Study on the Prevention of Muscle Pain and Injury in Pre-competition Training from the Perspective of DOMS

Jian Liang, Shijun Xu*, Yi Xie and Ge Luo
Lushan College, Physical Education College, Guangxi University of Science and Technology, Guangxi Sports Culture Research Center, Liuzhou China

*Corresponding author. Email: 627726050@qq.com

Abstract. Objective: Taking DOMS mechanism as the center, tries to find the countermeasures to deal with the muscle pain and prevent the injury in the pre competition training of college games. Methods: 125 students from Guangxi University of science and technology were randomly selected to participate in the training. The data of muscle pain and injury during the training were statistically analyzed. The mechanism of pain and injury was studied from lactate mechanism, glycolysis system, DOMS threshold and other aspects. Results: Muscle pain and injury mainly occur in pre competition training, especially in freshmen. Lack of rest after heavy load is easy to cause muscle pain, DOMS and muscle injury. Conclusion: Pain, DOMS, injury is a gradual process of comprehensive effects of exercise load, energy, material metabolism, etc; controlling load intensity, supplementing water, energy, material, can effectively prevent DOMS, and timely recovery after DOMS can effectively avoid sports injury.

Keywords: muscle pain, DOMS, DOMS threshold, Lactate, metabolism.

1. Introduction
The pre competition training of the school sports meeting after the freshmen enter the school in autumn is the concentrated period of the occurrence of sports muscle pain and injury in a large area. The sports meeting of Guangxi University of science and technology is held at the beginning of November every year, which is representative in southern colleges and universities in terms of time and nature. The research on muscle pain and injury in pre competition training is of sample significance to other colleges and universities. In the pre competition training, a large number of students have muscle ache, delayed onset muscle soreness (DOMS) and other symptoms, and some of them have muscle injury which is difficult to recover to participate in the sports meeting, even difficult to recover. Freshmen who just left high school and entered college have no experience to deal with the large increase of exercise load. They are the groups that are prone to exercise-induced muscle pain and injury. Sports training and competition are the main contents for college students to enrich their after-school cultural life and entertain their body and mind. The injury has a negative impact on the study, life, physical and mental health, as well as the development of the sports project, which weakens the enthusiasm of the injured students to participate in sports in the future. Combined with the influence of climate and environment, it is of great significance to analyze various factors that lead to muscle pain and injury, and to study the mechanism of pain, so as to find an effective way to deal with muscle pain and prevent DOMS and injury.
2. Objects and methods

2.1. Objects
During the training period of one month before the school games, 125 students were randomly selected from the track and field to participate in the training.

2.2. Methods
By means of interview, on-the-spot observation and mathematical statistics, the data of muscle pain and injury in the training process of athletes were obtained, and the data were consulted to explore the mechanism of muscle pain and injury based on the mechanism of DOMS.

Excel 2016 was used to analyze the basic condition of injury, pain type, degree, exercise ability and recovery time.

3. Result analysis

3.1. Basic information of pain and injury
The part of muscle pain in sports training is related to the muscle group involved in sports. In running events, the proportion of ache in middle and long distance race is lower than that in sprint, and the incidence of DOMS and injury is also lower than that in sprint. In jumping events, the incidence of ache, DOMS and injury is higher, among which the incidence of ache, DOMS and injury in triple jump is 100%, and the injury rate is 87.5%. In throwing events, the incidence of ache is 100%, DOMS and injury were the highest. It can be seen from table 1 that the total number of people with pain is 101, accounting for 80.8% of the total, the number of people with DOMS is 91, accounting for 72.8% of the total, the total number of people with injury is 65, and the total injury rate is 52%. DOMS is between pain and injury. Sudden muscle soreness can be recovered in a short period of time, and generally will not cause sports injury. If the recovery is unfavorable, a large part of it will be converted into DOMS, which will lead to damage. DOMS has a high correlation with muscle injury, and with exercise load intensity. Although aerobic exercise has a large load, such as middle and long distance race, the incidence of DOMS is low; the incidence of DOMS in throwing and jumping events with a large load intensity is high, which is very easy to cause muscle injury. Therefore, it is very important to study the mechanism of DOMS.

3.2. The mechanism of DOMS
DOMS is the feeling of muscle pain or discomfort after engaging in the unaccustomed exercise. The degree of discomfort occurs in the first 24 hours after exercise, reaches the peak in 24-72 hours, then gradually relieves, and disappears in about 5-7 days[1]. Since Hough discovered the phenomenon of DOMS in 1902, there is no unified explanation for the mechanism of DOMS at home and abroad. At present, there are mainly representative theories such as lactic acid theory, muscle spasm theory, injury theory, inflammation theory and enzyme escape theory[2], but the above single theories can not clearly explain the real cause of DOMS, and the prevention and control measures for DOMS can not really work. Therefore, it is necessary to summarize the existing research results, and explore the path of DOMS production, combined with various influencing factors. This paper mainly focuses on the metabolism of substance and energy, from the macro system integration effect to the micro combination of transverse bridge and actin in the theory of myofilament gliding, in order to provide a new way to clarify the mechanism of DOMS.
**Table 1.** Questionnaire on the incidence of muscle pain and injury.

| Project (people number) | Run(61) | Jump24) | Throw(40) |
|-------------------------|---------|---------|-----------|
|                         | Distance race(25), Sprint(36) | High jump(6), Broad jump(10), Triple jump(8) | Shot put(12), Back throw solid ball(16), Softball throw(12) |
| Pain of body parts      | Quadriceps, gluteus, gastrocnemius, biceps | Quadriceps, gluteus, gastrocnemius, psoas, dorsal, abdominal | Deltoid, erector, dorsal, abdominal, Triceps brachii, quadriceps femoris, medial thigh |
| Ache people number(%)   | 16(64) 30(83.3) | 5(83.3) 8(80) 8(100) | 10(83.3) 16(100) 12(100) |
| DOMS people number(%)   | 12(48) 24(66.7) | 5(83.3) 7(70) 8(100) | 9(75) 12(100) 14(87.5) |
| Injure people number(%) | 4(16) 20(55.6) | 3(50) 6(60) 7(87.5) | 8(66.7) 11(91.7) 6(37.5) |
| Project injury rate(%)  | 19.2    | 12.8    | 20        |

### 3.2.1. Lactic acid theory.

(Asmussen, 1956) studies have shown that lactate produced by exercise is not the cause of DOMS, (Dick & covangh, 1987), (dives, & white, 1981. Schwane, 1983), (Schwache, et al, 1983) et al. Showed that the energy consumption, oxygen consumption and lactic acid produced by muscle centrifugal contraction were less than that of centripetal contraction, but the DOMS produced was more serious. For example, the incidence of DOMS was 100% when the legs of the first and second jumps of the triple jump landed in the ground. Lactate may cause fatigue related muscle pain, but it cannot explain that lactate produced during exercise can cause delayed pain after 24-48 hours[3]. It can be seen that the production of lactate in muscle during exercise may lead to two different pain results: muscle soreness and DOMS. There are some similarities in the mechanism and path of the two, but there are obvious differences. There are two main ways of glycogen metabolism in human body: aerobic oxidation (with oxygen) and glycolysis (without oxygen); the tricarboxylic acid cycle is the common way for glycogen, fat and protein to decompose in vivo. Under certain conditions, the three major energy substances take the tricarboxylic acid cycle as the hub, and pyruvate, AcCoA, etc. as the intersection point for mutual transformation, as shown in Figure 1[4] 148-154.

\[
\text{Glycogen} \xrightarrow{\text{pyruvate}} \text{AcCoA} \xrightarrow{\text{tricarboxylic acid cycle}} \text{(aerobic oxidation)}
\]

**Figure 1.** Carbohydrate metabolism.

During strenuous exercise, the muscle is lack of oxygen supply, which produces lactic acid through glycolysis and releases energy for ATP re synthesis; due to the lack of enzyme in muscle that reversely transforms into glucose, the lactic acid in the muscle can no longer be converted into glycogen; when the oxygen supply is sufficient, most of the lactic acid can be oxygenated into CO\(_2\), H\(_2\)O, energy; about 17-25% of the lactic acid diffuses into the blood, and regenerate glycogen or glucose in the liver by gluconeogenesis, which is called lactate cycle, can avoid the loss of fuel and the accumulation of muscle lactate, leading to early muscle fatigue or acidosis[5]. Short time vigorous exercise, energy consumption mainly depends on glycolysis.

\[
\text{Glycogen} \xrightarrow{\text{pyruvate}} \text{Lactate} \xrightarrow{\text{energy (for muscle use)}} \text{O}_2 + \text{H}_2\text{O} + \text{energy} \xrightarrow{\text{diffuse into liver}} \text{Lactate} + \text{energy (for muscle use)} \xrightarrow{\text{energy}} \text{glycogen}
\]

**Figure 2.** Glycolysis.
The process of lactate production cannot explain DOMS alone, so it is necessary to combine with lactate removal pathway. Lactic acid produced by glycolysis can be removed mainly through three ways, as shown in Figure 2, and a small part can be directly removed from the body with urine and sweat. Under the action of lactate dehydrogenase, lactate is transformed into pyruvate when oxygen supply is sufficient, and then enters mitochondria to generate AcCoA, which is oxidized to CO₂, H₂O, energy through the tricarboxylic acid cycle.

3.2.2. Lactate and DOMS. When the body participates in the exercise without O₂, there are two situations: one is that the exercise load is light and a small amount of lactate is produced, but the body has adapted to achieve the dynamic balance of production and decomposition, so that the internal environment of lactate is kept at a low concentration level; the other is that the body cannot adapt to the increase of exercise load, and the large amount of lactic acid produced in an instant cannot be decomposed or removed in a short time, large amount of lactate cannot be decomposed or removed in a short time, and the dynamic balance between production and decomposition is broken, resulting in the accumulation of lactate. The hydrolysis and synthesis of ATP consume a lot of O₂ and energy; Energy materials such as glycogen are mainly supplied by glycolysis (as shown in Figure 3): ADP + CP + energy is used to synthesize ATP + C, which produces amount of CO₂ and metabolites (including lactic acid). CO₂ + H₂O = H₂CO₃ makes the internal environment acidified more seriously. With the increase of exercise load, fat and protein gradually participate in energy supply, producing acid phosphates, ammonium salts and other substances, making the internal environment of muscle tissue lose its steady state, pH drop, the inherent acid-base balance is broken, temperature rise makes the activity of enzyme decrease, leading to metabolic disorder, ATP energy supply blocked, energy loss cannot be supplemented in time, and metabolic product removal is blocked, the muscle tissue ache, the work ability drops. The receptors of nerve endings in muscle tissue continue to produce local inflammation and induce DOMS under the joint action of physical stimulation (mechanical strain, temperature rise) and chemical stimulation (internal environment acidification) generated by movement, DOMS cannot be eliminated before the inflammation disappears.

![Figure 3. ATP decomposition and synthesis.](image-url)

3.2.3. Energy supply system with lactate and DOMS. The relationship between different exercise loads and lactate and DOMS was discussed from three energy supply systems. Because lactate cannot explain DOMS alone, In addition to the production of lactate by glycolysis, the phosphagen system and the aerobic system were investigated. The working principle of muscle tissue confirms that the increasing exercise load until the sub maximum (such as marathon) due to the sufficient O₂ supply, glycogen decomposes completely without lactic acid accumulation and DOMS phenomenon, so the accumulation of lactic acid is related to the sudden increase of exercise load, which is beyond the adaptive range of the body. A large number of experiments have proved that DOMS can be produced by intensive exercise in a short period of 1-2 minutes, such as pull-up, sit ups and so on, which are mainly powered by glycolysis and phosphagen system. DOMS has a significant common feature, which is the decrease of ATP synthesis efficiency and the change of substance metabolism in cells[6]. Therefore, we focus on phosphagen system, which mainly provides energy for the fast maximum power, namely explosive power, in the first 10 seconds or so of exercise.

3.3. Inference of the relationship between pain, DOMS and injury degree
The injury degree of muscle tissue is directly proportional to the recovery time and inversely proportional to the exercise ability. The more serious the injury degree is, the longer the recovery time
is and the weaker the exercise ability is. The injury degree of DOMS can be indirectly inferred. Experiments show that in addition to DOMS produced by high-intensity centrifugal exercise, there will be a drop in muscle strength immediately after exercise[7], and a decrease in the range of joint activity lasting for 1-4 days, and then gradually recover[8]. From table 2, it can be seen that the injury degree of DOMS is between muscle ache and muscle strain. The part of muscle ache was unapparent, the part of DOMS was concentrated in the whole muscle, but the pain focus was not obvious, the pain focus of muscle strain was obvious. DOMS is a delayed subjective discomfort, involving the consumption of material and energy.

| Injury types | Recovery time | Ability to exercise | Pain focus |
|--------------|---------------|---------------------|------------|
| Muscle soreness | Recover in hours | Ability decline | Unapparent |
| DOMS | 5—7days | Dyskinesia | More concentrated |
| Muscle injury | About a month | Unable to exercise | Focus on one place |

3.4. DOMS threshold theory
The excitation and contraction of muscle tissue come from the action potential of muscle fiber, so does DOMS, so it has the similar characteristics of action potential full or none, non attenuation conduction and pulse type[4][26]. There must be a certain amount and intensity of motor stimulation to induce DOMS. The stimulation intensity to induce individual DOMS is called individual DOMS threshold, different individuals have great differences. Once any stimulus reaches the threshold value of individual DOMS, DOMS will be produced and reach the maximum value. The degree of pain will not change due to the stimulus, and then gradually subside to complete the whole process of DOMS. This explains that once DOMS is produced, it cannot be interrupted or stopped immediately, and various sports and treatment recovery methods are difficult to work. Exercise does not affect the natural recovery of DOMS, and the exercise induced by DOMS will not cause the accumulation of DOMS symptoms[9]. Once DOMS is generated, it will spread to the whole muscle participating in the movement, and the pain will not be weakened due to the increase of the transmission distance, which explains that the whole muscle tissue produces the same pain, and the focus of the pain is unapparent.

4. Conclusion
Strengthen sports health education for freshmen, popularize scientific exercise methods and prevention measures for general sports pain and injury, reasonably arrange exercise load in training, master the matching of exercise amount and intensity, and pay attention to the recovery of physical fitness. Under the dry and hot climate in South China in autumn, we should pay attention to water supplement and keep the relative stability of the internal environment, which is conducive to the material exchange of the internal environment and the timely elimination of metabolites. Supplement energy, maintain the normal operation of the energy supply system of the body, pay attention to nutrition diet before and after training, maintain the nitrogen balance of the body and the activity of various enzymes. Supplement inorganic salt, make action potential mechanism normal, maintain excitability of nerve impulse of muscle cell. Master the mechanism of muscle ache - DOMS - muscle injury, pay attention to the recovery of fatigue and muscle ache, take a rest in time after DOMS, reduce exercise to avoid developing into muscle injury. To prevent DOMS and to take timely rest measures after DOMS symptoms can effectively avoid the occurrence of sports muscle injury.

Acknowledgement
This work was supported by: 1. Research on the reform of the teaching and training of traditional national physical education in Universities (2019ZJY098).2. Scientific research and cultivation project support of Guangxi Sports Culture Research Center (GKDTYWH001).
References

[1] Clarkson PM, Nosaka K, Braun B. Muscle function after exercise-induced muscle damage and rapid adaptation. [J]. Medicine and science in sports and exercise, 1992, 24(5):512-520.

[2] Cheung Karoline, Hume Patricia, Maxwell Linda. Delayed onset muscle soreness: treatment strategies and performance factors. [J]. Sports Medicine, 2003, 33(2): 145-164.

[3] Xu Ji. A review on the mechanism of delayed onset muscle soreness [J]. Sports and Science, 1993(06):29-30.

[4] Wang Ruiyuan et al. Sports physiology [M]. Beijing: People's Sports Press, 2002:148-154.

[5] Wang bubiao et al. Sports physiology [M]. Beijing: Higher education press, 1992:247.

[6] Brown SJ. Changes in human skeletal muscle contractile function following stimulated eccentric exercise. [J]. Appl Physiol, 1996, 72(5-6):515-21.

[7] Wang Xuhui. Study on the effect of moxibustion on DOMS after exercise [D]. Shandong Normal University, 2015.

[8] Serravite D H, Perry A, Jacobs K A, et al. Effect of whole-body periodic acceleration on exercise-induced muscle damage after eccentric exercise. [J]. International Journal of Sports Physiology & Performance, 2014, 9(6):985-992.

[9] Zhuang Chong. Development of the research on delayed onset muscle soreness [J]. Journal of Physical Education, 2005(05):46-49.