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Research Article

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Pearson correlation study of the long jump athletic injury based on principal component analysis

Hailong Zhang

Department of Physical Education, Xinxiang University, Xinxiang, Henan, China

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ABSTRACT

In this paper, it takes the long jump sports injuries, for example, and obtains that the most relevant factor with long jump athlete's sports injuries is the technical action error by using principal component analysis and Pearson correlation analysis, uses the bio-mechanics and dynamics techniques to conduct research and analysis for the long jump run-up, jump preparation, jump, vacated, and landing five action essentials, obtains that the take-off angle increases with the decrease of the jump speed and the distance of the long jump increases with the increases of the take-off speed, thus obtains that the best take-off angle and speed not only improve athletic performance of the long jump athletes, but also provide a professional and scientific prevention method for the long jump sports injury.

Key words: Biomechanical parameters; principal component analysis; sports injuries; Pearson correlation analysis

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INTRODUCTION

Sports have become increasingly important in modern life of people, and it has become an integral part of human life. People can harvest healthy and joyful mood, but may also gain pain and sorrow in sport. Sports injuries caused by the movement are reality that we cannot evade, also the problems to be solved. In this paper, it takes the long jump as an example to conduct summarization and analysis on the causes of long jump sports injuries, and puts forward a reasonable and scientific way of prophylaxis and treatment.

In recent years, domestic and foreign experts have conducted intensive and in-depth research on the cause of the long jump sports injuries. Some experts pointed out that the causes of long jump sports injuries are that the exercise intensity is too large, insufficient preparation, unreasonable amount of exercise, technical movement error, the venue does not meet the requirements, flaunt one's superiority and several key factors [1]. Factors that causing long jump sports injuries are in various aspects, including environmental, psychological, and technical factors. Only by finding out the main cause of long jump sports injuries, studying it and coming to a reasonable solution, can we avoid the occurrence of sports injuries long jump radically.

Environmental factors, include space, equipment and weather, etc., can avoid the production of injure by replacing and transforming the venue and other methods. Players' mood can also affect the generation of injury, which can be avoided by psychological counseling and self-regulation and other means. For technical reasons it can only be fully solved through continuous research and improvement on the long jump technology. So long jump technique is the key factor affecting the long jump sports injuries, scientific and rational research for long jump technique is fundamental to solve sports injury. The basic method to study long jump technology is the principle of mechanics and dynamics. As early as 1984 Ralph Lindeman in an article "the mechanics principle of long jump techniques", conducted mechanics analysis on the run-up, jump preparation, jump, vacated, and landing five aspects of long jump technique[2]; Chen Feng (2013) conducted kinetics study on the take-off techniques of long jump[3]. By the paper "common sports injury causes and preventive measures for Long Jumpers" of Cai Bin, we know that the cause of long jump sports injuries are: that the exercise intensity is too large, insufficient preparation, unreasonable amount of

exercise, technical movement error, the venue does not meet the requirements, flaunt one's superiority and several key factors[1].

Through learning on previous research, this article takes jump movement as a physical process and analyzes the movement and the forces condition step by step. According to the principles of mechanics and dynamics, the forces are described using the physics equations to arrive at the optimal take-off angle and speed. It puts forward a scientific and effective prevention method for long jump sports injuries, also provides reasonable suggestions for long jumpers to achieve best results.

1. Main cause analysis on the long jump sports injuries

Long jump is a common and simple means of physical exercise; regular practice of long jump can improve the body's speed, strength, agility, can enhance the body's heart and lung function, make the nervous system more flexible, and improve the coordination of various body parts. And in all types of field events of our various schools, the long jump is an essential part. So sports injuries in the long jump are inevitable and the most common. Therefore, we must understand the reasons for the long jump sports injuries, and find a reasonable solution, provides a reference opinion and recommendation for coaches, physical education teachers and long jumpers in various schools, and makes long jump truly become a health and easy exercise way of human life.

Long jump consists of five successive phases, the approach, take-off preparations, take-off, vacated and landing, and it is a complex physical movement process. Approach speed and takeoff are considered the most important parts. At this stage it produces the horizontal velocity that makes the body forward and the vertical velocity that makes the body vacated. Since long jump has the characteristics of high speed and high strength, lower extremity of athletes need to bear the impact force that is several times over its own weight, and therefore long jump athlete's joints, muscles and other injuries phenomena often appear.

2.1 Principal component analysis on causes resulting in long jump sport injury

For many reasons of long jump sports injury, through mathematical dimension reduction method it identifies several variables that have relatively large correlation with the sports injuries to replace the original variables, so that these variables can represent the information amount of a lot of impact factors as much as possible, and they are unrelated to each other. Principal component analysis is to try to get the variables that may have some relevance with the long jump sports injuries through analysis, re-screen and combine into a new set of variables to replace the original variables.

The selected first linear combination namely the too large exercise intensity is denoted by x_1; we want it to reflect the relationship between it and sports injuries as much as possible, we use variance to express this "relationship", that is the greater $Var(x_1)$ is, the closer the relationship between x_1 and sports injuries becomes. So select the greatest variance x in all linear combinations, and call x_1 the first principal component. If the information amount of the first principal component is insufficient information on behalf of the original N affecting factors, and then we consider select x_2 namely the linear combination of inadequate preparation; in order to effectively reflect its relationship with sports injuries, the existing relationship of x_1 does not need to appear in x_2, that is to ask $Cov(x_1, x_2) = 0$, x_2 is called the second principal component, and so on we can find the third, fourth ..... the N th principal component.

Standardization process is a prerequisite of principal component analysis, and therefore when carry though principal component analysis on the physical and chemical indicators that lead to sports injuries, we need first standardize the data, the standardization equation is in the formula (1) below.

$$x_i = \frac{x_i - \min(x_i)}{\max(x_i) - \min(x_i)} \tag{1}$$

Using SPSS to conduct principal component analysis for the normalized data of long jump sports injury, and obtain the principal component analysis matrix, as follows:

Table 1: Principal component analysis matrix

The causes of injury	Component
Exercise intensity is too large	0.996
Insufficient warming up	0.996
Unreasonable amount of exercise	0.978
Technical action error	0.985
Site does not meet the requirements	0.981
Flaunt one's superiority	0.659

Seen from the above table 1, after analyzing the six factors that lead to the long jump sports injuries using principal component analysis we get five main components, namely: the exercise intensity is too large, insufficient preparation, unreasonable amount of exercise, technical movement error and the venue does not meet the requirements. Components of the five factors are all close to 1, and the relevance with sports injuries are all great; but the main ingredient of flaunt one's superiority is 0.659; apparently it has the minimum relevance with sports injuries. So these five factors are associated with sports injuries, can be taken as a major cause of long jump sport injury, only flaunt one's superiority do not have the condition of main component.

2.2 Pearson correlation analysis on causes resulting in long jump sport injury

The correlation coefficient r is defined as shown in the formula (2).

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - x)^2 (y_i - \bar{y})^2}} = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{n\sigma_X \sigma_Y} \tag{2}$$

Among them, n is the number of main reason for the jump sports injuries; $\bar{x}$、$\bar{y}$ are mean values of variables x、y; σ_x、σ_y are the standard deviations of x、y. The symbol of correlation coefficient r represents the direction of a linear correlation; the absolute value of r indicates the strength of the linear correlation; when r is close to zero, it indicates there is no linear relationship, but they may still have non-linear correlation; when the absolute value of r is close to 1 indicating the two variables have a strong linear relationship.

According to the analysis of the correlation analysis table, at the time $0 < p \le 0.1$, two factors are significantly correlated. It can be drawn that: the correlation between technical errors and long jump sports injuries is the biggest, so the technical action error is a major factor resulting in the long jump sports injuries.

2. Biomechanical analysis of technical action

Long Jump is divided into the run-up, jump preparation, jump, vacated, and landing five areas; in order to achieve the best results and reduce sports injuries, during the run-up it requires to achieve maximum controllable speed. During the whole process it does not receive air resistance and friction, only suffers gravity.

The motion process of run-up and jump preparation is shown in Figure 1. The athletes began to carry out accelerated motion from the starting moment, theoretically the speed reaches the maximum controllable speed when reaching springboard. The moment that reaches Springboard is the take-off preparation phase. At this time athletes need to control their horizontal speed, use the bounce of the body's lower extremities to give an upward force to the body, and have upward movement speed. Athletes complete the long jump movement with the role of the horizontal velocity of approach and the vertical velocity of jump.

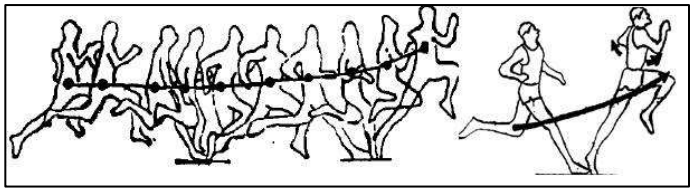

Figure 1: Schematic figure of approach and take-off preparation process

In order to facilitate the mechanics and dynamics analysis, conduct analysis and simplification on the process in Figure 1. At the moment of taking-off, the speed exploded view when the athletes are about to leave the pedal is shown in Figure 2:

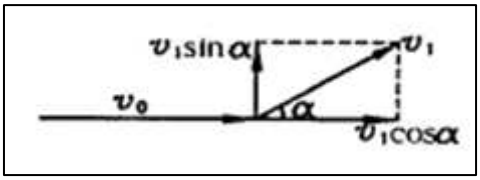

Figure 2: Speed exploded view

From Figure 2 we can suppose v_0 is the limit speed when people approach, v_1 is the initial velocity when take-off, $v_1 \sin\theta$ is the take-off speed in the vertical direction, $v_1 \cos\theta$ is the take-off speed in the horizontal direction, so the total energy when take-off is $E_0 = \frac{1}{2} m v_0^2$, the energy of the vertical direction when take-off is $E_1 = \frac{1}{2} m v_1^2 \sin^2\theta$, the energy of the horizontal direction when take-off is $E_a = \frac{1}{2} m v_1^2 \cos^2\theta$, due to gravity, air resistance, friction and other factors accompanied loss of energy when takeoff is rE_0.

Obtained by the energy conservation law:

$$E_0 = E_1 + rE_0 + E_a \tag{3}$$

$$v_1 = \sqrt{1-r}\, v_0 \tag{4}$$

Through the analysis and study on motion process the basic range in horizontal direction is:

$$R = \frac{v_1^2 \sin 2\theta}{g} = \frac{(1-r)v_0^2 \sin 2\theta}{g} \tag{5}$$

Seek the derivation of R on θ, and then we have:

$$\frac{dR}{d\theta} = \frac{(1-r)v_0^2 2\cos 2\theta}{g} = 0 \tag{6}$$

Then we have $\theta = \frac{\pi}{4}$.

According to the above analysis, in the case that the runaway speed and take-off speed both reach the optimal state, we can be sure that this value is the take-off angle that makes the jump long distances reach the maximum, also the best take-off position when the safe landing is the best. And we can see that the value is relevant with v_0 and r.

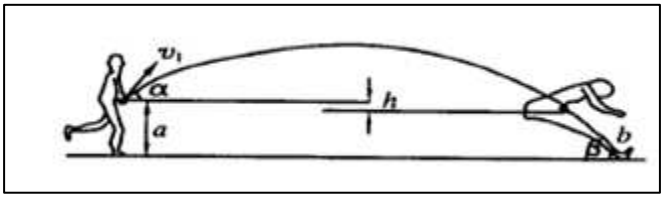

Figure 3: Landing point

In fact, in order to jump farther and reduce the impact of exposure to foot as much as possible, at the landing point athletes foot is usually out in the front of the body, and has a certain angle with the ground; The controlling of the angle has great significance for the reduction of sports injuries, as shown in Figure 3. In this position, the center of gravity of athletes is h lower than that when jump; and when landing the distance b between the body center of gravity of athletes and the feet is shorter than the distance a between the body center and the feet before jump. If the landing angle is β then we have $h = a - \sin\beta$.

In this case, we have the long jump distances:

$$R = \frac{v_1 \cos\theta}{g}(v_1 \sin\theta + \sqrt{(v_1 \sin\theta)^2 + 2gh}) + b\sin\beta \tag{7}$$

$$R = \frac{(1-r)v_0 \cos\theta}{g}(\sqrt{1-r}v_0 \sin\theta + \sqrt{(1-r)v_0^2 \sin^2\theta + 2gh}) + b\sin\beta \tag{8}$$

Theoretically in the allowable range, the smaller the landing angle β is the better, but it also must be greater than the angle between the legs and the ground, otherwise the buttock will touch the ground, and it is very easy to damage the knees and feet. Drawn from the experience, this angle is about 45 degrees. According to the definition of β, the angle between the thigh and the horizontal plane should be as small as possible, so it makes the athletes' center of gravity easy to be unstable, and results in the generation of falling over oneself and other phenomena. If $b\sin\beta$ can be seen as a constant, we can get the resolved value of best take-off angle when the long jump distances reach the maximum. Seek the derivation of the equation (6) on $l = \frac{(1-r)v_0^2}{g}$, set it to zero and simplify, we can get a transcendental equation:

$$p(l) = q(l) \tag{9}$$

$$p(a) = 2 + 12\beta + \sqrt{2}\csc a\sqrt{1 + 3\beta - (\beta + 1)\cos 2a} \tag{10}$$

$$q(a) = \left[6 + 4\beta + 3\sqrt{2}\csc a\sqrt{1 + 3\beta - (\beta + 1)\cos a}\ \right]\cos 2a \tag{11}$$

Equation (7) can be solved using as a graphing method or a numerical method. Taking a player's height (1.86m), for example, that is $a = 0.93m$, b is approximately $0.6m, B = 450$, we can approximately get $h = 0.51m$ and $L = 0.42m$. And command $C = 110$, equation (9) is calculated on both sides with method of increasing the take-off angle; the best take-off angle A_m corresponding to the maximum long jump distance can be obtained. In the data it gives values of each parameter when the initial velocity takes different values, obviously the take-off angle is smaller than the original calculated theoretical value 35.26. At the same time, A_m also increases slightly with the increase of v_0, the body tilt angle decreases with the increase of v_0, and R increases accordingly.

Table 2: The best take-off angle corresponding to the long jump distance

Initial speed m/s	Take-off speed m/s	Best take-off angle	Farthest distance m
10.0	8.35	32.65	7.59
10.5	8.75	32.87	8.26
11.0	9.16	33.06	8.96
11.5	9.57	33.23	9.69

As shown in the above table 2 it is the best take-off angle and speed. The method reduces the impact force that the lower limbs of athletes bear in the long jump movement as much as possible, thereby reducing the injuries of his ankle and knee. The training in accordance with such speed and angle is not only able to reduce the long jump sports injury rates to a minimum, but also continuously improves the quality and level long jump athletes, and enables them to achieve the best results. It also avoids long jump sports injuries fundamentally, and makes the athletes get the best results in the premise of the health and safety.

CONCLUSION

In this paper, it further studies the former cause of long jump sports injuries, obtains that the main reason resulting in the long jump sport injuries is technical action error by using principal component analysis and Pearson correlation analysis method. According to biomechanics and kinetic theory it puts forward safest, scientific and reasonable technical action recommendations for the long jump. In order to avoid sports injuries due to inadequate preparations, coaches or sports teachers should organize athletes and student to do modest and adequate preparation activities. Before exercise athletes can carry through general and professional two preparatory works. General preparation

work is mainly simple activities on the ankle joints, ligaments and other parts to make it gradually adapt to the gradually increasing exercise intensity.

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