Design and analysis of motorized treadmill based on ergonomics

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Abstract. The motorized treadmill is becoming more and more popular. In the design of the motorized treadmill, it is important to consider the human factor. In order to achieve a more comfortable treadmill, This paper uses the theory and method of Ergonomics to design the motorized treadmill in terms of motor selection, the arrangement of electronic display, handrail height, drum’s diameter, running belt area, chassis’s length, the length and width of running board, the width of side strip, etc.

1. Introduction
In the past few years, motorized treadmill has been widely adopted as an indoor body-building apparatus, and is especially popular among exercisers. At present, motorized treadmill design is mostly based on experiment and experience. It results in low productivity, high cost, and especially high energy consumption. With the development of society and market, the demand of mechanical properties and cost containment is increasing. Therefore, the design of motorized treadmill based on ergonomics becomes more important for users and body-building apparatus. Ergonomics provides human body structural parameters such as size, weight, body surface area, specific gravity, center of gravity, and the relationship and reach of various parts of the human body during activities [1].

The design of motorized treadmill is based on ergonomics, and regarding the physiological and psychological characteristics of people as an important principle, so as to promote user health and fitness. Only in this way, the running is closer to natural motion state, and the motorized treadmill is more popular.

2. The Composition of the motorized treadmill
The motor drives the rollers of the motorized treadmill to rotate, which drives the running belt to circulate. So that user experience is more similar to outdoor running, more effective and safer. The exerciser can run or walk on the running belt at the speed of equal and opposite with the running belt to maintain the position on the running belt, so as to achieve the purpose of exercise. The motorized treadmill is equipped with a slope adjustment function so as to improve the effect of aerobic exercise and consume more calories.

The motorized treadmill is mainly composed of 1. electronic display, 2. handrail, 3. vertical frame, 4. motor cover, 5. lifting motor, 6. main motor, 7. conveyor belt, 8. Pre and post rollers, 9. base, 10. Running belt, 11. chassis, 12. running board, 13. side strips, 14. regulators, as shown in Figure 1.
3. **Ergonomic design of the treadmill**

3.1. **Electronic display**

The layout of electronic display should provide visual information quickly, conveniently and accurately according to human visual characteristics. The position of the display is determined by the distance between the eye and the display panel when using the motorized treadmill.

The most appropriate distance between the panel and the human eye is $L=650\text{mm}$. The display is kept at $25^\circ$–$30^\circ$ with the horizontal plane so that the panel is vertical to the user's line of sight. Figure 2 shows that the best angle between the panel plane and the vertical line is $30^\circ$ and the adjustment range is $5^\circ$–$55^\circ$ when the fitness worker exercises on the treadmill.

The formula for calculating the center of gravity of the display is: $$h = EH \tan (5^\circ$–$55^\circ)$

The optimum height of center of gravity is: $$h = EH \tan 30^\circ$$

According to the average height of Chinese adult males and females, which is $1671\text{mm}$ and $1558\text{mm}$ respectively, the optimum height of center of gravity for electronic display is $932\text{mm}$.

![Diagram of height and angle of display](image-url)
3.2. Handrail
The height from handrails to the running belt should be keeping with the height of exercisers, which is generally designed according to elbow height while standing.

The 95 percentile of elbow height while male standing was selected to calculate the maximum height of handrail:

\[ H = A + B + C = 1096 + 200 + 25 = 1321 \text{ (take 1320)} \]  

\( A \) is the elbow height while male standing; \( B \) is the chassis height (including the height of the chassis itself and the height from the chassis to the ground); \( C \) is the correction value.

In order to make most people comfortable, the structure of column should be designed to be adjustable, ranging from the 5 percentile to the 95 percentile. The height of the handrail is calculated to be 1124mm according to the 5 percentile of elbow height while female standing. Thus the height of the handrail can be designed to be 1125~1320 mm. Only in this way, people can adjust as needed to ensure a comfortable fitness experience.

3.3. Motor
The motor's type of the motorized treadmill should be determined according to the application. The motor's power of the household is smaller, while the commercial one is larger. When purchasing a treadmill, the first must be considered is the horsepower of the motor. The horsepower is not the bigger the better. The other is the voice of the motor when working. The noise of the treadmill working will affect people's fitness experience. The main motor of the motorized treadmill is a high-voltage D.C. motor. D.C. motors are superior to A.C. motors in many respects. D.C. motors have low noise and stable output, and require little maintenance.

The motor of the motorized treadmill regulates slope by using an electric push rod. The electric push rod is an electric driver that converts the rotary motion of the motor into a reciprocating straight-line motion of the push rod. It can be used as an operating device in simple or complicated process, and can realize automatic control. As shown in Figure 3.

![Figure 3. Schematic diagram of the motorized treadmill lifting control system](image)

1-base; 2(5)-connecting piece; 3-retracting connecting rod; 4-lifting motor (electric push rod); 6-treader chassis; 7-caster

3.4. Pre and post rollers
The roller is fixed on the treadmill chassis, and its role is to drive the rotation of the running belt.

In general, few cycles occur in the same speed if the drum is large, which will lead to low pressure and long life of the machine. However, the drum’s size is restricted to the size of the treadmill and the power of the main motor. Generally, the diameter of the drum is 60mm.

3.5. Running belt
Running belt is an important part of the motorized treadmill, which is directly contacted with users. The performance of running belt directly affects the quality of treadmill and people's fitness experience. The running belt is made of a kind of composite composed of PVC rubber, polyester wire
mesh and warp and weft yarns. A high quality running belt has good anti-ductility, deformation resistance and long service life, which is to minimize stress and impact to user joints.

The longer and wider the running belt is, the more convenient it will be for the exerciser to use. Due to cost and size constraints, the area of the running belt should be appropriate to meet the needs of most people. Since the length of the running belt should not be less than the distance of the exerciser's maximum stride [2], and in different forms of exercise, the stride of the running is the largest, so the length of the running belt should be based on the stride of the trainer when he runs fast, as shown in Figure 4.

In order to satisfy the majority of exercisers, the maximum stride of 90 percent of the younger fitness person with higher height is selected \( A_1 = 1250 \text{mm} \). Considering the dressing correction value \( B_1 = 25-40 \text{mm} \), the front-end psychological correction value \( C_1 = 100-150 \text{mm} \), the back-end psychological correction value \( D_1 = 50-100 \text{mm} \), and the length of the running belt is \( X_1 = A_1 + B_1 + C_1 + D_1 = 1425 - 1540 \text{mm} \). According to human ergonomics, the best length of running belt is 1425mm.

![Stride difference](image)

The width of the running belt should be designed on the shoulder width of the exerciser basis. In order to achieve higher satisfaction, the width of the running belt is 469 mm, which is the 95 percentile of the male shoulder width. The dress physiological correction value is 10 mm. Therefore, the optimal width of the running belt is 480 mm.

The thickness of the running belt should be selected according to the purpose and the power of the motor. Generally, the running belt of the commercial treadmill is thicker (more than 3mm), and the household is thinner (less than 2mm).

3.6. Chassis
The chassis is mainly composed of two bottom pipes, a running board and pre and post rollers [3]. The chassis supports the weight of the human body and the impact of the dynamic load while running. So it is an important part in the whole motorized treadmill. Therefore, the wall thickness of the steel pipe must be more than 2 mm to ensure adequate stiffness.

The size of the main motor and the length of the running belt determines the length of the chassis. The length of the main motor is about 300~400mm, and the length of the running belt is 1425mm, combined with the center distance of the driving belt, so the length of the chassis is 1800mm. The length of two bottom pipes is determined by the width of the running belt and the side strips. The width of the running belt is 480mm, the width of the side strip is 120mm, combined with the function correction value, so the length of the bottom pipe is 650mm.

3.7. Running board
The running board is fixed on the chassis under the running belt. A cushioning device is installed on the running board to reduce the impact on the kneecap while running. The running board is made of
medium density fiberboard [4], which has smooth surface, uniform internal structure, moderate density, dimensional stability, strong resistance to deformation, high bearing capacity, and excellent physico mechanical properties. Since there is friction between the running belt and the running board during running, users can pre-wax or add a little high-quality silicone oil on the running board to reduce drag, as well as reduce noise and heat, and extend the service life of the running belt. The size of the running board is mainly determined by the size of the running belt. The length of the running board is 1355 mm, and the width is 540 mm.

3.8. Side strip
The two side strips is in left and right of running belt respectively. The side strip has two jobs. One provide the short break during the exercise, and the other provide enough Safety position when the treadmill fails, the exerciser can quickly separate two feet from the rotating running belt. The side strip should meet the weight of the 95 percentile human body, so it is necessary to use high-quality ABS. The width of the side strip refers to GB/T10000 [5]. According to the 95th percentile of the 16~80 age group, the foot width is 103 mm, and the psychological correction value is 20mm, so the width of the side strip is 120mm. The plane on the side strip is designed as a rough surface to prevent slipping and protect exerciser’s safe.

3.9. Regulator
When the running belt is loosened or pulling to one side, the regulator can change the position of the two ends of back-end roller to adjust the running belt tightness, so as to protect the back-end components. Generally, the regulator is made of high strength PP material.

4. Conclusion
According to the design theory of motorized treadmill and ergonomics, this paper presents a motorized treadmill, which has advantages of optimal size, user-friendly and confirming to ergonomics. Analysis shows that: 1. the optimum height of center of gravity for electronic display is 932 mm. 2. the height of the handrail can be designed to be 1125~1320 mm. 3. the diameter of the drum is 60mm. 4. the best length of running belt is 1425mm,and the width of the running belt is 480 mm. 5. the length of the chassis is 1800mm. 6. the length of the running board is 1355mm, and the width is 540 mm. 7. the width of the side strip is 120mm.

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