Fitness Rowing Ergonomics Analysis and Research

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Abstract: In this paper, the principle of ergonomics and fitness kinematics, the fitness of the concept of ergonomics and the use of its research and analysis of fitness rowing man-machine relationship. Fitness rowing man-machine relationship is divided into two parts: First, the human factor in the fitness rowing, including the body of the forces and force, operating posture and range of motion, human motion trip, the human visual space, etc. affect people in the fitness rowing machine fitness exercise for comfort, and convenience as well as the main components of fitness effects of man-machine relationship analysis, including grips, saddles, slides, displays, pedals, etc. to draw relevant conclusions and data, for reference in the design of fitness rowing machine, save the product development cycle.

Keywords: Ergonomics, man-machine relationship, fitness rowing, man analysis.

1. INTRODUCTION

In order to improve the quality of life and relieve the pressure of life, people began to participate in various sports activities [1]. Fitness rowing which is one of the world's top ten most popular fitness equipment has gradually become the people's favorite. So analyze and research Fitness Rowing can be more convenient for people to carry out fitness training. The ergonomic design of fitness equipment, fitness, security, comfort and a fitness effect of the increase if of great significance, but also to meet the fitness needs of our population, to improve the fitness enthusiasm of our people, promote quality of life improved [2].

2. THE HUMAN FACTOR ANALYSIS DURING ROWING

2.1. Human Actions Analysis During Worwing

In the analysis of ergonomics, we can make use of simulated human body template posture in motion, to understand the scope of activities of the various parts of the body under the hypothetical ideal premise. According to the characteristics of the following actions when people rowing, using the human template for analysis of these actions (Table **1**).

2.2. Analysis of Exercise Frequency and Related Joint Trajectory

In the fitness rowing exercise performed in the process, together with the various parts to complete a series of actions. In these parts of the body, ankle, hip, knee, shoulder, elbow played a key role [3, 4]. Assuming people cycle of rowing is T, and this value is determined based on the operating speed of the body portion and frequency limit, as shown in Table **2**. Therefore, people in the use of the fitness rowing exercise, the operating frequency should be between 1.2 to 2 times, between 30 to 50 beats / min most reasonable.

Around the knee and ankle angular velocity is *ω1*, Hip movement along the rail speed is *V1*, Shoulder with respect to the hip joint angular velocity is *ω2*, Elbow angular velocity relative to the shoulder is *ω3*, Is the x-axis slide , with hip origin, establish *X-Y* plane Cartesian coordinate system, as shown in (Fig. **1**).

Point of A (knee) trajectory equation:

$$\begin{cases} x = L_1 - L_1 \sin(\frac{\pi}{2} - \omega_1 t) \\ y = L_2 \cos(\frac{\pi}{2} - \omega_1 t) \end{cases} \tag{1}$$

Point of B (hip) trajectory equation:

$$\begin{cases} x = vt \\ y = 0 \end{cases} \tag{2}$$

Point of C (shoulder) trajectory equation:

$$\begin{cases} x = L_5 \sin(\theta_2 - \omega_2) + vt \\ y = L_5 \cos(\theta_2 - \omega_2) - L_5 \cos\theta_2 \end{cases} \tag{3}$$

Point of D (elbow) trajectory equation:

$$\begin{cases} x = L_5 \sin\theta_2 - L_5 \sin(\theta_2 - \omega_2) + vt + \\ L_4 \sin\theta_3 - L_4 \sin(\theta_3 - \omega_3 t) \\ y = L_5 \cos(\theta_2 - \omega_2) - L_5 \cos\theta_2 + \\ L_4 \cos\theta_3 - L_4 \cos(\theta_3 - \omega_3 t) \end{cases} \tag{4}$$

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Table 1. Human actions analysis when rowing.

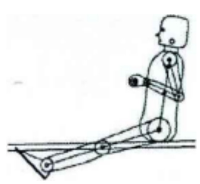
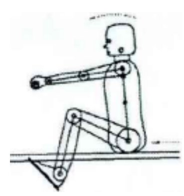
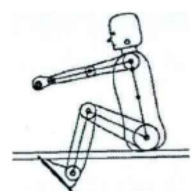
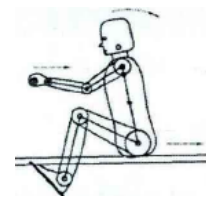
	The Stage of Paddle into the Water	The Stage of Initial State	The Stage of Paddle Out of the Water	The Stage of Paddling
Torso action	Moderate back	Moderate forward	Keep leaning forward	Expand the body and start back
Upper limb action	The grip on the bottom of the ribs	Shoulders relaxed and arms gradually straighten	Straight arm	Hand pull
Lower limb action	Legs fully extended	Slowly bend knees	Bending knees to a comfortable position	Legs to pedal force
Diagram of the human body template				

Table 2. Rowing part of the human body movement speed and frequency limits.

Action	Movement Speed and Frequency/Time
Hand range of motion (cm/s)	35
Hand bend and unbend (time/s)	1~1.2
Foot movement frequency /(time/s)	0.36~0.72
Body transfer /(time/s)	0.72~1.62

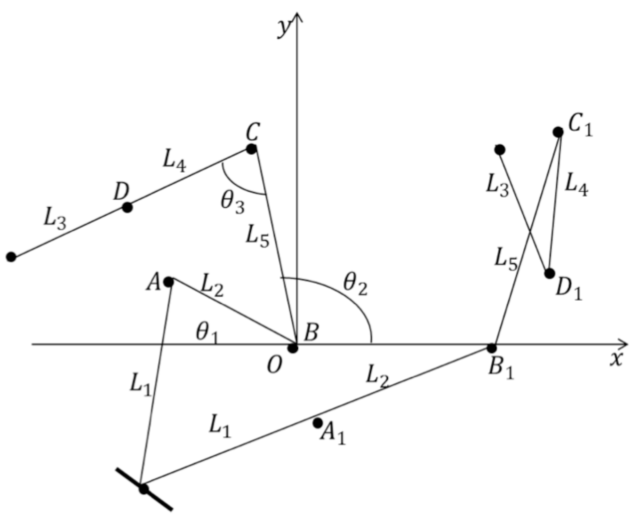


Fig. (1). Analysis of the trajectory.

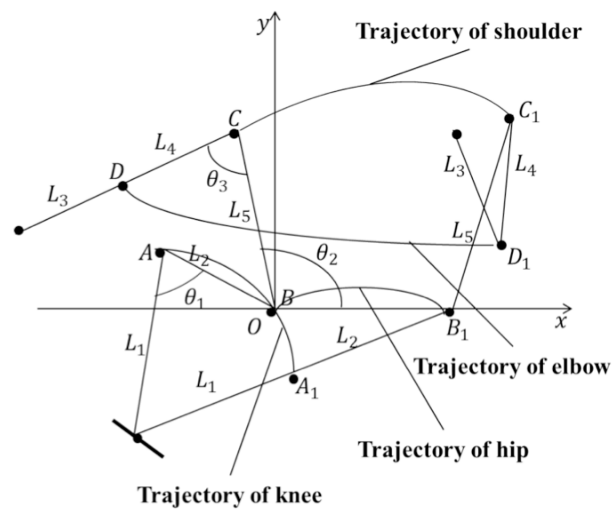


Fig. (2). Joint trajectory.

Learned from the above analysis, θ_1 activities angle range is 55^0~180^0, θ_2 activities angle range is 60^0~120^0, θ_3 activities angle range is 90^0~-30^0. Thus the trajectory of the knee is an curved trajectory. Hip trajectory is a straight line back and forth motion. The trajectory of the shoulder is an elliptical arc. Elbow movement is also an elliptical arc. As shown in Fig. (**2**).

2.3. Stress Analysis of Human Body

Making use of the fitness rowing, the body mainly influenced by cable tension, pedals reaction force, its own gravity, and friction etc [5-8]. As shown in Fig. (**3**). In the course of rowing, Weight , friction, reaction force of pedal is constant, so the equations is:

$$\begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \end{cases} \tag{5}$$

$$\begin{cases} \sum M_x(F) = 0 \\ \sum M_y(F) = 0 \end{cases} \tag{6}$$

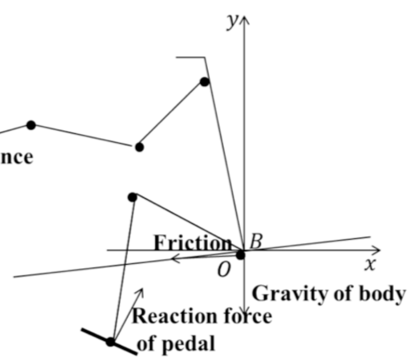


Fig. (3). Force during rowing.

The angle between slides and Horizontal plane which causes the body to produce its own gravity force in the direction of slides is small. So human body feel force mainly from the pedal (www.sports.china.com); [9, 10].

3. HMI ANALYSIS OF FITNESS ROWING OF MAIN COMPONENTS

3.1. HMI Analysis of Grip

The length of the hand grip portion is determined by the width of the person's palm, and different group of people is not the same as the width of the palm. From statistics the palm width of 5% of women and 95% of men is generally between 71mm ~ 97mm [11]. Therefore, the length of the grip should be between 71mm ~ 97mm.the hand force more reasonable when diameter of grip between 45mm ~ 50mm.

3.2. HMI Analysis of Saddle

When the body is sitting, the distance between ischial tuberosity and buttocks is about 10cm to 20cm. So the length of the back-end saddle should be about 10cm~12cm. the distance of female pelvis is about 23cm, and the distance of male is about 20cm. So the width of the saddle is about 25cm~26cm.

Saddle seat cushion is divided into two kinds of rigid and flexible cushion. Rigid saddle seat can cause numbness in the parts of the buttock. The flexible cushion is just the opposite, it can largely increase the contact area between the hips and the saddle which composed of an elastic material and masked material. Another saddle cushion material must have a high coefficient of friction.

3.3. HMI Analysis of Treadle

As aerobic exercise equipment, rowing is the role of the body in excess energy consumption. To ensure fitness resorted to a larger force, the relative distance between treadle and saddle should be minimal or even be zero.

The value of the angle of saddle and slide also affect the force of foot. Experimental results show that when the angle between saddle and slide is about 55~75, feet can make maximum force, whatever the leg is extension or curved. In order to ensure the safety of fitness, pedals must provide a fixed pin device, For example, pin belt, etc.

3.4. HMI Analysis of Slides

The length of the slides depends on the displacement of the body when rowing. By the analysis of human factor when rowing, the length of slides formula is:

$$L = L_2 \sin\alpha_2 + S + l + c \tag{7}$$

l is the length of bearing, c is the various correction value.

The width of the slide has a great influence on the fitness rowing ease of use [12, 13]. If the rail is too wide, body force difficult during exercise. If the slide is too narrow, it will affect the stability of the saddle. The width of slide and the convenience of body force to the pedal is related to the size of body. The minimum parallel distance between the two legs is about between 15.8cm and 18.3cm during rowing, so the width of slide is about between 12cm and 15cm.

4. LAYOUT OF FITNESS ROWING

From the above analysis we can infer fitness rowing in the size of each component [14, 15], as shown in Table **3-6**.

Table 3. Grip parameters.

The overall length of the grip	Grip diameter	The length of the grip	Horizontal distance between the center grip and 0 point	Vertical distance between the center of the grip and 0 point
45~48cm	4cm~4.5cm	10cm~12cm	50cm~54cm	50cm~52cm

Table 4. Saddle parameters.

The length of the saddle	The width of the saddle	Horizontal distance between the saddle and 0 point	Vertical distance between the saddle and 0 point
22cm~24cm	25cm~26cm	40cm~42cm	15.5cm~17cm

Table 5. Treadle parameters.

The Length of the Treadle	The Width of the Treadle	The Angle of Pedals	Horizontal Distance between the Pedals and 0 Point	Vertical Distance between the Pedals and 0 Point
27cm~29cm	11cm~12cm	65~70	7cm~10cm	3cm~5cm

Table 6. Slide parameters.

The Length of the Slides	The Width of the Slides	The Angle of Slides	Height of the Slides
155cm~160cm	12cm~15cm	5~8	35cm~38cm

Using the above parameters redesign fitness rowing, as shown in Fig. (**4**).

Fig. (4). Fitness rowing machine parts layout.

5. SUMMARY

In summary, using ergonomic principles fitness rowing machine, a series of research and analysis, inlucding reasonable comfort in the use of the fitness rowing machine rowing exercise, field of view, force, operating space aspects. The ergonomic design of fitness equipment, fitness, security, comfort and a fitness effect of the increase if of great significance, but also to meet the fitness needs of our population, to improve the fitness enthusiasm of our people, promote quality of life improved.

CONFLICT OF INTEREST

The author confirms that this article content has no conflicts of interest.

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