Exploring the design of a lower limb exoskeleton for the elderly based on the concept of humanistic care

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Abstract: With the development of economy and society and the advancement of science and technology, life expectancy per capita has generally increased and the number of elderly people is increasing day by day, which accelerates the trend of population ageing. The use of lower limb exoskeletons can effectively solve the problem of limited daily mobility of the elderly. Based on the study of the physiological and psychological characteristics of the elderly, the article introduces the design concept of humanistic care into the design of the lower limb exoskeleton for the elderly and explores the development direction of humanistic design of the lower limb exoskeleton for the elderly. The article innovatively proposes the concept of "humanistic care", summarizes the design factors of the lower limb exoskeleton at the physiological and psychological levels, and proposes corresponding design strategies for the structure, function, colour, material and form of the exoskeleton. It also proposes corresponding design strategies for the structure, function, colour, material and morphology of the exoskeleton. It elevates the exploration of humanistic design of the lower limb exoskeleton to a deeper level and provides new ideas and methods for the design of the lower limb exoskeleton for the elderly.

1. Research Background

1.1 Growing older population

China is the world's most populous country, with a huge population that is larger than the total population of the world's developed countries and regions. According to the latest figures released by the National Bureau of Statistics, China's total population has exceeded 1.4 billion. At the same time, China is facing demographic changes and the trend of population ageing in China is gradually deepening. The age of population ageing has made the issue of elderly people's retirement gradually become the focus of society's attention. Influenced by traditional Chinese culture, most elderly people in China choose the family model of retirement, which means that their children are mainly responsible for their daily needs. As a result of family planning policies, many younger generations are faced with the problem of supporting four elderly people, which seriously reduces the quality of life of young and middle-aged people. Therefore, how the elderly can enhance their ability to live independently and lead a happier life in their twilight years is a topic of concern for the whole society.

1.2 The weakening of the human body

As we age, the body's perceptual system, cognitive abilities, physiological functions and psychological functions change, with the body's tissues and organs gradually declining in function, slowing down of thinking and reactivity and decreasing vitality, making the psychological and physiological characteristics of older people different from those of younger people [1]. When the human body enters old age, the motor function becomes slower to get up and walk, the range of joint movements decreases and the ligaments and muscle strength decrease. The lack of autonomous activity in the elderly easily prolongs the static activity time and creates physiological inertia, which in turn causes muscle atrophy and joint stiffness, resulting in different degrees of motor dysfunction[2]. Therefore, the main focus of this paper is to design an assistive exoskeleton product that enhances the experience of using it for the elderly, taking into account the psychological and physiological changes

of the elderly users.

1.3 The continuing development of exoskeleton technology

An exoskeleton is a rigid external structure that provides conformation, construction and protection of a creature's soft internal organs, and its system is a wearable device that enhances bodily functions for its wearer. Exoskeletons have gradually proliferated from the dedicated military sector to the civilian sector, with an increasingly wide range of application scenarios to meet the diverse needs of different users. In recent decades, in order to reduce the consumption of power sources and increase the user experience, the development trend of exoskeleton modelling has gradually developed in the direction of light weight and flexibility, and new technologies and materials have been continuously developed and utilised, such as: 3D printing technology, flexible battery technology with elastomer matrix and embedded flexible materials, new technologies such as sensor technology that can be easily integrated with textiles and soft parts, new technologies such as carbon fibre, aerospace aluminium and Titanium alloy and other new materials, the application of these new technologies and materials to provide support for the lightweight and anthropomorphic appearance of the exoskeleton shape, for example, the Aurora electric augmentation suit designed by Superflex in the United States, made of flexible, lightweight fabric, overall not much different from the usual clothing, but in the torso, limbs and hips equipped with hexagonal sensors and power devices[3], which provides motor assistance via micro-electronic muscles, and an overall weight of approximately 1.8 kg.

2. Awareness of the elderly population

2.1 Physiological characteristics

(1) Changes in body shape

According to medical research on ageing, height decreases at a rate of 1 cm per decade after the age of 30, with a relative decrease of 2.5% to 3% after the age of 70, and there is a common problem of stooping posture in older people due to changes in the spine[4]. The pathology of O-leg is based on progressive degeneration, destruction and wear of the articular cartilage caused by a variety of pathogenic factors, which can cause a range of joint symptoms in up to 70% of these patients over the age of 50. Excessive pressure and friction leads to collapse and wear of the medial cartilage and laxity of the lateral collateral ligaments, which, when combined with these factors, gradually aggravate the O-leg in the elderly, leading to secondary osteoarthritis[5]. In the elderly, due to a decrease in cell proliferation in the epidermis, the stratum corneum becomes thinner and the elastic fibres and subcutaneous fat in the dermis decrease, resulting in thinning, laxity and reduced elasticity of the skin, which dries out and wrinkles appear.

(2) Decline in motor function

The ageing of the human body has a negative impact on bones, muscles and joints. Bone elasticity decreases, synovial fluid in joint cavities decreases and muscle fibres age, which in turn causes a decline in muscle strength and bone strength in the elderly, who show slow movement and an unsteady gait in daily life, a decline in balance, muscle The lack of elasticity and increased brittleness of the bones make it easy for the elderly to fall and break bones, which are not easy to recover from.

(3) Decreased perceptual ability

With the aging of the body organs, the sensory ability and information processing ability of the elderly will be weakened to different degrees, specifically in the visual, auditory and tactile senses, with the following characteristics: visually, the visual sensitivity of the elderly is reduced, and the judgment of the size and position of objects will have different degrees of deviation, and the ability to distinguish colors will also be reduced. In terms of hearing, deafness, deafness or deafness are the most common phenomena, and the decrease of hearing ability will directly affect the speech understanding and speech ability of the elderly. In terms of tactile sensation, studies have shown that seniors over the age of 60 have reduced sensitivity, as evidenced by numbness in the fingers and slowed perception of heat and cold.

2.2 Psychological characteristics

The process of population ageing brings with it a variety of ageing issues, and differential studies of older people focus not only on physiological changes, but also on psychological changes as they move from youth to old age.

(1) The frustration of weakened physical abilities

Reduced physical form, perception, cognitive ability and motor function can have different psychological effects on older people. The sensory process is the process of perceiving information, receiving information and digesting information. People communicate with the outside world through the joint action of various sensory organs such as hearing, vision, smell and touch. The degeneration of the senses, which has a greater impact on the daily life of the elderly, is the hearing and vision. Hearing loss in the process of communication with others, due to the inability to hear others' speech, makes the elderly more and more reluctant to communicate with others and more likely to to become negative-minded and live a closed life. The decline in vision affects the speed of daily observation and information reception, and the speed of reaction is greatly reduced. Weakened cognitive abilities make older people less able to learn, pay attention and remember, and feel unable to remember many things and to actively receive information beyond their own perception. The strength of older people is becoming weaker to the extent that older people are moving more and more slowly, relying on outside assistance when necessary to meet basic walking abilities. The combination of different emotions makes older people lament the fact that they cannot do many things when they are old.

(2) Loneliness of changing family structure

The residential status of the elderly is commonly in the form of living alone, widowed and living alone, living with a partner and living with children who are married, while their children are busier and do not care enough for them. In the long run, their inner needs are not met and they become emotionally sensitive and lonely.

(3) Sense of loss from changing social roles

After retirement, the elderly have more leisure time and some of them go out less frequently due to restricted physical activities, their recreational life becomes less, they lack spiritual support and lose their sense of self-worth and achievement, and are prone to feelings of loss and low self-esteem.

The physical decline of the elderly, changes in family structure and social roles all have an impact on the psychology of the elderly, making them prone to extreme emotional changes, loss of self-worth, negative and pessimistic psychological perceptions, increased loneliness, anxious and fearful mental states, sensitive self-esteem and other psychological states.

3. The ideological content of the concept of humanistic care

3.1 Humanised design

Humanised design refers to the design process with human beings as the starting point, according to human behaviour, physiology, psychology, culture and other factors, the redesign of existing products, as a way to achieve the coordination of function and emotion. The purpose of humanised design is to put people first and to respect their physiological and psychological needs in the design.

3.2 Overview of the concept of humanistic care

The concept of human-centred design was introduced in the 1950s as a way of designing products to meet the needs of disadvantaged people. In the current human-centred environment, the concept of care design should not remain in the familiar, superficial sense of care, but rather be user-centred, understanding their real needs, and designing products to meet their demands in different environments and under different conditions as far as possible.

As China's elderly population continues to increase, society is paying more and more attention to the elderly group and the elderly product manufacturing industry is gradually expanding. The elderly do not have an economic advantage and tend to age in life, they are a vulnerable group of people or a disadvantaged group in the field of health. Their health functions and states in terms of physiological, psychological and social adaptations are to varying degrees weaker than those of young adults, and thus require care and assistance from society, families and individuals [6]. Therefore, research on the

development of products for the elderly should be based on the decline of various indicators of physical functions, cognitive functions and perceptual functions of the elderly to carry out age-appropriate design, care for the physiological and psychological needs of the elderly according to these characteristics, and avoid a sense of compartmentalisation and frustration when the elderly use the products[7]. According to Maslow's Hierarchy of Needs theory, human needs are divided into physiological needs, security needs, social needs, respect needs and self-fulfilment needs, of which physiological needs are at the bottom of the pyramid and are the most basic needs, except for the physiological level the other four levels belong to the spiritual level needs. The design process is based on physiological needs, cross physiology, psychology, ergonomics, sociology, consumer science and other disciplines, to meet the aesthetic psychology, use psychology and consumer psychology of elderly products in the design of care.

4. Exploring the design of lower limb exoskeleton for the elderly under the concept of humanistic care

4.1 Design factors for exoskeletons under the concept of human care

4.1.1 Physiological aspects of care

(1) Safety

The safety of the exoskeleton is mainly reflected in the structure of the exoskeleton assembly, the precise selection of components, and the transmission of information between systems. The mechanical structure of the exoskeleton and how the structure is connected to achieve the best assistance effect while ensuring the safety of each user, if the choice of power exoskeleton in the design of the control system to consider fault-tolerant thinking, to prevent the procedure of the exoskeleton to the user caused injury, for these aspects if not enough attention, there is a high risk of safety hazards.

(2) Easy to put on and take off

When wearing the elderly due to the inflexibility of the body, for the product easy to wear requirements are higher, taking into account that the elderly body is far less flexible than young people, the design of the wearable exoskeleton should take into account the elderly bending and lifting the leg difficulties, finger inflexibility and other problems.Figure 1 is an exoskeleton walking knee brace for the elderly, the process of putting on is complicated, the strap needs to go through three connection holes, which are located above, inside and below the knee, the lower knee hole also needs to be fixed by wrapping the strap from the back of the knee to the front, which is complicated for young people, let alone the elderly with inflexible fingers and unclear vision, it takes longer, Figure 2 Using hook connection, the process of donning and doffing is convenient and fast, but physical activity, may lead to hook off. For the wearable senior-assisted exoskeleton, in addition to considering the overall design, for the elderly, how to wear more convenient and time-saving, in the details to reflect the care of the elderly.

Figure 1: Ailekesi exoskeleton assisted walking knee pads

Figure 2: Knee rehabilitation brace

(3) Comfort

The comfort of the design of the lower limb exoskeleton for the elderly is a multi-faceted experience in the process of using the product, so that it produces a tacit and harmonious relationship with the care product and presents a natural and comfortable state in the process of its use. The comfort of the lower limb exoskeleton can be reflected in visual comfort and experiential comfort, the degree of visual comfort depends on the control of the colour, shape and texture of the product, while experiential comfort can be considered from the material aspect. The material can be used to interpret the characteristics of the product and improve the comfort of the product.

(4) Ease of use

Ease of use means that consumers can easily and quickly understand and access information when using the product. In today's technologically advanced society, in order to meet the many needs of older people, designers will add functions, and the addition and superimposition of functions leads to complex and cumbersome operations. When designing an assisted exoskeleton, it is important to care for the needs of older people for simple and intuitive steps, and to design in a way that harmonises the relationship between functionality and ease of operation, so that the assisted exoskeleton can better serve the elderly.

4.1.2 Psychological aspects of care

(1) Concealment

In the modern environment of continuous development of technology, the various products designed for the elderly groups to facilitate their lives should not only be designed to meet the function and update the selection, but also care to the psychological needs of the elderly to comfort and care for the soul, through the analysis of the psychology of the elderly found that excessive care will increase their psychological pressure. For example, when the elderly take public transport, the beep of the senior citizen card, excessive distinction will cause them a certain amount of psychological pressure. Existing power-assisted exoskeletons are mostly outside of clothing, causing hidden psychological pressure on elderly users. Therefore, how to design a lightweight and simple hidden exoskeleton, so that the free movement state of the elderly reaches the same level as normal people, and in the process of using it will not increase the psychological pressure because of other people's strange eyes, so that they are more willing to accept and use exoskeleton products. The concealed design direction can be considered from three aspects: firstly, it can be worn directly into the clothes, secondly, it can be consistent with the dressing style of the elderly and coordinated with the clothing without feeling abrupt, and thirdly, it can be customised to meet the individual needs of the elderly and meet their preferences.

(2) Aesthetic

As the human body enters old age, the perceptual and cognitive abilities will have different levels of decline, making the information reception ability of the elderly weaker. When designing the exoskeleton the choice of shape and colour should be based on the characteristics of the elderly. The aspects that will be involved in the choice of colour and shape are the experiences and likes of the elderly group. In terms of modelling, the overall take a smooth, rounded shape, can be based on the nostalgic psychology of the elderly, preferences, habits and products related to it charge lines, modelling design, for the colour of the brightness, purity, hue to rationalise the application, in line with

the aesthetic psychology of the elderly.

4.2 Design strategies for lower limb assisted exoskeletons

4.2.1 Structural design strategy

(1) Adjustable structure

The use of the exoskeleton for the elderly takes into account the fact that the elderly may change in different ways, for example: swelling of the lower limbs, increase or decrease in clothing, requiring size adjustments. The design of the exoskeletal structure is influenced by the length and width data, the length of the human limb has a certain proportional relationship with the height. For people between 160 and 180 cm in height, the difference in circumference between the thighs and calves is approximately 6 cm. In order to accommodate most human body sizes, the exoskeletal structure should be designed to allow for adjustment in both the length and circumference directions[8].

(2) Limiting structures

When walking, squatting and walking up and down stairs, the knee and hip joints flex and extend around the coronal axis in the sagittal plane, and when designing the structure, it is necessary to combine the movement angle of the human body to limit the structure. The extreme range of motion of the knee joint in the sagittal plane is between 120-135° and the angle of extension is between 10-20°. Considering the ageing of the body, the ageing of the joints and the brittle bones of the elderly, the extreme angle is chosen as the minimum value from a safety point of view, so the limit of flexion of the knee joint in the sagittal plane is limited to 135°, the flexion of the hip joint in the sagittal plane is limited to 120° and the extension of the hip joint in the sagittal plane is limited to 10°.

(3) Tie-down structures

With safety and comfort as the starting point, the airbag structure moves in the pressure concentration area, and during the use of its internal gas flow with each other, the uniform pressure plays a shock-absorbing and cushioning role.The knee immobilizer of Ottobock, such as Figure 3, is designed with a removable airbag in the knee joint, which can protect the safety of the knee joint and make the knee joint area more comfortable. The selection of the fixation method of the restraint components is generally based on snapping, sticking, stall buckle and bar buckle, etc. The limb restraint connection usually chooses nylon sticking buckle, which is simple to operate and easy to adjust, and snapping or stall buckle in the parts of the waist and back that need to bear more force, which is durable and strong and easy to operate [9].

Figure 3: Knee immobilizer, Image source: Otto Blog China official website

4.2.2 Functional design strategy

(1) Hardware functional analysis

The goal of the exoskeleton's assistance is zero embodiment, when the user's lower limbs provide enough strength to achieve daily flat walking, the exoskeleton can not provide a source of strength, when the sensors detect a lack of lower limb strength, the exoskeleton provides assistance, the lack

may be due to up and down stairs, stand up and other large movements that require sufficient strength, or may be due to muscle fatigue caused by prolonged walking, muscle strength gradually increased after This is detected by sensors and fed back to the exoskeleton system to reduce the assistance, which is dynamically assisted by the exoskeleton.

The quadriceps muscle is the most affected part of the lower limbs by muscle atrophy in the elderly. The quadriceps muscle acts mainly on the quadriceps through local vibration, which drives the biceps and the muscles around the knee joint to stimulate muscle activity and muscle relaxation by means of vibration massage, using vibration frequency and amplitude.

(2) Software function analysis

In terms of software functions focus on the statistics and output of data, real-time recording of the wearer's data, with reminder functions, data branch function, the establishment of visual data interface, convenient for the wearer to obtain information accurately and quickly, in order to facilitate the use of the elderly, the need to simplify the interface interaction of information layers.

4.2.3 Colour Design Strategy

Colour is the most important element of visual communication in design, in design, colour is one of the important factors that cannot be ignored, it can not only touch people's hearts, but also convey different emotions, different colours will bring different emotional experiences, the emotional nature of colour comes from the association of colour, good colour composition, will leave a deep impression on people. Older people are more inclined to such versatile colours as black and white, because black gives a more serious and mysterious feeling, while white feels pure and refreshing, so the overall choice of the exoskeleton is white, and the details can be embellished with one of the colours chosen from orange, blue, red and green.

4.2.4 Material design strategies

The support material of the exoskeleton is chosen as a strong, stable, malleable and corrosion-resistant lightweight material, and carbon fibre is chosen as the main material. Carbon fibre material is lighter in mass than metallic aluminium, but stronger than steel, with the advantages of high strength, high hardness, light mass, high chemical resistance and high temperature resistance, which can achieve the effect of light weight to a greater extent; the flexible material is chosen as a sweat-absorbing and breathable material, because when worn on the human body The excess heat generated by the body cannot be discharged, which may cause local itching and affect the wearing experience. The parts in contact with the limbs can preferably be made of chitin, which is a natural, green and multifunctional material with the advantages of antibacterial, breathable, perspiration, anti-mould, deodorisation and odour removal, enhancing the experience of elderly users. The inner side of the support material can increase the thickness of the flexible layer or choose a padding material with good pressure-reducing properties. The bindings are made of elastic and wear-resistant fibres.

4.2.5 Form design strategy

The shape is the first representation of the product, and a good shape design contains or can convey information that influences people's attention and interest in the product. For the shape design of the exoskeleton, a reasonable shape can improve the efficiency of mobility assistance and achieve the unity of functional and formal beauty. The overall streamlined design style, rounded and without angles, the shape will fit more closely to the curve of the human body, and will also fit more closely to the action state of the human body when executing commands, reducing resistance and energy consumption.

5. Conclusion

The design of the lower limb exoskeleton for the elderly is based on the physiological and psychological characteristics of the elderly, with a better focus on the inner needs of the elderly. The lower limb exoskeleton takes the concept of "humanistic care" as the entry point to redesign the existing products, so as to meet the spiritual needs of the elderly and improve their quality of life. In

addition, in the context of China's ageing society, the development of lower limb exoskeletons for the elderly is of great relevance to China.

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