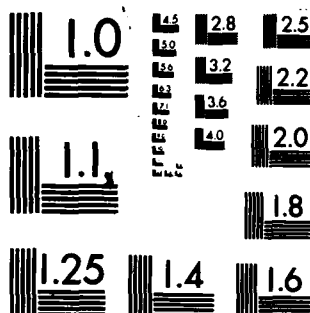


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A 10x10 grid of squares. The grid is mostly black, with a few white squares forming a pattern on the left side. The white squares are located at the following coordinates (row, column): (1, 1), (2, 1), (3, 1), (4, 1), (5, 1), (6, 1), (7, 1), (8, 1), (9, 1), (10, 1), (1, 2), (2, 2), (3, 2), (4, 2), (5, 2), (6, 2), (7, 2), (8, 2), (9, 2), (10, 2), (1, 3), (2, 3), (3, 3), (4, 3), (5, 3), (6, 3), (7, 3), (8, 3), (9, 3), (10, 3), (1, 4), (2, 4), (3, 4), (4, 4), (5, 4), (6, 4), (7, 4), (8, 4), (9, 4), (10, 4), (1, 5), (2, 5), (3, 5), (4, 5), (5, 5), (6, 5), (7, 5), (8, 5), (9, 5), (10, 5), (1, 6), (2, 6), (3, 6), (4, 6), (5, 6), (6, 6), (7, 6), (8, 6), (9, 6), (10, 6), (1, 7), (2, 7), (3, 7), (4, 7), (5, 7), (6, 7), (7, 7), (8, 7), (9, 7), (10, 7), (1, 8), (2, 8), (3, 8), (4, 8), (5, 8), (6, 8), (7, 8), (8, 8), (9, 8), (10, 8), (1, 9), (2, 9), (3, 9), (4, 9), (5, 9), (6, 9), (7, 9), (8, 9), (9, 9), (10, 9), (1, 10), (2, 10), (3, 10), (4, 10), (5, 10), (6, 10), (7, 10), (8, 10), (9, 10), (10, 10).



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Metabolic, Thermal and Cardiovascular Adjustments to
Cold Exposure With Special Reference to
Physical Work and Body Composition

Final Report

John R. Magel, Ph.D.

June 1982

Supported by

U.S. Army Medical Research and Development Command
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) VO ₂ and rectal temperature (T _{re}) were studied in 10 men and 8 women during 1 hr rest and exercise at 36W (8.2 kcal.min ⁻¹) in air and water at 20, 24 and 28°C. At rest, in all water conditions, the obese men (> 22% fat) maintained T _{re} at levels similar to control values in air. During work, T _{re} increased about 0.4°C under all conditions with essentially no difference in VO ₂ between work in air and the three water temperatures. For average (15-18%) and lean (< 12%) men, T _{re} decreased after 10-30 min rest at all water tempera- tures with the largest drop in T _{re} (-1.4°C; 35.8°C) and increase in VO ₂		

(760 ml) observed for lean men in colder water. Exercise prevented the drop in T_{re} in 24 and 28°C water for average men and 28°C water for lean men. For both groups, $\dot{V}O_2$ was rapidly and significantly elevated when T_{re} was reduced, with increases in $\dot{V}O_2$ inversely related to the fall in T_{re} . Although the women possessed nearly twice the % fat as their lean and normal male counterparts, their fall in T_{re} at rest was similar to the men at all water temperatures. Viewed somewhat differently, a female of 22% fat does not regulate T_{re} when exposed to cold stress at rest as effectively as a male of similar percent fat. This difference in temperature regulation at rest may be partly explained by differences in thermogenesis between men and women in response to cold stress. For a drop of 1.4°C in T_{re} , men increased their $\dot{V}O_2$ some 3.8 times rest while women showed a significantly lower 2.1 fold increase. This lower thermogenic response to cold stress for women was still apparent when differences in LBW are accounted for. The relatively greater cooling of women compared to men of similar percent body fat may also lie in difference in A_p/M ratio, for at a given level of fatness this ratio is larger for females compared to males. Exercise, however, prevented a fall in T_{re} at all water temperatures for both lean and average women.



A1

Narrative Summary

The enclosed final report differs from the previously submitted annual summary report by providing the following additional information:

1. All methods and procedures are fully described in the text of the report.

2. The results are reported for increased numbers of subjects as follows:

<u>Body Fat</u>	<u>Men</u> (N)	<u>% Fat</u>	<u>Women</u> (N)	<u>% Fat</u>
Low	4	< 12%	4	< 22%
Average	4	15-18%	4	24-27%
High	2	> 22%	-	-----

3. Anthropometric data for men and women grouped by body composition classification are reported in Table 1 (p.14).

4. Figure 1 A, B and C represent Oxygen Consumption and rectal temperature for men of high (A), average (B), and low (C) body fat for 1 hr at rest and during 36 W exercise in air and water at 20, 24, and 28°C. (pp. 16-21)

5. Figure 2 A and B represent Oxygen Consumption and rectal temperature for women of average (A) and low (B) fat for 1 hr at rest and during 36 W exercise in air and water at 20, 24, and 28°C. (pp. 22-25)

6. Figure 3 shows the relationship between percent body fat and surface area - to-mass ratio in men and women. Solid line represents the data of Kollias and colleagues. (p. 26)

7. An expanded discussion to include the data of all subjects.

8. An up-date and expansion of referenced literature in all sections of the report.

9. A newly written abstract to reflect completed data.

10. Appendix A.

Abstract of Paper presented at the National Meetings of the American
College of Sports Medicine, Minneapolis, Minn., May 27, 1982.

11. Appendix B.

Personnel Receiving Contract Support

Name

Degree

Thomas Gergley

M.S. in Exercise Science

Robert J. Spina

M.S. in Exercise Science

Abstract

Oxygen consumption
 $\dot{V}O_2$ and rectal temperature (T_{re}) were studied in 10 men and 8 women during 1 hr rest and exercise at 36W (8.2 kcal/min⁻¹) in air and water at 20, 24 and 28°C. At rest, in all water conditions, the obese men (> 22% fat) maintained T_{re} at levels similar to control values in air. During work, T_{re} increased about 0.4°C under all conditions with essentially no difference in $\dot{V}O_2$ between work in air and the three water temperatures. For average (15-18%) and lean (< 12%) men, T_{re} decreased after 10-30 min rest at all water temperatures with the largest drop in T_{re} (-1.4°C; 35.8°C) and increase in $\dot{V}O_2$ (760 ml) observed for lean men in colder water. Exercise prevented the drop in T_{re} in 24 and 28°C water for average men and 28°C water for lean men. For both groups, $\dot{V}O_2$ was rapidly and significantly elevated when T_{re} was reduced, with increases in $\dot{V}O_2$ inversely related to the fall in T_{re} . Although the women possessed nearly twice the % fat as their lean and normal male counterparts, their fall in T_{re} at rest was similar to the men at all water temperatures. Viewed somewhat differently, a female of 22% fat does not regulate T_{re} when exposed to cold stress at rest as effectively as a male of similar percent fat. This difference in temperature regulation at rest may be partly explained by differences in thermogenesis between men and women in response to cold stress. For a drop of 1.4°C in T_{re} , men increased their $\dot{V}O_2$ some 3.8 times rest while women showed a significantly lower 2.1 fold increase. This lower thermogenic response to cold stress for women was still apparent when differences in LBW are accounted for. The relatively greater cooling of women compared to men of similar percent body fat may also lie in differences in A_D/M ratio, for at a given level of fatness this ratio is larger for females compared to males. Exercise, however, prevented a fall in T_{re} at all water temperatures for both lean and average women.

Adjustment to external cold is not the same for all individuals with the insulatory benefits of body fat providing significant protection against heat loss (1, 3,4,7,10,15,23). Relatively fat men show a proportionately smaller metabolic, thermal, and cardiovascular response to cold water immersion as well as a greater work tolerance in comparison to leaner counterparts (17,18,19). Holmér and Bergh (12) noted a large shivering thermogenesis and corresponding fall in esophageal temperature in their leaner male subjects at rest and during swimming in 18 and 25°C water. For their fatter subjects only a small response to cold water was observed. For all subjects, however, as the caloric expenditure increased in heavier work the metabolic and physiologic differences observed between cold and warmer water became smaller suggesting that physical activity can contribute to thermoregulation in moderately cold water. In extreme cold, however, exercise may increase overall heat loss more than heat production and cause the core temperature of some individuals to fall at an even greater rate than at rest (4,11).

It appears that for each individual a water temperature exists at which the heat conserved via insulation and circulatory adjustments and heat generated by shivering and muscular work do not balance the heat flux induced by an elevated conductive heat transfer in water. While comparative data for cold exposure of men and women at rest and during exercise are sparse, data obtained predominantly from men suggest that this water temperature could be quite low for relatively fat subjects, especially when thermoregulation is aided by an increased caloric output from exercise. For lean subjects, the converse may apply and exercise in only moderately cool water may intensify cooling (14).

While a precise statement cannot be made as to the influence of body fatness on the thermoregulation of men and women it does appear that a person's body composition and exercise level significantly influence physiologic and performance data in response to cold stress. The present study was designed to systematically

study in the same unacclimatized young adult men and women, classified in terms of body fatness, the interrelationship between body composition, body surface area, water temperature, exercise, and thermoregulation. Such information will expand the relatively limited data available on women and extend knowledge of the potential physiologic strain for both men or women at rest or in prolonged exercise during cold water immersion.

Methods

Ten college-aged men and 8 women of prerequisite body compositions volunteered as subjects. All subjects signed informed consent and were medically cleared for vigorous exercise prior to their participation in testing. Based on initial body composition evaluation, subjects were assigned to a particular group. These groupings for men and women as well as relevant anthropometric data are presented in Table 1.

Body Composition Evaluation

Subjects, wearing nylon swimsuits, were weighed underwater in a stainless steel tank while sitting in a bent forward body position with arms clasped around the knees. Underwater weight was recorded to the nearest 10 g in water at 29-32°C after a forced maximal expiration. Six to ten weighings were taken and the last three averaged to constitute a true underwater weight score (13). Pulmonary residual lung volume was measured in a bent forward body position just prior to water submersion by use of the oxygen dilution technique (24). Body weight in air was measured on a Homs balance scale to the nearest 50 g. The formula of Brožek and colleagues (2) was used to convert body density to percent fat.

A Lange caliper was used to measure skinfolds at the chin, subscapular, chest, side, suprailium, abdomen, triceps, thigh, knee, and calf sites. Between three to five replicate measurements were taken on the right side of the body with the subject standing. An average value of the measurements was used as the skinfold score

for each site. Mean skinfold thickness was estimated from the average of the 10 sites.

Work and Metabolic Measurements

Work in air and in stirred water was performed on a specially designed cycle ergometer previously utilized by Craig and Dvorak (7,8) and McArdle and co-workers (17) in a tank 122 cm wide, 244 cm long, and 122 cm deep. Both arm and leg pedals were used and placed so that forces during pedaling would be exerted as much as possible in the horizontal plane. This method of exercise minimizes the effect of gravity being used as an aid to working the pedals and makes it possible to compare identical work in air and in water. Water in the tank was filtered and circulated to assure adequate stirring of the water bath. Water temperature was continuously monitored from a thermal sensor placed approximately 5 cm from the subject's chest and maintained within $\pm 0.5^{\circ}\text{C}$ during the 1 hour rest and work experiments. During tests in water, subjects were immersed to a level of the first thoracic vertebrae. Subjects were familiarized with the testing apparatus and test procedures on separate days prior to data collection and none of the subjects was previously cold acclimatized.

Rectal temperature (T_{re}) was continuously monitored at rest and during exercise on a calibrated telethermometer by means of a rectal probe (Yellow Springs Instruments, Inc. #43) inserted approximately 10 cm into the rectum. The probe was secured in place by means of specially designed cinch-type harness.

All metabolic measures were determined by standard techniques of open-circuit spirometry. The fractional concentrations of CO_2 and O_2 in expired air were monitored on-line by a rapid infrared CO_2 analyzer (Godart Capnograph) and S-3A O_2 analyzer (Applied Electrochemistry), respectively. The analyzers were frequently calibrated with known reference gases which were verified with the Haldane apparatus.

Procedures

Resting measures were taken on separate days while the subject sat quietly in the ergometer in air (25-28°C) and during 1 hour in water at 20, 24, and 28°C. Prior to all water immersion trials, subjects sat quietly in air for 10-minutes to establish a control baseline in air. During each 1 hour exercise period, subjects pedaled at 30 rpm and worked at 36 W (approximately 6-7 METs) in air and in water. All tests in air and at the three water temperatures were randomly assigned. $\dot{V}O_2$ was measured at minutes 4-5, 9-10, and every 10 minutes thereafter during all trials. T_{re} was recorded at 2 minute intervals throughout the measurement period. To provide a frame of reference for the metabolic demands of the arm-leg work task, peak $\dot{V}O_2^1$ on the cycle ergometer was determined on a separate day by means of a continuous, graded exercise test in air during which subjects worked for 2-minutes at successively higher work levels (25 W) until they would no longer continue. For the total group, peak values for $\dot{V}O_2$ averaged 2.58 and 3.49 $l \cdot min^{-1}$ for the women and men, respectively. Thus, submaximal work at 36 W represented an average of between 45 and 81 percent of the subjects' peak $\dot{V}O_2$ on the arm-leg ergometer. $\dot{V}O_{2max}$ was also determined for all subjects by means of a continuous, graded running test (16). Peak $\dot{V}O_2$ on the arm-leg ergometer averaged 88 percent and 94 percent of the treadmill $\dot{V}O_{2max}$ for men and women, respectively.

Statistical Analysis

Independent t-tests were used to evaluate the statistical significance of the difference between means obtained from two different groups of subjects. To evaluate the significance of the difference between two means obtained from the same subjects paired t-tests were applied. Analysis of variance for repeated measures and Duncan's Multiple Range test were utilized to evaluate the statistical significance of the differences between more than two means obtained in the same subjects. In all analyses the .05 level of significance was used.

¹ In this context peak $\dot{V}O_2$ refers to the highest oxygen uptake achieved. Since the traditional criterion for $\dot{V}O_{2max}$ (i.e., plateau in $\dot{V}O_2$ with increasing work) is generally not satisfied in this form of arm-leg ergometry, the term "peak $\dot{V}O_2$ " is perhaps a more appropriate representation of aerobic capacity.

Results

Figure/A,B, and C illustrates the oxygen consumption and T_{re} for men of high, average, and low body fat, respectively at rest and during 36 W exercise in air and in water at 20, 24, and 28°C. At rest, in all water conditions, the men classified as high in terms of body fat maintained T_{re} and $\dot{V}O_2$ at levels essentially similar to control values in air. In no instance did T_{re} fall more than 0.3°C from resting air values during the 1 hr water immersion. With exercise, T_{re} remained at resting air values during work at all water temperatures and slowly increased about 0.4°C during the 1 hr work period in air. $\dot{V}O_2$ remained at approximately 1.7 l $O_2 \cdot min^{-1}$ (8.2 kcal $\cdot min^{-1}$) and no differences were observed between work in air and at the three water temperatures.

For men between 15-18% body fat, T_{re} was maintained at control air values during the first 10-20 minutes of rest at the three water temperatures. Thereafter T_{re} steadily declined in all water conditions with the largest drop of 1.1°C ($P < .01$) observed in 20°C. Thermogenesis at rest was greatest in 20°C water where $\dot{V}O_2$ increased to about 500 ml $\cdot min^{-1}$ during the first 10 minutes of immersion, remained steady, and then gradually increased during the final 30 minutes. After 1 hr, resting $\dot{V}O_2$ averaged 610 ml $\cdot min^{-1}$ or approximately 2.0 times ($P < .05$) the resting level in air. Exercise at 36W prevented the fall in T_{re} observed at rest in 28 and 24°C water. In 20°C water, exercise did not totally counter a decrease in temperature and T_{re} began to fall after 25 minutes; after 1 hr of exercise T_{re} had fallen 0.7°C ($P < .05$) to 36.6°C. $\dot{V}O_2$ during exercise in water at 28 and 24°C was similar to that in air averaging about 1.6 l $\cdot min^{-1}$ (7.7 kcal $\cdot min^{-1}$) during the work period. After 20 minutes of work in 20°C water, however, $\dot{V}O_2$ averaged between 200-300 ml higher ($P < .05$) than in air or in warmer water throughout the immersion period.

For the lean men who averaged 9.2% body fat, the largest thermogenic effect and reduction in T_{re} with cold water immersion were observed. For these men T_{re}

remained at near control values during the first 10 minutes of rest in 20, 24, and 28°C water. Thereafter, T_{re} steadily decreased at all water temperatures with the largest reductions ($P < .01$) noted in 24°C (-1.3°C ; T_{re} 35.9°C) and 20°C (-1.4°C ; T_{re} 35.8°C) water. Resting $\dot{V}O_2$ in 20 and 24°C water was inversely related to water temperature and the fall in T_{re} , increasing rapidly during the first 5 minutes of immersion and rising steadily throughout the immersion period. Resting $\dot{V}O_2$ averaged 654 ml.min⁻¹ after 20 minutes in 20°C water and 1070 ml.min⁻¹ ($3.6 \times \text{rest}$; $P < .01$) at the 1 hr mark. In warmer water, increases in resting $\dot{V}O_2$ were somewhat less dramatic with $\dot{V}O_2$ after 60-min immersion averaging 710 ml.min⁻¹ and 390 ml.min⁻¹ in 24 and 28°C water, respectively. With exercise in air and 28°C water, $\dot{V}O_2$ for the lean men remained steady at about 1.6 l O₂.min⁻¹. In 24 and 20°C water, $\dot{V}O_2$ was about 200 ml and 400 ml higher ($P < .05$), respectively than in air or 28°C water. Whereas exercise of 36W (approximately 500 kcal. hr⁻¹) prevented the drop in T_{re} observed at rest in 24 and 28°C water for men of average body fat, the same work for the lean men was effective in preventing a drop in T_{re} only in 28°C water. With exercise in 20 and 24°C water, T_{re} began to fall after 10 minutes and progressively declined throughout the work period. However, the final T_{re} of 36°C reached during work in 24°C water was significantly higher ($P < .05$) than the final T_{re} of 35.9 observed at rest.

Figure 2 A and B depicts the time course for $\dot{V}O_2$ and T_{re} during 1 hr of rest and exercise at 36W for women classified as average and low body fat, respectively. For women of average body fat (24-27%), T_{re} deviated only slightly from control air values during the first 20 minutes of rest at all water temperatures. Thereafter, T_{re} steadily decreased with the largest reduction of 1.2°C ($P < .01$) noted in 24°C and 20°C water. Resting $\dot{V}O_2$ increased slowly during the immersion period. At the end of 1 hr, $\dot{V}O_2$ averaged 580 ml.min⁻¹ or about 2.0 times ($P < .05$) the resting level. Exercise caused an elevation of 0.4°C in T_{re} during the work period in air

and 24 and 28°C water, and prevented a fall in T_{re} in 20°C water. Exercise $\dot{V}O_2$ remained between 1.5 and 1.7 l $O_2 \cdot min^{-1}$ under all conditions.

For women of low body fat, T_{re} showed a steady decline throughout the immersion period during rest at all water temperatures reaching 35.8°C (-1.6°C; $P < .01$) after 1 hr at 20°C. Resting $\dot{V}O_2$ increased slowly during the immersion period reaching a high of 590 ml $\cdot min^{-1}$ or 2.1 times ($P < .05$) rest after 1 hr at 20°C. Exercise $\dot{V}O_2$ was essentially the same in air and at all water temperatures. During work in air T_{re} steadily increased to about 0.6°C above the pre-exercise resting level. In 28 and 24°C water, exercise prevented the fall in T_{re} observed at rest, while in 20°C water T_{re} fell 0.4°C with exercise compared to a significantly greater ($P < .05$) 1.6°C during the resting experiments.

Discussion

Because heat conduction in water is about 25 times greater than in air, immersion in cold water provides a considerable thermal stress and brings about thermoregulatory adjustments in a relatively short period of time. However, significant individual variability is noted among both men and women, with the amount of heat transferred to the water being primarily related to peripheral vasoconstriction and body composition including subcutaneous fat and its distribution. In addition, heat production associated with shivering and physical activity may contribute to thermoregulation during cold stress (4,7,20). In the present data, the benefits of body fat during cold stress are clear. For men classified as high for body fat little thermal strain was noted, at least as reflected by the small changes in T_{re} and $\dot{V}O_2$ values during 1 hr rest or exercise in air or water at 20, 24, and 28°C. For men of average and low body fat, however, heat loss exceeded heat production during 1 hr immersion at rest at all water temperatures. For these men, a gradual decline in T_{re} was noted after 10-20 minutes with the greatest drop in T_{re} ($T_{re} - 1.4^\circ C$) observed for the group with the lowest total body fat and skinfold thickness. In general, for both men and women at rest, the longer the exposure to cold water and the greater the intensity of the cold

stimulus, the greater the thermogenesis, and this closely paralleled the fall in T_{re} . Similar observations have been noted for men in water from 38°C to 24°C. (6)

While exercise can increase both total body heat conductance and the effective surface for heat loss due to an augmented blood flow to the limbs, in no instance did the present exercise facilitate a drop in T_{re} . Exercise of about 500 kcal.hr⁻¹ was beneficial in either preventing or retarding the fall in T_{re} during the immersion period. This beneficial effect of submaximal work is somewhat in contrast to the observations of Keatinge (14) and Hayward and Keatinge (11). They reported that when water was too cold to allow for the maintenance of deep body temperature at rest (5-24°C water depending on body fat), exercise intensified cooling by increasing conduction in the poorly insulated, highly perfused active peripheral areas (11). This caused T_{re} to fall at an even greater rate than at rest. Apparently, the present subjects were neither too thin nor the water too cold to negate the heat-generating effects of submaximal exercise in maintaining thermal balance. The exercise metabolism in the present study was greater than the 300-360 kcal.hr⁻¹ shown to facilitate heat loss (11,14), and high intensity exercise has been shown to delay a drop in T_{re} in 5-20°C water (5,12,19). Certainly, body fat, exercise intensity, and an individual's ability to maintain high levels of exercise are all important considerations in evaluating the potential benefits of exercise in offsetting hypothermia with cold water immersion.

For both men and women, $\dot{V}O_2$ was elevated at rest and during exercise when T_{re} was reduced below control values in air with the largest increases in $\dot{V}O_2$ generally accompanying the largest T_{re} reductions. This thermogenic effect for the relatively lean subjects during submaximal work in water under hypothermic conditions is in agreement with the observations of Craig and Dvorak (7) with identical arm-leg ergometry and the work of Nadel and colleagues (18) and Holmer and Bergh (12)

during free swimming. Whereas these investigators (12,18) observed increases in $\dot{V}O_2$ of approximately 500 to 700 ml.min⁻¹ during swimming in 18°C water compared to thermoneutral 33°C water, the present lean men showed increases in $\dot{V}O_2$ of between 300-400 ml.min⁻¹ at 36 W exercise in 20°C water compared to work in air. This relatively smaller thermogenic effect during exercise in cold water in the present data could be due to the lower water temperature and greater convective heat loss to the moving water during free swimming in a flume compared to the present stationary arm-leg work. It appears that the increased energy production at rest and during submaximum work in cold water is the result of the metabolic cost of shivering and the thermal insulation of body fat. Impaired mechanical efficiency with thermal stress may also contribute to the added energy cost of work in cold water.

In comparing the thermal responses of men and women at rest and during exercise (Figures 1 and 2), there appears to be a difference in the relationship between body fat and temperature regulation during cold stress and the role of exercise in maintaining thermal balance. Although the lean women possessed about twice the percent body fat and nearly 60% more skinfold fat as their lean male counterparts (Table 1), their relatively large reductions in T_{re} at rest were quite similar to the men at all water temperatures (Fig. 1C vs. Fig. 2B). Stated in somewhat different terms, a woman of 24 percent body fat (average fat) does not maintain T_{re} when exposed to cold stress at rest as effectively as a male of similar percent fat (Fig. 1A vs. Fig. 2B).

Part of the difference in temperature regulation during cold stress at rest between men and women of similar body fat levels may be due to differences in the thermogenic response. Whereas lean men (9.2% fat) were able to increase their oxygen consumption some 3.7 times above rest to 1100 ml O₂.min⁻¹ for a 1.4°C drop in T_{re} , lean women (18.5% fat) showed a significantly lower ($P < .01$) 2.1 fold increase to 590 ml.min⁻¹ for a similar drop in T_{re} . It could be argued that this 86 percent

larger thermogenic response for men for an equivalent drop in T_{re} is due to higher shivering thresholds on the part of males. This is unlikely, however, as Cunningham (9) has shown the opposite to be true in that the thermoregulatory system of women operates at slightly higher core temperatures than men and thus, women consistently begin shivering at a higher T_{re} . Part of the difference in thermic response to cold stress may be due to differences in lean body weight (LBW) and accompanying muscle mass between men and women. As shown in Table 1, the LBW of the men with low fat averaged 64.3 kg whereas the LBW of women of similar fat classification averaged 49.5 kg, a difference of 14.8 kg or 30 percent. When $\dot{V}O_2$ at the end of 60 min rest in 20°C water is expressed in relation to LBW, the $\dot{V}O_2$ of the women averaged 11.9 ml.kg⁻¹ . min⁻¹ while that of the men was still 44 percent higher at 17.1 ml.kg⁻¹.min⁻¹. Consequently, the difference in LBW does not entirely explain the difference in thermogenic response between men and women for an equivalent drop in T_{re} .

Another possible explanation for the relatively greater cooling of women compared to men of similar levels of body fatness lies in the differences in the surface area-to-mass ratio. This geometric component influences heat conductance to the environment -- a low surface area-to-mass ratio favoring heat conservation in a cold environment in both humans and animals (15,19,21,22). Figure 3 illustrates the relationship between percent body fat and surface area-to-mass in young adult men and women. Included in this figure are the data of Kollias and co-workers (15). For a given level of body fatness, females have a larger surface in relation to body mass compared to male counterparts. For example, at 24 percent body fat, the surface area-to-mass of the present women was approximately 2.70 m² compared to 2.22 m² for men of similar body fat. Consequently, under identical conditions of cold exposure and body fatness, women would cool at a faster rate than men. This is borne out in the present comparisons of men classified as high for body fat (27.6%) and women classified as high for body fat (25.2%). For the men, only small decreases

in T_{re} were observed after 60 min of rest in 28, 24, and 20°C water while for women T_{re} fell at all water temperatures during the same exposure period.

While the women fared less well than men during the resting experiments, exercise appeared to benefit the women to a greater extent in either preventing or retarding the fall in T_{re} during cold stress. For both lean and average women, exercise at 36 W generated sufficient heat to balance the heat transferred from the core-to-surface and thus prevented the decrease in T_{re} observed at rest at all water temperatures. This is in contrast to lean men for which exercise was only effective in preventing a fall in T_{re} in 28°C water or for men of average fat for which exercise was effective in 24 and 28°C. This apparent variability between the sexes as to the beneficial effects of exercise in retarding heat debt during cold stress is supported by Haywood and Keatinge (11) who reported that the thermal benefits of exercise are related to an individual's resting response to cold stress. Although these investigators did not compare the responses of their men and women, they did report marked individual variability in thermic responses at rest and during exercise. For those subjects who generated high metabolic heat during cold stress at rest, relatively low water temperatures were tolerated. For these individuals, however, exercise tended to increase peripheral heat loss and was of limited benefit to temperature regulation. Other individuals with comparable body fat showed little metabolic increase during cold stress at rest and could only stabilize deep body temperature in relatively warm water. For these individuals exercise greatly aided temperature regulation during cold stress. In the present study, the females as a group tended to show a blunted thermic response to cold stress at rest. In agreement with the observations of Haywood and Keatinge (11), this group showed the greatest benefits from exercise.

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Table 1. Relevant anthropometric data for male and female subjects grouped by body composition classification.

	Age, yr	Ht, cm	Wt, kg	% Fat	Sum of		LEW, kg	A _D	A _D /H x100
					Skinfolds, mm	Mean Skinfolds, mm			
<u>Men</u>									
Low (N=4) ≤ 12% Fat	24.5 (23-29)	175.0 (162-182)	70.8 (62-78)	9.2 (8-11)	76.1 (52-117)	7.6 (5-12)	64.3 (56-69)	1.86 (1.66-2.0)	2.69 (2.56-2.67)
Average (N=4) 15-18% Fat	23.0 (21-25)	169.9 (164-175)	76.3 (71-82)	16.8 (15-18)	125.8 (112-143)	12.6 (11-14)	63.5 (61-66)	1.89 (1.84-1.94)	2.48 (2.38-2.63)
High (N=2) > 22% Fat	22 (19-25)	190.0 (176-185)	101.7 (98-106)	27.6 (26-29)	221 (220-240)	22.1 (22-24)	73.6 (72-75)	2.22 (2.14-2.30)	2.18 (2.17-2.19)
<u>Women</u>									
Low (N=4) ≤ 22% Fat	22.5 (21-24)	171.0 (165-179)	61.0 (53-73)	18.5 (15-21)	120.8 (84-149)	12.1 (8-14)	49.5 (44-58)	1.73 (1.62-1.94)	2.85 (2.65-3.05)
Average (N=4) 24-27% Fat	23.2 (19-27)	164.7 (158-170)	66.5 (60-82)	25.2 (24-29)	176.6 (147-221)	16.7 (11-22)	49.7 (47-58)	1.73 (1.62-1.94)	2.62 (2.37-2.72)

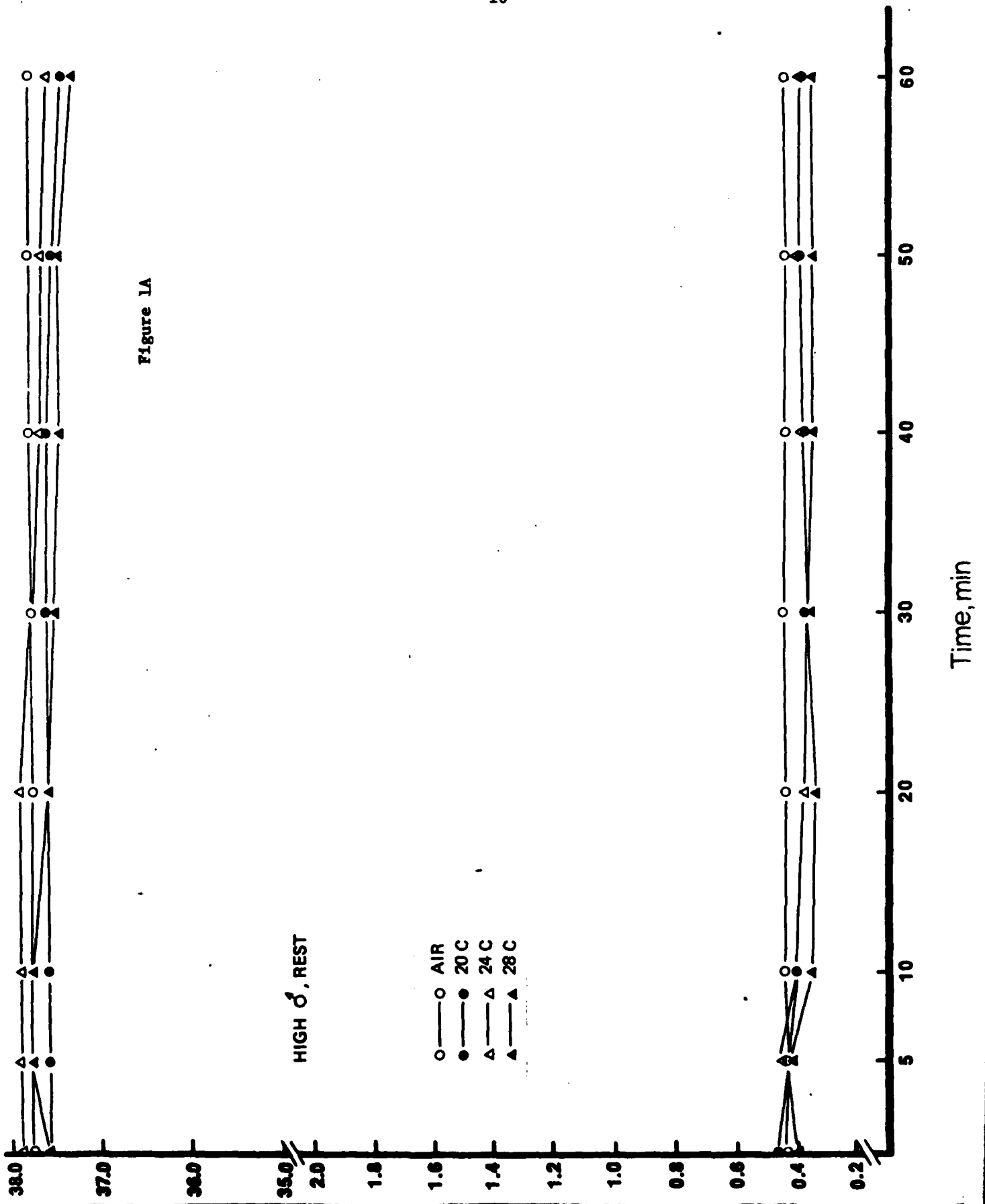
* Values are Means and (Range)

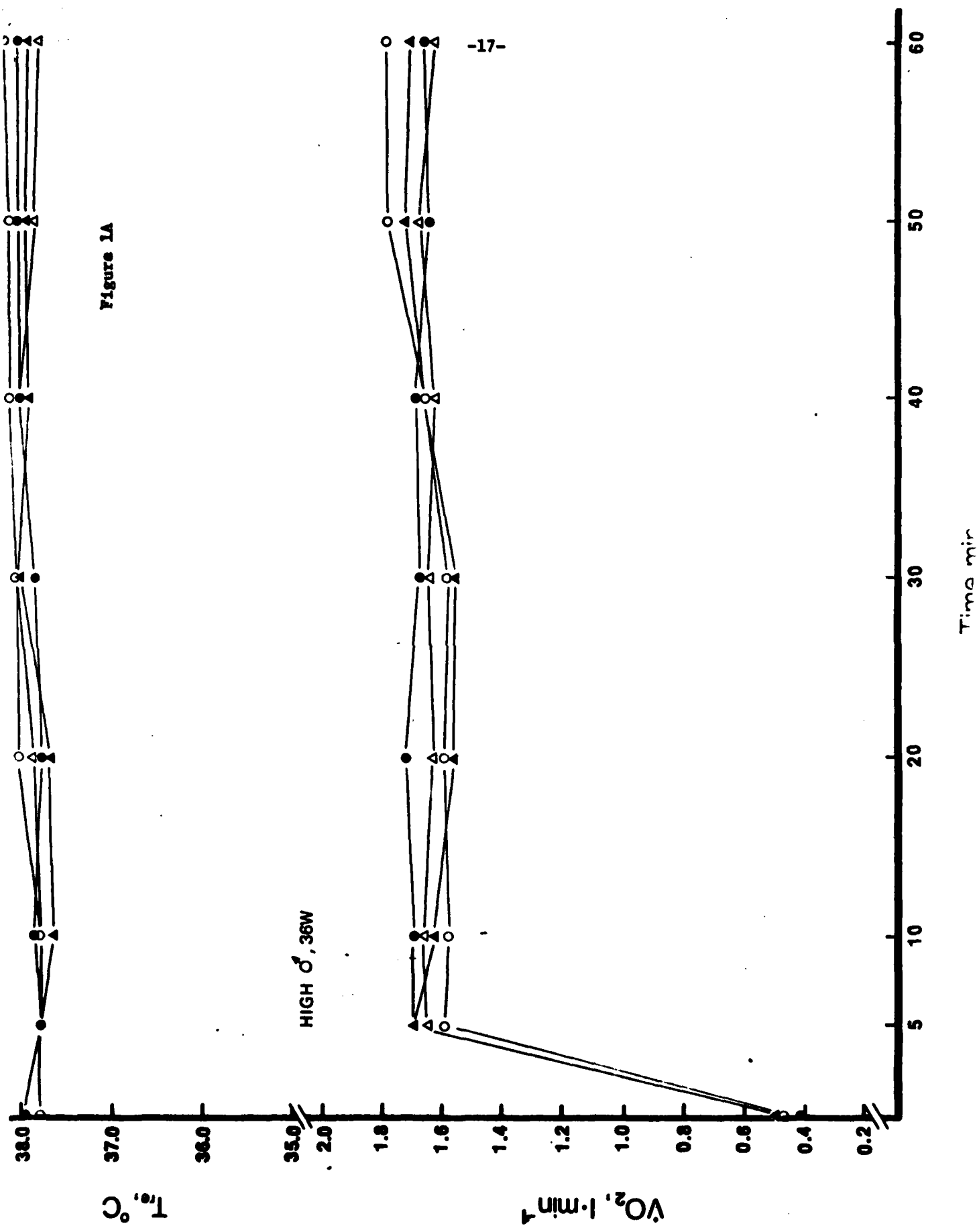
Legends For Figures

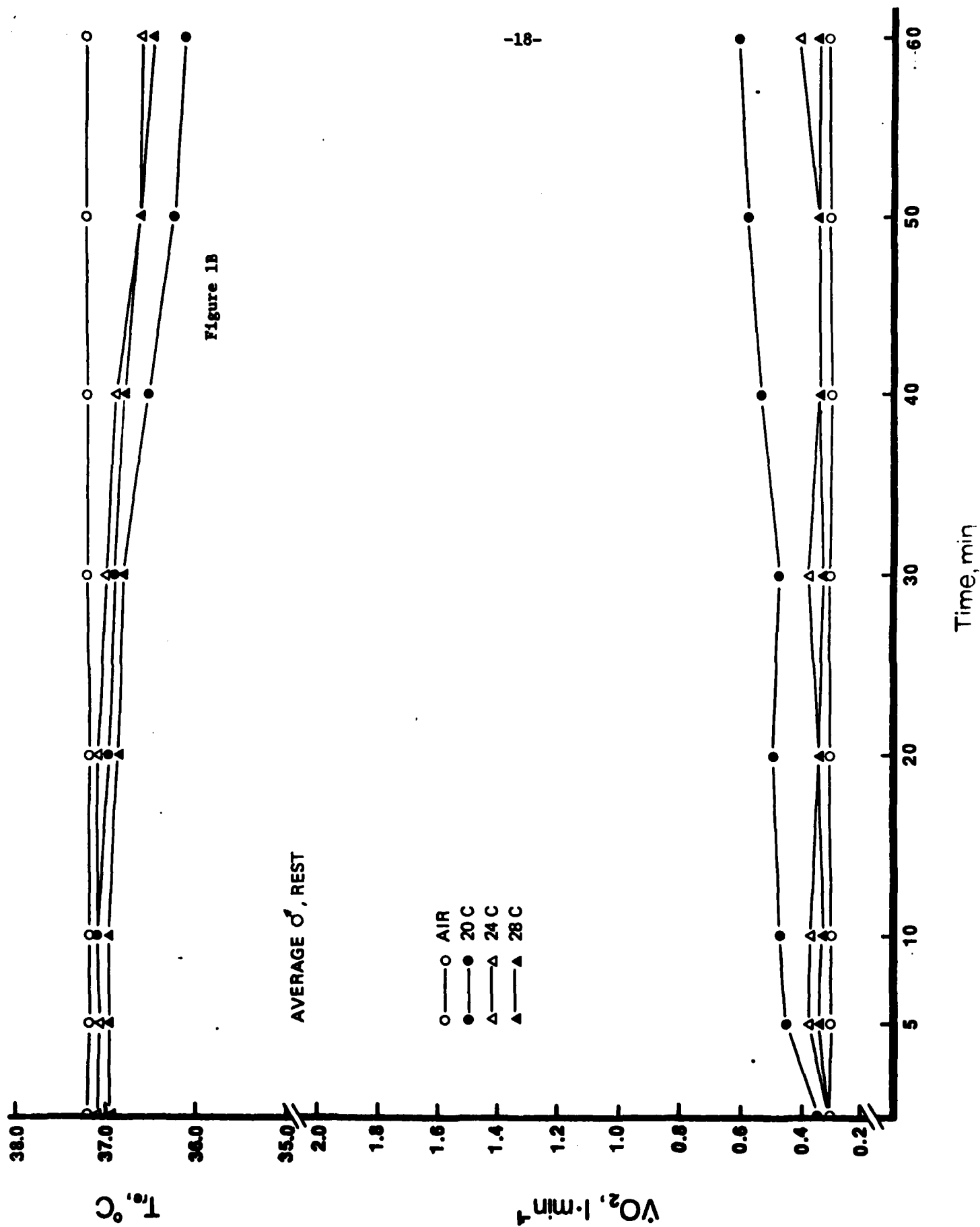
Figure 1 A,B, and C. Oxygen consumption ($\dot{V}O_2$) and rectal temperature (T_{re}) for men of high (A), average (B), and low (C) body fat for 1 hr at rest and during 36 W exercise in air and water at 20, 24, and 28°C.

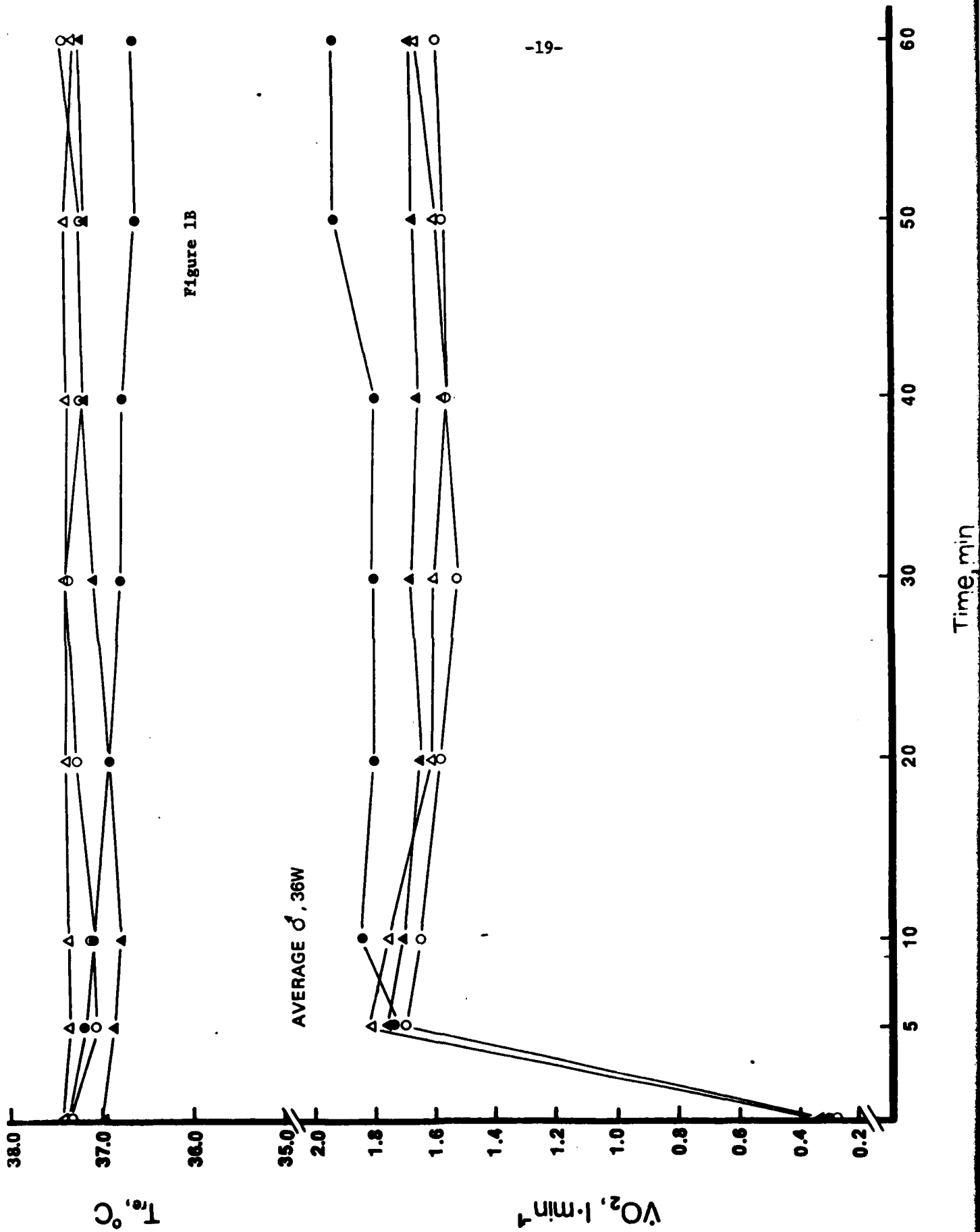
Figure 2 A and B. Oxygen consumption ($\dot{V}O_2$) and rectal temperature (T_{re}) for women of average (A) and low (B) fat for 1 hr at rest and during 36 W. exercise in air and water at 20, 24, and 28°C.

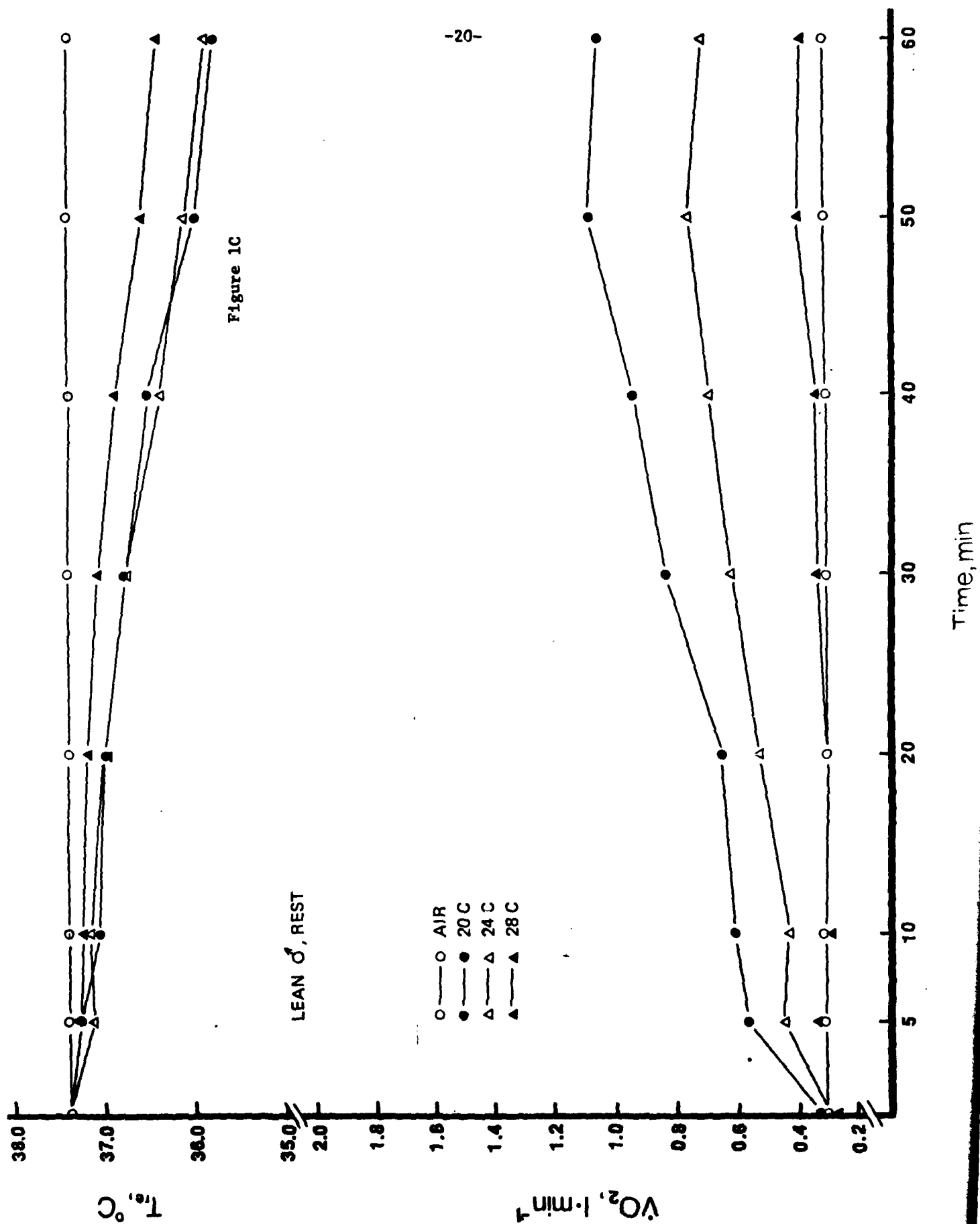
Figure 3. Relationship between percent body fat and surface area-to-mass ratio in men (•) and women (○). Solid line represents the data of Kollias and colleagues (15).



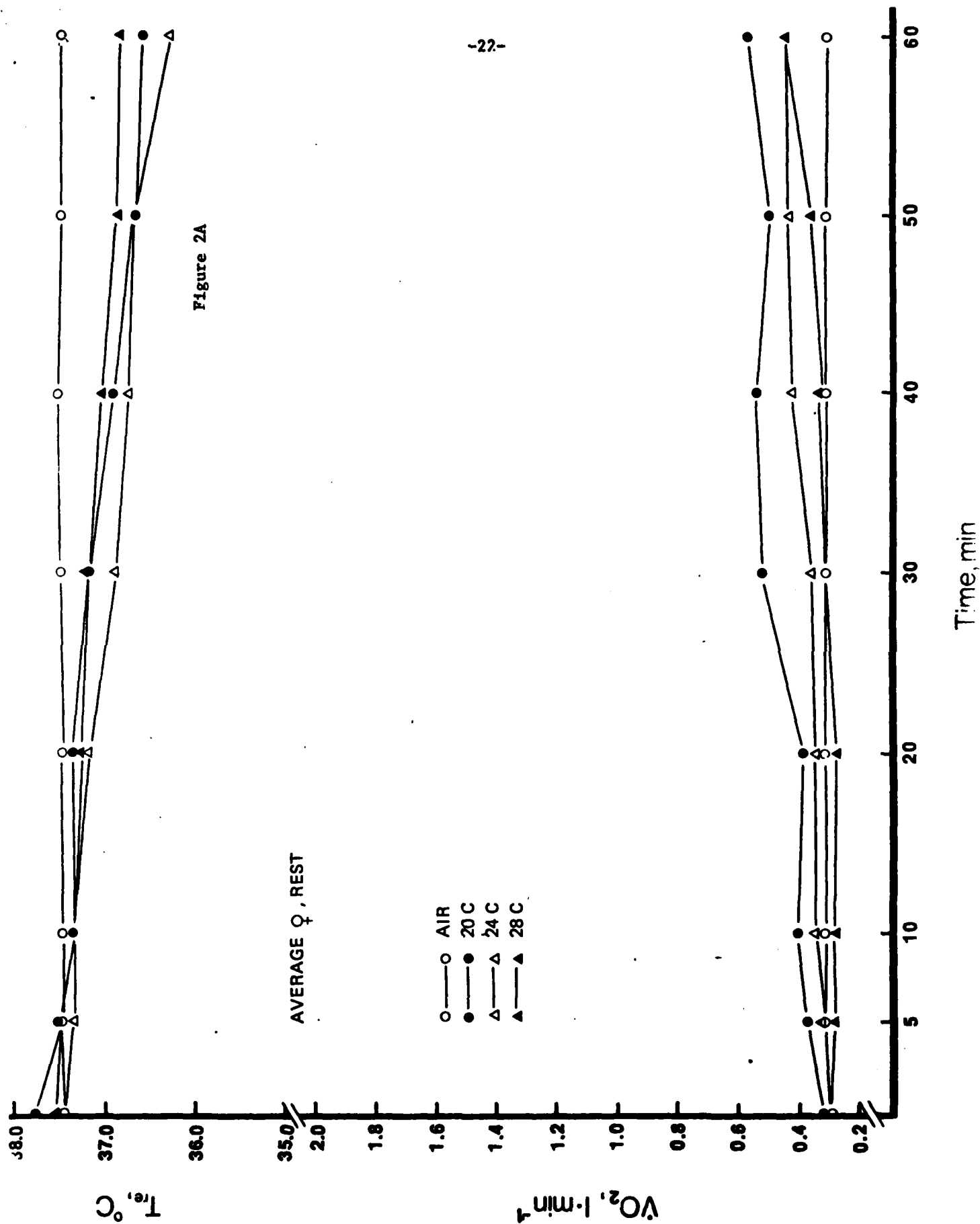


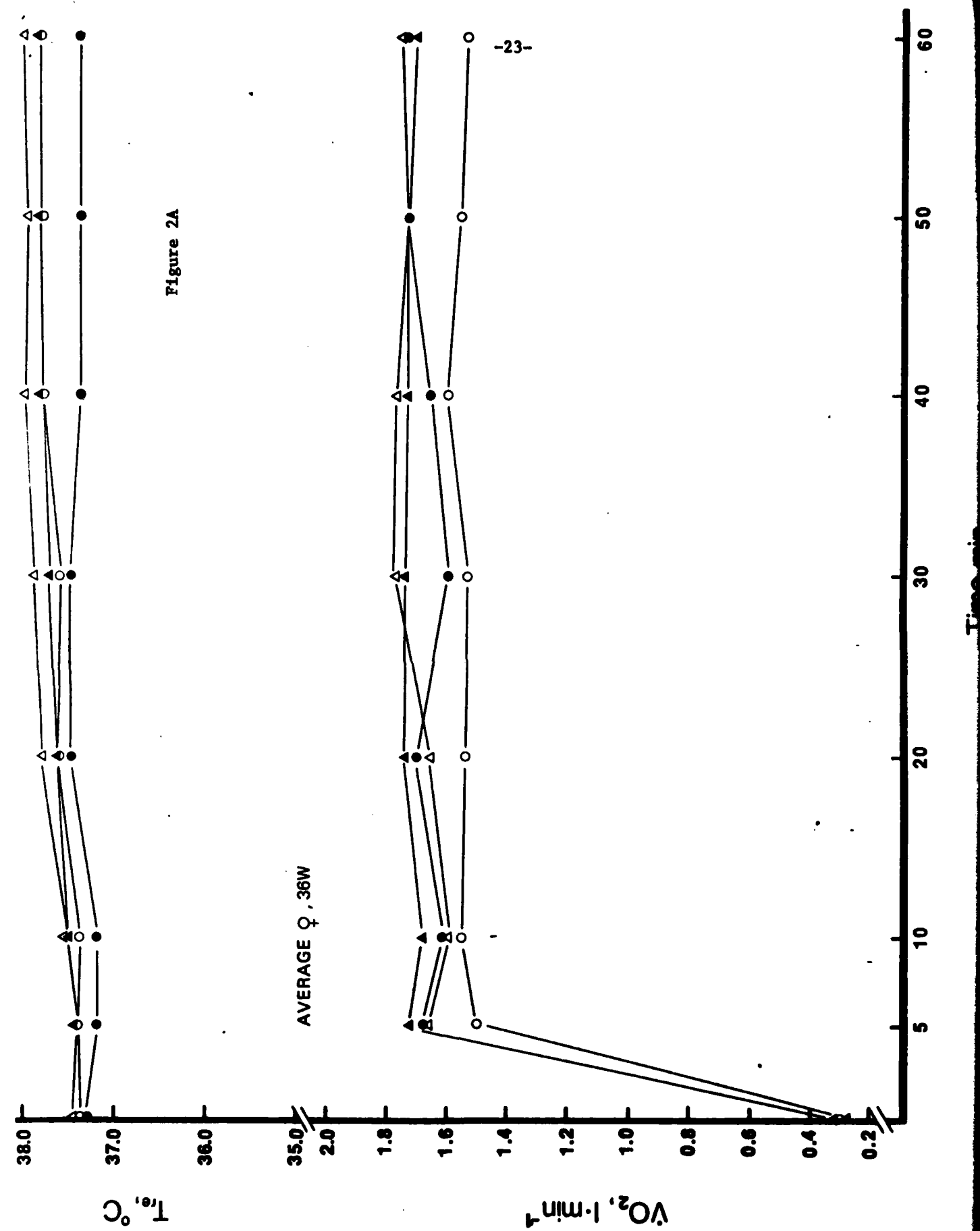


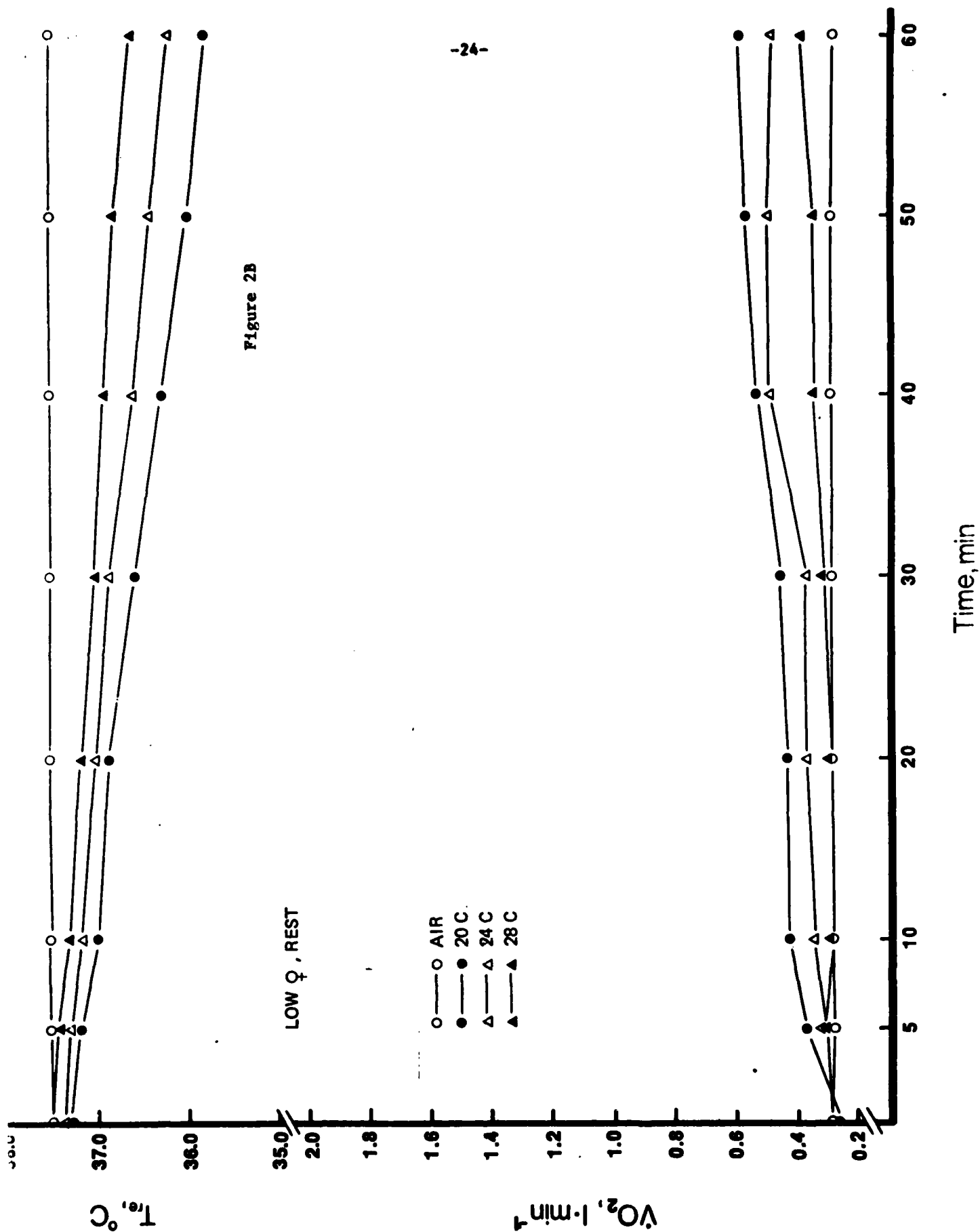












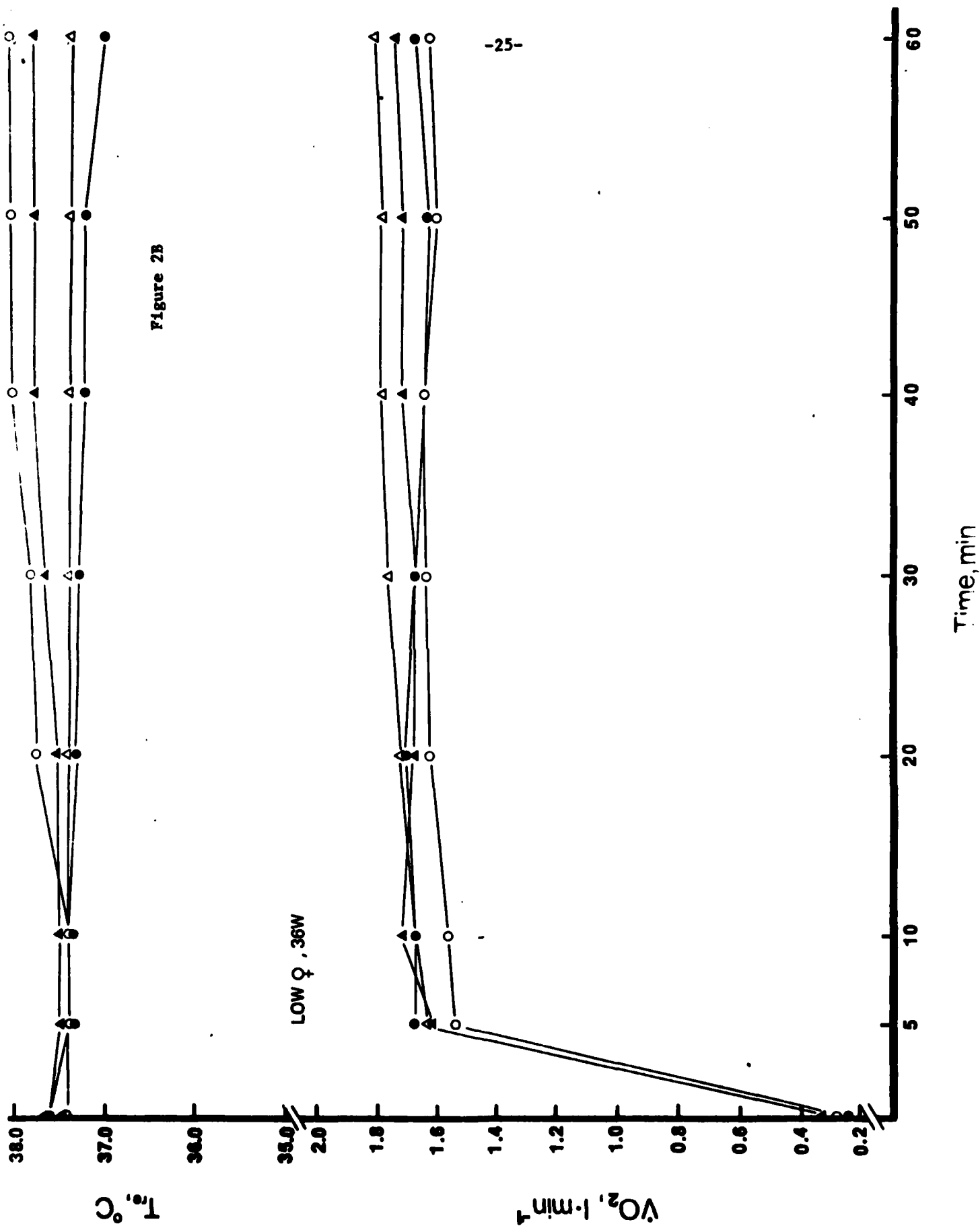
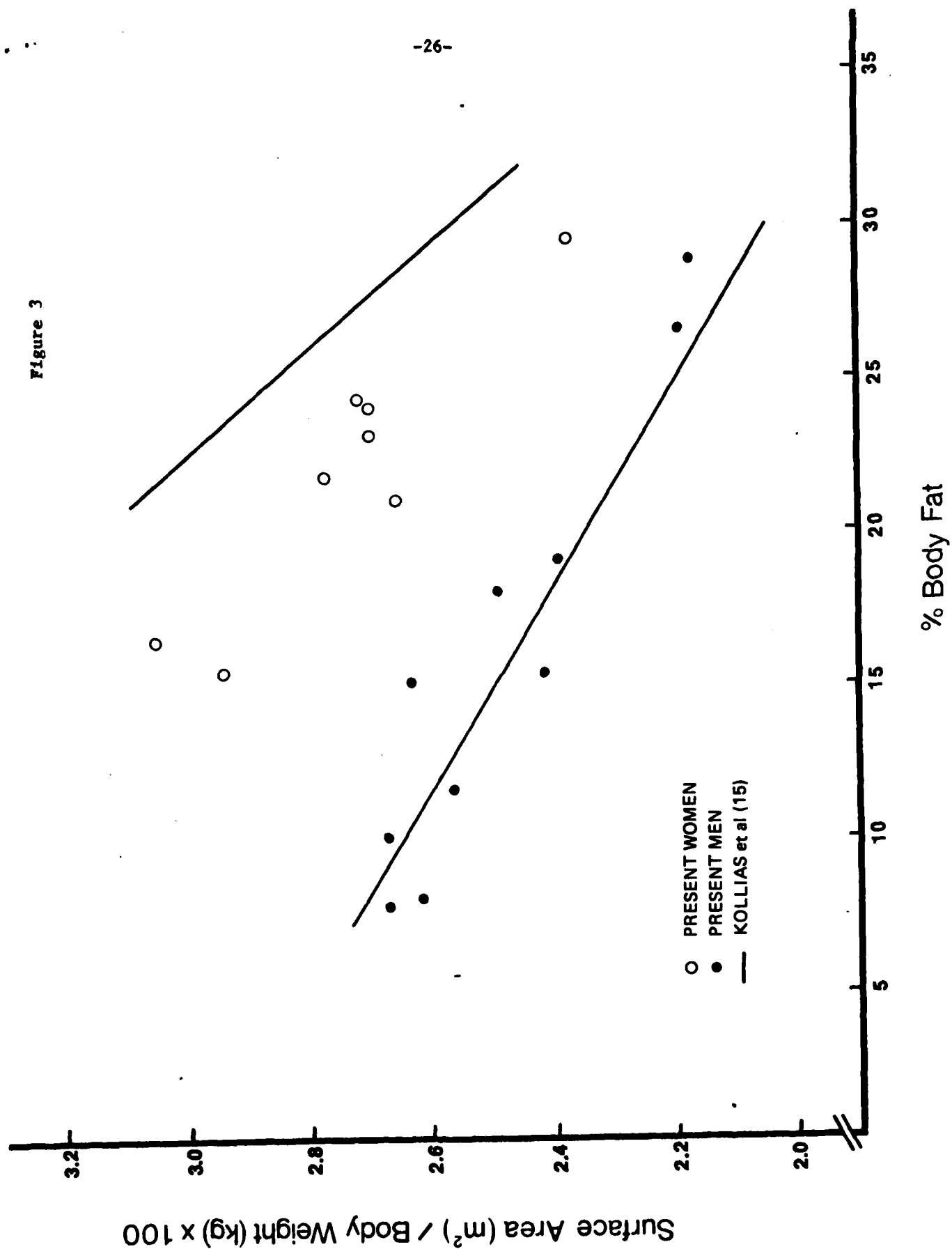


Figure 3



APPENDIX A

Abstract of Paper presented at
the National Meeting of the
American College of Sports Medicine,
Minneapolis, Minn., May 27, 1982

BODY COMPOSITION AND TEMPERATURE REGULATION FOR MEN AND WOMEN DURING REST AND EXERCISE IN AIR AND WATER

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$\dot{V}O_2$ and rectal temperature (T_{re}) were studied in 10 men and 8 women during 1 hr rest and exercise at 36W (8.2 kcal. min^{-1}) in air and water at 20, 24 and 28°C. At rest, in all water conditions, the obese men ($>22\%$ fat) maintained T_{re} at levels similar to control values in air. During work, T_{re} increased about 0.5°C under all conditions with essentially no difference in $\dot{V}O_2$. For average (15-18%) and lean ($<12\%$) men, T_{re} decreased after 20-30 min rest at all water temperatures with the largest drop in T_{re} (1.9°C) and increase in $\dot{V}O_2$ (760 ml) observed for lean men in colder water. Exercise prevented the drop in T_{re} in 24 and 28°C water for average men and 28°C water for lean men. For both groups, $\dot{V}O_2$ was rapidly and significantly elevated when T_r was reduced, with increases in $\dot{V}O_2$ inversely related to the fall in T_{re} . Although the women possessed nearly twice the % fat as their lean and normal male counterparts, their fall in T_{re} at rest was similar to the men at all water temperatures. Viewed somewhat differently, a female of 22% fat does not regulate T_{re} when exposed to cold stress at rest as effectively as a male of similar percent fat. This difference in temperature regulation at rest may be partly explained by differences in thermogenesis between men and women in response to cold stress. For a drop of 1.9°C in T_{re} , men increased their $\dot{V}O_2$ some 3.8 times rest while women showed only a 2.2 fold increase. Exercise, however, prevented a fall in T_{re} at all water temperatures for both lean and average women.

Supported by a grant from Dept. of Army, DAMD17-80-C-0150.

Paper presented at the National Meetings of the American College of Sports Medicine, Minneapolis, Minn., May 27, 1982.

APPENDIX B

Personnel Receiving Support Under

Contract No. DAMD 17-80-C-0150

<u>Name</u>	<u>Degree</u>
Thomas Gergley	M.S. in Exercise Science
Robert J. Spina	M.S. in Exercise Science

SUMMARY DATA SHEET

GROUP Normal Women		WORKLOAD		Rest		20		30		40		50		60	
		Rest	5	10	20	30	40	50	60						
HR		81	67	64	70	66	75	73	77						
$\dot{V}O_2$ l.min ⁻¹		.2978	.2854	.3144	.3374	.3449	.4249	.4332	.4695						
$\dot{V}_e$ l.min ⁻¹ (BTPS)		7.876	7.681	7.909	8.719	8.390	9.532	9.825	10.672						
R		.78	.88	.79	.80	.78	.75	.76	.76						
Rectal Temp, °C		37.5	37.3	37.3	37.2	36.9	36.7	36.6	36.3						
Skin Temp, °C		33.8	25.8	25.6	25.3	25.2	25.1	25.3	25.1						
1		34.2	26.2	25.4	25.2	25.0	25.1	25.0	25.1						
2		33.6	25.4	25.1	25.1	25.1	25.0	25.0	25.0						
3		31.4	25.0	24.8	24.8	24.8	24.8	25.2	24.8						
4		32.4	25.2	24.8	24.7	24.6	24.7	24.6	24.6						
5		32.8	25.3	25.1	25.0	25.0	24.9	25.1	24.9						
Mean Skin Temp °C															

SUMMARY DATA SHEET

GROUP		Fat Men	WORKLOAD		Rest	WATER TEMP. 24°					
			Rest	5	10	20	30	40	50	60	
HR		87		78	78	72	70	67	68	64	
$\dot{V}O_2$ l.min ⁻¹		.5350		.4538	.3776	.3537	.3427	.3814	.3770	.3740	
$\dot{V}_e$ l.min ⁻¹ (BTPS)		11.87		11.86	9.059	9.41	8.526	8.634	8.472	8.85	
R		.84		.9228	.90	.86	.87	.84	.84	.82	
Rectal Temp, °C		38.0		38.0	38.0	38.0	37.9	37.8	37.8	37.7	
Skin Temp, °C		36.0		26.2	25.4	25.2	25.2	25.2	25.0	24.9	
1		34.1		28.2	25.8	25.0	25.0	24.9	24.9	25.0	
2		32.6		25.8	24.9	24.8	24.8	24.8	24.9	24.9	
3		32.8		26.0	25.4	25.2	25.1	24.8	24.8	24.8	
4		33.0		25.6	24.9	24.8	24.9	24.8	24.7	24.8	
5		33.1		25.9	25.2	25.0	25.0	24.8	24.9	24.9	
Mean Skin Temp °C											

SUMMARY DATA SHEET

GROUP Normal Men		WORKLOAD Rest		WATER TEMP. 24°															
	Rest	5	10	20	30	40	50	60											
HR	71	66	65	59	56	57	57	55											
$\dot{V}O_2$ l.min ⁻¹	.287	.384	.365	.337	.366	.317	.330	.407											
$\dot{V}e$ l.min ⁻¹ (BTPS)																			
R																			
Rectal Temp, °C	37.1	37.1	37.1	37.1	37.0	36.9	36.7	36.6											
Skin Temp, °C	33.1	26.1	25.5	25.2	25.0	25.0	24.8	24.8											
1																			
2	33.1	25.6	25.2	25.1	24.9	24.8	24.7	24.7											
3	32.3	25.3	25.0	24.6	24.7	24.6	24.7	24.7											
4	31.7	25.8	25.6	25.2	25.1	25.0	24.9	24.8											
5	32.5	25.5	25.0	24.8	24.8	24.8	24.6	24.6											
Mean Skin Temp °C 1,3,4	32.2	25.7	25.3	24.9	24.9	24.8	24.9	24.9											

SUMMARY DATA SHEET

GROUP		Lean Women		WORKLOAD		Rest		WATER TEMP. 24°C	
		Rest	5	10	20	30	40	50	60
HR		71	82	69	69	67	66	75	71
$\dot{V}O_2$ l.min ⁻¹		.252	.376	.341	.363	.365	.499	.497	.473
$\dot{V}_e$ l.min ⁻¹		6.775	9.543	8.262	8.323	7.752	8.773	10.445	10.102
R		.84	.89	.88	.84	.83	.79	.84	.87
Rectal Temp, °C		37.4	37.3	37.2	37.0	36.9	36.6	36.4	36.2
Skin Temp, °C		32.8	26	25.6	25.4	25.2	25.2	25.0	25.1
1		33.2	26.8	26.2	25.6	25.3	25.2	25.2	25.2
2		32.9	26.4	25.8	25.8	25.5	25.4	25.6	25.7
3		30.8	24.6	24.4	24.3	24.4	24.4	24.6	24.7
4		31.8	24.6	25.3	25.2	25.2	25.1	24.6	25.1
5		32.49	25.696	25.592	25.528	25.35	25.264	25.156	25.4
Mean Skin Temp °C									

SUMMARY DATA SHEET

GROUP		Lean Men		WORKLOAD		Rest		20		30		40		50		60		WATER TEMP.		24	
		Rest	5	10	20	30	40	50	60												
HR		72	65	64	68	69	68	71	66												
$\dot{V}O_2$ l.min ⁻¹		.333	.450	.432	.536	.629	.703	.769	.710												
$\dot{V}_e$ l.min ⁻¹ (BTPS)		8.708	9.732	9.439	11.70	15.46	17.33	17.16	16.03												
R		.89	.86	.86	.85	.86	.84	.83													
Rectal Temp, °C		37.4	37.2	37.2	37.0	36.8	36.4	36.1	35.9												
Skin Temp, °C		33.8	26.3	25.6	25.2	24.9	24.9	24.8	24.8												
1		34.4	27.4	26.4	25.7	25.3	25.2	25.3	25.4												
2		34.4	26.2	25.6	25.4	25.2	25.3	25.3	25.4												
3		32.3	25.3	25.2	25.0	24.9	24.7	24.8	24.6												
4		33.2	25.8	25.4	25.1	24.9	24.9	24.9	24.9												
5		33.8	25.9	25.4	25.2	25.0	28.5	25.0	25.0												
Mean Skin Temp °C																					

SUMMARY DATA SHEET

GROUP NORMAL WOMEN		WORKLOAD			REST			WATER TEMP. 28°C		
		Rest	5	10	20	30	40			
N=4										
HR		82	74	76	76	78	81			
$\dot{V}O_2$ l.min ⁻¹		.2982	.2941	.2973	.2809	.3028	.3134			
$\dot{V}_e$ l.min ⁻¹		7.784	7.971	8.060	7.639	7.752	7.94			
(BTPS)										
R		.83	.87	.86	.86	.85	.83			
Rectal Temp, °C		37.6	37.5	37.4	37.3	37.2	37.0			
Skin Temp, °C		33.8	29.1	28.8	28.6	28.8	28.5			
1										
2		33.5	29.4	28.6	28.4	28.4	28.3			
3		32.6	28.4	28.2	28.2	28.2	28.2			
4		30.8	28.5	28.3	28.2	28.1	28.1			
5		32.2	28.4	28.3	28.3	28.2	28.2			
Mean Skin Temp °C		32.1	28.5	28.3	28.2	28.2	28.2			

N=4

SUMMARY DATA SHEET

GROUP LEAN WOMEN

WORKLOAD REST

WATER TEMP. 28°C

	Rest	5	10	20	30	40	50	60
HR	81	73	72	77	72	76	68	70
$\dot{V}O_2$ l.min ⁻¹	.280	.288	.272	.263	.292	.343	.347	.385
$\dot{V}_e$ l.min ⁻¹ (BTPS)	7.322	7.180	6.567	6.072	6.950	7.585	7.750	8.315
R	.80	.83	.83	.84	.80	.78	.79	.77
Rectal Temp, °C	37.5	37.4	37.3	37.2	37.0	36.9	36.8	36.6
Skin Temp, °C	34.2	29.1	28.8	28.9	28.8	28.7	28.6	28.6
1	34.6	29.3	29.1	28.9	29.0	28.8	28.7	28.6
2	34.1	30.0	29.7	28.9	29.0	28.8	28.7	28.8
3	31.5	28.9	28.7	28.6	28.6	28.5	28.4	28.4
4	32.5	29.1	29.0	28.8	28.8	28.7	28.7	28.7
5	33.1	29.5	29.1	29.1	28.8	28.7	28.6	28.6
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP		LEAN MEN		WORKLOAD		REST		WATER TEMP. 28°C	
	Rest	5	10	20	30	40	50	60	
HR	72	60	58	56	57	54	58	57	
$\dot{V}O_2$ l.min ⁻¹	.290	.310	.287	.312	.345	.330	.400	.384	
$\dot{V}e$ l.min ⁻¹ (BTFS)	7.684	6.621	6.648	6.029	6.624	5.997	7.955	7.344	
R	.85	.89	.88	.86	.84	.81	.77	.78	
Rectal Temp, °C	37.4	37.3	37.3	37.2	37.1	36.9	36.6	36.4	
Skin Temp, °C 1	33.8	29.6	29.3	28.8	28.7	28.6	28.7	28.6	
2	34.5	29.7	29.2	28.9	28.8	28.7	28.6	28.6	
3	34.0	29.2	29.0	28.9	28.7	28.7	28.7	28.7	
4	32.7	29.1	29.0	28.8	28.7	28.6	28.6	28.6	
5	33.2	29.2	29.1	28.8	28.8	28.8	28.7	28.7	
Mean Skin Temp °C	33.5	29.2	29.0	28.8	28.7	28.6	28.7	28.6	

SUMMARY DATA SHEET

GROUP FAT MEN WORKLOAD REST WATER TEMP. 28°C

	Rest	5	10	20	30	40	50	60
HR	78	76	68	66	68	64	68	62
$\dot{V}O_2$ l.min ⁻¹	.3880	.4285	.3186	.2908	.3526	.3436	.3424	.3154
$\dot{V}_c$ l.min ⁻¹ (BTFS)	10.34	11.30	8.676	7.456	8.154	8.315	8.406	7.906
R	.89	.95	.94	.90	.90	.83	.85	.86
Rectal Temp, °C	37.6	37.8	37.8	37.6	37.5	37.4	37.4	37.3
Skin Temp, °C	33.4	29.3	29.0	28.8	28.8	28.7	28.8	28.7
1	32.8	29.8	29.2	28.7	28.8	28.7	28.4	28.5
2	31.5	29.0	28.8	28.8	28.7	28.6	28.6	28.6
3	31.2	28.8	28.8	28.8	29.0	28.7	28.6	28.6
4	32.0	28.5	28.6	28.6	28.6	28.6	28.6	28.6
5	31.6	29.0	28.8	28.8	28.8	28.6	28.6	28.6
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP NORMAL MEN WORKLOAD REST WATER TEMP. 28°C

	Rest	5	10	20	30	40	50	60
HR	71	65	63	64	62	60	75	61
$\dot{V}O_2$ l.min ⁻¹	.313	.340	.333	.329	.324	.335	.333	.343
$\dot{V}_e$ l.min ⁻¹ (HTPS)	7.260	7.840	6.969	7.047	8.400	7.546	7.778	8.507
R	.81	.84	.84	.84	.84	.80	.81	.82
Rectal Temp, °C	37.0	37.0	37.0	36.9	36.8	36.8	36.6	36.5
Skin Temp, °C	32.6	28.8	28.6	28.6	28.4	28.3	28.3	28.2
1	33.0	28.7	28.6	28.4	28.3	28.2	28.2	28.2
2	32.9	28.8	28.9	28.6	28.4	28.4	28.3	28.2
3	31.9	28.6	28.5	28.4	28.3	28.3	28.3	28.2
4	31.6	28.2	28.2	28.1	28.0	28.0	28.0	28.0
5								
Mean Skin Temp °C 1.3.4.	32.5	28.7	28.7	28.5	28.4	28.4	28.4	28.2

SUMMARY DATA SHEET

GROUP	Normal Men	WORKLOAD					WATER TEMP. 20°				
		Rest	5	10	20	30	40	50	60		
HR		71	66	65	69	63	60	62	61		
$\dot{V}O_2$ l.min ⁻¹		359	461	481	497	473	533	578	609		
$\dot{V}_e$ l.min ⁻¹ (BTFS)		8.182	12.38	10.66	12.84	12.02	12.85	13.36	14.65		
R		.84	.92	.85	.86	.83	.81	.82	.86		
Rectal Temp, °C		37.2	37.1	37.1	37.0	36.9	36.5	36.2	36.1		
Skin Temp, °C		34.0	22.6	22.3	21.7	21.5	21.5	21.5	21.5		
1		34.1	22.7	21.9	21.7	21.4	21.3	21.3	21.3		
2		33.5	21.8	21.4	21.3	21.4	21.3	21.3	21.3		
3		32.9	22.0	21.7	21.5	21.5	21.4	21.3	21.3		
4		32.8	22.1	21.6	21.5	21.4	21.3	21.3	21.3		
5		33.4	22.0	21.6	21.3	21.4	21.3	21.3	21.3		
Mean Skin Temp °C	1,3,4,										

SUMMARY DATA SHEET

GROUP		Fat Men		WORKLOAD		Rest		WATER TEMP.		20°C	
		Rest	5	10	20	30	40	50	60		
HR		78	76	74	70	68	66	70	68		
$\dot{V}O_2$ l.min ⁻¹		.4595	.4394	.3884	.3326	.3612	.3525	.3569	.3578		
$\dot{V}e$ l.min ⁻¹		11.66	14.37	9.665	8.920	9.045	8.560	8.765	8.955		
(BTPS)											
R		.86	.93	.88	.86	.88	.84	.85	.84		
Rectal Temp, °C		37.6	37.6	37.6	37.6	37.6	37.6	37.5	37.4		
Skin Temp, °C		33.6	22.3	21.4	21.4	21.2	21.2	21.1	21.2		
1											
2		33.3	22.4	22.2	21.5	21.4	21.4	21.4	21.4		
3		32.1	21.6	21.2	21.0	21.2	21.1	21.1	21.0		
4		32.0	22.2	21.8	21.4	21.4	21.3	21.3	21.2		
5		32.1	21.6	21.2	20.8	20.8	20.8	20.8	20.8		
Mean Skin Temp °C		32.3	21.9	21.4	21.2	21.3	21.2	21.2	21.1		

SUMMARY DATA SHEET

GROUP	Normal Women	WORKLOAD	Rest	20	30	40	50	60
HR	Rest	5	10	20	30	40	50	60
	82	78	72	76	74	76	71	75
$\dot{V}O_2$ l.min ⁻¹	.3351	.3748	.3939	.3841	.5198	.5383	.48.8	.5834
$\dot{V}e$ l.min ⁻¹ (BTFS)	9.659	10.16	10.02	10.02	12.20	12.80	11.46	13.06
R	.88	.92	.89	.89	.83	.81	.82	.79
Rectal Temp, °C	37.8	37.5	37.4	37.4	37.2	36.9	36.8	36.6
Skin Temp, °C	.34	24.5	22.5	22.2	22.1	22.0	22.0	21.9
1	33.6	25.0	24.1	23.2	22.4	22.3	22.1	22.4
2	33.4	24.4	22.8	22.2	22.0	22.2	22.1	22.0
3	30.8	23.2	22.6	21.6	21.5	21.5	21.5	21.6
4	33.0	22.9	22.3	21.9	21.8	21.7	21.8	21.7
5	33.34	23.874	22.592	22.092	10.942	21.992	21.978	10.878
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP Lean Women WORKLOAD Rest WATER TEMP. 20

	Rest	5	10	20	30	40	50	60
HR	89	79	87	88	82	87	86	88
$\dot{V}O_2$ l.min ⁻¹	.264	.372	.427	.424	.444	.527	.566	.588
$\dot{V}_e$ l.min ⁻¹ (BTPS)	6.909	9.208	9.395	11.165	11.304	13.177	14.483	15.119
R	.793	.844	.790	.865	.890	.84	.86	.86
Rectal Temp, °C	37.3	37.2	37	36.9	36.6	36.3	36	35.8
Skin Temp, °C	35.6	23.7	22.5	22.5	21.9	21.9	21.7	21.7
1	33.9	23.9	22.4	22.2	21.8	21.6	21.6	21.5
2	33.6	24.5	23.2	23.1	23.0	23.0	22.9	22.9
3	31.4	22.2	21.8	21.8	21.4	21.3	21.4	21.4
4	32.2	23.2	22.3	22.3	21.9	21.9	21.9	22.2
5	33.1	23.6	22.6	22.5	22.3	22.2	22.2	21.9
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP		Lean Men		WORKLOAD		Rest		WATER TEMP. 20°C	
		Rest	5	10	20	30	40		
HR		72	69	74	78	79	74		
$\dot{V}O_2$ l.min ⁻¹		.322	.570	.622	.654	.849	.953		
$\dot{V}_e$ l.min ⁻¹ (BTPS)		8.214	11.960	13.36	15.35	17.30	20.92		
R		.81	.83	.83	.87	.81	.82		
Rectal Temp, °C		37.4	37.3	37.1	37.0	36.8	36.5		
Skin Temp, °C		33.8	24.1	22.8	21.8	21.5	21.6		
1									
2		34.0	24.0	22.4	21.7	21.5	21.3		
3		33.2	23.0	22.4	22.1	22.0	22.1		
4		32.4	23.1	22.1	22.6	21.3	21.1		
5		32.8	23.0	22.1	21.8	21.2	21.3		
Mean Skin Temp °C		33.0	23.2	22.4	21.9	21.7	21.7		

SUMMARY SHEET

SUMMARY DATA SHEET

GROUP	LEAN WOMEN	WORKLOAD	OWATTS	WATER TEMP. 28.0					
	Rest	5	10	20	30	40	50	60	
HR	82	82	100	96	96	98	94	92	
$\dot{V}O_2$ l.min ⁻¹	.2672	.7040	.6608	.6765	.6912	.6920	.7316	.6645	
$\dot{V}_e$ l.min ⁻¹ (BTPS)	6.623	15.00	14.40	14.43	14.51	14.30	15.20	14.07	
R	.79	.82	.84	.81	.80	.78	.78	.79	
Rectal Temp, °C	37.6	37.5	37.4	37.4	37.3	37.2	37.0	36.9	
Skin Temp, °C 1	35.9	37.5	37.5	37.4	37.3	37.2	37.3	36.9	
2	33.9	29.2	28.8	28.4	28.4	28.4	28.4	28.4	
3	34.5	28.5	28.4	28.4	28.4	28.4	28.4	28.3	
4	31.6	28.4	28.3	28.3	28.2	28.3	28.3	28.2	
5	32.6	28.7	28.6	28.5	28.5	28.5	28.4	28.4	
Mean Skin Temp °C	33.6	29.7	29.6	29.6	29.6	29.6	29.6	29.5	

SUMMARY SHEET

SUMMARY DATA SHEET

GROUP LEAN MEN		WORKLOAD		OW		WATER TEMP. 28°C				
	Rest	5	10	20	30	40	50	60		
HR	67	73	75	73	74	72	74	74		74
$\dot{V}O_2$ l.min ⁻¹	.3072	.6454	.6560	.6410	.6428	.6879	.7040	.7337		
$\dot{V}e$ l.min ⁻¹ (BTFS)	8.263	13.63	14.88	14.55	14.28	14.69	14.64	15.78		
R	.87	.84	.84	.88	.83	.83	.81	.80		
Rectal Temp, °C	37.2	37.2	37.2	37.0	36.8	36.5	37.4	36.2		
Skin Temp, °C	34.	29.0	28.9	28.7	28.6	28.6	28.6	28.6		
1	34.2	28.6	28.5	28.5	28.4	28.4	28.4	28.4		
2	33.4	28.6	28.5	28.4	28.4	28.4	28.4	28.4		
3	33.0	28.6	28.5	28.4	28.4	28.4	28.4	28.4		
4	32.6	28.6	28.5	28.6	28.4	28.4	28.4	28.3		
5	33.3	28.6	28.6	28.4	28.4	28.4	28.4	28.4		
Mean Skin Temp °C										

SUMMARY SHEET

SUMMARY DATA SHEET

GROUP FAT MEN		WORKLOAD 0			WATER TEMP. 28°C		
	Rest	5	10	20	30	40	
HR	83	88	88	91	88	88	
$\dot{V}O_2$ l.min ⁻¹	.2653	.8267	.8260	.7855	.7623	.7978	
$\dot{V}_E$ l.min ⁻¹ (BTPS)	6.41	19.20	19.47	19.11	19.07	19.25	
R	.77	.83	.82	.84	.85	.81	
Rectal Temp, °C	37.4	37.4	37.4	37.4	37.4	37.4	
Skin Temp, °C	33.5	29.0	29.1	29.0	28.5	28.4	
1							
2	34.1	29.2	29.1	29.0	28.5	28.5	
3	32.5	29.0	29.2	29.0	28.5	28.5	
4	33.1	29.2	29.3	29.0	28.5	28.5	
5	33.6	29.2	29.0	29.0	28.4	28.4	
Mean Skin Temp °C	32.8	29.1	29.2	29.0	28.5	28.5	

SUMMARY SHEET

SUMMARY DATA SHEET

GROUP		NORMAL MEN		WORKLOAD		OW		WATER TEMP. 28°C	
		Rest	5	10	20	30	40	50	60
HR		78	83	80	78	79	77	77	76
$\dot{V}O_2$ l.min ⁻¹		.2912	.6928	.7001	.7273	.7135	.7895	.7619	.7948
$\dot{V}_e$ l.min ⁻¹ (BTFS)		7.676	14.37	14.51	16.29	14.92	16.54	15.65	17.15
R		.87	.85	.86	.85	.82	.83	.81	.83
Rectal Temp, °C		37.2	37.2	37.1	37.0	36.8	36.7	36.6	36.6
Skin Temp, °C		33.9	28.6	28.5	28.4	28.3	28.3	28.3	28.3
1									
2		33.8	28.9	28.5	28.3	28.3	28.2	28.2	28.2
3		32.9	28.4	28.4	28.2	28.1	28.0	28.1	28.0
4		32.4	28.6	28.5	28.4	28.3	28.3	28.3	28.3
5		33.1	28.7	28.4	28.4	28.3	28.3	28.3	28.2
Mean Skin Temp °C		32.8	28.5	28.5	28.3	28.2	28.2	28.2	28.2

SUMMARY SHEET

SUMMARY DATA SHEET

GROUP NORMAL WOMEN		WORKLOAD		OWATTS		WATER TEMP. 28°C			
	Rest	5	10	20	30	40	50	60	N=3
HR	85	96	101	98	96	98	95	93	
$\dot{V}O_2$ l.min ⁻¹	.3150	.6728	.6864	.6354	.6323	.6613	.6229	.640	
$\dot{V}_e$ l.min ⁻¹ (BTPS)	7.353	15.66	16.27	15.14	14.81	15.13	14.37	14.11	
R	.83	.84	.84	.87	.85	.83	.82	.79	
Rectal Temp, °C	37.6	37.5	37.5	37.4	37.4	37.4	37.4	37.2	
Skin Temp, °C	33.5	29.1	29.0	29.0	28.7	28.7	28.7	28.4	
1									
2	33.5	29.2	28.8	28.6	28.4	28.2	28.3	28.2	
3	33.5	28.9	28.8	28.7	28.5	28.4	28.3	28.3	
4	32.9	28.8	28.8	28.6	28.2	28.4	28.4	28.2	
5	31.6	28.6	28.7	28.6	28.4	28.3	28.3	28.3	
Mean Skin Temp °C	33.3	28.9	28.8	28.7	28.4	28.4	28.4	28.3	

SUMMARY DATA SHEET

GROUP Fat Men		WORKLOAD		0		20		30		40		50		60	
		Rest		5		10		20		30		40		50	
HR		73		88		88		81		83		83		83	
$\dot{V}O_2$ l.min ⁻¹		.2816		.8062		.7392		.6917		.7000		.6910		.6736	
$\dot{V}e$ l.min ⁻¹		7.24		17.57		17.57		17.12		16.98		16.49		17.07	
R		.84		.83		.89		.90		.88		.86		.84	
Rectal Temp, °C		37.4		37.4		37.4		37.4		37.3		37.3		37.2	
Skin Temp, °C		34.0		25.1		25.0		24.9		24.9		24.9		24.9	
1		33.2		25.5		25.0		25.0		24.9		24.9		24.9	
2		31.6		24.5		24.3		24.5		24.5		24.6		24.5	
3		32.0		25.5		24.7		24.5		24.5		24.6		24.5	
4		32.6		24.5		24.5		24.5		24.5		24.6		24.5	
5		32.1		25.0		24.6		24.6		24.6		24.6		24.6	
Mean Skin Temp °C	1,3,4,	32.1		25.0		24.6		24.6		24.6		24.6		24.6	

SUMMARY DATA SHEET

GROUP Normal Men WORKLOAD ON WATER TEMP. 24°

	Rest	5	10	20	30	40	50	60
HR	78	82	82	81	81	83	79	79
$\dot{V}O_2$ l.min ⁻¹	.294	.838	.906	.810	.914	.902	.941	.959
$\dot{V}_E$ l.min ⁻¹ (BTPS)	7.562	18.64	19.98	15.02	18.35	17.95	20.53	18.87
R	.85	.84	.86	.83	.81	.80	.86	.80
Rectal Temp, °C	37.3	37.2	37.1	37.0	36.8	36.6	36.5	36.2
Skin Temp, °C								
1	33.1	25.3	25.1	25.0	24.9	24.9	24.9	24.9
2	33.4	24.9	24.9	24.6	24.5	24.4	24.4	24.4
3	32.4	25.0	24.5	24.4	24.2	24.2	24.2	24.2
4	31.9	24.7	24.5	24.4	24.4	24.4	24.4	24.3
5	31.7	25.1	24.9	24.7	24.6	24.6	24.6	24.6
Mean Skin Temp °C 1,3,4.	32.3	24.9	24.6	24.5	24.4	24.4	24.4	24.3

SUMMARY DATA SHEET

GROUP Lean Women WORKLOAD OW WATER TEMP. 24°

	Rest	5	10	20	30	40	50	60
HR	87	102	106	97	100	99	100	98
$\dot{V}O_2$ l.min ⁻¹	.284	.810	.806	.752	.798	.798	.898	.934
$\dot{V}_e$ l.min ⁻¹ (BTPS)	7.735	16.014	17.093	15.910	16.386	16.206	19.158	19.355
R	.82	.84	.88	.87	.84	.84	.85	.82
Rectal Temp, °C	37.6	37.4	37.2	37.2	37.0	36.8	36.5	36.4
Skin Temp, °C								
1	34.0	25.5	25.2	25.1	25.0	25.0	25.1	25.0
2	34.4	26.0	25.6	25.2	25.2	25.0	25.0	25.0
3	34.3	26.0	25.2	25.1	25.0	25.1	25.0	25.0
4	31.8	25.2	25.1	25.0	24.9	24.9	24.8	24.8
5	32.2	25.4	25.2	25.0	25.0	25.0	24.8	24.8
Mean Skin Temp °C	33.4	25.6	25.2	25.1	25.0	25.1	24.9	24.9

SUMMARY DATA SHEET

GROUP Normal Women		WORKLOAD		OWATTS		WATER TEMP. 24°C			
	Rest	5	10	20	30	40	50	60	
HR	84	102	99	101	96	98	96	94	
$\dot{V}O_2$ l.min ⁻¹	.2511	.8896	.7588	.7444	.7444	.7559	.7435	.7518	
$\dot{V}_E$ l.min ⁻¹ (BTPS)	7.001	19.54	17.81	17.24	17.12	17.08	15.89	16.98	
R	.86	.84	.87	.86	.86	.83	.82	.81	
Rectal Temp, °C	37.4	37.3	37.3	37.2	37.1	36.9	36.8	36.8	
Skin Temp, °C	33.0	25.3	25.1	25.0	25.0	25.0	25.0	24.9	
1	33.6	25.4	24.9	24.9	24.8	24.8	24.7	24.5	
2	32.6	24.9	24.6	24.6	24.6	24.6	24.6	24.5	
3	30.2	25.0	24.7	24.7	24.6	24.6	24.6	24.6	
4	31.2	24.8	24.6	24.7	24.6	24.6	24.6	24.4	
5	31.8	25.0	24.7	24.7	24.6	24.6	24.6	24.6	
Mean Skin Temp °C									

SUMMARY DATA SHEET

GROUP Lean Men WORKLOAD 0 WATER TEMP. 24°

	Rest	5	10	20	30	40	50	60
HR	63	76	76	78	79	80	78	79
$\dot{V}O_2$ 1.min ⁻¹	.3047	.8441	.8849	.9115	.9937	1.114	1.122	1.246
$\dot{V}_e$ 1.min ⁻¹ (BTGS)	7.753	18.73	18.72	20.18	22.75	24.73	28.27	28.00
R	.81	.86	.82	.87	.88	.84	.93	.88
Rectal Temp, °C	37.3	37.2	37.2	36.9	36.7	36.4	36.	35.7
Skin Temp, °C								
1	33.3	25.5	25.4	25.3	25.2	25.1	25.0	25.
2	34.2	25.6	25.2	25.1	25.0	24.9	24.9	24.8
3	33.5	25.2	25.1	24.9	24.8	24.8	24.8	24.8
4	32.6	25.1	25.0	25.0	25.0	24.9	24.9	24.9
5	32.3	25.2	25.0	25.0	25.0	25.0	25.0	25.0
Mean Skin Temp °C	33.2	25.2	25.2	24.9	24.9	24.9	24.9	24.9

SUMMARY DATA SHEET

GROUP NORMAL WOMEN		WORKLOAD		OW		WATER TEMP. 20°C					
		Rest	5	10	20	30	40	50	60		
N=4											
HR		94	103	100	102	99	100	102	102		
$\dot{V}O_2$ l.min ⁻¹		.2774	.7367	.7268	.7446	.7606	.8392	.9125	.9890		
$\dot{V}e$ l.min ⁻¹ (BTFS)		7.292	15.88	16.30	16.61	16.46	18.08	18.86	19.79		
R		.80	.78	.83	.82	.81	.80	.80	.81		
Rectal Temp, °C		37.4	37.4	37.3	37.2	37.2	36.7	36.4	36.5		
Skin Temp, °C		34.4	23.3	22.7	22.0	21.8	22.0	22.0	21.9		
1											
2		34.2	25.5	23.0	22.5	22.2	22.0	21.6	21.6		
3		34.3	22.8	21.8	21.4	21.4	21.5	21.5	21.5		
4		32.2	21.7	21.3	21.1	21.0	21.1	21.2	21.1		
5		33.4	22.0	21.5	21.3	21.2	20.2	21.4	21.2		
Mean Skin Temp °C		33.6	22.5	24.9	21.4	21.3	21.5	21.5	21.4		

SUMMARY DATA SHEET

GROUP Lean Women WORKLOAD OW WATER TEMP. 20°C

N=3

	Rest	5	10	20	30	40	50	60
HR	79	95	102	104	95	94	95	100
$\dot{V}O_2$ l.min ⁻¹	.2624	.7560	.8124	.9869	.9775	1.027	1.058	1.074
$\dot{V}e$ l.min ⁻¹ (BTPS)	7.156	15.73	17.36	22.28	21.02	25.73	25.46	25.37
R	.8281	.7896	.8460	.8640	.8472	.8721	.8531	.8261
Rectal Temp, °C	37.6	37.6	37.6	37.3	36.9	36.4	36.1	36.3
Skin Temp, °C	34.4	22.5	21.8	21.4	21.4	21.4	21.5	21.5
1	34.5	23.8	21.6	21.2	21.1	21.0	21.5	21.0
2	34.3	21.6	21.2	20.9	21.0	21.0	21.0	21.0
3	31.8	21.3	20.9	20.9	20.8	20.6	20.6	20.6
4	32.7	21.4	21.0	20.9	20.8	20.9	20.9	20.9
5	33.4	21.6	21.2	20.9	21.0	20.9	20.9	20.9
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP LEAN MEN WORKLOAD ON WATER TEMP. 20°C

	Rest	5	10	20	30	40	50	60
HR	74	79	86	88	86	85	88	90
$\dot{V}O_2$ l.min ⁻¹	.2754	.9464	.8632	1.170	1.285	1.201	1.426	1.382
$\dot{V}_E$ l.min ⁻¹ (BTFS)	7.360	18.78	20.00	27.15	29.83	26.91	30.60	31.48
R	.82	.82	.91	.90	.89	.84	.91	.94
Rectal Temp, °C	37.5	37.3	37.2	36.8	36.2	35.7	35.9	35.6
Skin Temp, °C	34.0	22.1	21.7	21.6	21.5	21.5	21.4	21.4
1	34.6	22.5	21.9	21.6	21.6	21.6	21.4	21.4
2	33.7	21.5	21.3	21.3	21.2	21.3	21.3	21.3
3	33.1	21.4	21.1	20.8	21.2	21.2	21.2	21.2
4	33.1	22.3	21.9	21.6	21.7	21.7	21.8	21.8
Mean Skin Temp °C	33.5	21.6	21.2	21.1	21.2	21.2	21.2	21.2

N=2 N=2

SUMMARY DATA SHEET

GROUP FAT MEN WORKLOAD 0 WATER TEMP. 20°C

	Rest	5	10	20	30	40	50	60
HR	83	94	100	88	88	88	75	75
$\dot{V}O_2$ l.min ⁻¹	.3826	1.0711	.8841	.8086	.7747	.74668	.7352	.7462
$\dot{V}_E$ l.min ⁻¹ (BTPS)	8.86	22.23	20.59	19.91	18.54	17.90	16.44	17.30
R	.80	.83	.92	.91	.86	.87	.82	.82
Rectal Temp, °C	37.5	37.5	37.5	37.7	37.6	37.5	37.5	37.4
Skin Temp, °C	32.9	21.6	21.3	21.2	21.4	21.2	21.3	21.3
1	32.2	22.7	21.6	21.3	21.4	21.4	21.4	21.4
2	31.2	23.4	21.9	21.6	21.4	21.4	21.4	21.5
3	32.1	21.6	21.5	21.5	21.5	21.5	21.5	21.4
4	32.3	22	21.6	21.5	21.5	21.4	21.5	21.4
5	31.8	22.5	21.7	21.5	21.4	21.4	21.4	21.5
Mean Skin Temp °C	31.8	22.5	21.7	21.5	21.4	21.4	21.4	21.5

SUMMARY DATA SHEET

GROUP NORMAL MEN WORKLOAD OW WATER TEMP. 20°C

	Rest	5	10	20	30	40	50	60
HR	70	87	86	89	75	77	80	81
$\dot{V}O_2$ l.min ⁻¹	330	788	939	1025	972	987	1063	1165
$\dot{V}_E$ l.min ⁻¹ (BTPS)	8.328	19.06	22.61	25.33	23.16	23.39	25.78	25.69
R	.85	.84	.85	.86	.86	.86	.86	.84
Rectal Temp, °C	37.2	37.1	37.0	36.9	36.7	36.5	36.3	36.1
Skin Temp, °C	34.0	32.0	21.4	21.3	21.1	21.1	21.3	21.1
1								
2	34.2	22.6	21.6	21.3	21.1	21.1	21.0	21.0
3	32.6	21.0	20.6	20.8	20.8	20.9	20.9	20.9
4	33.1	21.3	20.9	20.8	20.7	20.7	20.7	20.7
5	33.2	21.7	21.3	21.0	21.0	21.1	21.1	21.2
Mean Skin Temp °C 1.3.4.	33.0	21.2	20.8	20.9	20.8	20.8	20.8	20.8

SUMMARY DATA SHEET

GROUP Normal Men		WORKLOAD		OW		WATER TEMP.		AIR	
	Rest	5	10	20	30	40	50	60	
HR	67.8	79.5	82.7	79.8	77.7	82.3	77.5	80.0	
$\dot{V}O_2$ l.min ⁻¹	394	712.3	691.8	618.5	632.5	639	640.5	642.0	
$\dot{V}_E$ l.min ⁻¹	6.48	15.76	15.63	14.26	14.29	14.44	14.97	14.93	
R	.80								
Rectal Temp, °C	37.1	37.1	37.0	37.0	37.0	37.0	37.0	36.9	
Skin Temp, °C	33.4	33.3	33.7	34.1	34.3	34.6	34.6	34.7	
1									
2	33.8	34.3	34.3	34.4	34.3	34.6	34.6	34.6	
3	33.1	33.5	33.5	33.6	33.7	33.8	33.9	34.0	
4	32.3	32.2	32.1	32.2	32.4	32.4	32.5	32.4	
5	32.3	32.5	32.9	33.5	34.0	33.9	34.6	34.6	
Mean Skin Temp °C	32.9	33.1	33.1	33.2	33.3	33.4	33.5	33.5	
1,3,4									

SUMMARY DATA SHEET

GROUP <u>Lean Men</u>		WORKLOAD <u>OMATTS</u>		WATER TEMP. <u>AIR</u>													
		Rest	5	10	20	30	40	50	60								
HR		70	76	82	86	82	81	80	81								
$\dot{V}O_2$ l.min ⁻¹		.3066	.8148	.7638	.6828	.6828	.7048	.7132	.6676								
$\dot{V}_E$ l.min ⁻¹		7.851	16.32	14.64	14.64	14.66	14.76	14.56	14.19								
R		.80	.79	.84	.83	.83	.81	.79	.80								
Rectal Temp, °C		37.4	37.4	37.3	37.2	37.1	37.1	37.0	37.0								
Skin Temp, °C		33.9	34.0	34.4	34.4	34.5	34.6	34.6	34.6								
1		34.2	34.4	34.3	34.3	34.3	34.3	34.4	34.4								
2		33.9	33.7	33.7	33.8	33.9	34.2	34.2	32.5								
3		32.7	32.1	32.2	32.2	32.4	32.6	32.6	32.8								
4		32.7	32.4	32.5	32.8	33.1	33.4	33.5	33.7								
5		33.6	33.2	33.2	33.1	33.5	33.6	33.6	33.8								
Mean Skin Temp °C																	

SUMMARY DATA SHEET

GROUP Lean Women WORKLOAD OWATTS WATER TEMP. AIR

	Rest	5	10	20	30	40	50	60
HR	72	90	89	92	88	88	86	86
$\dot{V}O_2$ l.min ⁻¹	.266	.636	.621	.571	.545	.577	.599	.588
$\dot{V}_E$ l.min ⁻¹ (BTPS)	6.09	12.86	12.40	11.64	10.86	11.63	12.00	12.02
R	.81	.80	.82	.82	.81	.80	.80	.80
Rectal Temp, °C	37.4	37.3	37.2	37.3	37.2	37.2	37.1	37.0
Skin Temp, °C								
1	33.6	33.4	33.2	33.0	33.2	33.2	33.3	33.4
2	33.5	33.4	33.4	33.5	33.4	33.4	33.4	33.4
3	34.2	34.0	34.0	34.0	34.1	34.1	34.2	34.2
4	31.5	31.2	31.1	31.2	31.4	31.5	31.6	31.6
5	31.9	32.0	32.2	32.8	33.4	33.6	34.0	34.1
Mean Skin Temp °C	33.1	32.9	32.8	32.8	33.0	33.0	33.1	33.1

SUMMARY DATA SHEET

GROUP Fat Men		WORKLOAD			O		WATER TEMP.		AIR	
	Rest	5	10	20	30	40				
HR	60	94	88	88	88	88				
$\dot{V}O_2$ l.min ⁻¹	.293	.819	.7836	.7834	.7335	.7793				
$\dot{V}e$ l.min ⁻¹ (BTFS)	6.16	17.27	16.40	16.81	16.22	16.99				
R	.77	.77	.79	.81	.81	.82				
Rectal Temp, °C	37.4	37.2	37.2	37.2	37.1	37.1				
Skin Temp, °C	33.0	32.3	33.	33.0	32.6	32.9				
1										
2	33.4	33.9	34.3	34.4	34.1	34.1				
3	31.	32.1	32.5	32.5	32.5	32.4				
4	31.8	31.6	31.5	31.5	31.4	31.3				
5	31.5	32.0	32.1	32.2	32.2	32.3				
Mean Skin Temp °C	31.5	31.9	32.1	32.1	32.1	32.1				

SUMMARY DATA SHEET

GROUP		Normal Women		WORKLOAD		OWATTS		WATER TEMP.		AIR	
		Rest	5	10	20	30	40	50	60		
HR		89	102	103	105	106	106	104	107		
$\dot{V}O_2$ l.min ⁻¹		.2915	.7927	.7322	.6692	.6732	.6902	.6356	.6860		
$\dot{V}_e$ l.min ⁻¹ (BRPS)		7.920	16.65	17.07	15.36	15.42	15.51	14.47	15.61		
R		.79	.81	.84	.81	.81	.80	.81	.81		
Rectal Temp, °C		37.5	37.5	37.5	37.4	37.4	37.3	37.4	37.3		
Skin Temp, °C		33.2	32.8	33.1	33.4	33.7	33.9	34.0	34.1		
1		33.4	34.0	34.4	34.5	34.4	34.5	34.4	34.3		
2		34.2	34.0	34.2	34.5	34.6	34.8	34.6	34.5		
3		30.9	30.7	31.0	31.5	31.6	31.8	32.0	32.0		
4		31.8	32.0	32.7	33.3	33.7	34.2	34.4	34.5		
5		32.8	32.59	32.9	33.2	33.4	33.6	33.6	33.5		
Mean Skin Temp °C											

N = 4

SUMMARY DATA SHEET

GROUP FAT MEN WORKLOAD 18W WATER TEMP. AIR

	Rest	5	10	20	30	40	50	60
HR	53	107	115	107	118	125	115	115
$\dot{V}O_2$ l.min ⁻¹	.3135	1.508	1.512	1.575	1.722	1.608	1.634	1.656
$\dot{V}_e$ l.min ⁻¹ (BTFS)	7.43	31.00	32.09	33.91	37.49	37.85	36.40	36.99
R	.72	.82	.85	.86	.86	.92	.86	.86
Rectal Temp, °C	37.2	37.2	37.4	37.5	37.6	37.7	37.7	37.8
Skin Temp, °C	34.5	34.6	34.6	34.5	33.9	33.7	33.4	33.7
1								
2	34.1	34.4	35.0	36	35.9	35.5	35.1	35.2
3	32.5	32.5	32.6	32.8	32.6	32.8	32.8	33.3
4	32.5	32.0	32.1	32.5	32.6	32.8	33.0	33.0
5	34.3	34.0	34.4	35.1	35.1	35.1	35.0	35.2
Mean Skin Temp °C	32.7	32.5	32.6	32.9	32.7	32.9	33.0	33.2

SUMMARY DATA SHEET

GROUP <u>LEAN MEN</u>		WORKLOAD <u>18 WATTS</u>		WATER TEMP. <u>AIR</u>													
		Rest	5	10	20	30	40	50	60								
HR		70	104	101	104	101	102	104	101								
$\dot{V}O_2$ l.min ⁻¹		.3317	1.310	1.262	1.270	1.257	1.320	1.309	1.359								
$\dot{V}_E$ l.min ⁻¹ (STPS)		8.346	27.13	27.30	27.01	25.83	26.67	27.52	28.22								
R		.80	.84	.86	.89	.85	.83	.84	.82								
Rectal Temp, °C		37.5	37.4	37.4	37.4	37.4	37.4	37.5	37.5								
Skin Temp, °C		33.3	33.7	34.2	34.3	34.7	34.9	34.7	34.8								
1																	
2		33.9	34.0	34.2	34.8	34.9	34.8	34.6	34.4								
3		33.4	33.4	33.8	34.2	34.2	34.3	33.6	33.4								
4		32.2	31.8	32.2	32.7	32.8	33.2	33.2	33.1								
5		32.1	32.7	33.2	34.6	35.2	35.4	35.4	35.4								
Mean Skin Temp °C		33.0	32.9	33.8	33.7	33.8	34.0	33.6	33.5								

SUMMARY DATA SHEET

GROUP NORMAL WOMEN		WORKLOAD 18 WATTS			WATER TEMP. AIR				
	Rest	5	10	20	30	40	50	60	
HR	86	131	133	140	141	138	140	133	
$\dot{V}O_2$ l.min ⁻¹	.2943	1.293	1.270	1.347	1.353	1.335	1.344	1.249	
$\dot{V}_e$ l.min ⁻¹ (BTPS)	7.486	27.59	29.05	28.81	28.80	29.67	30.22	26.54	
R	.80	.84	.88	.86	.83	.81	.82	.80	
Rectal Temp, °C	37.4	37.4	37.5	37.6	37.7	37.8	37.8	37.8	
Skin Temp, °C	33.6	33.5	33.6	33.7	34.0	33.7	33.8	33.9	
1									
2	33.9	33.9	34.0	34.7	35.0	34.8	35.0	34.6	
3	33.0	33.4	33.6	34.0	34.0	33.8	33.9	33.8	
4	30.4	30.7	30.7	31.4	31.6	31.6	31.7	32.4	
5	32.6	32.8	33.0	34.4	34.8	34.6	34.6	34.3	
Mean Skin Temp °C	32.1	32.4	32.6	33.0	33.0	33.1	33.0	33.3	

SUMMARY DATA SHEET

GROUP LEAN WOMEN WORKLOAD 18 WATS WATER TEMP. AIR

	Rest	5	10	20	30	40	50	60
HR	71	110	114	118	115	116	115	120
$\dot{V}O_2$ l.min ⁻¹	.248	1.206	1.066	1.121	1.125	1.097	1.158	1.146
$\dot{V}_E$ l.min ⁻¹ (BTPS)	8.640	21.60	20.08	20.96	22.07	20.24	21.13	21.61
R	.74	.82	.86	.84	.83	.81	.81	.81
Rectal Temp, °C	37.3	37.3	37.3	37.4	37.4	37.4	37.4	37.4
Skin Temp, °C	33.4	33.2	33.5	33.9	34.2	34.0	34.2	34.1
1	34.0	34.0	34.3	34.9	35.0	34.9	34.9	35.2
2	34.0	34.3	34.8	35.2	35.2	35.0	34.9	34.7
3	31.9	31.9	31.4	32.0	32.3	32.5	32.5	32.5
4	31.8	31.9	32.7	34.1	34.8	34.9	35.0	35.0
5	33.2	33.8	33.4	33.8	34.0	34.0	33.9	33.9
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP NORMAL MEN WORKLOAD 18W WATER TEMP. AIR

	Rest	5	10	20	30	40	50	60
HR	67	98	98	98	100	100	100	100
$\dot{V}O_2$ l.min ⁻¹	.290	1.255	1.255	1.223	1.2245	1.2397	1.1778	1.2626
$\dot{V}_e$ l.min ⁻¹ (BRPS)	7.793	24.52	24.90	24.95	24.59	26.02	24.02	25.94
R	.88	.86	.88	.88	.87	.87	.86	.86
Rectal Temp, °C	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2
Skin Temp, °C								
1	32.4	33.0	33.0	33.6	34.0	34.1	34.2	34.2
2	34.0	33.4	33.8	34.7	34.8	34.6	34.6	34.7
3	32.9	32.7	33.2	33.4	33.6	33.6	33.6	33.6
4	32.4	32.2	32.3	32.6	33.2	33.2	33.2	33.3
5	31.4	31.8	31.9	33.8	34.6	34.9	35.2	35.2
Mean Skin Temp °C	32.6	32.6	32.8	33.1	33.5	33.6	33.6	33.6

SUMMARY DATA SHEET

GROUP		Fat Men	WORKLOAD		18W	WATER TEMP. 28				
		Rest	5	10	20	30	40	50	60	
HR		75	104	107	107	106	110	112	115	
$\dot{V}O_2$ l.min ⁻¹		.3003	1.426	1.495	1.449	1.477	1.525	1.667	1.623	
$\dot{V}_e$ l.min ⁻¹ (BTPS)		7.255	30.509	32.897	32.677	31.815	31.816	35.158	35.240	
R		.8142	.9027	.8953	.9217	.8820	.8650	.8736	.8836	
Rectal Temp, °C		37.0	37.0	37.0	37.4	37.5	37.5	37.5	37.5	
Skin Temp, °C		34.0	28.5	28.5	28.5	28.5	28.5	28.5	28.5	
1		32.5	30.5	29.8	29.0	28.6	29.0	29.5	29.5	
2		31.0	28.5	28.5	28.5	28.5	28.5	28.5	28.5	
3		31.5	28.4	28.4	28.2	28.2	28.4	28.4	28.2	
4		30.0	28.5	28.5	28.5	28.5	28.5	28.5	28.5	
5		31.6	28.5	28.5	28.4	28.4	28.5	28.5	28.4	
Mean Skin Temp °C										

SUMMARY DATA SHEET

GROUP		Normal Men		WORKLOAD		18W		WATER TEMP. 28°C	
	Rest	5	10	20	30	40			
HR	83	107	102	104	99	100			
$\dot{V}O_2$ l.min ⁻¹	.2864	1.362	1.344	1.262	1.266	1.242			
$\dot{V}_E$ l.min ⁻¹ (BTPS)	7.464	27.28	27.05	26.12	25.74	26.08			
R	.88	.85	.88	.86	.85	.85			
Rectal Temp, °C	37.3	37.3	37.2	37.2	37.1	37.0			
Skin Temp, °C	33.0	29.0	28.9	28.8	28.6	28.6			
1									
2	33.7	28.9	28.6	28.4	28.3	28.3			
3	33.6	28.5	28.4	28.3	28.2	28.2			
4	32.5	28.4	28.4	28.4	28.3	28.5			
5	32.1	28.8	28.6	28.4	28.4	28.3			
Mean Skin Temp °C	33.1	28.5	28.5	28.4	28.3	28.4			

SUMMARY DATA SHEET

WATER TEMP. 28°C

18W

WORKLOAD

GROUP Normal Women

	Rest	5	10	20	30	40 N=3	50 N=3	60 N=3
HR	85	131	134	132	133	124	126	126
$\dot{V}O_2$ l.min ⁻¹	.2962	1.245	1.265	1.257	1.245	1.151	1.235	1.167
$\dot{V}_e$ l.min ⁻¹ (BTPS)	7.283	27.33	28.57	28.48	26.52	24.31	26.93	25.70
R	.78	.85	.87	.84	.80	.78	.79	.77
Rectal Temp, °C	37.4	37.2	37.2	37.4	37.4	37.4	37.4	37.4
Skin Temp, °C	33.8	29.1	28.8	28.8	28.8	28.5	28.5	28.5
1	34.0	28.7	28.5	28.4	28.4	28.1	28.1	28.1
2	33.4	28.4	28.3	28.2	28.2	28.2	28.2	28.2
3	30.6	28.2	28.1	28.0	28.0	27.9	27.9	27.9
4	31.4	28.4	28.4	28.4	28.4	28.3	28.3	28.3
5	32.4	28.4	28.3	28.2	28.2	28.1	28.1	28.1
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP Lean Men WORKLOAD 18W WATER TEMP. 28°C

	Rest	5	10	20	30	40	50	60
HR	78	105	102	104	98	101	100	101
$\dot{V}O_2$ l.min ⁻¹	.292	1.422	1.399	1.297	1.308	1.262	1.363	1.401
$\dot{V}_e$ l.min ⁻¹ (BTPS)	8.377	28.40	29.52	28.92	27.85	27.31	28.39	29.66
R	.87	.86	.89	.89	.86	.86	.84	.84
Rectal Temp, °C	37.6	37.4	37.3	37.1	36.9	36.8	36.8	36.7
Skin Temp, °C	33.4	31.6	29.2	29.0	29.0	28.9	29.0	28.9
1	34.6	30.3	28.9	28.6	28.6	28.5	28.5	28.4
2	33.7	28.3	28.2	28.2	28.2	28.2	28.2	28.2
3	N=3 32.6	N=3 28.3	N=3 28.3	28.4	28.4	28.3	28.3	28.3
4	32.5	28.4	28.3	28.3	28.2	28.2	28.1	28.1
5	33.3	28.8	28.4	28.4	28.4	28.3	28.3	28.3
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP Lean Women		WORKLOAD		18W	WATER TEMP. 28°C					
	Rest	5	10	20	30	40	50	60		
HR	82	122	124	126	124	119	124	124		
$\dot{V}O_2$ l.min ⁻¹	.2813	1.243	1.206	1.216	1.236	1.174	1.191	1.250		
$\dot{V}_e$ l.min ⁻¹ (BTGS)	6.971	25.56	26.68	26.27	27.71	25.88	26.05	27.51		
R	.7841	.8337	.8949	.8598	.8521	.8276	.8209	.8183		
Rectal Temp, °C	37.4	37.4	37.3	37.3	37.4	37.5	37.4	37.4		
Skin Temp, °C	33.8	29.0	29.0	29.0	28.9	28.8	28.9	28.9		
1	33.8	28.7	28.4	28.6	28.6	28.7	28.7	28.7		
2	34.4	28.6	28.3	28.5	28.4	28.5	28.5	28.5		
3	32.8	28.1	28.6	28.4	28.4	28.4	28.4	28.4		
4	31.9	28.2	28.4	28.5	28.5	28.5	28.5	28.5		
5	33.7	28.5	28.5	28.5	28.5	28.5	28.5	28.5		
Mean Skin Temp °C										

SUMMARY DATA SHEET

GROUP	Fat Men	WORKLOAD	18W	20°C	30	40	50	60
	Rest	5	10	20	30	40	50	60
HR	84	114	106	106	101	106	107	104
$\dot{V}O_2$ l.min ⁻¹	.329	1.395	1.358	1.390	1.327	1.275	1.282	1.294
$\dot{V}e$ l.min ⁻¹ (BTPS)	7.74	29.20	28.52	29.51	28.131	27.34	26.35	27.21
R	.76	.81	.79	.79	.76	.77	.76	.78
Rectal Temp, °C	37.6	37.13	37.13	37.3	37.2	37.2	37.3	37.4
Skin Temp, °C	32.6	21.2	21.2	21	21	21	21	21
1	33.0	21.2	21.1	21.1	21.1	21.1	21.1	21.2
2	34.7	21.4	21.3	21.3	21.3	21.3	21.2	21.3
3	32.1	21.2	21.2	21.4	21.3	21.4	21.4	21.4
4	33.5	21.4	21.4	21.4	21.4	21.4	21.4	21.5
5	33.6	21.3	21.3	21.3	21.3	21.3	21.3	21.3
Mean Skin Temp °C 1,3,4								

SUMMARY DATA SHEET

GROUP		Normal Men		WORKLOAD			18W		WATER TEMP. 20°		
		Rest	5	10	20	30	40				
HR		75	108	111	110	105	104				
$\dot{V}O_2$ l.min ⁻¹		.326	1.515	1.641	1.605	1.531	1.543				
$\dot{V}e$ l.min ⁻¹											
(BTSP)											
R											
Rectal Temp, °C		37.0	36.8	36.8	36.7	36.6	36.5				
Skin Temp, °C		32.5	22.6	22.2	22.1	22.0	22.0				
1		33.2	25.3	22.8	22.1	21.9	21.9				
2		32.7	21.7	21.2	21.2	21.1	21.1				
3		32.2	22.1	21.7	21.7	21.7	21.7				
4		32.6	22.0	21.7	21.6	21.6	21.7				
5		32.6	22.1	21.5	21.5	21.5	21.5				
Mean Skin Temp °C	1,3,4										

SUMMARY DATA SHEET

GROUP	Lean Men	WORKLOAD	18W	WATER TEMP. 20°C					
		Rest	5	10	20	30	40	50	60
HR		73	106	104	102	106	110	106	108
$\dot{V}O_2$ l.min ⁻¹		.356	1.551	1.638	1.618	1.658	1.678	1.705	1.789
$\dot{V}e$ l.min ⁻¹ (BTFS)		8.950	30.69	33.02	37.19	36.90	36.94	37.25	37.95
R		.84	.85	.86	.91	.90	.86	.87	.86
Rectal Temp, °C		37.5	37.3	37.1	36.8	36.4	36.6	36.1	36.0
Skin Temp, °C		33.5	23.2	22.6	22.6	22.5	22.4	22.4	22.3
1		34.5	23.1	22.4	22.2	22.0	21.8	21.7	21.7
2		33.8	22.7	22.2	22.0	22.0	22.1	21.7	21.7
3		32.5	22.3	22.0	21.9	21.7	21.6	21.6	21.6
4		32.6	22.3	22.2	22.2	22.2	21.8	21.8	21.8
5		33.3	22.6	22.2	22.0	22.0	22.0	21.8	21.7
Mean Skin Temp °C									

SUMMARY DATA SHEET

GROUP		Normal Women	WORKLOAD 18W		WATER TEMP. 20°C					
		Rest	5	10	20	30	40	50	60	
HR		84	129	130	133	130	129	128	128	
$\dot{V}O_2$ l.min ⁻¹		.3081	1.270	1.296	1.203	1.303	1.320	1.310	1.330	
$\dot{V}e$ l.min ⁻¹ (BTFS)		8.491	29.87	30.18	27.79	29.14	28.86	28.07	27.55	
R		.87	.92	.90	.87	.85	.86	.84	.82	
Rectal Temp, °C		37.8	37.8	37.7	37.7	37.7	37.6	37.5	37.4	
Skin Temp, °C		34.1	22.7	22.2	22.0	21.9	21.9	21.9	21.9	
1										
2		35.2	22.6	21.8	21.4	21.4	21.2	21.2	21.3	
3		33.4	21.8	21.2	21.0	21.1	21.1	21.2	21.2	
4		32.4	21.2	21.2	21.1	21.1	21.1	21.2	21.2	
5		33.0	21.5	21.1	21.0	21.0	21.0	21.0	21.1	
Mean Skin Temp °C		33.1	21.7	21.3	21.2	21.2	21.2	21.3	21.3	

SUMMARY DATA SHEET

GROUP Lean Women WORKLOAD 18W WATER TEMP. 20°C

	Rest	5	10	20	30	40	50	60
HR	81	117	128	123	122	118	120	119
$\dot{V}O_2$ l.min ⁻¹	.2777	1.250	1.258	1.320	1.391	1.406	1.418	1.381
$\dot{V}e$ l.min ⁻¹ (BTPS)	7.998	28.06	29.50	31.96	30.92	30.62	30.52	30.48
R	.85	.89	.94	.90	.88	.87	.88	.86
Rectal Temp, °C	37.4	37.4	37.4	37.6	37.2	37.1	37.0	36.9
Skin Temp, °C	34.2	22.6	22.0	21.9	21.8	21.8	21.8	21.8
1	34.0	24.3	22.6	22.0	21.7	21.8	22.0	22.1
2	34.0	22.5	22.0	21.8	21.8	21.8	21.8	21.6
3	31.8	21.2	20.9	20.9	20.8	20.9	29.0	21.0
4	32.2	22.0	21.6	21.4	21.2	21.3	21.4	21.4
5	33.0	22.0	21.6	21.5	21.4	21.5	21.5	21.4
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP		Lean Men	WORKLOAD		18W	WATER TEMP.		24°C		
	Rest	5	10	20	30	40	50	60		
HR	66	98	102	102	100	99	100	99		
$\dot{V}O_2$ l.min ⁻¹	.288	1.459	1.450	1.493	1.518	1.556	1.565	1.583		
$\dot{V}_E$ l.min ⁻¹ (BTPS)	7.726	31.66	32.66	34.27	33.35	38.37	36.62	36.44		
R	.87	.92	.93	.93	.91	.90	.89	.88		
Rectal Temp, °C	37.5	37.3	37.1	36.8	36.6	36.3	36.1	36.3		
Skin Temp, °C	33.8	26.4	26.0	26.0	26.0	25.9	25.8	25.8		
1										
2	34.2	26.7	26.0	25.7	25.4	25.4	25.3	25.3		
3	33.8	25.5	25.2	25.0	25.0	24.9	25.0	24.9		
4	32.0	25.1	25.0	24.8	24.8	24.8	24.9	24.8		
5	32.9	26.0	26.5	25.6	25.4	25.4	25.4	25.4		
Mean Skin Temp °C	33.152	25.482	25.24	25.068	25.068	25.009	25.976	24.99		

SUMMARY DATA SHEET

GROUP		Lean Women	WORKLOAD	18W	WATER TEMP. 24°C					
	Rest	5	10	20	30	40	50	60		
HR	77	135	135	128	123	130	131	128		
$\dot{V}O_2$ l.min ⁻¹	.2832	1.476	1.401	1.326	1.326	1.392	1.329	1.380		
$\dot{V}_E$ l.min ⁻¹ (BTPS)	7.388	32.78	34.16	29.75	30.22	30.77	30.27	29.98		
R	.8484	.9215	.9641	.8820	.8763	.8881	.8916	.8460		
Rectal Temp, °C	37.6	37.5	37.5	37.5	37.4	37.3	37.3	37.2		
Skin Temp, °C	34.0	25.9	25.8	25.6	25.6	25.5	25.5	25.4		
1										
2	34.0	27.3	26.3	25.6	31.6	25.2	25.2	25.2		
3	33.8	26.1	25.3	25.0	25.0	24.8	25.0	25.0		
4	31.9	25.1	24.9	24.8	24.8	24.7	24.7	24.6		
5	32.6	25.8	25.4	25.1	25.0	25.0	24.9	24.9		
Mean Skin Temp °C	33.144	25.712	25.196	25.012	25.012	24.862	24.962	24.912		

SUMMARY DATA SHEET

GROUP	Normal Women	WORKLOAD	18W	WATER TEMP. 24°C						
	Rest	5	10	20	30	40	50	60		
HR	85	119	117	117	121	120	119	122		
$\dot{V}O_2$ l.min ⁻¹	.27.3	.262	.203	1.254	1.268	1.236	1.1284	1.322		
$\dot{V}_e$ l.min ⁻¹ (BTPS)	7.74	28.59	27.16	28.39	27.92	27.28	28.00	28.78		
R	.87	.90	.95	.89	.86	.85	.85	.84		
Rectal Temp, °C	37.3	37.3	37.2	37.3	37.2	37.3	37.0	37.0		
Skin Temp, °C	32.7	25.2	25.0	24.9	24.9	24.9	24.9	24.9		
1	4.1	26.6	25.7	25.2	24.8	24.7	24.7	24.7		
2	33.7	26.1	25.4	25.2	25.1	25.1	25.0	24.9		
3	32.0	25.3	25.1	25.0	24.9	24.9	24.9	24.9		
4	32.4	24.7	24.5	24.4	24.4	24.5	24.4	24.5		
5	32.9	25.7	25.2	25.1	25.0	25.0	25.0	24.9		
Mean Skin Temp °C										

SUMMARY DATA SHEET

GROUP		Normal Men		WORKLOAD		18W		WATER TEMP. 24°			
		Rest		5	10	20	30	40	50	60	
HR		76		104	104	103	102	98	95	92	
$\dot{V}O_2$ l.min ⁻¹		.300		1.398	1.405	1.323	1.3310	1.3312	1.341	1.329	
$\dot{V}_E$ l.min ⁻¹ (BTGS)		7.910		29.56	30.09	28.78	28.82	28.82	29.19	27.92	
R		.85		.83	.89	.87	.86	.82	.86	.83	
Rectal Temp, °C		37.2		37.11	37.11	37.1	37.0	37.0	36.9	36.9	
Skin Temp, °C		33.8		25.6	25.2	25.2	25.1	25.0	25.0	25.0	
1		34.0		25.5	25.0	25.0	24.8	24.6	24.6	24.7	
2		32.4		24.6	24.5	24.5	24.5	24.5	24.4	24.5	
3		33		24.6	24.6	24.6	24.6	24.6	24.6	24.6	
4		32.6		24.5	24.4	24.6	24.4	24.5	24.5	24.5	
5		32.8		24.8	24.6	24.6	24.6	24.6	24.6	24.6	
Mean Skin Temp °C											

SUMMARY DATA SHEET

GROUP		Fat Men		WORKLOAD		18W		WATER TEMP.		24°C	
		Rest	5	10	20	30	40	50	60		
HR		68	115	107	107	107	107	107	107		
$\dot{V}O_2$ l.min ⁻¹		.299	1.565	1.451	1.517	1.535	1.413	1.344	1.370		
$\dot{V}e$ l.min ⁻¹ (BTFS)		7.25	32.90	31.53	33.47	33.65	31.00	28.61	28.74		
R		.84	.88	.90	.88	.88	.86	.86	.87		
Rectal Temp, °C		37.2	37.3	37.4	37.5	37.5	37.5	37.5	37.6		
Skin Temp, °C		33.3	25.3	25.3	24.7	24.9	24.9	24.7	24.5		
1		33.3	26.5	25.3	24.1	24.0	24.0	24	24		
2		32.1	25.3	24.9	24.1	24.0	24.0	24	24		
3		32	25.4	25.1	24.4	24.4	24.3	24.3	24.3		
4		31.1	25.6	24.9	24.3	24.3	24.3	24.2	24.2		
5		32.2	25.3	25.0	24.4	24.3	24.2	24.2	24.2		
Mean Skin Temp °C	1.3.4										

SUMMARY DATA SHEET

GROUP		FAT MEN	WORKLOAD		36W	WATER TEMP.		AIR
	Rest	5	10	20	30	40	50	60
HR	33.5	115	118	120	120	120	124	126
$\dot{V}O_2$ 1.min ⁻¹	.444	1.594	1.573	1.591	1.577	1.647	1.778	1.744
$\dot{V}_E$ 1.min ⁻¹ (BTPS)	10.83	31.8	31.09	32.66	32.37	34.17	36.87	36.13
R	.86	.87	.88	.89	.85	.89	.88	.85
Rectal Temp, °C	37.8	37.8	37.8	38.0	38.0	38.1	38.1	38.2
Skin Temp, °C	33.5	33.7	33.8	34.1	33.4	33.4	33.7	33.6
1	34.0	34.0	34.0	34.4	34.2	34.4	34.4	34.2
2	32.2	32.5	33.2	34.0	34.0	34.0	33.9	34.0
3	32.2	31.8	32.2	32.2	32.4	32.5	32.9	33.4
4	32.0	32.6	34.0	35.0	35.1	35.4	35.6	35.4
5	32.4	32.4	32.9	33.4	33.3	33.4	33.5	33.7
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP	LEAN WOMEN	WORKLOAD	36 WATTS	20	30	40	50	60
		Rest						
HR		85	137	138	146	145	145	147
$\dot{V}O_2$ l.min ⁻¹		.2775	1.535	1.560	1.560	1.625	1.598	1.626
$\dot{V}_E$ l.min ⁻¹ (BRPS)		7.148	52.49	34.50	35.35	36.41	36.62	36.31
R		.8167	.8872	.9146	.9017	.8947	.8550	.8549
Rectal Temp, °C		37.4	37.4	37.4	37.7	37.8	38.0	38.0
Skin Temp, °C		33.9	33.8	34.1	34.8	34.9	34.8	34.8
1		34.6	34.6	35.0	35.7	36.1	36.0	35.8
2		34.3	34.9	35.2	35.4	35.1	35.2	35.0
3		31.8	31.4	31.8	32.6	33.0	33.1	32.8
4		32.1	32.1	32.6	34.1	35.2	35.5	35.4
5		33.34	33.48	33.822	34.308	34.316	34.388	34.18
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP		LEAN MEN		WORKLOAD		36 W		WATER TEMP.		AIR	
		Rest	5	10	20	30	40				
HR		63	110	115	118	118	122				
$\dot{V}O_2$ l.min ⁻¹		.411	1.538	1.604	1.568	1.494	1.581				
UI l.min ⁻¹ (STEP)		10.30	31.02	32.04	31.54	29.71	33.30				
R		.82	.87	.87	.86	.84	.83				
Rectal Temp, °C		37.4	37.3	37.3	37.3	37.4	37.4				
Skin Temp, °C		35.1	34.4	34.9	34.8	34.7	34.7				
1											
2		34.0	34.4	34.5	35.0	35.0	34.8				
3		33.5	33.2	34.0	34.8	34.7	34.4				
4		32.8	32.6	33.0	33.8	34.3	34.3				
5		32.7	32.8	33.6	35.0	35.3	35.4				
Mean Skin Temp °C		33.472	33.152	33.766	34.44	34.556	34.406				

SUMMARY DATA SHEET

GROUP		NORMAL MEN		WORKLOAD		36W		WATER TEMP.		AIR	
		Rest	5	10	20	30	40	50	60		
HR		68.5	116.7	119.8	117	117	116.8	117.5	117		
$\dot{V}O_2$ l.min ⁻¹		274	1707	1660	1583	1511	1546	1558	1572		
$\dot{V}e$ l.min ⁻¹ (BTPS)		6.289	33.19	33.85	32.28	31.20	31.58	31.66	31.24		
R		.82	.87	.89	.87	.88	.86	.84	.84		
Rectal Temp, °C		37.3	37.1	37.1	37.3	37.4	37.2	37.2	37.4		
Skin Temp, °C		32.2	32.8	33.6	34.0	33.9	34.2	34.4	34.6		
1		33.4	33.4	34.2	35.2	35.2	35.2	34.9	34.8		
2		35.4	33.4	34.2	35.1	35.1	35.1	35.0	34.8		
3		31.8	31.4	31.6	32.2	32.2	32.4	32.4	32.4		
4		32.1	32.0	32.2	33.9	34.6	34.8	35.0	35.2		
5		32.6	32.6	33.2	34.0	33.9	34.1	34.0	33.9		
Mean Skin Temp °C	1.3.4.										

SUMMARY DATA SHEET

GROUP	NORMAL WOMEN	WORKLOAD	36W	WATER TEMP.	AIR	N=3	N=3	N=3
HR	Rest	5	10	20	30	40	50	60
	85	144	143	151	142	145	146	148
$\dot{V}O_2$ l.min ⁻¹	.2956	1.498	1.546	1.540	1.531	1.595	1.546	1.530
UI l.min ⁻¹	7.774	31.27	32.75	32.57	31.83	34.90	34.1	33.75
(STPD)								
R	.84	.88	.88	.87	.86	.86	.87	.86
Rectal Temp, °C	37.4	37.4	37.4	37.6	37.8	37.85	37.85	37.85
Skin Temp, °C	33.2	33.0	33.9	34.6	34.7	34.7	34.7	34.7
1								
2	33.1	33.2	33.7	35.0	35.5	35.5	35.3	35.3
3	32.7	32.6	33.2	34.4	33.8	33.6	33.3	33.2
4	30.8	30.7	30.9	31.6	31.8	31.6	31.6	31.6
5	31.7	31.7	31.8	34.1	34.9	35.1	34.9	35.2
Mean Skin Temp °C	32.1	31.5	32.5	33.4	33.2	33.7	32.5	32.4

SUMMARY DATA SHEET

GROUP Fat Men

WORKLOAD 36W

WATER TEMP. 28°

	Rest	5	10	20	30	40	50	60
HR	78	116	117	116	116	117	116	115
$\dot{V}O_2$ l.min ⁻¹	.4972	1.7105	1.6335	1.574	1.5825	1.6495	1.739	1.696
$\dot{V}e$ l.min ⁻¹ (BTPS)	10.6305	35.222	33.777	33.3075	32.378	33.357	33.787	33.3305
R	.8052	.9046	.94375	.90045	.878	.87995	.87385	.89205
Rectal Temp, °C	37.8	37.8	37.7	37.7	38.0	37.8	37.9	37.9
Skin Temp, °C	32.6	28.6	28.8	29.0	29.0	29.0	29.0	28.8
1								
2	32.5	29.0	29.0	29.2	29.7	29.8	29.8	29.6
3	31.2	29.0	29.0	28.8	28.9	28.8	28.8	28.8
4	31.2	29.4	29.2	29.0	29.0	29.0	29.1	29.1
5	31.4	28.8	28.8	28.8	29.0	29.3	29.4	29.4
Mean Skin Temp °C	31.4	29.1	29.0	28.9	29.0	28.9	28.9	28.9

AD-A138 969

METABOLIC THERMAL AND CARDIOVASCULAR ADJUSTMENTS TO
COLD EXPOSURE WITH SP... (U) QUEENS COLL FLUSHING N Y
J R MAGEL ET AL. JUN 82 DAMD17-80-C-0150

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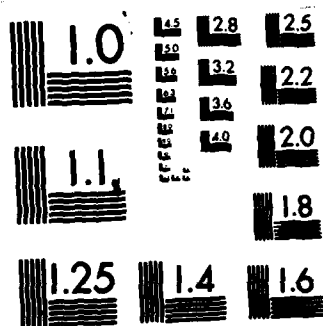
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SUMMARY DATA SHEET

GROUP Lean Men WORKLOAD 36 Watts WATER TEMP. 28°C

	Rest	5	10	20	30	40	50	60
HR	67	115	115	112	108	108	107	111
$\dot{V}O_2$ l.min ⁻¹	.334	1.662	1.651	1.584	1.625	1.680	1.708	1.710
$\dot{V}_E$ l.min ⁻¹ (BTPS)	8.784	34.38	35.12	33.25	34.22	35.14	35.22	37.35
R	.86	.91	.91	.88	.89	.86	.85	.88
Rectal Temp, °C	37.4	37.3	37.3	37.3	37.3	37.2	37.2	37.2
Skin Temp, °C	34.2	29.0	28.9	28.8	28.8	28.8	28.7	28.8
1	34.7	28.6	28.4	28.6	28.4	28.5	28.4	28.4
2	34.5	28.4	28.3	28.3	28.2	28.2	28.2	28.3
3	33.4	28.3	28.3	28.2	28.2	28.1	28.2	28.2
4	33.0	28.5	28.6	28.5	28.5	28.4	28.4	28.4
5	34.1	28.4	28.4	28.3	28.3	28.2	28.3	28.3
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP	Lean Women	WORKLOAD	36W	WATER TEMP. 28°C					
	Rest	5	10	20	30	40 N=3	50 N=3	60 N=2	
HR	78	133	136	144	141	144	143	143	
$\dot{V}O_2$ l.min ⁻¹	.329	1.642	1.719	1.682	1.686	1.710	1.711	1.738	
$\dot{V}_E$ l.min ⁻¹ (BTPS)	8.590	37.008	39.972	39.888	40.734	42.02	40.13	40.16	
R	.82	.94	.94	.90	.88	.89	.90	.87	
Rectal Temp, °C	37.6	37.5	37.5	37.6	37.7	37.75	37.75	37.8	
Skin Temp, °C	33.9	29.2	29.2	29.4	29.3	29.3	29.2	28.9	
1	33.6	28.6	28.2	28.4	28.4	28.5	28.5	28.5	
2	34.0	29.3	28.7	28.8	28.7	28.8	28.8	28.8	
3	31.4	28.8	28.5	28.6	28.6	28.6	28.6	28.6	
4	31.7	28.5	28.2	28.6	28.6	28.5	28.5	28.4	
5	33.05	29.106	28.698	28.812	28.748	28.51	28.75	28.77	
Mean Skin Temp °C									

SUMMARY DATA SHEET

GROUP Normal Men		WORKLOAD		36W	WATER TEMP.		28°		
	Rest	5	10	20	30	40	50	60	
HR	67	108	108	108	106	105	107	106	
$\dot{V}O_2$ l.min ⁻¹	.356	1.761	1.709	1.657	1.684	1.647	1.666	1.661	
$\dot{V}_E$ l.min ⁻¹ (l/min)	8.570	34.04	35.60	32.58	33.03	32.08	31.68	31.71	
R	.82	.84	.86	.84	.84	.81	.82	.81	
Rectal Temp, °C	37	36.9	36.8	36.9	37.1	37.2	37.2	37.2	
Skin Temp, °C	32.6	28.8	28.6	28.6	28.7	28.7	28.6	28.6	
1									
2	32.9	28.9	28.3	28.2	28.2	28.2	28.2	28.2	
3	32.5	28.3	28.2	28.2	28.3	28.3	28.3	28.3	
4	31.9	28.3	28.2	28.2	28.2	28.2	28.2	28.2	
5	32	28.5	28.4	28.4	28.4	28.4	28.4	28.4	
Mean Skin Temp °C	32.3	28.4	28.3	28.3	28.4	28.4	28.4	28.4	

SUMMARY DATA SHEET

GROUP Normal Women WORKLOAD 36 W WATER TEMP. 28°C

	Rest	5	10	20	30	40 N=3	50 N=3	60 N=3
HR	82	141	142	143	146	147	148	149
$\dot{V}O_2$ l.min ⁻¹	.2883	1.715	1.682	1.736	1.731	1.728	1.717	1.712
$\dot{V}_E$ l.min ⁻¹ (mlPS)	7.732	40.04	35.99	40.40	40.09	41.03	40.52	40.26
R	.82	.94	.90	.88	.86	.86	.87	.85
Rectal Temp, °C	37.4	37.4	37.5	37.7	37.7	37.8	37.8	37.8
Skin Temp, °C	34.0	28.7	8.4	29.1	29.2	29.2	29.1	29.0
1	34.2	28.8	28.8	28.8	28.9	29.0	29.1	29.1
2	33.8	28.7	28.5	28.4	28.4	28.5	28.5	28.4
3	31.6	28.2	28.1	28.2	28.2	28.1	28.1	28.3
4	32.2	28.3	28.3	28.3	28.4	28.4	28.3	28.3
5	33.0	28.5	28.3	28.4	28.4	28.47	28.47	28.4
Mean Skin Temp °C								

SUMMARY DATA SHEET

GROUP		Pat Men		WORKLOAD		36 W	WATER TEMP. 24°	
	Rest	5	10	20	30	40	50	60
HR	85	113	118	118	115	115	115	115
$\dot{V}O_2$ l.min ⁻¹	.4592	1.687	1.674	1.62	1.645	1.627	1.674	1.630
$\dot{V}_E$ l.min ⁻¹ (STPS)	10.72	34.97	35.19	35.04	33.63	33.60	34.03	33.51
R	.84	.90	.89	.88	.86	.90	.88	.86
Rectal Temp, °C	37.8	37.8	37.8	37.8	38.0	38.0	37.9	37.8
Skin Temp, °C	33.6	27.0	25.0	25.0	24.8	24.8	24.8	24.8
1		26.1	25.2	25.0	24.8	24.8	24.8	24.8
2		25.2	24.9	24.8	24.8	24.6	24.7	24.8
3		25.2	25.0	25.0	24.9	24.9	24.8	24.8
4		25.4	25.4	25.0	25.0	24.8	24.8	24.8
5		25.4	25.4	25.0	25.0	24.8	24.8	24.8
Mean Skin Temp °C	33.0	25.4	25.0	24.9	24.8	24.7	24.8	24.8

SUMMARY DATA SHEET

GROUP Lean Women WORKLOAD 36W WATER TEMP. 24

	Rest	5	10	20	30	40 N=3	50 N=3	60 N=3
HR	83	133	142	144	144	144	148	148
$\dot{V}O_2$ l.min ⁻¹	.2755	1.644	1.675	1.738	1.770	1.805	1.797	1.821
$\dot{V}_E$ l.min ⁻¹ (BTPS)	6.856	38.810	40.046	41.118	43.611	43.52	43.93	44.91
R	.81	.96	.94	.89	.89	.87	.88	.89
Rectal Temp, °C	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4
Skin Temp, °C	34.1	25.8	25.6	25.6	25.7	25.5	25.6	25.5
1								
2	34.6	28.2	27.5	26.2	26.2	26.1	25.8	25.8
3	34.4	25.2	24.8	24.7	24.7	24.6	24.6	24.6
4	32.2	25.5	25.2	25.0	25.1	25.1	25.1	25.0
5	33.0	25.4	25.3	25.2	25.2	25.3	25.3	25.2
Mean Skin Temp °C	33.56	25.4	25.1	24.9	24.9	24.9	24.9	24.9

SUMMARY DATA SHEET

GROUP Normal Men WORKLOAD 36 Watts WATER TEMP. 24°

	Rest	5	10	20	30	40	50	60
HR	80	114	115	111	109	111	107	109
$\dot{V}O_2$ l.min ⁻¹	2.892	1.815	1.754	1.612	1.601	1.547	1.583	1.646
$\dot{V}e$ l.min ⁻¹ (BTPS)	7.045	37.64	37.20	35.45	33.68	34.46	34.67	35.58
R	.88	.90	.90	.90	.88	.90	.88	.87
Rectal Temp, °C	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.3
Skin Temp, °C	33.7	25.4	25.2	25.0	25.0	25.0	24.9	24.9
1								
2	33.7	25.9	25.0	24.9	24.7	24.7	24.8	24.8
3	32.9	25.0	24.6	24.6	24.6	24.6	24.6	24.6
4	32.2	25.2	25.0	24.9	24.9	24.9	24.9	24.9
5	31.4	25.1	24.8	24.7	24.6	24.7	24.6	24.6
Mean Skin Temp °C	32.8	25.1	24.8	24.8	24.8	24.8	24.8	24.8

SUMMARY DATA SHEET

GROUP Normal Women WORKLOAD 36 WATER TEMP. 24°C

	Rest	5	10	20	30	40	50	60
HR	83.5	144	144	143	144	144	144	144
$\dot{V}O_2$ l.min ⁻¹	.3178	1.716	1.566	1.663	1.785	1.744	1.725	1.730
$\dot{V}_E$ l.min ⁻¹ (BTPS)	8.880	42.11	39.04	41.77	43.19	41.68	41.05	41.14
R	.84	.91	.91	.92	.89	.88	.88	.88
Rectal Temp, °C	37.5	37.14	37.5	37.8	37.9	37.95	37.95	38.0
Skin Temp, °C	34.0	25.5	25.4	25.6	25.7	25.7	25.7	25.75
1		26.8	26.6	26.0	26.4	26.3	26.3	26.3
2		25.2	25.0	25.2	25.2	25.3	25.4	25.4
3		24.6	24.8	25.0	24.9	24.9	24.9	24.9
4		25.1	24.9	24.8	24.8	24.8	24.9	24.9
5		25.0	25.0	25.2	25.2	25.2	25.2	25.3
Mean Skin Temp °C	32.8							

SUMMARY DATA SHEET

Lean Men

WORKLOAD

36 W

WATER TEMP. 24°C

	Rest	5	10	20	30	40	50	60
HR	68	108	108	108	107	109	105	104
$\dot{V}O_2$ l.min ⁻¹	.3130	1.710	1.823	1.805	1.799	1.762	1.830	1.814
$\dot{V}_E$ l.min ⁻¹ (BTPS)	8.554	36.46	38.99	39.67	38.84	38.13	40.16	41.14
R	.88	.94	.92	.93	.90	.90	.90	.89
Rectal Temp, °C	37.4	37.3	37.2	36.8	36.6	36.6	36.6	36.5
Skin Temp, °C 1	34.4	26.3	26.3	26.1	26.0	26.0	26.1	25.9
2	34.4	26.8	26.6	26.2	25.9	25.5	25.8	26.0
3	33.7	25.3	25.1	25.0	25.0	24.9	24.9	24.9
4	33.3	25.2	25.2	25.0	25.0	24.9	25.0	25.0
5	33.2	25.5	25.3	25.2	24.8	24.8	24.9	24.8
Mean Skin Temp °C	33.6	29.1	25.3	25.2	25.1	25.0	25.1	25.1

SUMMARY DATA SHEET

GROUP Normal Men WORKLOAD 36W WATER TEMP. 20°

	Rest	5	10	20	30	40	50	60
HR	70	114	116	112	114	116	118	115
$\dot{V}O_2$ 1.min ⁻¹	303	1737	1846	1794	1802	1785	1928	1922
$\dot{V}\bar{a}$ 1.min ⁻¹	7.54	38.13	39.99	38.43	37.38	35.17	39.41	41.23
VI (mls) STPD								
R	.83	.90	.91	.89	.85	.89	.87	.87
Rectal Temp, °C	37.3	37.2	37.1	36.9	36.8	36.7	36.6	36.6
Skin Temp, °C	34.0	21.9	21.8	22.0	21.9	21.8	21.8	21.8
1								
2	33.9	23.1	23.7	21.7	21.8	21.4	21.3	21.4
3	32.8	21.7	21.1	21.1	21.0	21.0	21.0	21.0
4	32.2	21.7	21.8	21.9	21.8	21.8	21.6	21.6
5	32.3	22.7	22.0	21.6	21.6	21.4	21.4	21.3
Mean Skin Temp °C 1,3,4,	32.8	21.8	21.5	21.6	21.4	21.4	21.4	21.4

SUMMARY DATA SHEET

GROUP Lean Women WORKLOAD 36W WATER TEMP. 20°C

	Rest	5	10	20	30	40	50	60
HR	80	139	144	144	140	145	142	142
$\dot{V}O_2$ l.min ⁻¹	.2476	1.678	1.670	1.706	1.674	1.640	1.604	1.670
$\dot{V}_E$ l.min ⁻¹ (BTPS)	6.896	39.11	40.78	41.56	39.70	40.64	37.91	40.30
R	.8286	.9306	.9160	.9126	.8917	.9264	.9036	.9034
Rectal Temp, °C	37.6	37.4	37.4	37.3	37.3	37.2	37.2	37.0
Skin Temp, °C								
1	33.9	23.1	22.2	21.9	21.9	21.8	21.7	21.7
2	33.8	23.7	22.8	22.3	21.7	21.8	21.8	21.8
3	34.2	22.6	21.2	21.1	21.1	21.1	21.1	21.1
4	31.8	21.4	21.0	21.0	21.0	21.0	21.1	21.1
5	32.3	21.4	21.1	20.9	20.9	21.0	21.0	21.0
Mean Skin Temp °C	33.3	22.2	21.3	21.2	21.2	21.2	21.2	21.2

SUMMARY DATA SHEET

GROUP Normal Women WORKLOAD 36W WATER TEMP. 20°

	Rest	5	10	20	30	40	50	60
HR	89	153	156	159	147	150	152	150
$\dot{V}O_2$ l.min ⁻¹	.3024	1.697	1.607	1.703	1.588	1.659	1.720	1.727
$\dot{V}_e$ l.min ⁻¹ (RTPS)	7.868	45.02	40.62	42.36	38.68	39.62	41.95	41.86
R	.84	.94	.90	.89	.86	.86	.87	.87
Rectal Temp, °C	37.3	37.2	37.3	37.5	37.5	37.4	37.4	37.4
Skin Temp, °C								
1	34.0	22.4	22.2	22.2	22.2	22.2	22.1	22.1
2	34.2	22.3	21.7	21.6	21.6	21.7	21.7	21.7
3	34.4	21.6	21.3	21.2	21.2	21.1	21.0	21.2
4	32.1	21.2	21.1	21.1	21.1	21.2	21.2	21.2
5	32.9	21.4	21.2	21.2	21.2	21.2	21.2	21.15
Mean Skin Temp °C	33.5	21.6	21.4	21.3	21.3	21.3	21.2	21.3

SUMMARY DATA SHEET

GROUP Lean Men WORKLOAD 36WATTS WATER TEMP. 20°

	Rest	5	10	20	30	40	50	60
HR	79	110	106	105	106	106	105	150
$\dot{V}O_2$ l.min ⁻¹	.367	1.687	1.764	1.823	1.824	1.882	1.928	1.971
$\dot{V}_E$ l.min ⁻¹ (BTPS)	7.752	33.73	34.96	38.70	38.61	41.06	42.24	43.73
R	.86	.88	.88	.92	.90	.91	.89	.90
Rectal Temp, °C	37.5	37.4	37.3	37.2	36.7	36.3	36.0	35.8
Skin Temp, °C								
1	33.3	21.9	21.8	21.7	21.7	21.6	21.6	21.6
2	34.2	22.4	22.1	21.7	21.6	21.5	21.6	21.4
3	33.5	21.8	21.8	21.4	21.3	21.2	21.2	21.1
4	33.0	21.6	21.4	21.3	21.2	21.3	21.2	21.2
5	32.4	22.1	21.8	21.7	21.8	21.8	21.8	21.8
Mean Skin Temp °C	33.3	21.7	21.6	21.4	21.3	21.3	21.2	21.2

SUMMARY DATA SHEET

GROUP		Fat Men	WORKLOAD	16W	WATER TEMP.		20°	30	40	50	60
		Rest	5	10	20	30	40	50	60		
HR		91	118	111	116	118	120	118	120		
$\dot{V}O_2$ l.min ⁻¹		.4144	1.695	1.706	1.721	1.681	1.686	1.634	1.656		
$\dot{V}_e$ l.min ⁻¹ (BTPS)		11.14	26.29	32.99	35.14	34.20	33.12	32.42	32.76		
R		.88	.83	.84	.94	.90	.89	.88	.90		
Rectal Temp, °C		38.0	37.8	37.8	37.7	37.9	38.0	38.0	38.0		
Skin Temp, °C		33.0	22.6	22.6	22.6	22.4	22.2	22.4	22.2		
1		33.4	22.4	21.6	21.4	21.4	21.4	21.4	21.4		
2		32.0	21.4	21.6	21.0	21.0	21.0	21.0	21.2		
3		31.8	20.4	20.4	21.4	21.4	21.4	21.4	21.4		
5		32.4	22.4	21.4	21.2	21.1	21.1	21.2	21.2		
Mean Skin Temp °C		32.1	21.2	21.3	21.4	21.3	21.3	21.3	21.4		