



Research Article

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Hurdler injury factors correlation research based on biomechanics

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ABSTRACT

With the development of sports, hurdler has become more and more high in the pursuit of performance, the competition has grown fiercer, the training load has been increasing accordingly, and so sports injury has also been increasing. Liu Xiang has quitted the competition because of injury in 2012, which strengthen people's attention to sports injury again. This paper makes analysis research on hurdle sports injury from the perspective of sports medicine, with an aim to make suggestions for hurdler technical motions and reduce sports injury occurrences. In research process, it firstly do questionnaire investigation to 400 hurdlers, get the most sever body parts that suffer sports injury are successively as ankle joint, knee joint, shoulder and elbow, which respectively cover the total number of injured people as 31%, 17% and 16%. Then combine with relative knowledge of sports medicine, human structure, mechanics to make research analysis respectively on hurdle ankle joint, knee joint, shoulder and elbow injure causes. Finally make reasonable suggestions from medicine perspective, with an aim to standardize technical motions and reduce hurdler injury and make contribution to our country's hurdle technical development.

Key words: Hurdle cycle, sports medicine, statistical analysis, biomechanical analysis

INTRODUCTION

Hurdle belongs to stronger technical athletics; it needs the perfect cooperation with speed, strength, flexibility, sensitiveness and other factors. Due to hurdle technique is very complicated and strict with body; therefore hurdler also is prone to injuries. For many years, sports injury always seriously influences on hurdler training and competition. Sadness scene of Liu Xiang's felling because of injury in 2012 has left a deeply impression in Chinese minds, then sports injury accordingly is taken more seriously by coaches and hurdlers. Hurdlers with seriously sports injury have to end their sports life in advance, which seriously affect our country's athletic levels improvement. Therefore it is very important to research on hurdle injury causes and make suggestions.

For hurdle injury, lots of scholars have put forward their thoughts and made efforts to reduce sports injury by which our country hurdle techniques has been fast developing. Among them, Zhang Shou-Wei Makes research analysis of Liu Xiang 110 meters hurdle running technical features, points out that Liu Xiang took big grounding angle, near grounding distance, big swing leg ankle joint angle in grounding moment, unremarkable passive buffer of ankle joint and little buffer range that easily lead to ankle joint instantaneous bears great force and gets injured when grounding[1]. Shi Zheng-Kai Analyzes hurdle injury and points out those main causes for hurdle injury are technical mistakes, excessive load. Excessive jumping causes excessive load of knees which is prone to suffer kneecap strain [2]. Shan Mei-Juan Makes research on ankle joint motion features when starts running and pulls legs flat to one side to cross the hurdle, and points out that proper tense ankle joint and draw upwards of foot tips in running and pulling leg flat to one side to cross the hurdle is helpful to avoid the occurrence of sports injury [3, 4].

This paper based on previous research, respective analyze hurdle ankle joint, knee joint as well as shoulder and elbow injury from medicine perspective combining with human structure features, and make suggestions on each part injury, with an aim to standardize technical motions, reduce hurdler injury and make contributions to our

country's hurdle techniques development.

STATISTICAL ANALYSIS OF HURDLERS INJURY CURRENT SITUATIONS

Hurdle injury is an important factor that affects hurdler training and competition performance, this paper makes questionnaire survey to 400 hurdlers, from which male hurdlers are 250 while female hurdlers are 150, it can get Figure 1.

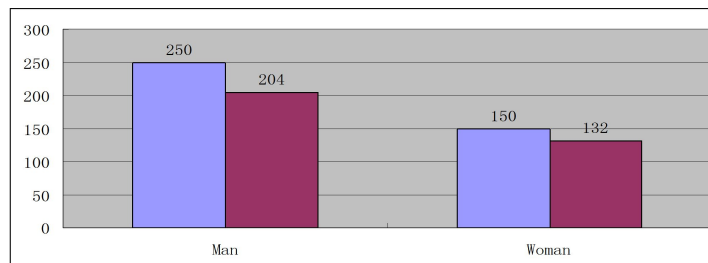


Figure 1: Hurdlers injury conditions statistics

From Figure 1, it can be known that hurdle injury is quite universal, 204 people out of the investigated 250 male hurdlers have got injury, while 132 people out of the investigated 150 female hurdlers have got injury, and it can be found that sports injury has no remarkable correlation with gender. Numbers of injured male and female hurdlers covers 84% of total hurdlers numbers, which need to be taken seriously by coaches and hurdlers, safety should be paid attention to in future training [5].

Make questionnaire survey to 336 injured hurdlers, and make statistics of their injured body parts can get Figure 2.

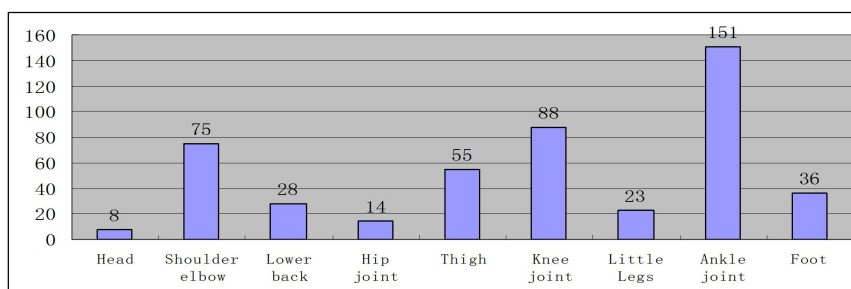


Figure 2: Hurdle injury parts statistics

According to Figure 2 to analyze investigation result can get Figure 3.

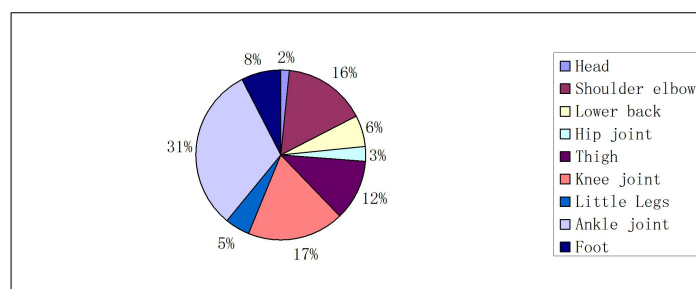


Figure 3: Each injury part percentage

From Figure 3, it can be found that in sports injury, ankle joint injury covers the highest proportion that total 151 person get such jury which is 31% of total person, the next is knee joint, shoulder elbow injury cover the higher percentage that are respectively 88 person and 75 person suffer injury and be respectively 17%, 16% of total injury people, thigh injury covers 12% of total injury people, and other parts cover small proportions. From Figure 2, it can be known that all body happened to get injured, but major in lower limbs injury that is 63% of injury people, upper limbs injury cover 34% of injury people; head injury covers 2% of injury people.

Then, this paper according to each body part injury proportions, based on medicine perspective makes research on each body part injury and prevention.

HURDLER EACH BODY PART INJURY MECHANISM AND PREVENTION

Ankle joint injury

According to human structure anatomy, it is known that ankle joint is composed of lower end of tibiofibula and talus of foot. To hurdle, foot movements are fulfilled by subtler joint and ankle joint common movements. Due to ankle joint area is quite small, it is the smallest part of human movement cross section to whole human body especially to hurdle, one ankle joint is needed to support whole human gravity and falling impact force, therefore it bears huge force. Huge impact force suffered in hurdle takeoff and landing moment (Figure4) caused stress concentration that lead to ankle joint injury. Hurdler ankle joint injury reason statistics is as Table 1 shows.

Table 1: Ankle joint injury reasons statistics

Causes	Numbers of people	%
Court not flat	23	15
lack of leg muscle strength	42	28
ankle joint partial under excessive heavy load	74	49
insufficient warm-up	12	8

From Table 1, it is known that ankle joint partial under excessive heavy load covers 49% of total ankle joint injury people, which is caused by stress concentration. Lack of leg muscle strength covers 28% of total ankle joint injury people, ankle joint muscle cannot supply enough strength to support that would strengthen ankle joint force burden, which leads to stress concentration and then gets injured. Court not flat is easier for ankle sprains, and insufficient warm-up would cause unreasonable ankle joint force and so gets injured.

To sum up, it can be known that factors caused ankle joint injury essentially all because of stress concentration occurrence. Therefore, how to reduce stress concentration is an important plan to protect ankle joint against injury, the deduction of stress computational formula is as following.

Variables explanation as Table 2

Table 2: Scalar explanation

Variable	Description
f	air resistance in vertical direction
σ	ankle joint pressure stress
F	ankle joint pressure
g	gravity accelerated speed
m	human quality,
a	resistance accelerated speed
v	hurdler speed in vertical direction
A	ankle joint force area
h	gravity changeable height

Hurdler's human body gravity height change during one movement cycle is as Figure 4 shows.

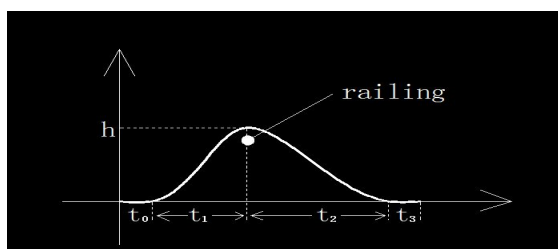


Figure 4: Hurdle gravity height one cycle change schematic diagram

In Figure, t_0 shows takeoff stage, t_1 shows stage after takeoff to top point arriving, t_2 represents falling from top point to leg grounding stage, t_3 represents foot bears impact force stage after grounding. According to experiences,

it is known that the largest ankle force stage occurs to takeoff stage t_0 and grounding stage t_3 .

Stress analysis in t_0 stage

According to physics, it is known that movement of hurdler takeoff and foot tips away from the ground belongs to oblique projectile movements, for which only vertical direction movements is taken into consideration in this paper, therefore this paper simplifies oblique projectile movements into vertical up cast movements. In soaring stage, due to hurdler at larger speed and human volume is larger, therefore air resistance effects should be considered. Assume that vertical direction air resistance is always f , then can determine resistance accelerated speed as:

$$a = \frac{f}{m} \quad (1)$$

According to Figure 4 and combine with kinematics formula, it can get

$$h = \frac{1}{2}(g - a)t^2 \quad (2)$$

$$v = (g - a)t \quad (3)$$

$$mv = Ft \quad (4)$$

According to structural mechanics stress definition, it can know

$$\sigma = \frac{F}{A} \quad (5)$$

From above formula (1), (2), (3), (4), (5), it can get stress computation formula as following.

$$\sigma_0 = \frac{\sqrt{2mh(mg + f)}}{At_0} \quad (6)$$

Stress analysis in t_3 stage

The computational method in stage t_3 is the same as that in t_0 stage, the difference between the two stage is resistance accelerated speed is in the same direction as gravity accelerated speed in t_0 stage while resistance accelerated speed is in the opposite direction of gravity accelerated speed in t_3 , therefore computational formula in t_3 stage is

$$h = \frac{1}{2}(g + a)t^2 \quad (7)$$

$$v = (g + a)t \quad (8)$$

Therefore, ankle joint stress in t_3 stage is

$$\sigma_3 = \frac{\sqrt{2mh(mg - f)}}{At_3} \quad (9)$$

From formula(6) and (9), it is known that in hurdler training and competition, if it is required to reduce stress and avoid ankle joint sports injury, takeoff height h should be reduced, the lower the takeoff height h is, the smaller force supply is required in t_0 stage, the smaller stress would be. In training and competition, it should seriously

control takeoff height h size, neither too big nor too small, if the height too small that it is impossible to cross the hurdle and would be stumbled by hurdle and get injured. From medicine sports injury avoiding perspective, it is needed to extend take off time t_0 in training and competition, or extend grounding time t_3 , so that reduce ankle joint stress, but extend. t_0, t_3 would surely affect competition performance, therefore in actual training and competition, it is needed to shorten t_0, t_3 as much as possible on the condition that ankle joint bearing capacity guaranteed so as to get good scores. For other factors in formula (6) and (9), they are belongs to constants that cannot change, so this research would not analyze them.

Ankle joint injury prevention

Combine with above research analysis, this paper makes 2 suggestions from medicine perspective to ankle joint protection as following.

Design reasonable and scientific training plan: In training process, it should according to hurdler itself conditions design reasonable training plan, especially in the aspect of sports strength, which should be paid seriously attention to. It cannot go beyond ankle joint bear extremes, and avoid by all means blind pursuit of performance and so strengthen training intensity without considering consequences.

Strengthen leg muscle strength training: Increase muscle strength that let ankle joint muscle share ankle joint pressures so as to reduce ankle joint pressure burden.

Knee joint injury

Knee joint is one of the important parts in human skeleton structure. Any lower limbs movements cannot be done without knee joint, which is more important to hurdler; Knee joint is common composed of femur inferior particular surface, tibia superior particular surface and kneecap. Knee joint stability relies on muscle support as well as cruciate ligament and collateral ligament effects, while cartilage also plays partial consolidate role in it to some extent. Three large muscle groups take effects on knee, make its stability strengthen and ensure the strength of quadriceps femora's and gastronomies muscle [4].

To hurdle, knee joint suffers huge force and is short of elastic buffer. Sports injury is very obvious, and once knee joint gets injured, it cannot be cured easily or even leave squeal and influence on career. Therefore, protection of knee joint should be taken seriously by hurdlers and coaches. This paper makes statistics on hurdler knee joint injury types as Table 3 shows.

Table 3: Knee joint injury types statistics table

Common injury types	numbers of injured people in each type injury	percentage%
Ligament injury	36	41
Meniscus injury	11	13
Kneecap strain	41	46

From Table 3, it is known that kneecap strain and ligament injury both cover high percentage, which are respectively 40%, 46%, meniscus injury covers smaller percentage as 11%, other injury covers 3%. Most reason of knee joint injury is caused by outside force, larger external force impact, forced adduction and abduction would cause medial and lateral ligament rupture, such injury is prone to happened in hurdle. In hurdle technique, if takeoff height h is not high enough, bent knee would crash the bar at that time, and due to hurdler is at fast running process, so once crash occurs, impact force is bigger that easily cause injury or even fell down that leads knee crash with firm ground and generate knee cap fracturing. Hurdler knee joint injury causes statistics is as Table 4 shows.

Table 4: Knee joint injury reasons statistics table

Injury causes	numbers of people	percentage%
incorrect technical motions	56	63
court not flat or too slippery	24	28
without safeguard procedures	8	9

From Table 4, it is known that incorrect technical motions are the main cause for knee joint injury that covers 63%. In future training, standardize knee joint technical motions should be strengthen in future training so as to avoid injury generated by technical faults. Court not flat or excessive slippery also is the important factors that lead to knee joint injury which cover 27% of total injury reasons, in training it should add requests of court, select good

conditions training court, stop training because of raining or other reasons caused road slippery. Without safeguard procedures covers 8%, hurdler should strengthen safety consciousness in daily training, they cannot enter into court for training without safeguard procedures. Safety is foundation of sports, only in the condition that safety is guaranteed that hurdler can get better results through long-term training.

Knee joint injury prevention

According to above knee joint injury causes and injury type's statistical analysis, this paper makes suggestions as following some points with an aim to reduce knee joint sports injury.

Sufficient warm-up: The purpose of warm-up is to overcome human each tissue and organ physiological sluggishness, shorten joint transformation time from normal state to sports state, through step-to-step extension of ligament, increase joint flexibility and sports intensity. Any high impact sports all need to do warm-up in advance, which especially for hurdle.

Increase lower limbs muscle strength: Knee joint surrounding muscle short of strength would cause ligament weakness, so that generated knee joint injury, therefore increase lower limbs strength and ligament extension force, it would be more helpful to prevent knee joint sports injury. Meanwhile knee joint muscle and ligament extensiveness should also be trained so as to make joint steady and flexible.

Shoulder elbow injury

Combine with human skeleton structure knowledge, it can know that shoulder mainly depends on deltoid muscle, rotator cuff muscle and ligament effects to maintain its stability, is the most unstable joint in human body while also is the largest human activity joint. Shoulder and elbow are very fragile that they cannot withstand fiercely striking. To hurdler, since in normal condition, shoulder would not crash with other part, and it is not required to supply great strength, main cause of shoulder injury is indirect cause that is when hurdler falls off, arms support ground that leads to shoulder abruptly bear huge force or shoulder directly crash with ground. From hurdler questionnaire, it can get acknowledge of shoulder injury causes as Table 5 shows.

Table 5: Shoulder injury causes statistics table

Injury causes	numbers of people	percentage%
When falling off, single arm support and abduction caused elbow injury	21	28
When falling off, single arm support caused shoulder injury	37	49
When falling off, single arm support caused shoulder, elbow injury	10	14
When falling off, shoulder lateral side grounding caused injury	7	9

From Table 5, it can be found main causes of shoulder, elbow injury is due to attack hurdle leg or swing leg crashes with hurdle when crossing the hurdle; when body gravity center not stable caused falling off, single support makes shoulder or elbow instantaneous bear huge force that covers 91%, Shoulder lateral side directly grounding injury covers 9%. Through questionnaire analysis, it can know that shoulder lateral side directly grounding caused injury is farther serious than other causes injury, because single arm support plays a buffer role, while shoulder lateral side directly grounding without buffer. Therefore, when falling off, it should try one's best to control posture, do not make shoulder lateral side directly grounding so that reduces injury degree as much as possible.

Shoulder, elbow injury prevention

1) Increase shoulder, elbow stability: For shoulder, elbow injury prevention, firstly should strengthen its stability, which is strengthening shoulder girdle, elbow, and wrist muscle strength exercise. Improve shoulder, elbow tolerance.

2) Learn self-protective tumbling: It is hard to avoid falling off in hurdle training. When falling off, it should learn follow-through tumble so as to achieve buffer and reduce shoulder and elbow impact force purpose, avoid shoulder, elbow joints bearing huge impact force and get injured.

CONCLUSION

This paper made analysis summary for hurdle injury parts, got the most serious sports injury body part are successively ankle joint, knee joint, shoulder elbow, which respectively covers total number of people as 31%, 17%, 16%; In paper, it made physics force analysis of ankle joint, pointed out ankle joint is prone to occur stress concentration caused partial excessive force and lead to injury, and put forward stress σ computational formula through calculation, from which it can be known that changeable factors that influence stress are mainly takeoff

height h , takeoff, grounding time as t_0 , t_3 . Considering from medicine perspective, it should increase takeoff, grounding time t_0 , t_3 , reduce takeoff height h so that reduce ankle joint partial stress σ .

Summarized ankle joint, knee joint injury causes, and made suggestions, it needed to strengthen lower limbs muscle strength exercises, lack of lower limb muscle strength would make it impossible to provide powerful support for hurdle technical motions. Therefore, increase lower limbs strength and ligament extension force, is helpful to perfect technical motions and make body more flexible; For shoulder, elbow injury prevention, it suggested that hurdler are requested to learn self-protective tumbling motions when falling off, follow-through tumbling so as to achieve buffer to reduce shoulder, elbow impact force purpose, avoid shoulder, elbow joint bear huge impact force and so get injury.

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