The Relation between Exercise Duration and Intensity on Phosphocreatine (PCr) Level: an Article Review

Aprilia Durotun Nasikhah[1], Roy Januardi Irawan[2], Trias Mahmudiono[3*]

[1]Bachelor of Nutrition, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia, [2]Doctoral of Public Health, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia, [3]Health Nutrition Department, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia

Abstract

Exercise is a physical activity that planned, structured, and sustainable. Exercise has 4 criteria, that is frequency, intensity, type, and duration. During exercise, phosphocreatine (PCr) depletion increases, and early intracellular acidosis has occurred. These changes contribute to a decrease in training capacity in terms of training duration. This literature review aimed to determine the relationship between the intensity and duration of exercise with the concentration of PCr and recovery factors. The literature study has carried out by selecting an Experiment research design. The results of the review showed that PCr was the largest energy contributor in the first 10 seconds of exercise in the heavy-intensity exercise where phosphocreatine triggers energy without oxygen or anaerobic. The recovery of PCr influenced by a person's health condition and age. The concentration of PCr in children was higher than in adults because of the relatively high rate of oxidative ATP formation. It proved that there was a significant relationship between PCr and the duration and intensity of exercise.

Keywords: *Exercise duration, Exercise intensity, PCr, Phosphocreatine*

Introduction

Health is considerable for humans. Everyone must be healthy to maintain physical fitness so that they can carry out daily activities. According to the Indonesian Law No. 23 of 1992 concerning health states that health is a state of well-being of body, soul, and society which enables everyone to live productively socially and economically(1). Health can be pursued in various ways, one of which is by exercising.

Exercise is a physical activity that has planned, structured, and continuous by involving regular and repeated body movements to improve physical fitness and achievement(2). Exercise is useful for maintaining and increasing mobility and independence to move in human bio-psycho-sociologic life(3). Exercise has four criteria, that is frequency, intensity, type, and duration(4).

Corresponding author:
Trias Mahmudiono
Email: trias-m@fkm.unair.ac.id

Exercise can stimulate the disruption of homeostasis and change the physical and chemical environment of cells. Exercise can cause body temperature to increase, increase blood acidity, decrease oxygen in fluids, and increase CO2. Environmental changes in the body start at the receptors, namely body cells that will stimulate complex response pathways. This pathway causes changes in nerve activity (nerve pathways), hormonal changes (hormonal pathways), and exchanges in specific pathways (intrinsic pathways). Also, chemical, mechanical and thermal stimuli affect changes in metabolic, cardiovascular, and ventilator functions to meet increased demand(5).

Exercises of longer duration (2-3 minutes) that rely primarily on oxidative metabolisms, such as swimming and long-distance running, are classified as aerobic activities. Many sports activities require a combination of anaerobic and aerobic metabolism. In stop and go sports, about 60% -70% of energy comes from ATP storage from phosphocreatine (PCr) and anaerobic glycolysis, the remaining 30% from oxidative processes(6).

Phosphocreatine (PCr) is a high-energy compound that has a high-energy phosphate bond that can be hydrolyzed into energy and can resist ATP. In physical activity or strenuous exercise such as sprinting, PCr in the skeletal muscles makes a big contribution for the first 10 seconds. The storage of PCr will quickly run out but, in the first few seconds of exercise, PCr provides a significant buffer before other aspects of metabolism are activated(7).

During exercise, physical activity, or exercise, PCr depletion increases, and early intracellular acidosis has occurred. These changes contribute to a decrease in training capacity related to exercise duration(8).

Material and Method

This study used a literature review method. The article search strategy has carried out by using international or national journal articles that ware searched through Google Scholar and PubMed. Through the keywords searched were exercise duration, exercise intensity, phosphocreatine, and PCr, from Google Scholar website founded 31 articles of search results and on the PubMed website as many as 13 articles. Then, screening has carried out by selecting articles that were relevant to the topic, namely the effect of exercise duration on phosphocreatine (PCr) levels. The articles selected were articles with inclusion criteria using Experiment research methods. The exclusion criteria in this literature review were articles that were not related to the topic of the effect of exercise duration and intensity on phosphocreatine levels.

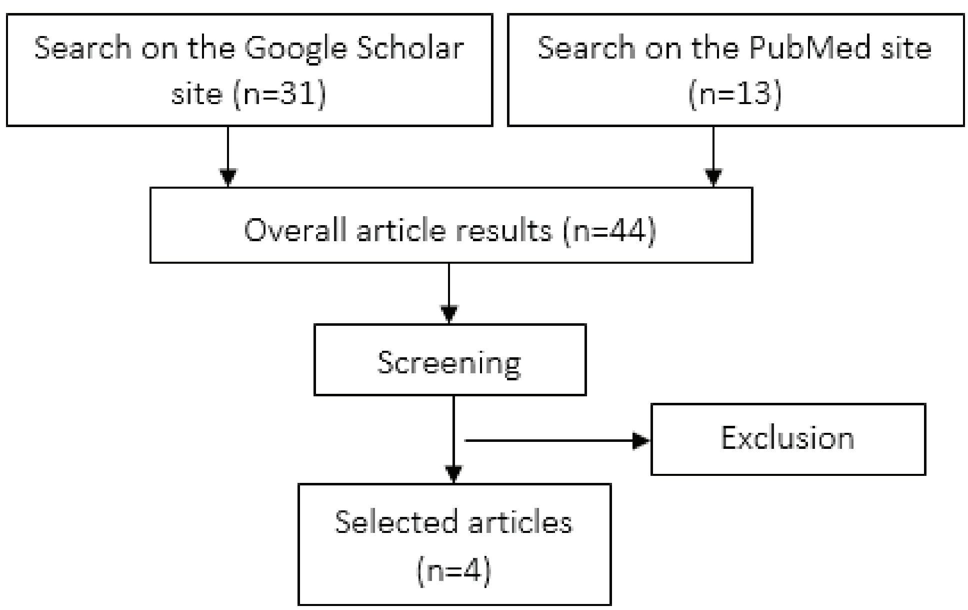

Figure 1. Consort diagram of research articles Effect of Exercise Duration and Intensity on Phosphocreatine Levels (PCr).

Results and Discussion

Various types of sports can be an option to maintain body fitness. However, it is considerable to note in planning exercise activities that at least four criteria are met, namely the frequency of exercise, intensity/weight of exercise, type of sports activity, and length of time exercising(4). In sports, various kinds of metabolism will produce different types of waste products, one of which is creatinine.

Creatinine is a chemical waste molecule that results from muscle metabolism. Creatinine has produced from creatine, a molecule that is essential for energy production in muscles. About 2% of keratin in the body is converted to creatinine every day. Creatinine is transported through the bloodstream to the kidneys. Creatinine levels are determined by the amount of muscle mass (protein catabolism rate), in addition to how our body's metabolic activity, for example, increases when we are sick (heat/infection). Creatinine is produced during skeletal muscle contraction through the breakdown of creatinine phosphate[9].

Muscles use phosphocreatine during the first few seconds of intense muscle contraction, such as during weight lifting or sprinting. Unlike aerobic contraction, which utilizes oxygen to produce energy, phosphocreatine triggers energy without oxygen or is anaerobic[10].

Bogdanis et al. stated that aerobic metabolism provides a significant part (~ 49%) of energy during the second sprint, whereas PCr availability is important for high power output during the initial 10 s[11]. This is supported by the statement of Hall and Trojian that creatine monohydrate can improve muscle performance in a short duration, and high-intensity resistance training will rely on the transport of phosphocreatine to become adenosine triphosphate so that an increase in the level of total creatine in cells will allow for the faster synthesis of phosphocreatine[10]. Increasing the creatine level in the body can delay fatigue because creatine can be re-synthesized and sent back to the site of ATP use more quickly[12]. Fatigue during short-term high-intensity exercise is related to the availability of PCr because PCr can regenerate ATP at very high rates, and its concentration in muscle is limited[13].

The energy at the start of a workout or exercise that uses very high-intensity muscle work (85% -100% of maximum capacity) and has a short duration (up to 10 seconds) has determined from the small amounts of ATP and PCr stored in muscle cells [5,11]. The total energy available in the stored ATP-PCr is sufficient for short duration exercises, such as lifting weights, high jumps, or 10-second sprints[14].

The amount of energy generated from the PCr has limited because of the intramuscular pathway. The high anaerobic demands on the muscles can decrease muscle PCr concentration. At the same time, in a short period of maximum exercise, the anaerobic utilization of muscle PCr and glycogen will trigger muscle contraction[15]. Short-term contractions are associated with metabolic changes in the muscle so as decreased muscle phosphocreatine[16].

According to Haseler, Hogan, and Richardson, in skeletal muscle, PCr recovery from submaximal exercise is a measure of muscle-oxidative capacity. PCr recovery was significantly altered by FIO2 and after submaximal exercise, in normoxic conditions, PCr recovery was limited by O2 availability[17]. Also, The PCr recovery time constant is prolonged in patients with the symptomatic peripheral arterial disease (PAD), whether differences in PCr recovery time result entirely from changes in tissue blood flow, alterations in skeletal muscle at a cellular level, or a combination of both deserves further investigation[18].

In patients with PAD symptoms, the PCr recovery time constant is longer than that of ordinary people, so it is recommended for PAD sufferers to do sports with a long duration of intensity[19]. Also, there is the notion that phosphate regulation and muscle O2 utilization is fully mature in peri-pubertal children, which may be due to the comparable capacity for mitochondrial oxidative phosphorylation in child and adult muscles[19]. The relatively higher rate of oxidative ATP build-up in children's muscles to mask the ATP demand from high-intensity intermittent exercise compared to adults, allows children to start each exercise interval with a much higher concentration of PCr and lead to more muscle acidification. Low overall[20].

Conclusion

From the review above, it can conclude that PCr has a significant relationship with exercise duration and intensity. PCr is the largest energy contributor in the first 10 seconds of exercise in a heavy-intensity exercise where phosphocreatine triggers energy without oxygen or anaerobic, so with an increase in creatine phosphate capacity, very high-intensity exercise performance can be improved. PCr concentration is not only influenced by the duration and intensity of exercise, but also by health conditions and age.

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