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Design and implementation of competitive basketball wheelchair based on ergonomics

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Abstract. Wheelchair basketball, as one of sport-assisted wheelchairs, can help handicapped people play special basketball games on the playground. For the athletes who join wheelchair basketball sports event, it is necessary for them to have basketball wheelchairs. Because this sports event has a strong confrontation, athletic wheelchairs are frequently collided, even tip-over. Therefore, athletes would be hurt to large extent, and got secondary damage. Thus, it is of prime importance to add ergonomics to the design of basketball wheelchair. The existing basketball wheelchair is made a new project design based on ergonomic theory. Deficiencies in different parts are improved, and analysis determination is made to some static sizes of the new-design basketball wheelchair seat. Improvement project is fundamentally completed. It is positively significant to improve the performance of basketball wheelchair and develop the sports for the disabled.

Key words. Basketball wheelchair, ergonomics, static size, sports injury.

1. Introduction

In every country, the existence of handicapped people is an unavoidable real issue [1]. Inconvenience brought by physical disability makes their sports become unusual [2]. Although handicapped people have some irretrievable deficiencies in their physical bodies, their hearts are eager to get understanding and respect like normal people. Therefore, auxiliary equipment, especially wheelchair series, is significantly important for physical and mental recovery of handicapped people. As one of sports event that handicapped people can take part in, wheelchair basketball game has a twenty-year development history in China, but the development of basketball wheelchair in China is far lower than international standard. If it is unable to keep pace with the development of basketball wheelchair, this game in China would be influenced in the long term and is harmful for handicapped people to recover their sports [3]. So it is essential to design and research basketball wheelchair.

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Foreign research on competitive basketball wheelchair, such as A. Faupin et al. [4] meticulous researches are made to obliquitous parameters of basketball wheelchair; D. Y. Vanlandewijck et al. [5] and others make relative research on correlation between the design of basketball wheelchair and injury of players. However, organizations that research this type of basketball wheelchair is still very rare in domestic, which makes many participating teams use imported wheelchairs to join games. The existing sports wheelchairs in domestic are reformed from ordinary wheelchairs by manufacturers combining with previous wheelchair experience. Without scientific development and experiments, there are still obvious deficiencies in some aspects such as security, cushioning and comfort [6]. For the above situation, some deficiencies of the existing basketball wheelchair are improved and a new design plan of basketball wheelchair is put forward. And analysis determination is made to some static sizes of the new-design basketball wheelchair seat, which contributes to its meagre strength for the development of handicapped sports.

2. A design of basketball wheelchair based on ergonomics

2.1. Ergonomic theory in basketball wheelchair

The design philosophy of ergonomics puts the factors related to human first, highlighting the interdependent relationship between users, industrial products, used circumstances and society [7]. So, from the perspective of ergonomics, the design process of basketball wheelchair can be regarded as "integration between human and machine and environment". Among them, "human" refers to the user of basketball wheelchair; "machine" is basketball wheelchair; and here "environment" means a working place of games for basketball wheelchair users. Based on satisfying ergonomic performance, the design of basketball wheelchair is human-centered. Not only should all the properties of components be researched, but also the overall property is paid more attention. So the optimal result of system can be acquired.

2.2. Design requirements of basketball wheelchair based on ergonomics

In the design of basketball wheelchair, several parts of basketball wheelchair that touched with human need to be adjusted in terms of human body. It tries its best to make users fell convenient and comfortable when they manipulate the wheelchairs. More specifically, according to ergonomic theory, there are some points need to be abided by:

1. Manipulation of basketball must be simple, so the users can quickly master the skills.

2. Basketball wheelchairs must have adjustability, so all different people can adapt to the driving space.

3. Apart from asking basketball wheelchairs to satisfy the basic requirements, it also needs to meet nimble and convenient requirements.

4. The basketball wheelchair should have comfort whose boundary dimension

also should roughly meet the requirement of human body.

3. Improvement plan of the existing basketball wheelchair

3.1. Improvement plan between principal axis, foot plate and barycenter of basketball wheelchair

In the wheelchair basketball training and games, it often occur phenomenon that principal axis of wheelchair is out of shape, even dehiscent. It makes basketball wheelchair not meet training and match requirement, but does harm to athletic body. A solution to this problem is that finite element analysis is made to choose a better twice bending method. Besides, highly adjustable model is designed for and adjustable range is fixed between 0 and 110 mm. in the training and matches, basketball wheelchairs are always in fast forward and backward as well as instantly revolving states. From the perspective of physics, gravity center of human body is properly moved back to make the gravity center of wheelchair closer to gravity center of two bull wheels, which increases the stability of wheelchair.

3.2. Improvement plan between principal axis, foot plate and barycenter of basketball wheelchair

A redesign is made for hand wheel of basketball wheelchair, adding a hand protection tile between hand wheel and bull wheel, which properly increases the contact area between palm and hand wheel. So players can save labor to manipulate the wheelchair, and their discomfort in hands is relieved, and unnecessary damage is avoided. The existing basketball wheelchair is equipped with stainless steel spoke of wheel cobwebbing. This spoke easily causing bending or broken-off situations without impact-resistance,which does harm to handicapped players. So the new designed wheel spoke uses composite material that is made from flame core injection process. Compared with common steel wire, it has high corrosion resistance, good quake-proof circle effect, strong hardness and better recoverability. The specific wheel pattern is shown in the following Fig. 1.

3.3. Improvement plan about quake-proof circle of basketball wheelchair

In the designing scheme, as a dismountable single component, quake-proof circle uses shock absorber to connect with frame theme. Quake-proof circle is improved its impact-resistant intensity in order to have an equal force, so its exterior shape adopts stream-line pattern. In addition, intensity of quake-proof circle is matched with its stand intensity as much as possible. And reasonably intensifying stand intensity is helpful to increase collision avoidance system to absorb collision energy. A damper spring is loaded in joint between quake-proof circle and car body in order to minimize shake when wheelchair is collided directly. Accordingly, it can guarantee the handicapped player's comfort and protect their injured body from second injury. And the specific pattern is shown in the following Fig. 2.

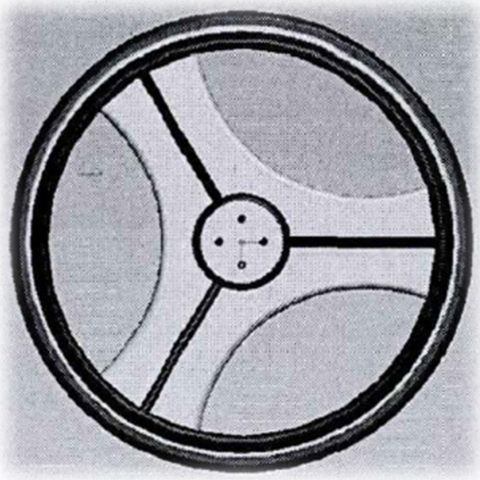

Fig. 1. Improved wheel

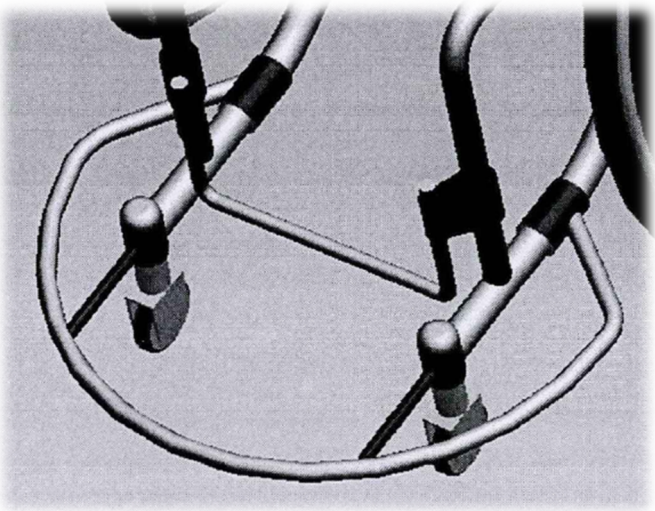

Fig. 2. Improved quake-proof circle

4. Ensuring some static sizes of basketball wheelchair seat

4.1. Size design of seat width and chair surface

Before making sure its specific sizes, an analysis is made for human body sitting postures from age group between 18 and 38. And the result is expressed in following Table 1. The design of seat width must meet people with large figures, so No. 95 percentile size data of shoulder breadth between sitting posture and two elbows is

selected with the addition of function correction value. And the length of seat width is (387+13) mm. The length of chair surface is designed according to sitting size. The seat depth of No. 5 percentile female is selected as size gist and added posture correction. Thus, the length of chair surface is (401+44+13) mm.

Table 1. Human body sitting postures size (unit: mm)

Measurement project	Female percentile				Male percentile			
	5	50	90	95	5	50	90	95
Shoulder breadth	344	375	397	403	320	351	371	377
Hip breadth	282	306	327	334	290	317	340	346
Shoulder breadth between sitting posture and two elbows	371	422	473	489	348	404	460	478
Sitting hip breadth	295	321	347	355	310	344	374	378
Sitting height	809	855	891	901	858	908	947	958
Sitting elbow height	215	251	277	284	228	263	291	298
Sitting thigh thickness	113	130	146	151	112	130	146	151
Sitting knee height	424	458	485	493	456	493	523	532
Shank and foot height	342	382	399	405	383	413	439	448
Seat depth	401	408	461	469	421	457	486	494

4.2. Size design of seat surface angle

Inclination angle of seat surface refers to this angle cannot be too big or too small. It is a reasonable range from four degree to eight degree under normal circumstance. Body pressure distribution is one of key factors to choose inclination angle of seat surface. According to numerous experiment data, it is known that when human sits straight, the pressure under ischium is biggest. With the expansion of pressure point, body pressure is gradually decreased out from ischium. It reaches the smallest pressure until thigh. It is a reasonably ideal pressure distribution of sitting posture that is specifically shown in the following Fig. 3. Finally, evaluated and compared by ergonomics, it is closest to ideal body pressure distribution when inclination angle of seat surface is 5 degree under no-cushion circumstance. So inclination angle of seat surface with 5 degree is finally selected.

4.3. Size design of foot plate and hand rail

The product's design purpose is suitable for operating requirements of most people, so foot rest of basketball can be designed as zoom mode. And its size can be determined by shank and foot height data of No. 95 male percentile and No. 5 female percentile in Table 1. The correction of foot plate is not considered because of its adjustability. The adjustable length of foot plate is 0–(448–342) mm. Due to the

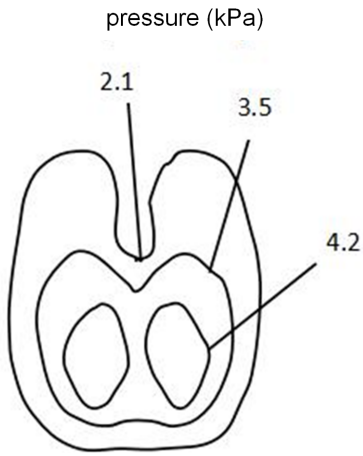

Fig. 3. Body pressure graph of sitting posture in ideal state

particularity of basketball wheelchair, the range of choice is from 0 to 110 mm. In the design of basketball wheelchair, strict design of hand rail is made according to relevant size of body tercile. The part's size takes median value from No. 50 male and female terciles as setting reference, and the height of hand rail is $(263+251)/2-13$. Because handrail height of public chair should be slightly lower than this height, the handrail height is selected as 240 mm.

5. Conclusion

With numerous research analyses, an analysis is made for design requirements of basketball wheelchair based on ergonomics and a new design is made for competitive basketball wheelchair. In response to the problems of existing wheelchairs in principal axis, foot plate, hand wheels and quake-proof circle, analysis is made and relevant solutions are put forward, which improves security, cushioning and comfort of basketball wheelchair to some extent. Besides, from body characteristics, analysis determination is made for some static sizes of basketball wheelchair, making the overall design of new plan more reasonable.

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