THE CHANGES IN PSYCHOMOTOR PERFORMANCE DURING PROGRESSIVE ENDURANCE EXERCISE

by

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The study was aimed at the evaluation of psychomotor performance during an incremental endurance exercise in dependence on the concentration of lactate (LA), adrenaline (A) and noradrenaline (NA) in the blood. Twenty two 3rd league soccer players aged 21.3±1.4 years with an average maximum oxygen uptake (VO_{2max}) of 53.8 $ml \cdot kg^{-1} \cdot min^{-1}$ volunteered to take part in the experiment. During an incremental cycling exercise the choice reation time (CRT) and the number of proper reactions (NPR) were recorded at consecutive workloads during which venous blood samples were drawn for analyses of LA, A and NA in order to determine the lactate, adrenaline and noradrenaline tresholds. Two phases were identified in the workload-dependent changes in psychomotor performance. During the first phase of the incremental endurance exercise the choice reaction time (CRT) decreased significantly ($p<0.001$) while NPR increased, whereas during the second phase there was an opposite tendency ($p<0.001$) to an increase in CRT with a concomittant decrease in NPR. The highest psychomotor performance was recorded at 76% VO_{2max} (HR=164 ± 4.7 $beats \cdot min^{-1}$). The shortest CRT and the highest NPR were recorded at the workloads exceeding LA, A and NA tresholds.

Introduction

Psychomotor fitness plays an important role in competitive sport and everyday life activities of men. It depends on mental processes as well as on peripheral elements of the movement system. Psychomotor fitness plays a significant role in soccer, since during the game great changes in workload occur as well as frequent changes in game situations. This form of fitness is necessary not only for the evaluation of particular game situations through fast, precise and valid cognition, reaction and anticipation of player's own activities,

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those of his partners and opponents. Psychomotor fitness is also necessary for information processing that enters the CNS and efficient decision making and conducting especially under conditions of increasing fatigue. The application of all these psychomotor abilities during a competitive game situation is related to optimal steering and regulation of motor activities of players.

The commonly applied methods for evaluation of psychomotor fitness under different conditions of physical activity include the measurements of reaction time (Geblewicz 1973). In many of the scientific centers reaction time is treated as one of the basic coordination abilities (Blume 1981, Raczek and Mynarski 1992). These abilities reflect the complex relationships between neuro-psychological factors of the CNS which allow for effective motor control of human movement (Raczek 1991).

Many authors (Baylor and Spiriduso 1988, Rikly and Busch 1986, Jette et al. 1988, Chmura et all. 1990, 1993) undertook research attempting to evaluate the effects of physical exercise on reaction time. These studies were most often conducted under conditions of rest and immediately after the cessation of exercise protocol. Very few research projects evaluated the changes in reaction time during exercise of submaximal or maximal intensity (Seyler 1990, Schriedt 1990, Ziemba et al. 1999). The research of Chmura et al. (1994, 1998) indicated that choice reaction time during physical exercise of progressive intensity gradually decreases until a certain workload and then after exceeding it increases drastically.

During competitive sports of particular importance is the maintenance of high psychomotor fitness during situations of growing fatigue. The current review of literature does not clearly explain the relationships between metabolic, hormonal and psychomotor changes during intensive physical efforts.

The goal of this research was to analyze the relationships between two basic components of psychomotor fitness: choice reaction time and the number of proper reactions with lactate concentration as well as plasma adrenaline and noradrenaline during a endurance exercise of graded intensity.

Material and methods

The research project included 22 soccer players of the 3rd league aged 21,3 ±1,1 years with a average maximal oxygen uptake of 53,8 ml/kg/min. The research included only healthy subjects, which gave written consent for participation. The endurance exercise test was performed on an ergocycle (Siemens, Germany) with a maintenance of steady frequency of pedaling (60 rpm). The starting load for the test was 50 W, which was increased every 3 minutes also by a value of 50 W until maximal oxygen uptake was reached (VO_{2max}). During the exercise heart rate was monitored by the use of the sport tester (PE3000, PolarElectro, Finland) and oxygen uptake was evaluated through the use of a MEDGRAPHICS analyzer (AVL, Austria). The one minute rest interval was used between consecutive workloads during which blood samples were drawn from antecubital vein for the determination of lactate concentration (LA), adrenaline (A) and noradrenaline (NA).

The measurements of choice reaction time (CRT) and the number of proper reactions (NPR) were conducted with the use MRK432 apparatus (ZEAM, Poland).

To become familiar with the multiple reaction time tests the subjects performed 5 to 7 test trials. The CRT test included 15 positive (red light or a sound) and 15 negative (green and yellow light) stimuli applied in randomized order. The subjects were asked to press and release, as quickly as possible a button on a right handlebar of the cycle in response to a red light, the button on the left handlebar in response to a sound, and not to react to negative stimuli. The CRT was determined to the nearest 0,01 s and the results are given as a mean of 15 responses to the positive responses. Choice reaction time and a number of the proper reactions were measured at rest and during the last two minutes of each 3 min. workload until a maximum load was reached.

After each workload the concentration of LA, A, and NA were evaluated in the blood. Lactic acid threshold was calculated using the two segmental linear regression log LA vs. log exercise intensity according to Beaver et al. (1995). The same method was applied to calculate adrenaline and noradrenaline thresholds.

Blood lactate was evaluated enzymatically with the use of commercial kits (Boehringer, Manheim, Germany). The level of adrenaline and noradrenaline were determined with the use of a radioenzymatic method of Da Parada and Zucher (1979) with the application of Chemapol CO tests (Czech Republic).

The statistical analysis was performed using non-parametric Wilcoxon and Mann-Whitney U test and significance was assumed for $p \leq 0,05$. The linear regression was also calculated to determine the relationship between obtained variables.

Results

During graded endurance exercise CRT decreases significantly ($p \leq 0,001$) until reaching the level of the optimal load (first phase). The shortest reaction time (SRT) was registered at a workload corresponding to 76% of VO_{2max} and heart rate of 164±4,7 beats per min. After exceeding this workload a drastic increase in CRT occurs (fig.1) until the moment of cessation of the test (second phase). The reaction time obtained during the last workload was 105 ms longer from the SRT ($p \leq 0,001$). The changes in the second variable representing psychomotor fitness, the number of proper reactions were similar to those of CRT. During the first phase of the SRT 100% of the reactions were conducted properly (fig. 1).

The changes in blood lactate, adrenaline and noradrenaline concentrations during progressive endurance exercise have a threshold character. The threshold workloads were respectively: TLA -189±5,3 W, TA - 204±11 W and TNA - 208±10. The noradrenaline threshold was significantly higher ($p \leq 0,05$) from the lactate threshold. In case of the adrenaline threshold (TA) a similar tendency was observed, but the difference in relation to the lactate threshold was statistically insignificant.

This research indicated that SRT and the highest differentiation of visual and auditory stimuli occurs above the lactate and catecholamine thresholds.

Discussion

This research project evaluated the influence of progressive endurance exercise on two basic indicators of psychomotor fitness in relation to metabolic and hormonal changes. A bi-phasic character of changes of choice reaction time and the number of proper reactions confirm the threshold character of changes in psychomotor fitness during exercise of progressive intensity. This indicates, that not only metabolic and hormonal indices, but psychomotor ones have a threshold character during graded exercise. This data confirmed the earlier experiments conducted by Chmura et al. (1993, 1994).

This research allowed to indicate that the SRT and highest number of proper reactions appeared above the lactate threshold determined on the basis of blood lactate concentration. In relation to absolute workload expressed in watts, the highest level of psychomotor fitness occurred at a level exceeding the threshold value. The results of this study project did not confirm our assumptions that a rise in the concentration of lactate would impair motor control processes. From the psychophysiological point of view it appears that efficiency of the CNS, and especially centers which are responsible for reaction time and properness of reactions individual optimal intensity is reached. The conducted research allowed to state that after passing the anaerobic threshold reaction time may be improved up to a certain workload and state of fatigue which is dependent on the physical fitness of particular athlete (Buła and Chmura 1984). The above mentioned observation is also confirmed under competitive game conditions during which the SRT and a highest level of differentiation occurred under lactate levels exceeding the anaerobic threshold (5,2 mmol/l). Such a conclusion possesses a high practical value because it appears now that training sessions requiring psychomotor efficiency can be conducted at intensities above the lactate threshold. The study suggests that other components of speed, especially speed of perception and anticipation as well as the speed of information processing and decision making may improve at exercise intensities exceeding the anaerobic threshold. One can suspect that similar changes will occur in relation to other coordination abilities.

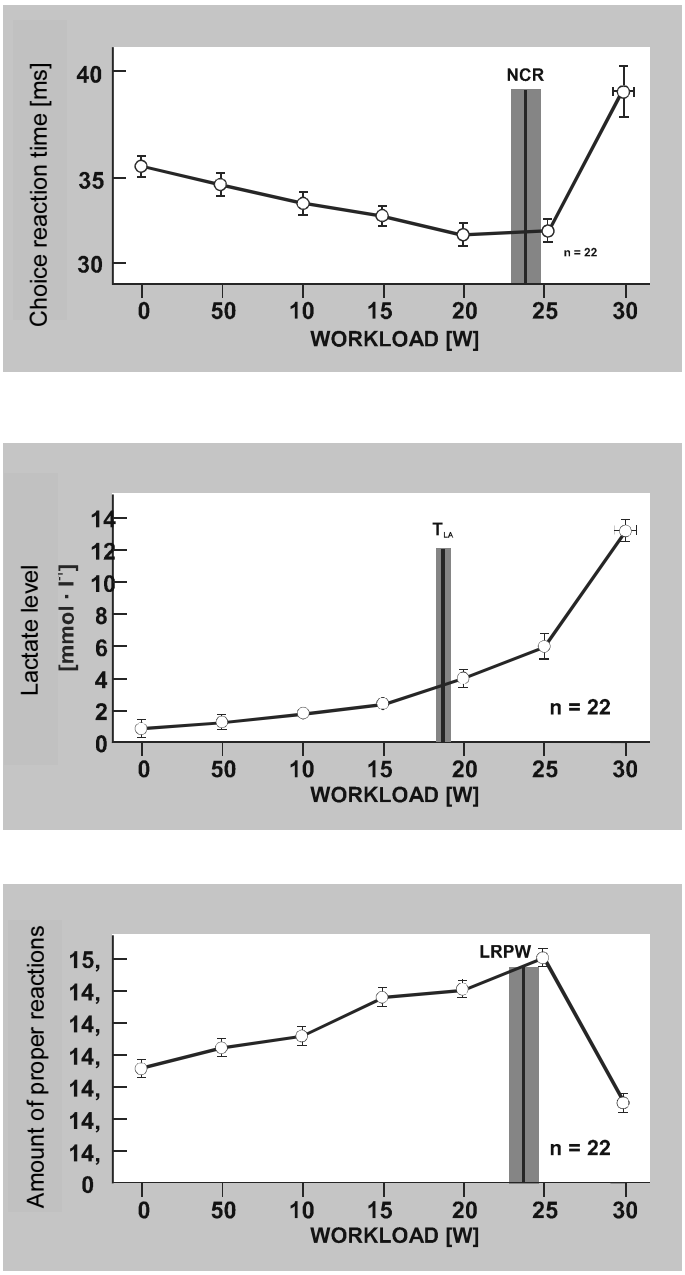

Fig. 1 Results of reaction time, amount of proper reactions and lactate level

The relation between CRT, A and NA concentration in blood plasma has a hyperbolic shape of letter U, which confirms Duffy's hypothesis in light of which psychomotor fitness increases with the arousal of the CNS up to an optimal point. Further arousal of the CNS causes decreases in psychomotor fitness. It is well known that the concentration of catecholamines in blood plasma reflects indirectly the stimulation of the sympathetic nervous system. Despite that, its increase is a commonly accepted indicator of reactions of this system to the psychological and physiological stimuli, including physical exercise (Kjaer 1989, Sothmann et al. 1991, Wallin 1984). The mechanisms of rapid increase in plasma catecholamine concentration at a particular workload is yet not fully explained. It is still not known to what degree the catecholamine threshold is dependent on CNS stimulation by the stimuli from motor centers, and to what degree on the peripheral mechanisms; initiated by stimuli from muscular chemoreceptors (Kjaer 1989).

This research indicates that at the catecholamine threshold blood plasma activation of the CNS does not exceed optimal values for the processing of stimuli occurring during the measurement of reaction time. A quick and significant increase in catecholamine concentration during further workloads up to the maximum individual load reflects the exceeding of the level of optimal CNS activation which results in a drastic decrease in psychomotor fitness.

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