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Analysis and Research on Experimental Model of Exercise-Induced Fatigue

Houyong Zhong [1, 4], Cuimei Wang[1], Zhen Wan[2], Jinpei Lei [3]

1. Faculty of Physical Education, Gannan Normal University, Ganzhou 341000, China
2. Kaiping maternal and child health care family planning service center of Guangdong Province, Kaiping, 529300, China
3. Kaiping Central Hospital of Guangdong Province, Kaiping, 529300, China
4. Research and Training Center for Enhancing Quality of Life of Working-Age People, Khon Kaen University, Khon Kaen 40002, Thailand

ABSTRACT. *Exercise-induced fatigue is a common physiological phenomenon for all of the athletes, and it is a research hotspot in the field of sports and sports medicine. How to cause exercise-induced fatigue is a very important step for this kind of research. This article analyses and researches the experimental models of exercise-induced fatigue used by researchers in the previous studies. There are two kinds of experimental model of exercise-induced fatigue, which include animal models and human models. Then, each model has many different examples.*

Keywords: *Exercise-induced fatigue; Experimental model; Animal model; Human model*

1. Introduction

Exercise-induced fatigue is a physiological phenomenon that occurs during exercise. Research on the mechanism of exercise fatigue has been one of the most concerned projects in the field of sports medicine. But one of the problems that must be solved before this is how to cause exercise fatigue. It is necessary to determine the experimental model of exercise-induced fatigue before the research. Therefore, it is very meaningful to sort out, statistics, analysis, and research on the experimental models used by researchers.

2. Experimental models of Exercise-induced fatigue

Most of the experimental studies on exercise-induced fatigue are carried out under experimental conditions. Hence, how to make the experimental object to achieve the predetermined exercise-induced fatigue is an important part of the study. There are several methods or criteria to separate the exercise-induced fatigue models, and subject is the most popular classification of it. According to this criterion exercise-induced fatigue models can be divided into animal model and human model.

2.1 Animal models of exercise-induced fatigue

In the clinical research, a number of tests have some harm on the human body, or because it is unsuitable to use human to do the early period experiments, so animal instead human is a better choice. Considering the limitations of the experiment, such as economic conditions, test cycle, the mouse became the first choice, studies have shown that the mouse gene and human similarity can reach more than 98%, which ensures the reliability of the study, the rat breeding cycle Short, reproductive ability is also very conducive to the experiment. In the study of exercise-induced fatigue, the researchers have established some systematic and standard models of exercise-induced fatigue.

In the current sports research, treadmill model and swimming model is more widely used in animal experiment study. Some researchers use swimming model (see table 1) to induce exercise fatigue, and they often use the weight swimming method to add the exercise intensity. Some researchers use treadmill model (see table 2) to induce exercise fatigue, and they often gradually increase the exercise load through increasing the treadmill slope and speed to add the exercise intensity. There are different ways to diagnose exhaust exercise-induced fatigue, and different exercise-induced fatigue degrees have different appearances (see table3). The results show that the maximal load of lactic acid (MLLA) is similar anaerobic threshold, which is the critical load of transition from aerobic to anaerobic metabolism. The human body experiment has confirmed the blood lactic acid concentration and the exercise intensity exponential relationship; the study found that in rats' treadmill model, when the speed reaches 20m / min, then the rat will appear MLLA and anaerobic threshold. In rats swimming model, when the load reaches 5% -6%, MLLA and anaerobic threshold will appear. So speed in 20m/min and load 5%-6% is the critical point, if the intensity more than it, exercise type belongs to anaerobic. In contrast, if the intensity less than it, exercise type belongs to aerobic. Most scholars have formed a consensus that swimming model is better than treadmill model. The reasons include: firstly, easy to maintain exercise intensity at a high level. Secondly, most of the required equipment is easily available. Thirdly, swimming has a more pronounced effect on the heart. Fourthly, the subjects can suffer from less adverse stimuli.

Table 1 Exercise-induced fatigue swimming models of rats

study	**Exercise-induced fatigue models**
Ahmet et al.	Just swimming no weight
Gouvea HA et al.	Weight 5% of the body, a low intensity
Marangon L et al.	Graduate to add the weight, 5%, 7%, 9%, 11%, 15%
Raul et al.	Weight 8% of the body
Manchado et al.	Weight >5% of the body and <5%% of the body respectively

Table 2 Exercise-induced fatigue treadmill models of rats

study	Exercise-induced fatigue models
	The same load models
Ghanbari et al.	Slope 0^o, speed 26m/min
YQ Liu et al.	Slope 0^o, speed 30m/min
Hokari F et al.	Slope 0^o, speed 26m/min
Noble EG et al.	Slope 2^o, speed 26m/min
Yoshimura A et al.	Slope 6^o, speed 26m/min
Comachione A et al.	Slope -16^o, speed 26m/min
	Gradually increasing the load
Jongoh et al.	Slope 0^o, increase speed from 2m/min to 8m/min gradually
Adaliene et al.	Slope 0^o, increase speed from 12m/min to 16m/min gradually
Hatice et al.	Slope 8^o, speed 12m/min ,22m/min, 25m/min, respectively
Halil et al.	Slope $5\text{-}8^o$, increase speed from 10m/min to 27m/min gradually

Table 3 Exercise-induced fatigue level scale of rats

Exercise forms	Exercise-induced fatigue level scale	
Treadmill	Mild fatigue:	Rats could not keep pace with the intended speed, but were able to keep up with the predetermined speed after repeated stimulation.
	Moderate fatigue:	Rats completely unable to keep up with the scheduled speed, but after reducing the speed of exercise, and repeated stimulation, then rats still can perform exercise.
	Severe fatigue:	Even if the treadmill speed is reduced to zero, after repeated stimulation to drive the rats still cannot exercise, the rat abdomen completely attached to the treadmill, repeated stimulation of the limbs no longer exercise, muscle system function loss.
Swimming.	Mild fatigue:	Rats swimming action just appeared uncoordinated, water submerged nose, but less than 10s still surfaced, placed on the plane can complete the righting reflex.
	Moderate fatigue:	Rats swim obvious inconsistency, sinking into the water 10s cannot surface, but on the plane can complete the righting reflex.
	Severe fatigue:	Rat swimming action completely uncoordinated, struggling, sinking into the water 10s cannot surface, placed on the plane cannot complete the righting reflex.

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2.2 Human model of exercise-induced fatigue

2.2.1 Whole body fatigue models

In the sports research, most of the researches use bicycle fatigue model and treadmill fatigue model to induced exercise whole body fatigue. Gordon BA et al, use treadmill fatigue model to study chronic fatigue syndrome, the experiment protocol is **"**Using the initial speed of 5km / h, slope of 0o, and then maintain the same running speed, every 2min increase of 2o of the slope until the treadmill slope to 14%, the slope is no longer changed, this time every 1min Increase 0.5km / h, until the movement is terminated.**"** Erling A et al, use treadmill severe fatigue model to study quantifying training, the experiment protocol is **"**the treadmill slope was maintained at 3%, the initial velocity was 7 km / h, and then increased speed 0.75 km / h per 1 min until exhaustion.**"** Michael L et al use bicycle fatigue model to compare the physiologic responses with other protocol, the bicycle fatigue protocol was administered on an electronically controlled bicycle ergometer (Quinton Instruments, Model 844) that allows work load to remain constant at variable pedal rates. Subjects were encouraged to pedal at between 60 and 70 rpm. The bicycle test work load began at 200 Kilopond meters per minute (Kpm/min) for 3 minutes and was subsequently increased by 100 Kpm/min every 3 minutes thereafter, the termination point for test was volitional exhaustion.

2.2.2 Local fatigue models

Exercise-induced knee muscles fatigue model: Fernando et al use Exercise-induced knee muscles fatigue model to study fatigue effects on position sense of the knee in the elderly. Experiment protocol (see figure 1) **"**The local load applied to the lower limb extremity consisted of 30 consecutive maximal gravity corrected concentric contractions of the knee extensors and flexors on the isokinetic dynamometer (Biodex System 2, NY, USA) at an angular velocity of 120^{o}/ s(2.09 rad/s)[1]. Verbal encouragement was given to the subjects motivating them for working maximally. Before the protocol, the subjects performed a warmup consisting 5 min of cycling in a mechanically braked cycle ergometer (Monark E-824, Vansbro, Sweden) with a fixed load corresponding to 2% of body mass, and also performed nine submaximal concentric contractions of the knee extensors and flexors, immediately followed by one maximal contraction at the test speed on the isokinetic dynamometer in order to familiarize with the isokinetic device. Subject positioning and joint alignment was per- formed according to previous works (Magalhaes et al. 2004): subjects were seated on the dynamometer chair at 85% inclination (external angle from the horizontal) with stabilization straps at the trunk, abdomen and thigh to prevent inappropriate joint movements. The knee of the exercised limb was positioned at 90^{o} of flexion (0^{o}= fully extended knee) and the axis of the dynamometer lever arm was aligned with the distal point of the lateral femoral condyle. Subjects were also instructed to hold their arms comfortably across their chest during exercise, to further isolate knee joint flexion and extension movements[2]. Local fatigue of the knee muscles was evaluated by measuring

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changes (decline) in peak torque from the beginning to the end of the fatigue protocol. A fatigue index was calculated according the formula: Fatigue index = (initial peak torque × final peak torque) / initial peak torque ×100. Initial peak torque and final peak torque were the average of the first and the last five repetitions peak torques of the fatigue protocol.**”**

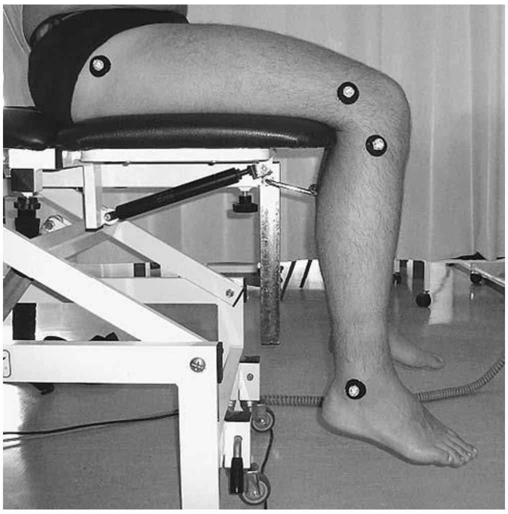

Figure 1 Exercise-induced knee muscles fatigue model

Exercise-induced back muscles fatigue model: Hidetoshi et al, use Exercise-induced knee muscles fatigue model to study the effect of massage on blood flow and muscle fatigue. Experiment protocol (see figure 2) **“**Before each session, subjects were asked to lie in a prone position on a treatment table with their hands crossed behind their heads. After the proper attachment of electrodes was confirmed, subjects were instructed to slowly extend their trunks until the inferior portion of their rib cage no longer rested on the table. Subjects then held this position for 90 seconds before slowly returning to the resting position (Load I). They then received either massage on the lumbar region or rested for 5 minutes. Subjects were then asked to extend their back in the same manner as before (Load II).**”**(Hidetoshi Mori, 2007). There are some others protocols to induce exercise back muscle fatigue, such as, figure 3, 4, 5, 6.

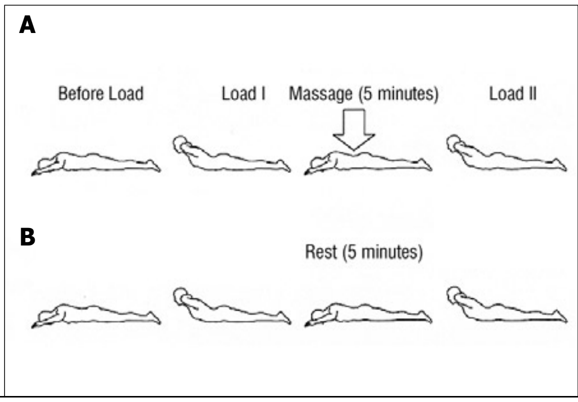

Figure 2 Exercise-induced back fatigue model

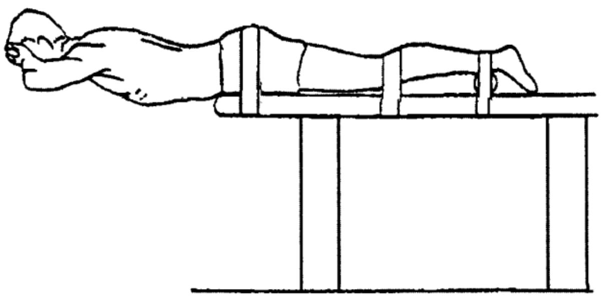

Figure 3 Testing position for Sorensen test. Subject holds horizontal position either to fatigue or to a set stopping time. This figure illustrates modified Sorensen position, because hands are at side of head rather than crossed in front of chest[4].

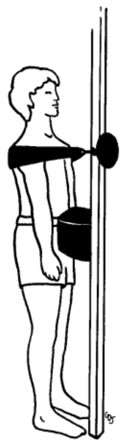

Figure 4 Drawing shows pulling test described by Jorgensen and Nicolaisen. Subject stands facing strain-gauge dynamometer, is then strapped to dynamometer, and attempts maximal backward extension while pelvis is supported. Subject pulls at 60% of MVC under control of supervisor until no longer able to maintain 60% value[5].

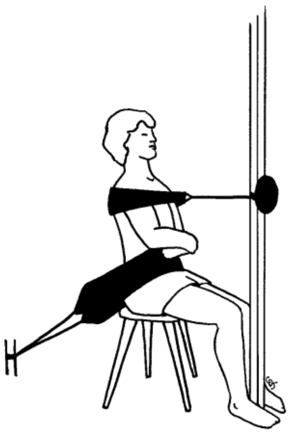

Figure 5 Drawing shows Darcus strain-gauge dynamometer. Subject sits on stool facing testing apparatus, vertical bar is fixed to axis of dynamometer, and subject is attached to bar with strap around shoulders. Strap around hips prevents forward movement of pelvis[6].

Figure 6 Protocol to test fatigue of the trunk muscles, tests were carried out using the Cybex Norm Isokinetic Dynamometer (Henley Healthcare, Sugarland, Texas, USA) with an incorporated trunk flexion/extension unit[7].

However, there are numerous others exercise-induced fatigue models for experimental research, the above examples are only part of it[8][9]. The literature review about exercise-induced fatigue model showed that most of the models are static contraction; nevertheless, most of the exercise-induced fatigue is caused by dynamic contraction. Therefore, more exercise-induced fatigue models of dynamic muscle contraction should be established in the future, which are more in line with the sports and training reality of athlete.

Conclusion

Exercise-induced fatigue is the hotspot in the field of sports and sports medicine. The exercise-induced fatigue and its recovery mechanism have a very important impact on the improvement of athletes' ability and potential. There are two kinds of exercise-induced fatigue model, animal model and human. In the course of research, it is unrealistic to conduct human experiments directly, because many experiments have certain damage to the human body. Therefore, in the early stage of research, the establishment of animal models of exercise fatigue is particularly important. When considering the experimental subject, the mouse is the first choice. Studies have shown that the genetic similarity between the mouse and humans can reach more than 98%, which ensures the reliability of the research.

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