EFFECT OF EXERCISE-INDUCED ACTIVATION
ON SIMPLE REACTION TIME

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運動による生体賦活度と単純反応時間との関係

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生体賦活の程度によって、パフォーマンスがどのように変化するかについては、逆U字型を示すという報告がみられる。生体の賦活を運動によって引きおこした場合に、パフォーマンスは逆U字型を示すのか、示すならばパフォーマンスが最高を示す時の生体賦活状態が見出せるので、その状態を知る目的で、この研究を行った。

パフォーマンスとしては単純反応時間を選び、坐位、運動中（トレッドミルでの歩行として80m/分，100m/分，走行として150m/分，200m/分）にほぼ10秒間に1回の割合で連続測定した。同時に、心拍数，その他の生理的機能も連続測定した。被験者は大学男子18名である。

その結果、心拍数が100bpmのときに、最も反応時間が短かく、拍数が100bpmよりも増加しても減少しても、反応時間は延長した。いわゆる逆U字カーブが見られた。

呼吸数は15〜30回/分、換気量は8〜30l/分、酸素摂取量は0.4〜1.2l/分、エネルギー消費量は2〜8Cal/分の範囲内が最も反応時間の短縮を示した。しかしながら、心拍数のような明確な逆U字カーブは、この実験方法からは見られなかった。

Abstract

The volunteers for this study were eight male college students, aged 18~23 years. Each subject performed the simple reaction time trials under the various levels of exercise. Physiological measures of exercise-induced activation were chosen among the heart and lung functions.

The theoretical relationship between activation and performance is represented by an inverted U-curve. The optimal performance of heart rate (HR) seemed to be demonstrated
at the point of HR of 100 bpm; that of respiratory rate (RR), below the point of RR of 30 breaths/min; that of \( \dot{V}_E \), below the point of \( \dot{V}_E \) of 30 1/min; that of \( \dot{V}_O_2 \), below the point of \( \dot{V}_O_2 \) of 1.2 1/min; and that of energy expenditure, below the point of calory of 8 Cal/min. HR as an indicant of exercise-induced activation forms an inverted U in the relationship between activation and performance. The implications of these findings are discussed.

Little research has been made focussing on the effect of exercise-induced activation (EIA) on motor skill performance. Näätänen (5), and Levitt and Gutin (4) have recently investigated the above mentioned problem. Näätänen (5) reported that the effect of the induced heart-rate increased on the simple reaction time (RT), randomized interstimulus intervals varying from 1.5 to 2.5 seconds as measured during the 30-sec period immediately after cycling. In the study simple RT was examined while the subjects were pedaling a bicycle ergometer at loads of 300, 600, 900, and 1,200 kpm/min. The highest workload brought about a mean heart rate (HR) of 142 beats per minute (bpm). Optimal performance was demonstrated at the load of 600 kpm/min in which the mean HR was 106 bpm. It should be pointed out, however, that an identical workload was given to all subjects in the study. This undoubtedly, therefore, led the individuals to attain somewhat different HR depending on their degrees of physical fitness.

It was found by Levitt and Gutin (4) that five-choice RT was optimal at a HR of 115 bpm and was worst at 175 bpm, thereby, supporting the hypothesis of an inverted U which represents relationship between activation and choice RT. The improvement in performance at 115 bpm over the rest condition, however, was not significant.

The authors of this study have found it difficult to hold HR relatively constant at specified levels. No study has been made concerning the effect of exercise-induced activation (hereafter EIA) comparing with the heart and lung functions. The present study, therefore, was undertaken to provide more information about optimal point of simple RT in cardiorespiratory and also about inverted U curves to various degrees of exercise.

Methods

Eight male undergraduate students at Kochi University volunteered as subjects. Each subject performed the RT trials under the following different conditions: at rest and during runs on a motor-driven treadmill (0 % grade) at 80, 100, 150, and 200 m/min of speed. The treadmill (Takei) with which running speed ranges from 50 to 280 m/min was also used in order to control the EIA. A red light was situated 1.5 meters in front of the treadmill runway. Continuous measurements were made during the ten-minute running of each load as well as the ten-minute resting period.

The HR was successively monitored by means of radiotelemetry (Sanei TM-201).
Fig. 1 Experimental apparatus. A-stimulus, B-microswitch, C-precordial electrodes, D-transmitter, E-oxygen and carbon dioxide analyzer, and F-motor-driven treadmill.

Fig. 2 Relationship between minimum reaction time and other parameters: heart rate (HR), respiratory rate (RR), expired ventilation (VE), O₂ uptake (VO₂), and energy expenditure (Cal).
Duplicate measurements of O$_2$ and CO$_2$ fractions, ventilatory volumes and respiratory rates were continuously recorded with an analyzer (Fukuda Electrometabolor BMS-600) (Figure 1).

Results

Figure 2 illustrates the minimum RT at each level of EIA. It appears that optimal performance was demonstrated when the parameters are such as follows: HR is the point of 100 bpm; respiratory rate (RR) is less than 30 breaths/min; $\dot{V}O_2$ is less than 1.2 l/min; and energy expenditure is less than 8 Cal/min.

Discussion

Physical exercise has a great effect on variety of the organs and systems of the body. For example, experiences indicate the increased force and rate of the heartbeat, and the increased ventilation accompanying with vigorous activities. Persons interested in athletic performance have attempted to determine the effects of prior exercise on subsequent performance in various athletic events. This type of study refers to warm-up or fatigue effects. Up to now, the effect of such exertion on the performance has been a neglected area in the sport-medical field. Concerning physical work capacity, however, Åstrand and Rodahl (1) in their textbook remark that the performance capacity is related to the maximal oxygen uptake in exercises with large muscle groups vigorously involved for one min or longer. No one can attain top results in such exercises without a high performance, since technique and psychological factors may have a modifying influence in a positive or negative direction. It is certainly desirable to determine optimal performance of such tasks, and many sports require skilled performance and decision making during or immediately after strenuous exertion.

The central nervous bombardment from the stimuli originated from various muscles (cardiac, respiratory, and skeletal) increases metabolic activity in the tissues of the organism at any moment. Activation level can obviously be affected by muscular exercise. The relationship between activation and performance theoretically takes the form of an inverted U, that is, as activation level increases, performance improves up to an optimal point and then deteriorates with further increases in activation. The level of activation that is optimal for one task, however, may not be optimal for other tasks.

Sjoberg (6) examined dual choice RT. Subjects worked at loads of 150, 300, 450, 600, and 750 kpm/min for 5.5 minutes and then performed the RT trails while continuing to pedal. EIA levels ranged from relatively low to moderately high. The results took a clear-cut inverted U form with best performance occurring at the 450 kpm/min workload. The mean HR at this workload was 121 bpm.

Näätänen (5) reported a study of HR and simple RT for different power levels; 0, 300, 600, 900, and 1,200 kpm/min during the 30-sec period immediately after cycling. Optimal performance was demonstrated at 600 kpm/min, at which load the mean HR was 106 bpm.

Gutin, et al., (3) conducted the study that examined the effect of 5~6 min of prior exercise...
on a bicycle ergometer at HR of 100, 130, and 160 bpm on arm steadiness. There was no significant difference between the performances following the exercises with which the HR was 100 and 130 bpm, respectively. Using prepedaling performance as the baseline, the decrement in performance due to EIA was 35, 53, and 181% for the HR of 100, 130, and 160 bpm, respectively. No inverted U curve appeared.

Levitt, et al., (4) found with optimal performance at 115 bpm and the poorest performance at 175 bpm. Subjects walked on a treadmill at HR of about 80 (standing still), 115, 145, and 175 bpm. After several minutes of walking at the specified HR, the subject performed a 5-choice RT task. A curvilinear relationship between EIA and 5-choice RT was shown by an inverted U curve.

In 1972, Burke (2) also measured the effect of exercise which raised HR to 120, 140, 160, and 180 bpm on dynamic balance performance. He found an inverted U function with optimal performance following 7 minutes of the exercise at 120 and 140 bpm, being followed by performance dropping off sharply following the exercise at 160 and 180 bpm.

In general, the results of this experiment support the hypothesis that an inverted U relationship exists between performance level and the level of arousal, although they obviously do not show optimal point. A follow-up study now in progress will employ dual choice RT that the subject has to inhibit his movement until he decides to which of the two directions to move.

**Conclusion**

As the level of exercise-induced activation increases, performance improves up to an optimal point and then deteriorates with further increases in exercise-induced activation. Heart rate as an indicator of exercise-induced activation shows the form of an inverted U. However, optimal point between exercise-induced activation and other physiological responses was not clear.

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