**Abstract**

Due to the popularity and development of medical technology, the average human life expectancy is raised year by year. Because of the increasing elderly population, new business opportunities are created for a growing number of senior citizens, who will put more emphasis on the quality of life and the way to enjoy their life. On one hand, decreased muscle strength will make walking difficult and affect the basic life skills. For the purpose of enabling older persons to exercise in order to maintain basic body functions, this study intends to improve the existing stepper machine for the elderly to exercise and maintain good health in an easier way.

The first stage of this study is to understand the habits in sports and needs of the elderly through questionnaires, inquiring the preferred functions and features of a stepping machine for the older consumers. The second stage is using the creative problem-solving theory (TRIZ) to resolve technical contradictions encountered at product improvement design. Through a wide range of thinking and design improvements, the study proposes a design of a stepper machine suitable for the seniors to exercise. Features of the designed stepper machine are described as follows: higher strength and hardness of an aluminum alloy is selected as the main material for bracket and pedal; handrails installed to prevent users from falling because of losing the center of gravity; a strap attached onto the top of the pedal to prevent foot slip; and additional wheels on both sides of stepping machine for easy movement. In the end, this study completes the 3D graphics of the proposed stepper machine with SolidWorks and produces a product prototype using 3D printing.

Keywords: Stepper Machine, TRIZ, Seniors

1. **Introduction**
2. Background

In 2011, those who were born after 1946, or the baby boomers, started to turn into 65, which became the unprecedented “aging boomers.” The impact of an aging society began to appear. The popularity and development of medical technology raised the life expectancy, which brought the aging signs to both physical and mental condition. The degradation in physiological aspects includes functions in exercising, visual and auditory sense; the degradation in muscles also affects walking function as well as basic living skills.

Since the body functions of the elderly are inferior to those of younger people, there are lots of fitness products not suitable for the seniors. In fact, most of the fitness equipment in the current market is mainly targeting younger generation, which might bring risks to older customers who are suffering from degradation in body functions. As a result, this study aims at improving stepper machines in current market, so that the elderly can easily operate the equipment without concerning their health issues.

The main purposes of this study are as follows:

1. Understanding the characteristics and needs of the elderly
2. Analyzing questionnaires to find out the needs of elderly toward the functions of stepper machines
3. Designing a suitable style for the elderly
4. Producing a product prototype to test its expected functions

**2. Literature Review**

1. The importance of daily exercise to the health of the elderly

The cellular tissue degradation happens as people age, and the aging process not only appears in the change of appearance but in the dysfunction of organs, at an unexpectedly high rate. The degradation can be categorized into three types: motor function degradation, consciousness degradation, and cognitive impairment (李傳房，2006).

As people age, number of myofibrils decreases, which weakens the muscle strength of the elderly. At the same time, the control ability of the central nervous system (CNS) decreases, which affects the sensibility and speed in their motions. According to Japanese elderly research scholar 林玉子, the physical disabilities of the elderly could be categorized into two types: upper and lower extremity functions. Disability in upper extremity functions would result in being unable to perform elaborate skill activities, such as rotating the handlebar or using the adjuster; disability in lower extremity functions would cause the elderly to be in need of crutches or walking sticks to assist their movement (古京讓, 2006). Exercises for the elderly should mainly be set at mild level, starting from mild exercise intensity (35-55% of maximum heart rate) to moderate exercise intensity (55-65% of maximum heart rate), so that it can properly improve the health of the elderly (謝宛玲等，2010).

There are several exercise plans for the elderly, which include muscle strength, cardiopulmonary function, flexibility and balance training. These plans not only improve the functions in body during daily life as well as the quality of life, but they assist the osteoarthritis (degenerative arthritis) patients to relieve pain in the joints during different motions. During flexibility training, the motions in joints should be at least not causing any pain; if in pain, swelling or slowing down during the motions, the activity should be halted. The duration of cardiopulmonary training should start from a short period of time (10 min) and be extended gradually to 30 min (林宗慶 ,2011). Related studies indicated that keeping a daily workout of 15 min could increase a person’s life expectancy by 3 years on average and decrease the death rate by 14% (蔡英美、王俊明，2011). Also, engaging in regular physical activities brings comfortable and peaceful feelings to overcome bad moods, enhance immunity, and improve health condition (劉春來等，2014).

1. The impact of lower body muscle on health of the elderly

The lower body contains 70 percent of the body’s overall muscle mass. Hence, there is a saying goes, “The aging process starts from legs.” Muscles can be regarded as human’s second heart, which secretes a kind of hormone that prevents aging by breaking down body fat and stabling blood pressure. 春山茂雄, a MD-Ph.D. at University of Tokyo, pointed out that only lower body muscles (gluteus maximus, gastrocnemius, tibialis anterior, and peroneus longus) formed in 4 months from exercising, could secretes that specific hormone, which happened rarely in upper body muscles regardless of a young age. Dr. 石原結實mentioned that as long as the exercise of muscles occurred, the hippocampus in the brain would be activated due to blood circulation, which would help strengthen the memory and prevent dementia. And according to the research conducted at New York University (NYU), doing weight training such as lifting dumb bells could improve the function of hippocampus, which would be helpful to the maintenance and recovery of memory (良醫健康網, 2013).

1. The seniors market

As the world’s population is getting older, the spending power of the elderly ought to be taken into consideration; however, there are not many kinds of product designed especially for the elderly. It should be clear enough that the senior market will keep growing, and in the future, it will be a trend for companies to promote products targeted at senior people (林聰良, 2008).

Prof. 李傳房(2006) claimed that designers in these days are mostly taking healthy and/or young people as their target customers rather than considering the need of the elderly, whereas the latter have higher spending power and a growing proportion in the society. It would be a valuable market to develop from an economic point of view, as the elderly became a potential consumer group. And what should be considered includes accessibility, product popularity and generalized cost.

高雅玲、陳文棠(2013) also mentioned that the current “aging boomers” in Taiwan could be said the most wealthy group of people. Compared to previous generations, they are more comfortable with new technology, good at enjoying life, and paying more attention to quality of life.

1. TRIZ

Using 39 engineering parameters, an improvement parameter and a deterioration parameter can be found in accordance to a technical contradiction problem. And by referring to contradiction matrix chart and 40 innovation principles, a suggestive rule will be generated in order to assist in solving the problems occurred in design and/or improvement stage of the product.

**3. Research Methods**

1. The questionnaire

A questionnaire was created and distributed to target customers to investigate their requirement preference in functions, and the product is designed and improved based on the results. 107 questionnaires were handed out, 100 were valid, which took up 93.46% of questionnaires. The results generated from the questionnaires were analyzed with both Microsoft Excel and SPSS. The interviewed sample group could be described as follows: more male than female; retired as the major group, followed by service industry; time of exercise from 30 min to 1 hr; and mostly doing jogging and/or brisk walking. On the other hand, the requirement preference in features and functions were discovered, as “accident prevention” the most valued, followed by “slippery prevention” (Chart 3.1) with Cronbach α = 0.711.

Chart 3.11 Requirement preference in functions of a stepper machine

|  |  |  |
| --- | --- | --- |
| Ranking | Feature or Function | Weighted Score |
| 1 | Accident prevention | 409 |
| 2 | Slippery prevention | 408 |
| 3 | Shake prevention | 404 |
| 4 | Durability | 403 |
| 5 | Simplicity | 396 |
| 6 | Occupancy rate | 375 |
| 7 | Lightness | 374 |
| 8 | Heart rate | 356 |
| 9 | Heat radiation | 351 |
| 10 | Handlebar | 350 |
| 11 | Resistance | 346 |
| 12 | Appearance | 325 |
| 13 | Waist twist | 319 |
| 14 | Music | 316 |
| 15 | Voice | 305 |
| 16 | Heat generation | 286 |

1. Using TRIZ with innovation to develop the principles of solving problems in product design

In this study, TRIZ is applied to improve and enhance the product design, with an emphasis on the first eight features from the questionnaire. The problematic situations are described as follows:

Problem 1 – To improve the force on the frame will increase the endurable weight, but the degree of system complexity will also be raised.

Improvement parameter: 11 Stress or pressure

Deterioration parameter: 36 Degree of system complexity

Innovation principle: 1 Segmentation, 19 Periodic action, 35 Parameter changes

The #35 Parameter changes principle is applied in this study to replace the material of the frame with a light and firm type.

Problem 2 – To install a handlebar onto the stepper machine will enhance its safety and stability, but the handlebar will increase the volume of the stepper machine.

Improvement parameter: 27 Reliability

Deterioration parameter: 8 Volume of fasteners

Innovation principle: 2 Separation, 24 Intermediary, 35 Parameter changes

The #2 Separation principle is applied, as the handlebar are separated from the machine itself and only installed when in need

Problem 3 – The interviewed sample group emphasized the “lightness” feature, so the weight of the stepper machine is set to be reduced, which will nonetheless drop the stability of the object composition.

Improvement parameter: 2 Weight of fasteners

Deterioration parameter: 13 Object stability

Innovation principle: 1 Segmentation, 26 Copying, 39 Inert atmosphere, 40 Composite materials

The #40 Composite materials principle is applied, and the metal part of the machine is replaced by alloy material in order to reduce the overall weight and to strengthen the stability.

Problem 4 – Wheels are to be installed onto the machine to enable the elderly to move the machine easily, but this will also reduce the safety of the machine.

Improvement parameter: 33 Easiness of operation

Deterioration parameter: 27 Reliability

Innovation principle: 8 Weight compensation, 17 Dimensionality change, 27 Cheap disposables, 40 Composite materials

The #17 Dimensionality change principle is applied, so that wheels are installed only on both sides of the machine to enhance safety while enabling the machine to be moved easily.

Problem 5 – Larger pedals will help the elderly to stand firm, but if the force is uneven on a larger area, the pedals may shake.

Improvement parameter: 5 Area of a moving object

Deterioration parameter: 14 Force

Innovation principle: 7 Nested doll, 9 Preliminary counteraction, 14 Curvature increase, 15 Dynamic parts

The #9 Preliminary counteraction principle is applied, so that only one even force from below is supporting the pedals to ensure the stability

1. **Results & Graphics**
2. Results

According to the questionnaire, it was revealed that most customers take safety, slippery prevention, stability and durability of the stepper machine as their prior considerations. Hence, the additional features are added to the product design as follows:

1. Using aluminum as main material to keep the lightness and firmness of the product
2. Installing a handlebar to prevent senior people from falling and losing center of gravity
3. Installing a strap onto the pedals to create fixed position for foot as well as to prevent slippery and enhance safety

On the other hand, the design in product appearance is adjusted, which are described as follows:

1. Installing a shock-absorbing sleeve under the pedal to reduce noise of the machine
2. Adding trendy elements of 50s and 60s (i.e. Popeye the Sailor Man) onto the product appearance design
3. Creating a control panel that is easy to operate, especially for the elderly
4. Properties and product features

In this study, 4 major properties are generated through TRIZ problem solving application in order to analyze required features and design the product:

1. Materials properties
2. Using aluminum as the main material of the frame and the handlebar for the following merits:
   1. Light weight (one third of the weight of steel)
   2. Strong, as its strength level could be raised up to 2kg/m2~60kg/m2 under heat treating
   3. Generally, aluminum alloy is intolerant of high temperature. However, researchers have discovered a new aluminum alloy material that can resist heat up to 427 ℃ [16].
3. Rubber is used as the base material for pedals.
4. Design properties
5. Strap buttons are installed on the pedals and a strap put on to tie the foot and prevent slippery.
6. Optional handlebar is installed for the elderly, which can be removed depending on users’ sense of balance. The diameter of the handlebar = 35mm.
7. Wheels are installed on each side of the machine to enable users to move the machine around.
8. Function properties
9. The handlebar can detect the heart rate and enable users to keep track of their exercise and heart activities.
10. Stepping modes can be divided in to automatic and non-automatic, which are optional for users
11. The height of the handlebar is adjustable up to 5 levels, from 90-110 cm.
12. Appearance properties

The top part of the handlebar is designed as the arms of Popeye the Sailor Man from the 50s in order to have a dose of nostalgia and energy, as well as to wish users a strong and healthy life.

1. Design analysis

In this study, SolidWorks is used to illustrate 3D design graphics of the stepper machine, which is designed to have an optional handlebar that can be installed when in need. Figure 4.1 shows a perspective view of the stepper machine by itself, and when users need to increase safety, a handlebar can be installed, as shown in Figure 4.2.

Fig. 4.1 A perspective view of the stepper machine

Fig. 4.2 A perspective view of the stepper machine with a handlebar

Figure 4.3 shows a right side view of the stepper machine, from which the wheels are revealed as installed on the side of the machine, so that the machine can be moved easily without being raised up.

Fig. 4.3 A right side view of the stepper machine

Figure 4.4 shows a rear view of the stepper machine, from which the strap buttons are revealed as on both sides of the pedals. To prevent slippery while using the machine, a strap can be installed onto the pedal (Fig. 4.5) to enhance the stability of the foot. A shock-absorbing sleeve is also installed on the supporting frame of the pedal in order to reduce noise of the machine.

Fig. 4.4 A rear view of the stepper machine

Fig. 4.5 Straps installed on the pedals

Figure 4.6 shows a top view of the stepper machine, from which the slot for installing the handlebar and the display screen are revealed; Figure 4.7 shows the Popeye the Sailor Man design of the handlebar; and Figure 4.8 and Figure 4.9 are engineering drawings of the stepper machine, which show that the height of the handlebar = 1000mm, diameter of the handlebar = 35mm, diameter of the handlebar slot = 20mm, and the distance between the slot and the ground = 30mm. The relevant dimensions of this design refer back to the results of 許勝雄(2013) and 黃室苗(2010).

Fig. 4.6 A top view of the stepper machine

Fig. 4.7 The Popeye the Sailor Man design of the handlebar

Fig. 4.8 An engineering drawing of the handlebar -1

Fig. 4.9 An engineering drawing of the handlebar -2

1. Exploded view drawing

Figure 4.10 shows an exploded view drawing of the stepper machine.

Fig. 4.10 An exploded view drawing of the stepper machine

**5. Conclusion**

In this study, the elderly is considered as the target user. Hence, the main product is designed and improved based on the need of the elderly. In the first stage, a questionnaire was created and distributed to the target users, from which the required functions and the degree of importance of a stepper machine for the elderly were revealed. In the following stages, related literatures, patents and product information were collected, and the innovation principles were identified to solve the potential problems using TRIZ engineering parameters and contradiction matrixes. Finally, an innovative product was designed, with features described as follows:

1. The materials properties include using the new aluminum alloy as the main material of the main body of the stepper machine, for its lightness, strength and heat resistance.
2. The design properties, based on the results of questionnaires, are focusing on safety, slippery prevention, stability and durability. Modifications are made accordingly, which include installing a handlebar for the safety concerns, adding small dots onto the pedals to increase friction, installing foot strap to prevent slippery, and applying the new aluminum alloy to enhance the durability.
3. For the handlebar, a Popeye the Sailor Man design is applied to add a dose of nostalgia and energy.
4. For the elderly’s convenience and safety while moving the stepper machine, wheels are installed on both sides of the machine.

Two special features are designed during this study as well: First, there are two stepping modes, automatic and non-automatic, to switch easily on the machine. Normally, stepper machines available in the market are separated by these two different modes; however, this feature mainly assists the elderly in keeping the exercise even while lacking the physical strength, so that their bodies can still be trained, and their immune systems can be enhanced. Secondly, straps are installed onto the pedals for keeping the foot from slipping and falling from the machine during stepping activities. In this way, the safety of the elderly can also be protected.

**References**