Research and Development of the First Generation of Multifunctional Home Fitness Recliner

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Abstract. The first generation of multifunctional home fitness recliners is a kind of home-use portable fitness equipment that coexists with multiple functions and can be easily adjusted for strength. The fitness equipment adopts the bionic "fish-shaped" design, and uses the principle of morphological bionics to achieve the simplicity required by design and meet today's aesthetics. While improving the aesthetics of the design equipment, it also meets the requirements of ergonomics, thereby improving the user's sports experience. The device uses polyformaldehyde plastic, ABS plastic, shell ABS plastic (natural plastic in the groove), polyamide fiber, PVC artificial leather, plywood, sponge, rubber sponge and other plastic materials that meet national standards. 35 # steel, cold rolled steel rectangular tube, spring steel, tungsten steel and other materials that meet various technical indicators. Under the premise of safe use of equipment, multiple exercise uses can be realized.

1. Introduction
The fitness equipment on the market can't satisfy the exercise of core muscles of multiple people and multiple parts, and the intensity of exercise lacks adjustability. Due to the limitation of time and fitness costs, not everyone has the conditions to walk into the gym to exercise, so people need a fitness equipment that can exercise multiple parts without leaving the house and has a variety of exercise intensity. Fitness has also become a fashion in today's society. It has developed into a stable and relatively potential in other small and medium cities in developed cities, but it is also an industry with extremely uneven development. To solve the above problems, we designed the fitness recliner device.

2. Overall design of recliner
The device is provided with a spring on the handle, and the number of first springs connected is adjusted through a hook to adjust the exercise intensity. A free spring structure replaces the weight plate. Through the cooperation of various parts such as lying boards, load-bearing stands, foot pads, etc., "flying birds"
"sit-ups", "leg muscle training" and other sports can be realized to exercise the hand, abdominal and leg muscles.

![Fitness lounge chair diagram]

**Figure 1.** Partial detail of fitness lounge chair

3. **Partial design functions**

3.1. *Technical key*

The new spring structure is used to replace the weight piece of the traditional fitness equipment, which solves the problem that the traditional fitness equipment is too bulky and achieves the purpose of exercising with different strengths.

3.2. *Main technical indicators*

The maximum weight capacity of the fitness equipment is 175 kg, and the useful life of the spring is controlled from 8 to 12 years.

3.3. *Technical content*

The multifunctional recliner includes multiple parts. The main structure of the fitness equipment is divided into the following parts:

1. Seat base connecting part—including a backrest support device, a seat cushion support rod, and a footrest support rod. The upper end of the backrest support device is hinged on the backrest, and the lower end of the backrest support device is hinged on the base portion. The upper end of the seat cushion support rod is fixed on the seat cushion, the lower end of the seat cushion support rod is fixed on the base portion, one end of the foot pedal support rod is hinged on the foot pedal, and the other end of the foot pedal support rod is hinged on the base part.

2. Base part—including rocker, bearing block, thrust ball bearing, threaded slider I, screw, threaded slider II, guide plate, positioning shaft, cylindrical roller bearing, main shaft, and chassis base. The chassis base includes A chassis mounted on the ground and a U-shaped seat fixed on the chassis, the main shaft is transversely penetrated between two side walls of the U-shaped seat, a cylindrical roller
bearing is sleeved on the main shaft, and the lower surface of the guide plate faces upward. A semi-circular fixing plate is protruded downward, a fixing hole is provided in the middle of the fixing plate, and a plurality of holes are provided along the fixing plate. The fixing plate is placed between the two side walls of the U-shaped seat and the fixing plate is fixed through the mounting hole. Fitted on the outer ring of a cylindrical roller bearing, the positioning shaft passes through the two side walls of the U-shaped seat and the holes of the fixed plate in order to fix the fixed plate on the U-shaped seat, and the lower end of the seat cushion support rod is fixed on the guide. The guide plate is provided with a screw. Both ends of the screw are threadedly connected with a threaded slider I and a threaded slider II. The lower end of the backrest support device is hinged to the threaded slider I. The foot pedal the other end of the support rod is hinged on the threaded slider II, said the bearing seat is arranged at both ends of the guide plate, and the screw, the threaded slider I and the threaded slider II are fixedly installed on the guide plate through the thrust ball bearing and the bearing seat. The rocker is located outside the threaded slider I and passes the nut and the screw Consolidation; under the drive of the rocker, the threaded slider I and the threaded slider II slide along the axial direction of the screw.

(3) Foot pedal—It is L-shaped as a whole, which includes a connecting plate, a pedal, and a limit rod. One end of the connecting plate is hinged on the seat cushion, and the pedal is fixed vertically at the other end of the connecting plate. The position stick is hinged on the pedal.

(4) Backrest support device—including a caliper, a handle, and a connecting ruler, the upper part of the caliper is hinged on the backrest, and a plurality of adjusting holes are provided at the lower part of the caliper. The handle passes through the slot and the adjustment hole on the caliper to fix the lower part of the caliper on the connecting ruler, and the lower part of the connecting ruler is hinged on the threaded slider I.

4. Product related calculations

4.1. Tension calculation

Spring birds are used in bird training. Adults use scientific training methods to do 15 groups per group, do 4 groups, rest for 1 minute between groups, stay for 2 seconds each, and average 10 pulls per minute. The spring used by the spring tensioner is a tension spring.

In addition to the size of the spring, the design data of the pressure spring need to calculate the maximum load and the load of the displacement dimension; the spring constant: expressed in k, when the spring is compressed, each additional 1 mm distance load (kgf / mm); Spring constant formula (unit: kgf / mm): \( k = \frac{(G \times D_1)}{(8 \times D_m \times N_c)} \)

\( G = \) steel modulus of wire: piano wire \( G = 8000 \); stainless steel wire \( G = 7300 \), phosphor bronze wire \( G = 4500 \), brass wire \( G = 3500 \)

\( d = \) wire diameter

\( D_0 = \) OD = outer diameter

\( D_i = \) ID = inner diameter

\( D_m = \) MD = middle diameter = Do-d

\( N = \) Total number of turns

\( N_c = \) effective number of turns = N-2
The spring constant used in this exercise machine is calculated as follows:

\[ k = \frac{G \times d^4}{8 \times D \times m^3 \times N_c} = \frac{(7300 \times 24)}{(27 \times 203 \times 65)} = 0.125 \text{ kgf/mm}. \]

Wire diameter = 3.0 mm, outer diameter = 22 mm, total number of turns = 55 turns, wire material = stainless steel wire

\[ k = \frac{G \times d^4}{8 \times D \times m^3 \times N_c} = \frac{(7300 \times 24)}{(27 \times 203 \times 65)} = 0.125 \text{ kgf/mm}. \]

The initial tension of the tension spring: The initial tension is equal to the force required to adequately pull apart the springs that are close to each other, and the initial tension occurs after the spring is rolled into shape. When making tension springs, the initial tension of each tension spring is uneven due to differences in wire material, wire diameter, spring index, static electricity, grease, heat treatment, and plating. Therefore, when installing the tension springs of various specifications, it should be pre-tensioned to be slightly separated between each parallel ring—the force required for some distance is called the initial tension.

Initial tension = \( P \times (K \times x \times \text{tensile length}) \)

\( P \): Maximum load / limit load 27

\[ P_s (N) = \tau \times S \times 3.1427 / 8 \times 22 = 295N \]

Adult stretch length is about 300 mm

Initial tension

\[ P \times (K \times x) = 695 \times 0.125 \times 300 = 257.5N \]

4.2. Energy calculation

Bird training energy calculation:

The left hand pull of a normal adult is 421N, and the right hand is 556N. Taking 30 minutes of training as an example, considering that training is a long-term exercise, take 300N in the left hand and 400N in the right hand, 0.3m each pull-up displacement, and the average rate is 10 times / min, then the output power \( E_1 = 0.296 \text{ kw} \), and the generated energy is \( W_1 = 0.793 \text{ kw} \cdot \text{h} \)

Sit-up training energy calculation:

The power for an average adult to do sit-ups is 0.3 kw / h, a fitness exercise is often 0.5h, the sustainable output power is \( E_2 = 0.15 \text{ Kw} \), and the energy produced is \( W_2 = 0.225 \text{ kw} \cdot \text{h} \)

5. Three major design functions

5.1. Leg muscle training

The first leg muscles are divided into the following sections:
(1) The thigh muscle group consists of the front quadriceps (including the rectus femoris, middle femur, inner femur, and outer femoris), the sartorius muscle, and the fascia lata muscle. Adductor and pubic muscle, etc:
   (2) Biceps femoris, semitendinosus and hemimenis muscles behind the thighs;
   (3) The buttocks have glutes and glutes;
   (4) The calf muscle group includes the medial and lateral heads of the gastrocnemius muscle and the soleus muscle.

Training method for the second leg muscles
(1) Target muscle: quadriceps;
(2) Synergetic muscles: gluteal muscle, soleus muscle, hamstring muscle;
(3) Starting position: The body is lying on the back of the “leg lifter” diagonally, legs are raised up, knees are bent, and the soles of the feet are leaned on the resistance board;
(4) Action process: Inhale, push the resistance plate diagonally upward with both legs until the legs are fully straightened, and try to contract the quadriceps at the same time;
(5) Stop for 3 to 4 seconds. Then exhale and slowly bend your knees to lower the resistance plate to the starting position;
(6) Action essentials: During the whole process of movement, the back should always be close to the cushion, and the abdominal muscles should be tightened to reduce waist pressure. Do not kick too fast or too hard;
(7) Breathing method: inhale at the same time, exhale when the action is restored;
(8) Yi Fan error: lean forward.

Coach tip: Heel strength, not forefoot.

5.2. Sit-ups (mainly exercise abdominal muscles)
Abdominal muscles are an important part of human knot-hoof tissue, including rectus abdominis, external obliques, internal obliques, and transverse abdominal muscles. The exercises for abdominal muscles on a home fitness lounge chair are divided into the following sections:
First, put your feet down. Put your feet above the foam. 90 degrees to the ground, then lay back with your body without the head on the supine board;
Second, when doing sit-ups, the person should lie down, drop their center of gravity, put their hands on their ears, and slowly get up. The abdominal muscles should be tightened and paused for a short time, to roll the abdomen, and then slowly lower the body back to its original position;
Then, when the back is attached to the supine board, the next cycle can be started. When doing sit-ups, the abdomen must be rolled up. Roll up your upper body to form an arc. If you feel tired, you can put your hands on the abdomen and slowly take advantage of it;
Finally, when you do a prone position, your body should lie on the fitness chair, and your feet should be fixed in a fixed position. When doing this, you must remember that it must be the waist and not the legs. To the lower back serratus, latissimus dorsi, internal oblique, external oblique.

Precautions:
(1) Be sure to relax when doing sit-ups, not to strain your body;
(2) The head does not need to lean on the supine board, and the entire body must not be lying directly on the supine board;
(3) When practicing the abdomen, the span must not move, and it must be close to the supine board.
(4) When doing a prone position, your feet should not be disturbed, and you should keep close to the fixed surface, otherwise your body will roll over.

5.3. Flying Birds (Spring Tensioner Training Method)
The spring tensioner exercises the deltoid muscle, biceps brachii, triceps brachii, flexor brachii, and latissimus dorsi.
(1) Practicing the deltoit muscle
The spring tensioner can well exercise the front deltoid muscle. The exercise method is to stand with two feet in parallel, fix one end of the tensioner to the right foot, and hold it firmly with the right hand. The direction of extension is forward until the entire arm is parallel to the ground and then slowly lowered. The left and right arms are alternately exercised.

(2) Practicing the biceps

In the spring tensioner exercise, arm flexion is performed, and the biceps brachii is a muscle with two muscle heads. Its main role is to flex the arm. Therefore, the biceps brachii can be fully exercised in the spring tensioner;

Exercise: Stand with your feet in parallel, step on one end of the puller under your right foot, hold one end of the puller, keep your upper arm still, and then forcefully retract your forearm and stretch up and down repeatedly.

(3) Practicing the triceps

Triceps is also used when flexing the arms. The main exercise methods are standing with your feet in parallel, back tensioner, left hand at the bottom left of the back, holding one end of the spring tensioner still, and holding the right hand. Stretch the other end up.

(4) Practicing the flexor brachialis

The brachioradialis muscle is the main muscle of the upper forearm. In the use of spring tensioners, it not only acts on flexion of the arm, but also lateral flexion can strengthen the brachialis muscle.

(5) Practicing the pectoral muscles

Using a spring tensioner to clamp the chest can allow the chest muscles to be squeezed to the greatest extent. The arms can be stimulated by crossing the arms. The chest muscles continue to be tense, thereby achieving the effect of training the chest muscles.

(6) Practicing the latissimus dorsi

The spring tensioner exercise can exercise the latissimus dorsi muscles. When stretching the spring tensioner, the contraction force of the latissimus dorsi is needed. The main way to train the latissimus dorsi is to pass the tensioner around the column, like an iron pillar of a clothes rack; or to fix two spring tensioners in one place, hold each end with both hands, stand parallel to your feet, and stretch repeatedly toward the body spring tensioner.

6. Conclusion

According to the current development of the fitness industry, although it cannot fully achieve universal and balanced development in each city, in the future, the industry is continuously improving. We sincerely hope that the first generation of multifunctional home fitness lounge chairs will serve as a high-quality product in the fitness industry. Is widely used. Designing more high-quality, convenient, well-structured fitness equipment and recognized by professional fitness professionals is a pioneering path. With the development of technology, many new things are constantly emerging. I believe that in the future, there will be more and more types of high-quality fitness equipment on the market. All walks of life can compete with each other on the premise of quality and provide more choices for the relevant market of the fitness industry.

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