduce effects of non-uniformity of error. The fixed and random effects for endurance time were converted to equivalent effects on performance time or speed in a time trial of the same duration by dividing the log-transformed effects by 15 before back-transformation.[7]

Descriptive statistics are shown as mean ± standard deviation. Uncertainty in the true (population) values of effects is presented as 90% confidence limits, and chances of benefit (for performance). An effect was inferred to be unclear if its confidence interval spanned substantial positive and substantial negative values. For running speed in a time trial, the smallest substantial value was assumed to be 0.5%.[7]

Results

Training sessions during the control period lasted 53 ± 8 min and were performed 7.7 ± 2.3 times per week, with 53% of total training time spent at hard or very hard intensity. During the sauna period training sessions were of similar duration (52 ± 7 min) and intensity (45% hard or very hard) but were a little less frequent (6.7 ± 2.2 times per week). Subjects spent a total of 385 ± 81 min in the sauna, spread over 12.7 ± 2.1 sessions. The average session lasted 31 ± 5 min (mean ± between-subject S.D. of subjects' session averages), at a temperature of 89.9 ± 2.0 °C, producing a maximum heart rate of 140 ± 11 beats min^{-1}, a minimum diastolic pressure of 42 ± 6 mmHg and a minimum systolic of 114 ± 3 mmHg. Water intake during a session was 990 ± 210 ml; without this intake, loss of mass was 1.5 ± 0.4 kg, representing sweating and respiratory evaporation in the sauna.

Effects of the control and sauna treatments on performance, blood parameters and body mass are shown in Table 1. The 32% increase in run time to exhaustion was equivalent to a change in time for a 5000 m time-trial of 1.9 ± 0.7% (90% confidence limits 1.3—2.4%); for a smallest worthwhile change in performance of 0.5%, the real effect was almost certainly beneficial (chances of benefit, 99.3%). There was a substantially greater effect on equivalent time-trial time for the second run than for the first: 2.2 versus 1.4%, a difference of 0.8% (0.2—1.4%). The sauna treatment resulted in substantial increases in total blood volume, although for red cell volume the confidence limits show that the real effect could have been a small decrease. The increase in body mass (0.4 kg) was similar to the increase in the total blood volume (0.45 L, or 0.45 kg, assuming blood density of 1.0). The correlation between percent change in run time and percent change in total blood volume for the best linear fit forced (appropriately) through the origin and adjusted for degrees of freedom was −0.94 (confidence limits −0.66 to −0.99). The corresponding correlation for red cell volume was −0.48 (−0.90 to 0.40), while that for plasma volume was −0.96 (−0.76 to −0.99).

Discussion

The precision of the estimate for the change in performance leaves little doubt that 3 wk of sauna

Table 1 Performance, blood parameters and body mass following control and sauna treatments for the six athletes

	Control, mean ± S.D.	Sauna, mean ± S.D.	Sauna-control (%), mean (90% confidence limits)
Run time to exhaustion (min)	14.1 ± 2.1	18.2 ± 2.0	32 (21—43)
Total blood volume (L)	6.26 ± 0.18	6.61 ± 0.26	5.6 (4.2—7.0)
Plasma volume (L)	3.58 ± 0.16	3.84 ± 0.14	7.1 (5.6—8.7)
Red cell volume (L)	2.68 ± 0.09	2.78 ± 0.17	3.5 (−0.8 to 8.1)
Hemoglobin concentration ($g L^{-1}$)	144.2 ± 6.2	142.3 ± 5.4	−1.3 (−4.0 to 1.6)
Hematocrit (fraction)	0.428 ± 0.013	0.420 ± 0.014	−2.0 (−5.0 to 1.2)
Body mass (kg)	80.7 ± 4.7	81.1 ± 4.7	0.5 (−0.7 to 1.7)

Run time to exhaustion is the mean for each subject's two runs performed after each treatment.

bathing produces a worthwhile enhancement. The sample size in this study would normally be too small to produce such a clear outcome, but the run to exhaustion produced a small error of measurement when the change in performance was expressed as change in time-trial time.

Increases in plasma and total blood volume following the sauna treatment were also clear, again because of the low error of measurement. The increase in red-cell volume was not clear, but an increase of a few percent (see Table 1) could occur over the 3 wk of the sauna treatment via accelerated release of immature red cells[8] as well as via a net increase in the usual erythropoiesis rate.[9]

The correlation between changes in plasma and blood volume and changes in performance suggests these measures are responsible for the performance enhancement, given that plasma volume expansion alone can improve endurance performance in sedentary and moderately trained subjects.[4] Nevertheless, the effects of sauna bathing on performance and blood volumes need to be substantiated with a larger sample and especially with athletes at the elite level, who may experience smaller gains. Such athletes apparently do not benefit from an expansion of plasma volume alone,[10] but they presumably would benefit if sauna bathing produces an accompanying substantial increase in red-cell volume. It seems unlikely that changes in blood volumes were responsible for the difference in enhancement between the first and second runs. Recovery from a fatigue effect of the sauna treatment may have been involved.

Adaptations other than an increase in plasma or red-cell volume that result in greater cardiac output and/or greater oxygen delivery to muscles could also be responsible for the enhancement of endurance performance, mediated, for example, via the increased release of hormones of the rennin—angiotensin—aldosterone system following sauna bathing.[1] The end result of such adaptations should be an increase in maximum oxygen consumption, which also needs to be investigated.

Practical implications

- Sauna bathing that can be tolerated for half an hour immediately after a training run provides an additional training stimulus.
- After 12 bathing sessions spread over 3 wk, endurance performance of sub-elite runners is enhanced by a useful 2%, probably via an increase in blood volume.
- Elite endurance athletes may experience smaller gains from such sauna bathing.

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