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PERCEIVED EXERTION OF ABSOLUTE WORK DURING A
MILITARY PHYSICAL TRAINING PROGRAM

**U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE**
Natick, Massachusetts

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were measured at the end of each min. of a 6-min. run at an absolute workload of 6 mph, 0% grade on the treadmill. At T_1 , Group II had a significantly lower HR at each min of work but no difference existed in RPE between groups at any time during the run. At T_2 , both groups showed a significant decrease in HR and RPE during each min when compared longitudinally. The data suggest that the perception of the intensity of absolute work does not differ in groups differing in their level of fitness when studied cross-sectionally. However, significant reductions in perceived exertion occur following physical training.

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PERCEIVED EXERTION OF ABSOLUTE WORK DURING
A MILITARY PHYSICAL TRAINING PROGRAM

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This human research study, in protocol form, was reviewed and approved by the Office of The Surgeon General for the Department of the Army in accordance with Army Regulation 70-25.

ABSTRACT

The purpose of this study was to compare the rating of perceived exertion (RPE) and heart rate (HR) in two groups of 40 military personnel who differed in their level of fitness as determined by $\dot{V}O_2$ max. At an initial testing period (T_1), Group I represented a sample of personnel not participating in a training program while Group II had engaged in an endurance program (2-4 mile run/day) for 5 months. Six months later (T_2), Groups I and II were retested after having participated in the program for 6 and 11 months, respectively. RPE and HR were measured at the end of each min of a 6-min run at an absolute workload of 6 mph, 0% grade on the treadmill. At T_1 , Group II had a significantly lower HR at each min of work but no difference existed in RPE between groups at any time during the run. At T_2 , both groups showed a significant decrease in HR and RPE during each min when compared longitudinally. The data suggest that the perception of the intensity of absolute work does not differ in groups differing in their level of fitness when studied cross-sectionally. However, significant reductions in perceived exertion occur following physical training.

Index terms: Cross-sectional study, longitudinal study, maximal oxygen uptake, submaximal ventilation

Introduction

During the past few years it has become evident that perceptual responses to physical work greatly complement the physiological indicators commonly used in exercise studies (7,8,15). Indeed, the subjective rating of the intensity of exertion as perceived by the individual has been proved a reliable and valid physiological stress indicator (5,6). However, measurements of physiological-perceptual responses of work intensity in the evaluation of physical training programs have received little emphasis and have met with conflicting results (7,8,11).

As part of a large-scale study designed to evaluate the efficacy of a physical training program in a U.S. Army infantry division, the opportunity was presented to evaluate both the physiological and perceptual responses to physical training. The objective of the present experiment was to determine whether differences exist in the perception of an absolute workload in groups differing in their level of fitness and whether it changes as fitness changes with a training program.

Methods

Subjects were 80 young male military personnel who underwent two tests (T_1 and T_2) of physiological-perceptual evaluation which were separated by a period of 6 months. At T_1 , two groups of 40 subjects each were comprised as follows: Group I was a sample of personnel who had just been assigned to the division and therefore, had not, as yet, participated in the physical training program; Group II consisted of subjects who were selected randomly from units within the division who had been participating in the training program for a

period of 5 months. At T_2 , all subjects from both Groups I and II were retested after having been in the training program for 6 and 11 months, respectively.

The physical training program consisted of a daily (5 days/week) one-hour mandatory physical training session which was comprised of a calisthenic warm-up followed by a 2-4 mile run at 5-7 mph.

Maximal oxygen uptake ($\dot{V}O_2$ max) was determined on all subjects using a modified version of the interrupted treadmill test described by Taylor, Buskirk and Henschel (16). Each subject performed a submaximal warm-up at an absolute workload of 6 mph, 0% grade for 6 minutes. This was followed by from 2 to 4 interrupted runs of 3-4 minutes duration until a plateau in oxygen uptake occurred with increasing workload. A 5-10 minute rest period was allowed between runs. Expired air was collected in Douglas bags during the last minute of each workload and analyzed with a Beckman E-2 O_2 analyzer and a Beckman LB-1 CO_2 analyzer. Expired air volumes were measured with a Collins chain-compensated gasometer. Heart rate was recorded during the final minute with a Hewlett-Packard Model 1511 electrocardiograph. All subjects were explained the objectives of the study, familiarized with the testing procedures, and signed an informed consent statement prior to participation.

During the last 15 secs of each minute of the 6-minute absolute workload, heart rate (HR) was recorded and the subjects were asked to give a rating of perceived exertion (RPE) according to the psychophysical scale devised by Borg (4). This scale is numbered from 6 to 20 and the uneven numbers are anchored with descriptive terms (i.e., 7, very, very light; 9, very light;

11, fairly light; 13, somewhat hard; 15, hard; 17, very hard; 19, very, very hard). Subjects were told to combine all sensations and feelings of physical stress, effort and fatigue and to thus concentrate on their total feeling of exertion.

A series of two-way analyses of variance for repeated measures were computed for both the HR and RPE.

Results

A summary of the physical characteristics and indices of the level of fitness of both groups during each testing session is presented in Table I. No differences were seen in physical characteristics between the two groups from either a cross-sectional or longitudinal approach. With respect to physiological data, Group II at T_1 had a significantly higher $\dot{V}O_2$ max (7%) and lower HR submax compared to Group I. This suggests a significant difference in the level of cardiorespiratory fitness between the two groups. From a longitudinal evaluation (T_2 vs T_1), Group I showed a significant training effect as evidenced by an increased $\dot{V}O_2$ max (5%) and a decreased HR submax. Group II did not show a further improvement in aerobic power but did show a significant decrease in HR submax.

Figure 1 shows the HR and RPE taken at the end of each minute of the 6-minute absolute workload (6 mph, 0% grade) in Groups I and II at T_1 . This represents a cross-sectional comparison of perceptual responses. HR increased linearly with time reaching a steady-state by 5 minutes of exercise. A significantly lower HR is seen at each minute of work in Group II compared to Group I reaching a mean difference of 14 b/min by the 6th minute. RPE is also seen to increase linearly with time but no difference occurred in RPE between the two groups at any point in the 6-minute run during the pretest.

RPE and HR values with absolute work in Group I during both T_1 and T_2 are shown in Figure 2. This represents, therefore, a longitudinal comparison of the training program. HR again is seen to increase linearly with time during exercise. As a result of 6 months in the training program, the HR decreased significantly (T_2 vs T_1) amounting to 18 b/min during the final minute of exercise. Correspondingly, the RPE also decreased approximately 1 RPE unit at T_2 . Although this was not a large difference (11.7 at T_2 vs 9.9 at T_1 at 6 minutes), it was significant ($p < .05$) during each minute of the workload.

Figure 3 shows the HR and RPE in Group II at both T_1 and T_2 . A significant decrease in HR submax of 8 b/min was seen at T_2 . The HR-RPE relationship again did not change on a longitudinal basis as RPE also decreased significantly during each minute of the run with continued physical training.

Figure 4 shows the HR and RPE data for the two groups compared on a cross-sectional basis during T_2 . No differences in HR or RPE occurred at any time during the 6-minute absolute workload.

Submaximal and maximal ventilations ($\dot{V}_E$) for each group at both testing periods is shown in Figure 5. $\dot{V}_E$ submax was taken during the final minute of the 6-minute absolute workload. At T_1 , $\dot{V}_E$ submax was significantly lower in Group II compared to Group I but this was a difference of only 5 l/min. By T_2 , both groups showed a significant decrease in $\dot{V}_E$ submax of approximately 9 l/min. With respect to $\dot{V}_E$ max, it was somewhat higher (4 l/min) in Group II compared to Group I at T_1 but this was not significant. During the 6-month training period, however, Group I showed a significant increase in $\dot{V}_E$ max of approximately 10 l/min. Group II also showed a slight increase in $\dot{V}_E$ max with continued training but this was not significant.

Discussion

The linear relationship between HR and RPE during submaximal exercise has been demonstrated by several investigators (3,12,16). Indeed, in most work situations HR mirrors the physical strain subjectively experienced. On the other hand, RPE has been shown not to follow HR, per se, when exercising under the influence of heat (14) or drugs (8). In the present study, the HR-RPE relationship was also found to change between two groups who differed in their level of fitness when studied using a cross-sectional design. The data showed that the perception of the intensity of an absolute workload is not reflected by differences in aerobic power due to training. This is somewhat surprising since one would intuitively expect that a more fit individual would perceive an absolute workload as being less strenuous. This would be due presumably to a lesser strain on the cardiorespiratory system and in an improved functioning of working muscles as a result of the training. Results from other cross-sectional studies dealing with perceptual responses to absolute work have suggested that active subjects perceive a given workload to be less strenuous than do sedentary subjects (2,15). However, in neither of these studies was $\dot{V}O_2$ max determined so that the degree of cardiovascular fitness could not be assessed between groups. Furthermore, Nagle et al. (11) in studying successful and unsuccessful Olympic wrestling candidates, found no difference in RPE between these two groups despite the successful group having a higher $\dot{V}O_2$ max and a lower HR submax at the same workload.

Although the reasons for the change in the HR-RPE relationship seen cross-sectionally are not readily apparent, two possibilities exist which could account for such a finding. First, it may be that RPE is not as

sensitive an indicator of the degree of exertion as are various physiological indices. Some suggestion of this is seen in view of the fact that Groups I and II were working at approximately 80% and 75% of their respective maximal oxygen uptakes. This may not represent a large enough difference with respect to perceiving the amount of work being performed.

- Another possible explanation lies in the type of work that was done.

It has been shown that RPE during submaximal bicycle exercise is higher than equivalent work performed on the treadmill (2,8,16) due presumably to a greater local factor contribution, i.e., feeling of strain in the working muscles (8). This would assume that with treadmill work local factors are not as dominant and such central factors as HR, $\dot{V}_E$ and $\dot{V}O_2$ become more important. Reports in the literature relating to the mechanisms by which the intensity of exertion is perceived support the concept that ventilatory variables are more readily perceived during exercise than other central factors (8,10,13,14). Indeed, Bakers and Tenney (1) have shown that ventilatory rate and volume can be perceived with a high degree of correlation between actual (physical) and estimated (psychological) magnitude of variable. Therefore, the small change of 5 l/min in $\dot{V}_E$ seen in the present study between the two groups at T_1 , may be a significant reason for the absence of any change in the perception of absolute submaximal work despite an improved maximal aerobic capacity.

In most longitudinal studies, the HR-RPE relationship has been shown to remain unchanged with training in that both are reduced at the same submaximal workload (7,8,9). Linderholm (9) studied Swedish military conscripts before and after 4 months of training. Both HR and RPE were reduced approximately

20% at the same submaximal workload following training. Essentially the same finding was reported by Docktor and Sharkey (7). Ratings at a HR of 150 were not altered following a 5-week training program. However, the time to reach a HR of 150 was significantly increased, thus it occurred at a higher workload. In another investigation at given submaximal $\dot{V}O_2$ levels, RPE was reduced 1.5-2.0 points following training (8). Results from the longitudinal portion of the present study support the above findings as seen by the decrease in HR and RPE in Group I during the 6-month training period. This is, of course, important to consider since a given work task in daily life activity, such as in manual work, should be perceived more easily. However, the findings in Group II of a decrease in HR and RPE during submaximal work despite no further change in $\dot{V}O_2$ max with continued training is perplexing. It may be that naive subjects, such as used here, undergo a certain degree of "habituation" to the work or increase their efficiency during submaximal work which is reflected by decreases in both physiological and psychological responses to the workload. This may represent an inherent problem in the use of such subjects in a longitudinal study. Another problem in the longitudinal approach are the demand characteristics placed on the subjects which become important in such volitional assessments as RPE. One or both of these factors may be partially responsible for the changes seen in the longitudinal portion of the study.

Although it was not the intention of this study to examine the mechanisms by which the intensity of exertion is perceived, it is of interest to note that changes in $\dot{V}_E$ submax correlate well with the changes seen in RPE for both the cross-sectional and longitudinal comparisons. Although RPE, as measured by the Borg scale, is a general response resulting from multiple physiological inputs (8,12,13), it is suggested that ventilation is one of the primary cues to the perception of the intensity of submaximal work.

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FIGURE LEGEND

Figure 1. Perceived exertion and heart rate during absolute work in Groups I and II at T_1 . $\bar{X} \pm SE$.

Figure 2. Perceived exertion and heart rate during absolute work in Group I at T_1 and T_2 . $\bar{X} \pm SE$.

Figure 3. Perceived exertion and heart rate during absolute work in Group II at T_1 and T_2 . $\bar{X} \pm SE$.

Figure 4. Perceived exertion and heart rate during absolute work in Groups I and II at T_2 . $\bar{X} \pm SE$.

Figure 5. Submaximal and maximal ventilation in Groups I and II during both T_1 and T_2 . $\bar{X} \pm SE$.

Table I. Physical Characteristics, Submaximal Heart Rate and Maximal Oxygen Uptake of the Two Groups at Both Testing Sessions.

	T ₁		T ₂	
	Group I	Group II	Group I	Group II
Age (yr.)	21.7 ± 0.7	22.3 ± 0.5	22.2 ± 0.7	22.3 ± 0.5
Height (cm)	175.2 ± 1.1	176.9 ± 0.8	175.4 ± 1.2	176.7 ± 0.9
Weight (kg)	71.0 ± 1.9	71.1 ± 1.3	70.7 ± 1.6	72.1 ± 1.4
HR submax	178 ± 2	164 ± 2*	161 ± 2**	157 ± 2 [†]
$\dot{V}O_2$ max (ml/kg min)	50.1 ± 0.1	53.7 ± 0.1*	52.5 ± 0.1*	52.8 ± 0.1

$\bar{x} \pm SE$; *p < .01, Group II vs Group I at T₁; **p < .01, Group I at T₂ vs Group I at T₁; †p < .01, Group II at T₂ vs Group II at T₁

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