2 Physiology of Jogging

MB DIKSHIT

THE importance of exercise towards maintenance of positive health has been recognised since 10 AD and to date physicians continue to prescribe it for a more healthy living. As such the body is built to be active and thrives on exercise. A regimen of physical activity builds up endurance of the heart, lungs and muscles, stimulates various other organs such as the liver and kidney, reduces nervous tension and is said to promote "well being".

Each individual has his own exercise and fitness continuum. The reasons for a fitness programme are as follows depending on the age group of the individuals :

15-25 years	:	For competitive sports,
26-35 years	:	Keeping weight under control,
36-45 years	:	Keeping fit to avoid coronary heart disease and other diseases.
46 and above	:	To keep generally fit.

The importance of having physically fit personnel, especially aircrew, in the Air Force needs no stressing. Variety of fitness programmes may be followed which include jogging, on the spot running, walking, ball and racquet games and swimming.

Jogging has been found to be a favourable medium for a 'keep fit' programme. By definition jogging means 'slow monotonous trotting'[10] and involves the muscular effort for running. The physiology of jogging, therefore, is more clearly understood on considering the bio-mechanics and physiology of running.

Bio-mechanics of Jogging/Running

Running involves work against gravity (vertical displacement of the centre of gravity) as well as work generated while attaining forward motion. The total mechanical work in running up to speeds of 15-20 kph is about 0·4 to 0·5 Kcals/Kg/Km (Cavagna et al[3]) and for slower running speeds, as in jogging, is expected to be lesser. Running efficiency is quite high (40—50%) and is due to the elastic recoil of muscles/tendons. The speed of running is attained by the length of the stride and number of movements per unit time[1] and from this it becomes obvious that both dimensions are dependent upon the frequency and power of muscle contractions. Therefore an important aspect of the physiology of jogging involves the understanding of physiology of muscle contraction, its effect on oxygen consumption and the responses of the cardiorespiratory system to meet with these requirements

Muscle Physiology in Jogging

Through nervous control, muscles of the body (in this case mainly of the lower extremities) are commandeered to contract. These contractions are transferred to the skeletal system through the tendon attachments. Electron microscopy has revealed that during contraction the actin and myosin filaments slide over one another to generate tension and produce contraction. This in turn determines the chemical energy release in the contracting muscle.

The Fuel for Muscle Contraction

The main sources of energy for muscular contraction are carbohydrate and fat. The breakdown of glycogen or glucose aerobically produces 39 moles of ATP which in turn are used up for the energy needed in contracting the muscle by splitting up ATP to ADP and Pi (energy). The ATP is resynthesised by the donation of a high energy P bond from creatine phosphate. It is this step that is oxygen dependent. During aerobic submaximal exercise as in running, this process of break up of and resynthesis of ATP to generate energy which in turn is transduced to mechanical energy and heat is kept matched. The amount of oxygen and glycogen delivered are adequate for the purpose. However, during intense exercise or under conditions where oxygen transport is not adequate to resynthesise the ATP, the extra ATP must be any how provided. This comes from formation of lactic acid because here the lactic acid must be the acceptor of H_2 from NADH which should normally have been oxidised to NAD by oxygen. Unfortunately, the lactic acid energy yield is poor being only about 1/20th of the aerobic glucose oxidation[1]. Hence, in mild to moderate exercise when the muscle is able to meet its energy requirement aerobically the blood lactate does not increase. But in severe to exhaustive exercise when anaerobic energy yield becomes a necessity, blood lactate increases markedly.

Oxygen Consumption during Exercise

An excellent method of gauging the efficiency of the individual while performing exercise is his oxygen consumption. An increased muscular efficiency and physical fitness are indicated by improving VO_2. Cooper[5] has based his 12 minutes test on the VO_2. He correlates the distance covered in a period of 12 minutes with this parameter. Greater the distance covered (in miles) in 12 minutes, greater is the VO_2 max and hence the physical fitness. In the IAF a fit individual is expected to cover one mile in 10 minutes or if looked at from Cooper's classification, 1·2 miles in 12 minutes. This corresponds to a maximum oxygen consumption of 25-34 ml/Kg/min or about 2·1 L/min. An extremely fit and trained individual will have an oxygen consumption of about 52 ml/Kg/min. Horvath[7] reports the highest value of 88 ml/Kg/min. Jogging in terms of energy output gives about 5-8 Kcal/Kg/min equivalent to about 1·5 litres VO_2/min which for an average individual amount to about 70% of the max VO_2[1]. Cardiorespiratory fitness is by far the most important aim of exercise and therefore the submaximal exercise cardiovascular responses would aptly describe the changes that occur in jogging.

The main physiological response to exercise is a coordinated chain reaction, probably by some higher centres, and involves the cardiopulmonary, endocrinal and thermoregulatory systems[7]. The main aim of the involvement of the various systems is to supply adequate oxygen to the working muscles because in the final analysis it is the availability which determines endurances to prolonged work and therefore the oxygen transport mechanisms play a vital role in tolerance/training to exercise.

The Cardiovascular System during Exercise

The cardiovascular system contributes by an increase in heart rate and increased power of contraction of the myocardial muscles. The response is initiated probably by higher centres which results in an increased sympathetic drive with a withdrawal of parasympathetic tone. The cardiac output is increased and redistributed with the working muscles getting a bulk of the share. Blood flow to the splanchnic areas and skin reduces due to the vasoconstriction produced by sympathetic stimulation. The large scale vasodilatation of the resistance vessels with an increased tone in capacitance vessels increases markedly the venous return to the heart. This is also the likely factor in the increase of heart rate during exercise by initiation of the Bainbridge's reflex, though most believe that during exercise in an intact animal, this may not be an important factor.

The increase in blood pressure is mainly in the systolic pressure with a slight increase or no change in the diastolic pressure. In fact an increase in diastolic pressure during even sumaximal work out by 15 mm Hg has been taken as an indication of coronary artery disease[13]. The increase in systolic blood pressure should normally lead to a reflex fall in heart rate through the carotid baroreceptor mechanisms. But this does not happen, probably because the baroreceptor reflex is turned off during exercise[9].

The increase in heart rate during exercise is one of the major factors aiding the cardiovascular system to maintain a high level of cardiac output. This increase during moderate exercise as met with in jogging (about 50-70% of VO_2 max) should be around 130 beats/min[1]. The rise occurs initially because of a release from parasympathetic tone and later due to increased sympathetic drive[11]. A number of factors have been thought to be contributing to the neural regulation of heart rate and include afferent reflexes from working muscles and tendons[9], and involvement of higher centres and from chemoreceptors[11].

The stroke volume also increases during exercise. This increase is more dependent upon greater systolic emptying due to increased myocardial contractility rather than the Starling mechanism[11]. In submaximal exercise some contribution of stroke volume to increased cardiac output has been suggested. The increase in stroke output due to exercise becomes more obvious in the erect posture[1].

Respiration during Exercise

Ventilation increases during exercise. This increase is both rate and volume dependent. At VO_2 of about 1 - 1.5 L/min as in moderate exercise the minute ventilation (VE) is about 25 L and expected to be around 30—35 L/L of oxygen consumed during max work, during submax exercise the steady state in ventilation is reached within few minutes and adjusted to meet the oxygen requirements and provide adequate carbon dioxide excretion. But even at maximal exercise the VO_2 and VE is the limiting factor.

A further help in delivery of the much needed oxygen to the tissue is given by the rightward shift of the oxygen dissociation curve which ensures a more rapid delivery of oxygen to the tissues.

Exercise Training

Physical fitness in young Indians is lesser than that found in subjects of more developed countries and one of the contributing factors is less participation in physical activity[2]. Physical training promotes cardiorespiratory endurance and at this stage the various physiological changes that occur in an individual during exercise training will be considered.

By far the most significant changes of even submaximal exercise training are reflected upon the cardiovascular system and as jogging is considered to be submaximal in nature, it is expected to produce cardiovascular adaptations. The major cardiovascular training effects are :

a) a reduction in resting and submaximal exercise heart rate,

b) an increase in stroke volume, obvious mainly at maximum exercise,

c) an increase in cardiac output manifested during maximum exercise, and

d) reduced peripheral vascular resistance in trained muscles.

The most obvious change is a reduction in resting and submaximal exercise heart rate[4] though the maximum heart rate does not alter[7]. For such change to be established the training sessions should be severe enough to produce heart rates above 130/min.[12] The mechanism of this phenomenon is not clear. The training bradycardia usually erases itself in about three weeks if training is discontinued[1,12]. Bradycardia effect is most obvious when the exercise is performed with trained muscles while a part of the bradycardia also manifests itself with exercise with untrained muscles.

Myocardial contractility increases with training[4,7] and this is a factor contributing to increased stroke volume. The maintenance of a normal cardiac output is due to the increased stroke volume aided by the increase in circulatory fluid volume. In fact in highly trained individuals the cardiac output during submaximal exercise may actually diminish.

Submaximal exercise training produces a variable effect on resting blood pressure. There may be no change or a slight reduction in both systolic and diastolic pressures.

Exercise training results in increased VO_2 max. This occurs because of a greater delivery of nutrients to the working muscles due to a reduced resistance to blood flow, an increase in the oxidative capacity in skeletal muscles due to an increase in size and/or number of the muscle cell mitochondria, as well as an increase in enzymes content and activity. There is also an increase in the number of capillaries per unit area in the muscle[7].

Physiologically, exercise training with running/ jogging does produce beneficial effects. There are certain principles, however, on which an exercise trainining programme must be based[6]. These are :

a) Balanced aim of the fitness programme, i.e., keeping fit, shedding excess weight and above all to promote cardiorespiratory endurance by inclusion of correct exercises.

b) Specificity of exercise programme and its regularity must be strictly followed. It should be indulged in at least three times a week and up to a maximum of five times per week.

c) It is very essential to 'warm up' before an exercise and 'cool down' after it.

d) The most important aspect of physiologic training is to overload the system for adequate cardiopulmonary adaptation. This overload must manifest itself as a heart rate of 130 or more beats per minute in healthy young individuals or about 60—70% of maximum heart rate. In older individuals the maximum heart rate reduces and therefore the level of cardiovascular overload which must be given also reduces slightly.

Conclusions

a) Jogging as a form of exercise to keep fit or to improve cardiorespiratory adaptation is strongly recommended.

b) For an effective programme, the exercise must be performed at least thrice weekly to a maximum of five times a week and the aim should be to achieve a heart rate of around 130 per minute.

c) A pre-exercise warm up is a must.

d) Pre-training level of physiological state is reached in about three weeks time and breaks from exercise should not exceed that time if cardiorespiratory fitness is to be maintained.

e) Jogging is a way of living with fitness and should be included in the normal life style of ever individual.

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