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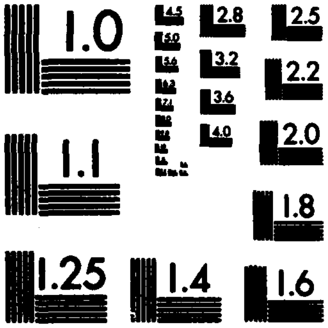
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This study examined whether prolonged exercise employing upper or lower body muscle groups led to significant alterations in differentiated ratings of perceived exertion (diff RPE). Multiple regression analyses were used to identify those physiological respones which accounted for the greatest variability in diff RPE. Nine volunteer males performed 60 min of arm crank (AC) and cycle (CY) exercise at similar absolute (ABS) and at similar relative (REL) exercise intensities. There were no significant differences (P>0.05) between AC and CY for oxygen uptake (VO_2) during the ABS tests ($\sim$1.60 $l \cdot min^{-1}$) or in percent

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ergometer specific peak VO_2 during the REL tests (∿60%). Diff RPE included local RPE (muscle and joint exertion), central RPE (ventilatory and circulatory exertion), and overall RPE. During the ABS tests, the final means for all three diff RPE were lower ($P<0.05$) for CY than AC exercise. No differences ($P>0.05$) were found during the REL tests between AC and CY exercise for any of the diff RPE. Local RPE was generally higher than central RPE. Selected physiological responses accounted for more total variance in all diff RPE for AC than CY exercise (ABS and REL-AC: median $R^2 = 0.99$; ABS and REL-CY: median $R^2 = 0.75$). Lactate and ventilatory equivalent of oxygen made the greatest contribution to R^2. These data indicate that diff RPE may be more closely related to relative exercise intensity, and perceptual cues may be more readily monitored from smaller muscle masses such as the upper body.

DIFFERENTIATED RATINGS OF PERCEIVED EXERTION AND SELECTED PHYSIOLOGICAL RESPONSES DURING PROLONGED UPPER AND LOWER BODY EXERCISE

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Summary. This study examined whether prolonged exercise employing upper or lower body muscle groups led to significant alterations in differentiated ratings of perceived exertion (diff RPE). Multiple regression analyses were used to identify those physiological responses which accounted for the greatest variability in diff RPE. Nine volunteer males performed 60 min of arm crank (AC) and cycle (CY) exercise at similar absolute (ABS) and at similar relative (REL) exercise intensities. There were no significant differences ($P > 0.05$) between AC and CY for oxygen uptake ($\dot{V}O_2$) during the ABS tests (~1.60 $l \cdot min^{-1}$) or in percent ergometer specific peak $\dot{V}O_2$ during the REL tests (~60%). Diff RPE included local RPE (muscle and joint exertion), central RPE (ventilatory and circulatory exertion), and overall RPE. During the ABS tests, the final means for all three diff RPE were lower ($P < 0.05$) for CY than AC exercise. No differences ($P > 0.05$) were found during the REL tests between AC and CY exercise for any of the diff RPE. Local RPE was generally higher than central RPE. Selected physiological responses accounted for more total variance in all diff RPE for AC than CY exercise (ABS and REL-AC: median $R^2 = 0.99$; ABS and REL-CY: median $R^2 = 0.75$). Lactate and ventilatory equivalent of oxygen made the greatest contribution to R^2. These data indicate that diff RPE may be more closely related to relative exercise intensity, and perceptual cues may be more readily monitored from smaller muscle masses such as the upper body.

about

Key words: Arm cranking - Leg cycling - Perceived exertion

Introduction

Over the last two decades, the number of published citations concerning rated perceived exertion (RPE) and physical exercise has increased exponentially (Pandolf 1983). Borg (1962) originally noted that the overall perception of effort during physical exercise represented the integration of various physiological sensations. Others (Ekblom and Goldbarg 1971; Pandolf 1978) have suggested that the major sensory cues arise from feelings of strain in the exercising muscles and joints, and from feelings associated with the cardiopulmonary system. Much of the published literature related to RPE has been concerned with attempts to identify the primary sensory cue(s) underlying the effort sensation and/or investigations of the interplay of multiple sensory cues and RPE (Mihevic 1981; Pandolf 1978; Pandolf 1983).

Two studies (Morgan 1973; Noble et al. 1973) independently concluded that selected physiological responses accounted for approximately two thirds of the variance in RPE during cycle exercise. The remaining unexplained variance (~33%) was suggested to be related to factors of a psychrometric nature (Morgan 1973) and/or other unmeasured physiological responses (Noble et al. 1973). It has also been suggested that the subjective feeling of strain during exercise may be related to the metabolic rate (anaerobic and aerobic) per square area of muscle (Åstrand and Rodahl 1970). Therefore, the association between selected physiological responses and RPE may be different between upper and lower body exercise.

Although the absolute oxygen uptake ($\dot{V}O_2$) has be shown to be highly correlated with RPE (Edwards et al. 1972; Smutok et al. 1980), some studies (Sargeant and Davies 1973; Skinner et al. 1973) strongly suggest that the relative aerobic demand (%$\dot{V}O_2$ max) is a more important determinant of RPE during exercise. While the supportive evidence appears stronger for relative

$\dot{V}O_2$ (Mihevic 1981; Robertson 1982), a systematic evaluation of upper body compared to lower body exercise at similar absolute and relative exercise intensities may provide further clarification. The purposes of the present investigation were (a) to compare differentiated ratings of perceived exertion during upper and lower body exercise at the same absolute and relative exercise intensities, and (b) to examine through the use of multiple regression analyses the identification of those selected physiological responses which accounted for the greatest variability in differentiated RPE. The differentiated RPE included local RPE (muscle and joint exertion), central RPE (ventilatory and circulatory exertion), and an overall (integrated) RPE.

Methods

Subjects. Nine healthy young men volunteered to participate in this study. All subjects gave their written consent to participate after having the procedures and nature of the potential risks of the experiments explained. These subjects had a mean (±SE) age of 22.2 ± 0.9 yr, height of 172.1 ± 2.8 cm, weight of 71.4 ± 2.3 kg, body fat of 13.5 ± 1.8%, cycle peak $\dot{V}O_2$ of 3.44 ± 0.17 $l \cdot min^{-1}$, and arm crank peak $\dot{V}O_2$ of 2.46 ± 0.14 $l \cdot min^{-1}$.

Procedures. All subjects initially completed peak oxygen uptake tests on both arm crank and cycle ergometers according to the procedures outlined by Sawka et al. (1983) and McArdle et al. (1973), respectively. The peak $\dot{V}O_2$ was defined as the highest $\dot{V}O_2$ attained during a maximal effort test for each specific mode of ergometry (Sawka et al. 1983). For these experiments and all subsequent exercise tests, a pedalling rate of 70 rpm was employed for both arm crank and cycle exercise.

After the peak $\dot{V}O_2$ determinations, all subjects completed a submaximal exercise test on the arm crank and cycle ergometers. These two submaximal exercise tests employed a progressive intensity, discontinuous protocol with power output (PO) levels increasing by approximately 16 W for the arm crank and approximately 30 W for the cycle ergometer. The exercise duration at each PO was six min separated by 15-min rest periods. Each of these two submaximal exercise tests was terminated when the subjects reached a $\dot{V}O_2$ (steady state) in excess of 75% of their ergometer specific peak $\dot{V}O_2$. These experiments enabled the determination of individual PO levels for arm crank and cycle exercise at similar absolute and relative intensities.

During the final experiments, all subjects completed two arm crank and two cycle ergometer exercise tests. After a 20 min rest period, each subject exercised for 60 min at a PO that corresponded to a $\dot{V}O_2$ of approximately 1.6 $l \cdot min^{-1}$ or 60% of his ergometer specific peak $\dot{V}O_2$. The order of presentation of these four tests was randomized and each test was separated by a minimum of three days. Environmental conditions for these tests were 24^{o}C, 20% rh.

Measurements. The Borg scale for ratings of perceived exertion (Borg 1970) was used to elicit differentiated RPE. These differentiated RPE were elicited after 10 min of exercise and every 10 min thereafter. During these rating periods, subjects were asked to indicate a "local" muscular rating from feelings of strain in the exercising muscles and joints, a "central" rating for sensations involving the cardiorespiratory system and an "overall" general rating (Pandolf et al. 1975; Pandolf 1978; Pandolf 1982). For the overall rating, the subjects were instructed to integrate their local and central ratings with whatever weightings they deemed appropriate. Questions relative to the mechanics of the rating procedure were addressed but no feedback was provided relative to the translation of feelings or sensations into perceptual ratings.

During these experiments, rectal and skin temperatures were monitored continuously. Rectal temperature (T_{re}) was recorded from a thermistor probe inserted about 10 cm beyond the anal sphincter. A five-point thermocouple skin harness (chest, back, thigh, calf and forearm) was used to monitor skin temperature with mean skin temperature ($\bar{T}_{sk}$) calculated as $\bar{T}_{sk} = 0.21\ T_{chest} + 0.19\ T_{forearm} + 0.16\ T_{calf} + 0.21\ T_{back} + 0.23\ T_{thigh}$.

Respiratory and metabolic measurements were determined by open-circuit spirometry at collection times similar to those used for elicitation of the differentiated RPE. For expired air collections, subjects breathed through an Otis-McKerrow two-way breathing valve connected to 150-liter Douglas bags. Expired O_2 and CO_2 concentrations were determined with an Applied Electrochemistry S-3A fuel cell and a Beckman LB-2 infrared analyzer, respectively. Expired gas volumes were measured using a Tissot spirometer. From these measures, minute ventilation ($\dot{V}_E$, $l \cdot min^{-1}$ BTPS), $\dot{V}O_2$ ($l \cdot min^{-1}$STPD), CO_2 production ($\dot{V}CO_2$, $l \cdot min^{-1}$ STPD), respiratory exchange ratio (R), and ventilatory equivalent for oxygen ($\dot{V}_E/\dot{V}O_2$) were calculated.

During these exercise tests, electrocardiograms were obtained from chest electrodes (CM5 placement) and displayed on an oscilloscope-cardio-tachometer unit (Hewlett-Packard) for the purpose of determining heart rate (HR, $b \cdot min^{-1}$). Systolic (SBP) and diastolic (DBP) blood pressures were measured utilizing a sphygmomanometer on the subject's right arm. To allow this measurement during arm exercise, subjects cranked the ergometer with the left arm while a technician assisted by cranking the right pedal during the measurement period. As an index of myocardial oxygen uptake, rate pressure product (RPP) was calculated as equal to heart rate ($b \cdot min^{-1}$) x systolic blood pressure (mmHg) x diastolic blood pressure (mmHg) x 10^{-4}.

During exercise, venous blood samples were taken at 20, 40 and 60 min of exercise from an indwelling catheter (without interrupting two-arm cranking) placed in a forearm vein. Blood lactate (La) was determined by the enzymatic method of Gutmann and Wahlefeld (1974).

Statistical Treatment. Means, standard deviations, standard errors, and repeated measures analyses of variance were calculated on a desktop computer (Hewlett-Packard 9825). When statistical significance was noted, critical differences were calculated using Tukey's test. Statistical significance was accepted at the $P < 0.05$ level. Forward selection multiple regression analyses were conducted on final values (60 min) for 12 independent variables with differentiated RPE (local, central and overall) as the dependent variable. All 12 variables were stepped down to determine the total accountable variance (R^2) for each of the three differentiated RPE during each of the two arm crank and two cycle ergometer tests.

Results

Each of our nine subjects completed the entire 60 min of exercise for the four prolonged tests. During the tests at the same absolute exercise intensity, similar ($P > 0.05$) $\dot{V}O_2$ values of 1.57 ± 0.19 (arm crank) and 1.64 ± 0.19 $l \cdot min^{-1}$ (cycle) were indeed found. In addition, the tests at the same relative exercise intensity had similar ergometer-specific intensities of 59 ± 2 (arm crank) and $62 \pm 3\%$ ($P > 0.05$).

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TABLES 1 AND 2 ABOUT HERE

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Because of the exploratory nature of this study, no statistical criterion (F test) was used to determine whether each of the 12 independent physiological variables contributed significantly to the R^2. At each step, the physiological variable possessing the highest partial R and greatest contribution to the total accountable variance (R^2) was simply added to the regression. Tables 1 and 2 display the results of the multiple regression analyses with final RPE (local, central and overall) as the dependent variable for absolute (ABS) and relative (REL) arm crank (AC) exercise, respectively. The 12 independent physiological variables used in these and subsequent analyses were T_{re}, $\dot{V}_E$, $\dot{V}O_2$, $\dot{V}CO_2$, R, $\dot{V}_E/\dot{V}O_2$, HR, SBP, DBP, RPP, La, and the ergometer specific $\dot{V}O_2$ peak. The total accountable variance for these AC analyses ranged from 96.2 (overall RPE-REL) to 99.8 (local RPE-ABS). The median R^2 for all differential RPE comparisons during both absolute and relative arm crank exercise was $R^2 = 0.99$.

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TABLES 3 AND 4 ABOUT HERE

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Tables 3 and 4 present the results of the multiple regression analyses for final differentiated RPE during absolute and relative cycle (CY) exercise, respectively. For cycle exercise, the total accountable variance ranged from 38.6 (Local RPE-REL) to 96.7 (Overall RPE-ABS). The median R^2 for all of these differentiated RPE contrasts during absolute and relative cycle exercise was $R^2 = 0.75$. It also appears that the total accountable variance is lower at similar RPE contrasts for relative compared to absolute cycle exercise.

In general, the total accountable variance from these selected physiological responses was much higher for arm crank than cycle exercise for all differentiated RPE contrasts (ABS and REL-AC): median $R^2 = 0.99$; ABS and REL-CY: median $R^2 = 0.75$). Blood lactate and the ventilatory equivalent for oxygen generally made the greatest contribution to the R^2. It also appears that both systolic and diastolic blood pressures are high contributors to the R^2.

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FIGURES 1, 2 AND 3 ABOUT HERE

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Figures 1, 2 and 3 present the absolute and relative exercise intensity comparisons for arm crank and cycle exercise over time pertaining to the local, central and overall ratings of perceived exertion, respectively. Local, central and overall RPE are seen to differ significantly ($P < 0.05$) for all time period comparisons between arm crank and cycle exercise at the similar absolute exercise intensity. In contrast, no differences ($P > 0.05$) were observed during the relative exercise intensity tests between arm crank and cycle exercise for any of the three differentiated RPE. However, there was a trend for the local, central and overall RPE to be somewhat higher for cycle exercise at this relative exercise intensity. In general, local RPE was higher than central RPE at comparable points in time for both of the absolute and relative tests. Interestingly, none of the three differentiated RPE for arm crank exercise at either the absolute or relative intensity reached steady-state values over this 60 min exposure. While local RPE for cycle exercise also did not approach steady-state for the absolute or relative intensity, central and overall RPE reached near steady-state values after 40 min of absolute or relative intensity exercise.

Discussion

Previous studies (Åstrand et al. 1965; Sawka et al. 1982) have shown that upper body exercise (arm cranking) elicits approximately 70% of the peak oxygen uptake seen for lower body exercise (cycling). Our data are in direct support of this contention as the peak $\dot{V}O_2$ for arm crank exercise was 72% of that obtained for cycling exercise. Non-significant differences in $\dot{V}O_2$ between arm crank and cycle exercise during the absolute intensity tests (~1.60 $l \cdot min^{-1}$) and in the percent of ergometer-specific peak $\dot{V}O_2$ during the relative intensity tests (~60% $\dot{V}O_2$ peak) further provide the appropriate methodology to enable comparisons of differentiated RPE at equivalent absolute or relative exercise intensities. In addition, the utilization of a specially constructed arm crank ergometer and a crank rate of 70 rpm (Sawka et al. 1983) facilitated the successful completion of these prolonged exercise tests. To our knowledge, research has not been reported which attempts to quantify changes in differentiated RPE over one hour of prolonged exercise.

Similar to a previous study (Noble et al. 1973), the purpose of the extensive multiple regression analyses performed in this study was not to identify the individual physiological factors linked to differentiated RPE, but rather trends in these physiological responses in terms of greatest accountable variance associated with these differentiated exertional perceptions. In general, blood lactate and the ventilatory equivalent of oxygen made the greatest contributions to R^2 (Tables 1-4). Previous investigators (Allen and Pandolf 1977; Edwards et al. 1972; Ekblom and Goldbarg 1971; Gamberale 1972; Young et al. 1982) have suggested the importance of blood lactate as a major cue in the perception of effort during exercise. However, more recent studies (Löllgen et al. 1980; Robertson et al. 1979) fail to demonstrate any relationship between muscle lactate, blood lactate or blood pH and the perception of effort.

From these combined findings, Mihevic (1981) cautions that if blood lactate influences exertional sensations it's effect is not mediated by the metabolic acidosis. On the other hand, Young et al. (1982) provides compelling evidence in support of the association between $\dot{V}_E/\dot{V}O_2$, as an indicator of respiratory effort, and exertional perceptions. In our study, systolic and diastolic blood pressures also made key contributions to the accountable variance observed in these analyses particularly for arm crank exercise. For a given absolute submaximal exercise intensity, Miles et al. (1983) have demonstrated a greater arterial blood pressure response for arm crank compared to cycle exercise. Both Mihevic (1981) and Robertson (1982) suggest that hemodynamic responses such as blood pressure may provide significant central signals to the effort sensation.

The total accountable variance from these selected physiological responses was greater for arm crank (median $R^2 = 0.99$) than cycle exercise (median $R^2 = 0.75$). In a study employing differentiated RPE, Gamerale (1972) implies that the ability to express feelings of exertion may be greater during exercise employing small muscle groups compared to exercise involving large muscle groups. The perception of effort from smaller exercising muscle groups may be more keen because (a) less extraneous sensory information is processed, and/or, in the case of these experiments, (b) sensory information from the upper body (arms) is more acutely perceived due to greater prior learning from past experiences involving these muscles. During these experiments, it is clearly possible that arterial blood pressure responses contributed as greater perceptual cues for arm crank than cycle exercise. It is also possible, though not probable, that the other selected physiological responses employed in these analyses were more appropriate perceptual predictors for arm crank than cycle exercise.

Over a decade ago, Pandolf et al. (1972) showed that the undifferentiated RPE progressively increased over a 30 min exercise duration with no indication of approaching steady-state values at a similar cycling exercise intensity (~69%$\dot{V}O_2$ max). In the present study, only central and overall RPE reached near steady-state values for absolute and relative intensity cycle exercise after 40 min. For arm crank exercise, however, steady-state RPE was never achieved. These findings indicate that (a) since steady-state values are achieved for cycle exercise but not arm crank exercise the physiological cues may be different and (b) a perceptual steady-state for exercise is reached in a far different manner than a physiological steady-state; and, if at all after a comparably longer time period. In addition, these same differentiated RPE observations provide strong supporting evidence that the relative rather than absolute exercise intensity is more critical in dertermining exertional ratings.

In conclusion, blood lactate and the ventilatory equivalent for oxygen made the greatest contribution to the total accountable variance of differentiated RPE during arm crank and cycle exercise. Arterial blood pressure also appeared to contribute significantly as a perceptual predictor particularly for arm crank exercise. In general, the total accountable variance from these selected physiological responses was much greater for arm crank than cycle exercise. During prolonged exercise, the differentiated RPE appears more closely related to the relative rather than absolute exercise intensity for both arm crank and cycle exercise. In addition, steady-state RPE was occasionally found for lower body exercise but never observed for upper body exercise.

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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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Table 1. Results of the Multiple Regression Analyses of Absolute Arm Crank Exercise

Final RPE	Step	Independent Variable	R	R^2 x 100
LOCAL RPE	1.	DBP	.741	54.8
	2.	DBP, La	.840	70.6
	3.	DBP, La, HR	.894	79.9
	4.	DBP, La, HR, $\dot{V}_{CO_2}$	.929	86.3
	5.	DBP, La, HR, $\dot{V}_{CO_2}$, R,	.961	92.4
	6.	DBP, La, HR, $\dot{V}_{CO_2}$, R, T_{re}	.998	99.7
	7.	DBP, La, HR, $\dot{V}_{CO_2}$, R, T_{re}, RPP	.999	99.8
CENTRAL RPE	1.	$\dot{V}_E$	.747	55.8
	2.	$\dot{V}_E$, SBP	.854	72.9
	3.	$\dot{V}_E$, SBP, HR	.916	83.9
	4.	$\dot{V}_E$, SBP, HR, DBP	.965	93.1
	5.	$\dot{V}_E$, SBP, HR, DBP, La	.975	95.1
	6.	$\dot{V}_E$, SBP, HR, DBP, La, $\dot{V}_{CO_2}$	.994	98.8
	7.	$\dot{V}_E$, SBP, HR, DBP, La, $\dot{V}_{CO_2}$, $\dot{V}O_2$	.998	99.6
OVERALL RPE	1.	La	.709	50.2
	2.	La, DBP	.828	68.6
	3.	La, DBP, HR	.896	80.3
	4.	La, DBP, HR, $\dot{V}_{CO_2}$	.964	93.0
	5.	La, DBP, HR, $\dot{V}_{CO_2}$, R	.973	94.7
	6.	La, DBP, HR, $\dot{V}_{CO_2}$, R, T_{re}	.993	98.6

Table 2. Results of the Multiple Regression Analyses of Relative Arm Crank Exercise

Final RPE	Step	Independent Variable	R	$R^2 \times 100$
LOCAL RPE	1.	R	.603	36.4
	2.	R, SBP	.944	89.2
	3.	R, SBP, La	.975	95.1
	4.	R, SBP, La, DBP	.986	97.3
	5.	R, SBP, La, DBP, T_{re}	.992	98.5
CENTRAL RPE	1.	R	.491	24.1
	2.	R, SBP	.947	89.7
	3.	R, SBP, La	.978	95.7
	4.	R. SBP, La, RPP	.991	98.2
	5.	R, SBP, La, RPP, HR	.992	98.4
OVERALL RPE	1.	R	.564	31.8
	2.	R, SBP	.928	86.1
	3.	R, SBP, La	.972	94.4
	4.	R, SBP, La, DBP	.977	95.4
	5.	R, SBP, La, DBP, HR	.981	96.2

Table 3. **Results of the Multiple Regression Analyses of Absolute Cycle Exercise**

Final RPE	Step	Independent Variable	R	R^2 x 100
LOCAL RPE	1.	$\dot{V}_E/\dot{V}O_2$	.749	56.1
	2.	$\dot{V}_E/\dot{V}O_2$, SBP	.771	59.4
	3.	$\dot{V}_E/\dot{V}O_2$, SBP, HR	.817	66.7
	4.	$\dot{V}_E/\dot{V}O_2$, SBP, HR, $\dot{V}O_2$ peak	.845	71.4
CENTRAL RPE	1.	$\dot{V}_E/\dot{V}O_2$	.695	48.3
	2.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$	.738	54.5
	3.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$, La	.835	69.7
	4.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$, La, R	.913	83.3
	5.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$, La, R, T_{re}	.949	90.0
	6.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$, La, R, T_{re}, RPP	.975	95.0
OVERALL RPE	1.	$\dot{V}_E/\dot{V}O_2$	.617	38.1
	2.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$	.687	47.2
	3.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$, La	.787	61.9
	4.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$, La, R	.890	79.2
	5.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$, La, R, T_{re}	.940	88.3
	6.	$\dot{V}_E/\dot{V}O_2$, $\dot{V}_{CO_2}$, La, R, T_{re}, $\dot{V}O_2$ peak	.983	96.7

Table 4. Results of the Multiple Regression Analyses of Relative Cycle Exercise

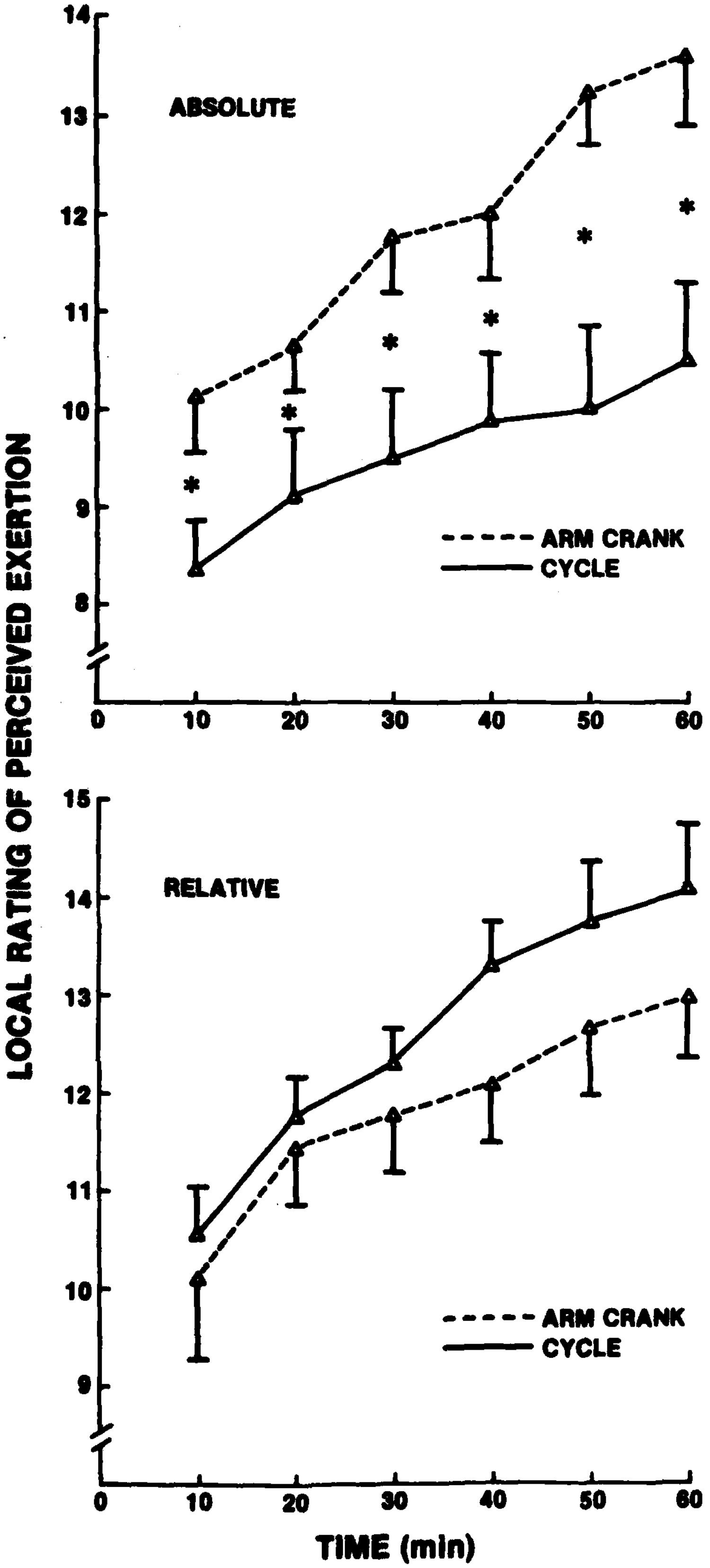
Final RPE	Step	Independent Variable	R	$R^2 \times 100$
LOCAL RPE	1.	$\dot{V}_E/\dot{V}O_2$	.467	21.8
	2.	$\dot{V}_E/\dot{V}O_2$, SBP	.532	28.3
	3.	$\dot{V}_E/\dot{V}O_2$, SBP, T_{re}	.588	34.6
	4.	$\dot{V}_E/\dot{V}O_2$, SBP, T_{re}, R	.621	38.6
CENTRAL RPE	1.	La	.707	50.0
	2.	La, $\dot{V}_E/\dot{V}O_2$	.754	56.8
	3.	La, $\dot{V}_E/\dot{V}O_2$, SBP	.825	68.0
	4.	La, $\dot{V}_E/\dot{V}O_2$, SBP, T_{re}	.860	73.9
	5.	La, $\dot{V}_E/\dot{V}O_2$, SBP, T_{re}, $\dot{V}O_2$ peak	.885	78.4
	6.	La, $\dot{V}_E/\dot{V}O_2$, SBP, T_{re}, $\dot{V}O_2$ peak, R	.901	81.2
OVERALL RPE	1.	La	.636	40.4
	2.	La, T_{re}	.723	52.3
	3.	La, T_{re}, HR	.840	70.5

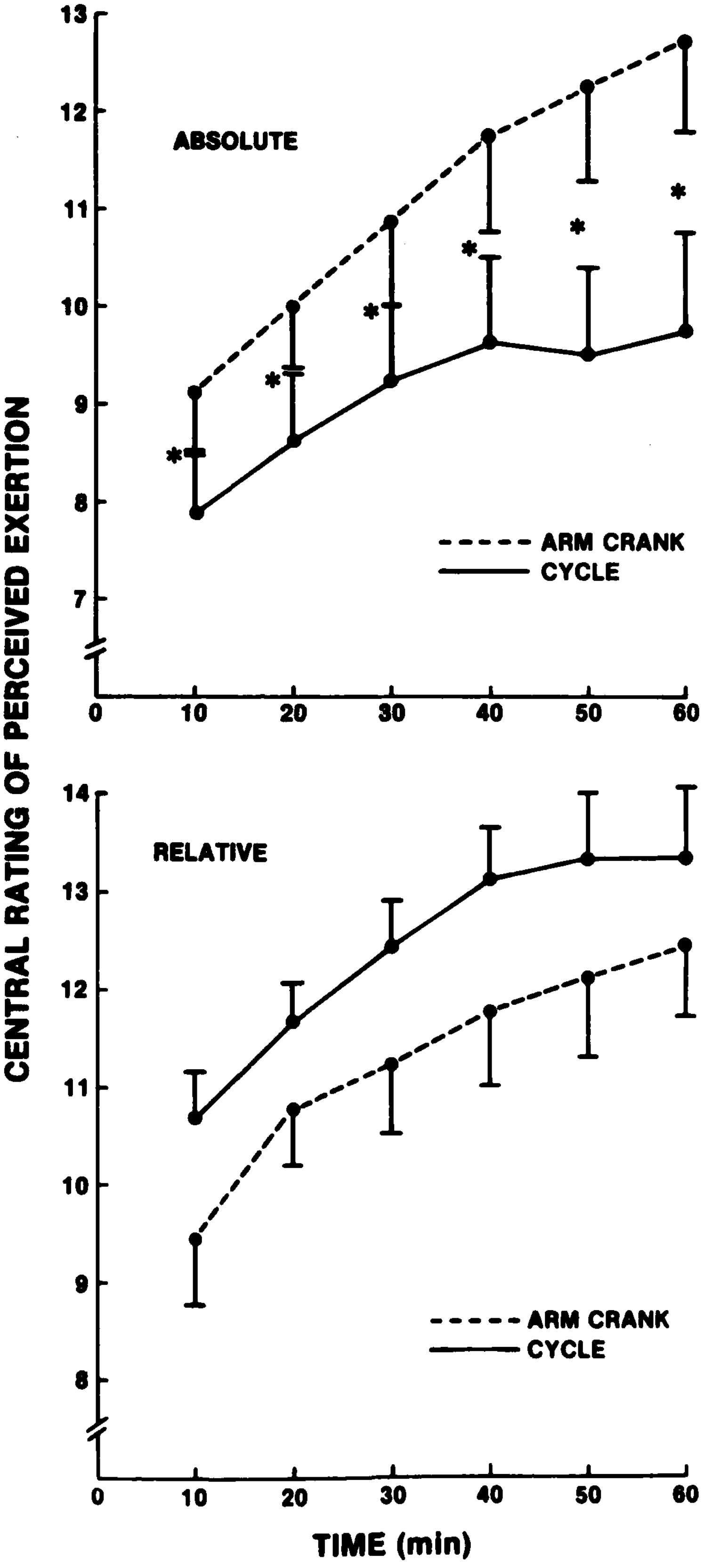
FIGURE LEGENDS

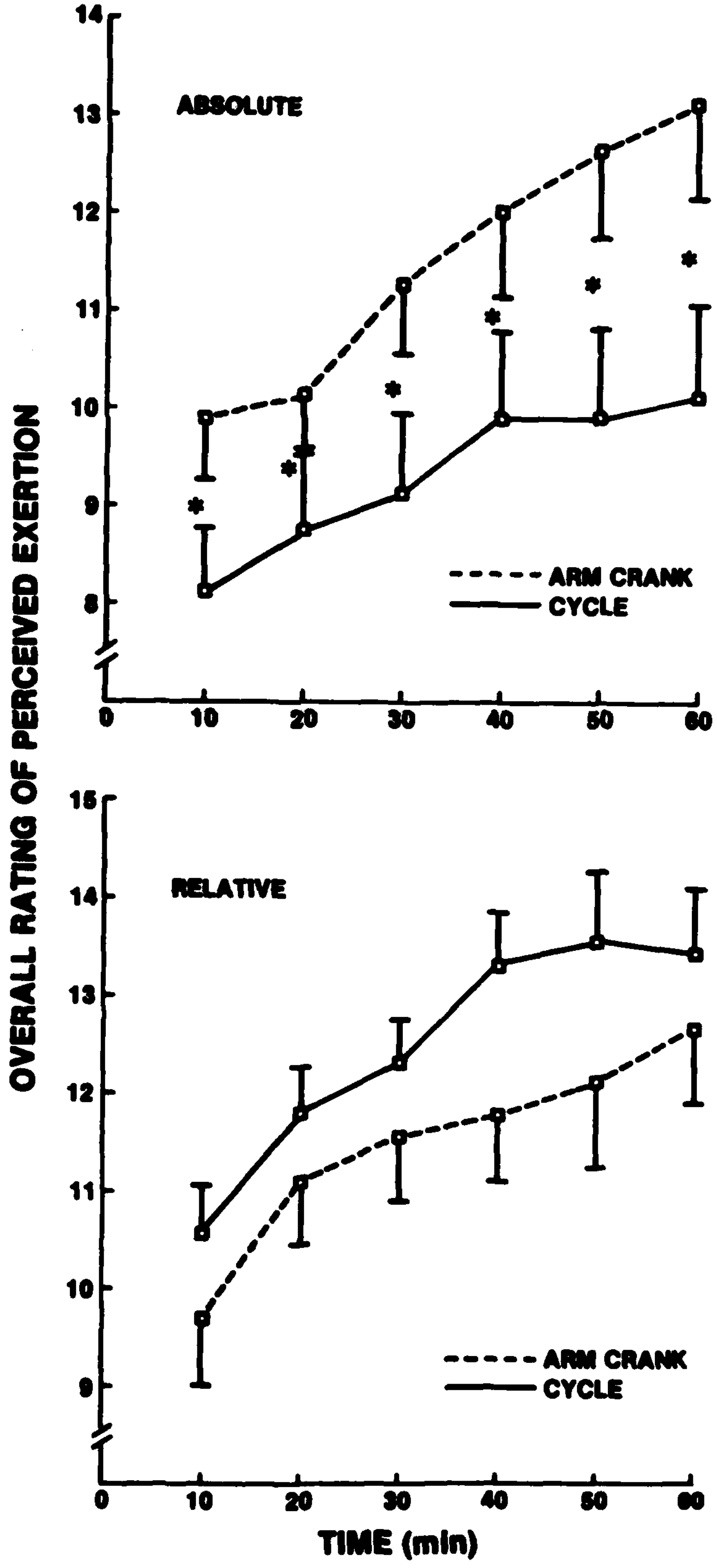
FIG. 1. Local ratings of perceived exertion during prolonged bouts of arm crank and cycle exercise at equivalent absolute and relative exercise intensities. These values represent the mean and plus or minus the standard error at each time point. Asterisk denotes $P < 0.05$.

FIG. 2. Central ratings of perceived exertion during prolonged bouts of arm crank and cycle exercise at equivalent absolute and relative exercise intensities. These values represent the mean and plus or minus the standard error at each time point. Asterisk denotes $P < 0.05$.

FIG. 3. Overall ratings of perceived exertion during prolonged bouts of arm crank and cycle exercise at equivalent absolute and relative exercise intensities. These values represent the mean and plus or minus the standard error at each time point. Asterisk denotes $P < 0.05$.


LOCAL RATING OF PERCEIVED EXERTION
ABSOLUTE
14
13
12
11
10
9
8
0
10
20
30
40
50
60
ARM CRANK
CYCLE
*
RELATIVE
15
14
13
12
11
10
9
0
10
20
30
40
50
60
ARM CRANK
CYCLE
TIME (min)


CENTRAL RATING OF PERCEIVED EXERTION
ABSOLUTE
13
12
11
10
9
8
7
0
10
20
30
40
50
60
*
ARM CRANK
CYCLE
RELATIVE
14
13
12
11
10
9
8
0
10
20
30
40
50
60
ARM CRANK
CYCLE
TIME (min)



OVERALL RATING OF PERCEIVED EXERTION
ABSOLUTE
14
13
12
11
10
9
8
*
*
*
*
*
*
ARM CRANK
CYCLE
0
10
20
30
40
50
60
RELATIVE
15
14
13
12
11
10
9
ARM CRANK
CYCLE
0
10
20
30
40
50
60
TIME (min)