AD-A155 984 WEIGHT LOSS RECTAL TEMPERATURE AND HEART RATES FOLLOWING THE 1984 BOSTON. (U) ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE NATICK MA W L DANIELS ET AL. 1/1

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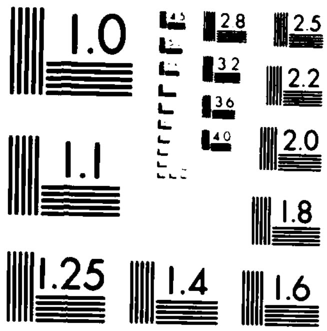
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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: M29/85
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): Weight Loss, Rectal Temperature and Heart Rates Following the 1984 Boston Marathon
5. TYPE OF REPORT & PERIOD COVERED:
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): William L. Daniels, Ph.D., Bruce H. Jones, M.D., William T.Matthew, B.S., Patricia I. Fitzgerald, Ph.D., Patricia Szlyk, Ph.D. and Pamela Evans,M.S.
8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army Research Institute of Environmental Medicine, Natick, MA 01760-5007
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Medical Research and Development Command, Fort Detrick, Frederick, MD 21701
12. REPORT DATE: May 1985
13. NUMBER OF PAGES:
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report):
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report): DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DTIC ELECTE JUL 3 1985 S D A

18. SUPPLEMENTARY NOTES: To be published in Physician and Sports Medicine
19. KEY WORDS (Continue on reverse side if necessary and identify by block number): Weight loss, heart rate, Rectal temperature
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the physiological changes that occurred in runners following the 1984 Boston Marathon. The marathon took place under cool and rainy weather conditions (WBGT range 6.5-10.5). Subjects for this study consisted of 57 males and 10 females. Their average age was 40.5 years (range 22-61 years). Average marathon pace was 219.1 m/min (X time = 3 hrs 12 min 36 sec). During the race, these runners drank an average of 581 mls. of fluid. As a result of running a marathon, heart rate increased from 61.3 bts/min to 91.2 bts/minute; body weight decreased from 67.3 kg. to 65.7 kg., and rectal

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) temperature (T_{Re}) was not significantly changed. Post-heart rate and T_{Re} were affected by how soon after finishing the race an individual was measured. Runners who reported to the post-test site soonest tended to be younger and faster than those reporting later. Age and average weekly mileage correlated significantly with mean marathon pace. Our results with heart rate and T_{Re} provide medical personnel with some guidance on the effect of the marathon on these parameters in uninjured runners.

Weight Loss, Rectal Temperature and Heart Rates

Following the 1984 Boston Marathon.

by

William L. Daniels, Ph.D., Bruce H. Jones, M.D., William T. Matthew B.S.,

Patricia I. Fitzgerald, Ph.D., Patricia Szlyk, Ph.D and Pamela Evans, M.S.

The popularity of the marathon has increased tremendously in the past decade. Recently, interest has also increased in the medical problems and physiological responses associated with running this distance [1,2]. While marathons are run under a variety of environmental conditions, the greatest threat to the otherwise healthy runner is heat stress.[3] Therefore, most of the previous reports have indentified the physiological effects of running a marathon in moderate to warm weather. [4,5,6] Although not at the same severity or magnitude, marathons run during almost ideal weather conditions have a significant incidence of injury/illness associated with them[1]. Little is known about the physiological responses of the average runner during a cool weather marathon. This report presents data on normal physiological changes that occurred in uninjured runners after running a marathon in a cool environment and compares them with those reported in the literature for other marathons under warmer conditions. This report provides a data base for medical personnel to make comparisons between injured and uninjured runners in terms of post-race heart rates and rectal temperatures (T_{re}).

METHODS

Measurements were made on runners before and after the 1984 Boston marathon. Subjects were recruited for the study by placing large signs at the registration area the day before and on the day of the race. On race day, a section of the gymnasium near the registration site, was screened off. Subjects were informed about the nature of the study and signed a consent form. Data collected on each subject included name, race number, age, sex, and estimated training miles per week for the last 2 months. Subjects were then weighed to the nearest 0.1 kg dressed in running shorts and T-shirts. Next, while sitting on a folding metal chair, heart rate was measured. The heart rate was determined by measuring, with a stop watch, the time for 15 pulses in the radial artery. Charts were readily available which converted time in the nearest 0.1 second to beats per minute based on the following formula:

$$x \text{ bts/min} = \frac{15 \text{ bts}}{\text{No. of seconds for 15 bts}} \times 60 \text{ seconds/min.}$$

Finally, in those runners who were willing, a rectal temperature (T_{re}) was taken using a Yellow Springs electronic thermometer. Individuals were instructed on how to insert the thermometer and then went behind a cloth screen where they inserted the probe and measurements were read by an investigator outside the screened area.

After all pre-measurements were collected, the data collection team moved to the finish line and set up in the Prudential garage near the medical treatment and refeshment area. Runners had been requested to look for this area and report as soon as possible after they finished the race. Runners who participated in the pre-measurements had a bright orange dot placed on their race number. Spotters were placed at the end of the finishing chutes to help direct participants to the post-measurment site. At the end of the race, heart rate, body weight, and T_{re} measurements were repeated as decribed above. In addition, time for the race, estimated fluid intake and time of day were recorded. Fluid intake was estimated by asking each runner to estimate the number of cups of fluid they drank either along the route and this value was multiplied by 4 ounces, which was the average volume of the cups used by race officials. The average fluid intake was estimated by converting ounces to milliliters using the formula 1 ounce = 26.9 milliliters. Time of day was recorded in order to determine how long after finishing the race that the measures were recorded.

During the race, ambient temperature was monitored with a Reuter-Stokes wet bulb globe temperature meter. Statistical analyses consisted of t-tests, linear regression, and analysis of variance, as appropriate.

RESULTS

Ambient temperatures measured at 3 points on the race course are listed in Table 1. Temperatures were lowest at the start and increased as the race progressed. It should also to noted that there were intermittent rain showers during the race.

Pre-race measurements were obtained on 109 runners. Of these, 67 reported for post-measurements. Comparison of the pre-values for those who did and did not report for post-testing are listed in Table 2. There was no initial difference between those who did and did not report back. Table 3 summarizes the data collected on all subjects both pre- and post-run. The average marathon time of 3 hours and 12 minutes was similar to that reported in the 1983 Boston marathon for a group aged 40-45 years[7]. Average fluid intake was estimated to be 581 ml. per runner tested. Five of the runners reported 0 intake of fluid during the race. If these five are dropped, the average estimated intake of runners who actually took fluid during the race was 629 ml.

One of the difficulties associated with a study of this type is that the time between finishing the race and actually taking the measurements varies considerably. Figures 1 & 2 illustrate how heart rate and rectal temperature decreased as the time between finishing the race and taking of the measurement increased. However, it should be noted that the speed with which an individual completed the race and age of the runners are also factors that may affect post-race heart rate. In 28 runners whose heart rate was measured within 10 minutes of finishing, 15 finished in less than 3 hours while the other 13 completed the course in over three hours. Table 4 compares age and pre- and post-heart rates in this group. Similar results can be seen in the T_{re} for runners. Table 3 shows that the overall group did not show any significant change in T_{re}. However, when comparing 12 runners whose T_{re} was taken within 15 minutes of the finish, there is a marked difference between the post- T_{re} of these and those whose T_{re} was measured later (Figure 2). Table 5 is a correlation matrix which lists the results obtained on 33 runners on whom complete data was collected. The results of this analysis showed a significant correlation between average speed and age ($r = -.507$), post heart rate ($r = .436$), Δ heart rate ($r = .430$), post-T_{re} ($r = .469$), ΔT_{re} ($r = .599$) and average weekly mileage ($r = .466$).

DISCUSSION

Ambient temperature is much cooler in the present study than in previous reports dealing with physiologic responses during marathon running. The results of this study differ somewhat from those previously reported primarily because of the differences in ambient temperature. Table 2 suggests that there is no difference between runners who did and did not return for post- race measures. However, only 65% of those who pre-tested were able to be post-tested. We feel that a large part of this is due to the fact that this is a point to point race. Our suggestion would be that future studies be done at races which start and finish at the same point. Some of the delay in runners reporting to the post-test site was due to the fact that they had difficulty finding it because of the crowded conditions in the garage after the race.

In 1967, Pugh et al[6] reported an average weight loss of 2.85 kg in 77 marathoners at an ambient temperature of 23°C. Maron et al[8] reported similar results under similar weather conditions (21.7°C) in six highly trained marathoners. In the present study, runners averaged a 1.6 kg weight loss with a range of 0.4 -4.1 kg. This difference is probably due to the fact that the lower ambient temperature resulted in less sweating. Fluid intake estimates in the present study were similar to, or lower than, those previously reported (6,8,9). Therefore, it seems unlikely that increased fluid uptake accounted for the lack of weight loss. It must be kept in mind that the present values of fluid intake are based upon the runners recall not on any actual measurements. Runners estimated their intake to be 581 mls in the present study. This is very similar to the 520 mls that Maron et al[8] measured in six runners. Pugh et al[6] estimated an average fluid intake of 420 ml in 75 runners in 1967. However, both of these values are substantially lower than the 1379 ml that was consumed by three runners in a 1982 report.[9] The fact that the lowest fluid intake is reported in 1967 may reflect the increased emphasis that has been put on fluid intake during long races since then. We were particularily surprised to find 5 out of the 67 runners reported drinking no fluid during the race. None of these individuals showed significant signs of dehydration. Body weight loss during the race ranged from 0.7 to 1.7 kg in these 5 runners. While these runners did not appear to be significatnly dehydrated, it is interesting to note that 4 of there 5 had a race pace slower than the group average of 219.1 m/min.

In 1967, Pugh[6] suggested that "tolerance of a high body temperature is a necessary condition of success in marathon running." Maron et al[8] reported a significant correlation between post race rectal temperature and time. Both reports found the highest rectal temperature in the fastest runner.

In the present study we found a significant correlation between race pace and ΔT_{re}. However, post- T_{re} was affected considerably by how soon after finishing the marathon that the measurement was taken (Figure 3). In fact, the correlation between ΔT_{re} and the time after finishing that it was taken was significant ($p < 0.05$; $r = -.375$). In an effort to eliminate the effect of time on post-race measurement, we repeated the correlation between race pace and post- T_{re} and ΔT_{re} on the 12 runners who were measured withing 15 minutes of finishing. Correlations were not significant for the 12 runners, ($r = .286$ and $.394$ for post T_{re} and ΔT_{re} respectively). Interestingly, the highest T_{re} which we recorded (39.5°C) was in our fastest female runner, 10 minutes after she finished. This compares favorably with the reports by Pugh et al[6] and Maron et al[8] who found the highest T_{re} in their fastest runners. However, in our male runners this was not the case. The high correlation reported by Maron et al[8] between time and post-race T_{re} did not occur in our 12 runners. The reason for this is not clear but several explanations are plausible. It may be due to the small number of subjects and the similar degree of fitness exhibited by Maron et al's[8] subjects. All their subjects finished within 11 minutes of one another. In the present study, finishing times for these 12 runners varied considerably more. These 12 runners, whose T_{re} was measured within 15 minutes had race times varying from 2:31 to 3:55. Thus, it is not clear whether the difference in relation between post race T_{re} reported by Maron et al[8] and the present study is due to the wider range of capabilities or the lower ambient temperature in the present study. Obviously, more research is required. Our experience indicates that it would be preferrable to select a race where runners would be able to report to the same site for pre and post measures.

The present study provides some useful information for marathon medical personnel by providing guidelines for the types of decrease in post-race T_{re} and heart rate. Figures 1 and 2 illustrate these values. At this ambient temperature, post-race T_{re} will return to pre-race levels in approximately 30 minutes. Maron et al[5] also reported rapid declines in T_{re} in two runners under warmer conditions. The present results indicate that race officials and race medical personnel should be prepared to provide shelter and rapid access to warm clothing (e.g., space blankets or runner's own apparel) in cool weather marathons. None of the runners in our study reported for medical treatment after the marathon. However, information collected by one of the authors (BHJ) revealed that 18.3% of those reporting for medical treatment suffered symptoms of hypothermia.

Figure 1 also provides medical personnel with important information regarding post- race heart rate decline. While the results shown in Figure 1 may be somewhat specific to ambient temperature, they provide a general guide as to the decline in heart rates seen in runners who have no medical problems after the race. Little information is available in the literature on the normal recovery of the average runner from the marathon stress. Obviously, a runner who fails to exhibit a decline in heart rate as post-race time increases or who shows a very marked drop below 60 beat/minute deserve careful attention. Table 4 also indicates that younger runners are more likely to be faster and to have higher heart rates immediately after the race (i.e. within 10 minutes of finishing.) than their older counterparts.

In summary, although post-race heart rate and T_{re} correlated significatly with average racing speed (Table 5), the physiological meaning of this relationship is difficult to assess under the present conditions because heart rate and T_{re} were affected by how soon after the race they were measured. Thus the two most important factors in determining performance in the present study become age and average weekly mileage. Both these factors were important variables in the equation developed by Hagan et al[10] for predicting marathon time. Our results with heart rate and T_{re} provide medical personnel with some guidance on the effect of the marathon on these easily measured parameters. In order to gain a complete picture of the physiological reponses to marathon running, future assessments should be performed at a variety of ambient temperatures.

TABLE 1. WBGT(^{0}C) during 1984 Boston Marathon.

Place	Time	DB	WB	GT	WBGT
Hopkinton (Start)	12:00	6.4	6.3	8.3	6.5
Natick	12:30	8.0	7.5	8.4	7.7
(10.5 miles)	12:50*	8.0	7.9	9.4	8.0
	13:00	6.9	7.1	7.8	7.0
	13:20	7.2	7.1	9.4	7.3
Boston	14:00	7.7	7.7	8.4	7.8
(Finish)**	14:30	8.7	8.3	8.6	8.2
	15:00	8.4	8.3	8.8	8.2
	16:25	10.5	10.1	11.2	10.5

* 1st Runner
** Winning Time: 2:10:34.

TABLE 2. Comparison of Pre-race values of subjects who completed only pre vs. both phases of testing.

	WT(kg)	HR(bts/min)	T_{re} (°C)
Only Pre-Tested(n=42)	67.5 ± 17.8	62.3 ± 12.8	36.7* ± 0.3
Both Pre- and Post (N=67)	67.3 ± 9.2	61.3 ± 10.7	36.5** ± 0.5

* n=25
** n=34

TABLE 3. Summary of Data Collected on All Subjects.

	Pre	Post	p-value
Heart Rate (n=67) (bts/min)	61.3 ± 10.7	91.2 ± 17.0	> 0.005
Body Weight (n=67) (kg)	67.3 ± 9.2	65.7 ± 8.9	> 0.005
Rectal Temperature (=34) (°C)	36.5 ± 0.5	37.0 ± 1.9	N.S

Average Marathon Time (n=67)	-	3:12:36 (219.1m/min)
Average fluid intake (estimated)	-	581 mls. (19.63 oz)
Average Age (range)	-	40.5 yrs (22-61)
Males (n=57)		
Females (n=10)		

TABLE 4 Comparison of Sub 3 hour and Over 3 hour marathoners by age and post-heart rates measured within 10 minutes of finish.

Race Time	Under 3-hours	Over 3 hours
Age (years)	34.0 ± 6.1	44.3 ± 10.1**
Heart Rate (pre)	63.1 ± 13.3	61.7 ± 10.1
Heart Rate (post)	107.2 ± 17.7	94.2 ± 11.9*
n	15	13

*p > 0.05
**p > 0.01

TABLE 5: Correlation Matrix on 33 Runners Who Completed All Data Collection.

	1 Age	2 Pre Weight (kg)	3 Δ Weight	4 % Wt. Loss	5 Pre Heart Rate	6 Post Heart Rate	7 Δ Heart Rate	8 Pre T_{RE}	9 Post T_{RE}	10 Δ T_{RE}	11 Fluid Intake (ml)	12 Average Weekly Mileage	13 Speed (m/min)
1	1.000												
2	−0.038	1.000											
3	0.084	−.268	1.000										
4	−.079	.023	−.968	1.000									
5	−.103	−.420	.292	−.179	1.000								
6	−.524	.032	−.207	−.208	−.192	1.000							
7	−.385	.210	−.297	.249	−.593	.904	1.000						
8	−.085	−.033	.359	−.351	.110	.003	−.046	1.000					
9	−.215	.103	−.349	.345	−.055	.522	.452	.181	1.000				
10	−.165	.115	−.512	.505	−.107	.502	.459	−.316	.876	1.00			
11	.223	.100	.257	−.289	.090	−.203	−.206	−.068	−.241	−.199	1.000		
12	−.095	−.164	−.174	.218	−.025	.266	.230	−.388	.123	.308	−.257	1.000	
13	−.507	.045	−.307	.306	−.165	.436	.430	−.299	.469	.599	−.134	.466	1.000

		X	±	S.D.
1	Age (yrs)	43.1	±	9.0
2	Pre-Weight (kg)	67.6	±	7.6
3	Δ Weight (kg)	−1.62	±	0.67
4	% Weight Loss	2.40	±	0.90
5	Pre-Heart Rate	56.9	±	8.0
6	Post-Heart Rate	90.5	±	15.1
7	Δ Heart Rate	33.6	±	18.4
8	Pre-T_{RE} (°C)	36.5	±	0.5
9	Post-T_{RE} (°C)	37.0	±	1.0
10	Δ T_{RE}	0.5	±	1.1
11	Fluid Intake (mls)	509.5	±	421.7
12	Average Weekly Mileage	56.9	±	15.3
13	Speed (m/min)	222.7	±	24.0

for $p<0.05$, $r>.340$
for $p<0.01$, $r>.437$

Acknowledgements

The authors wish to thank the runners who participated for their outstanding cooperation. We also want to thank the expert technical assistance of the staff of the U.S. Army Research Institute of Environmental Medicine who participated: SSG David Burnell, III, SGT Bruce Ruscio, SP 5 Margaret A. Kinney, SP 5 Jorge Tejada, SP 4 Eric Bertrand and Ms. Denise McQuade. We also want to thank the Boston Medical Marathon Team especially Dr. Marvin Adner for their support in carrying out this study.

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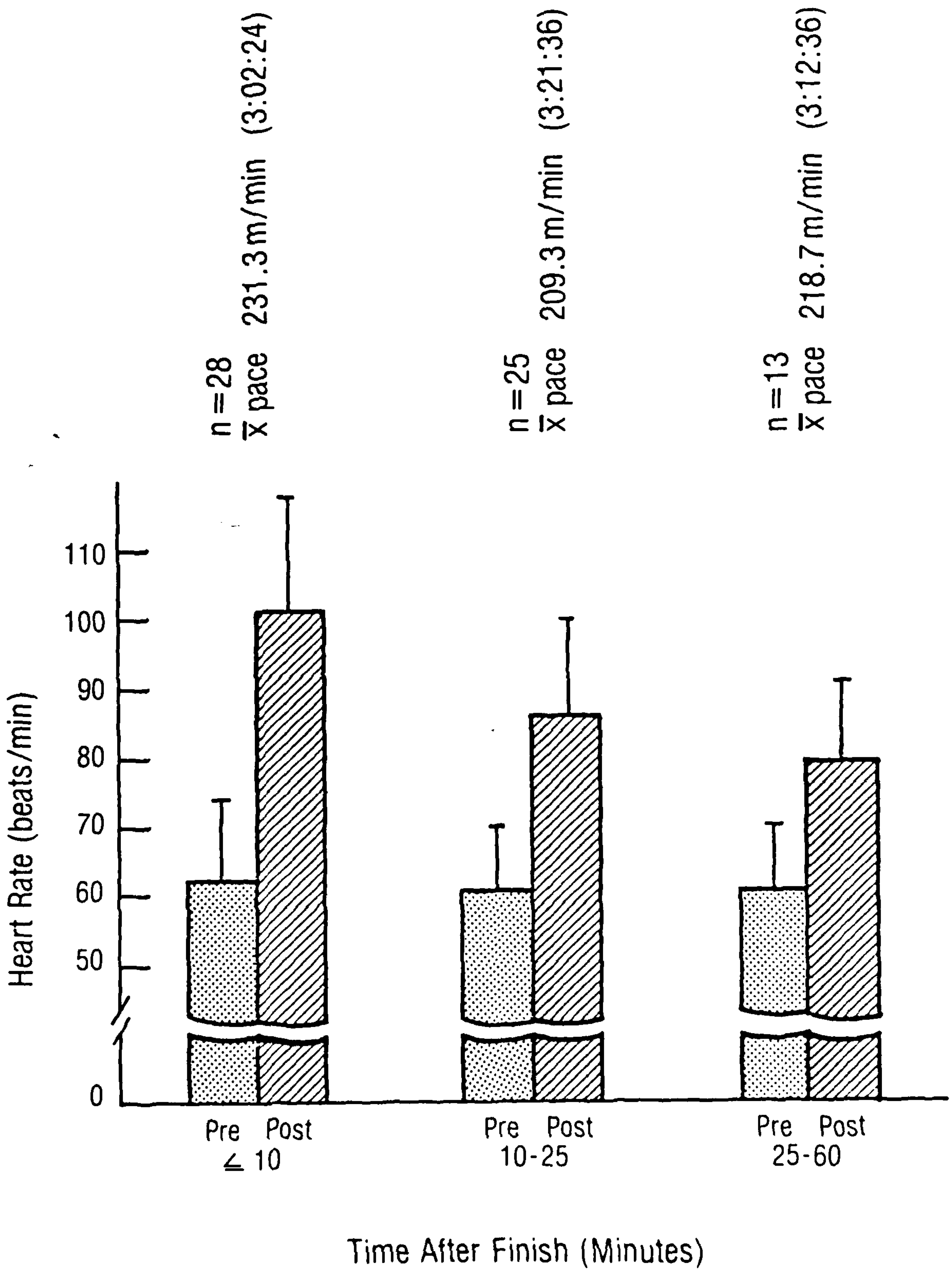

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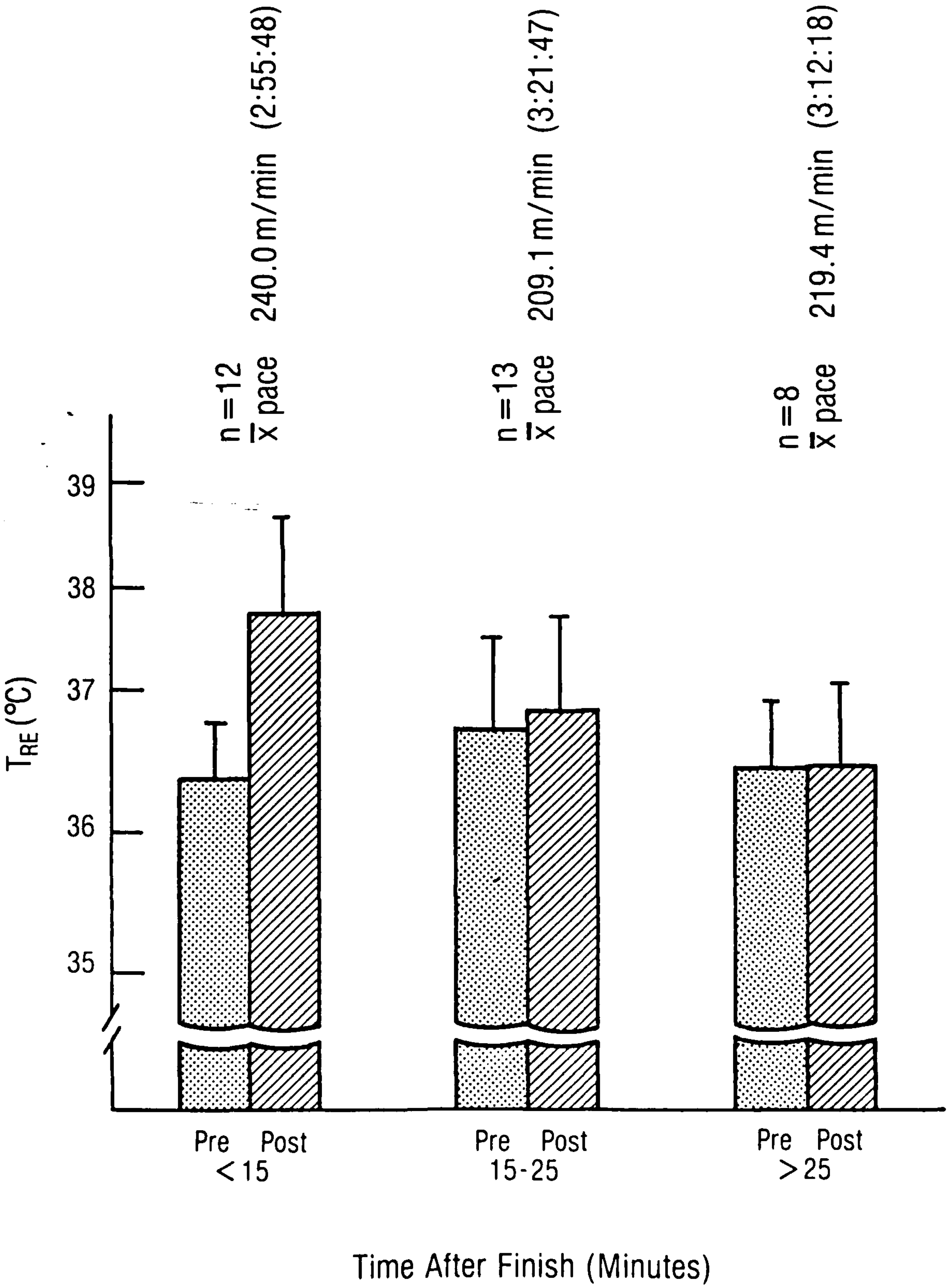
n = 25
x̄ pace 209.3 m/min (3:21:36)
n = 13
x̄ pace 218.7 m/min (3:12:36)
Heart Rate (beats/min)
110
100
90
80
70
60
50
0
Pre Post
≤ 10
Pre Post
10-25
Pre Post
25-60
Time After Finish (Minutes)



n=12
x̄ pace 240.0 m/min (2:55:48)
n=13
x̄ pace 209.1 m/min (3:21:47)
n=8
x̄ pace 219.4 m/min (3:12:18)
T_RE (°C)
39
38
37
36
35
Pre Post
<15
Pre Post
15-25
Pre Post
>25
Time After Finish (Minutes)

LEGENDS TO FIGURES.

Figure 1. The effect of increasing time between finish of race and measurement on post-race heart rates.

Figure 2. The effect of increasing time between finish of race and measurement on post-race rectal temperature (T_{re}).

HUMAN RESEARCH

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

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