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Research on the method in evaluating the balance function of old people

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ABSTRACT

The purpose of the paper is to research a new method of detecting and evaluating balance function of old people for improving the quality of balance evaluation. The methods of evaluating balance function include as follows. Firstly, intuitional methods include observatory and questionnaire. Secondly, the Center of Pressure (CoP) and Center of gravity (CoG) of an old people are detected to evaluate static and dynamic balance function with scientific equipment. The dedicated micro-machining accelerometer and angular rate sensors are effective in detecting the center of gravity (CoG). Finally, different algorithms were applied respectively to evaluation of static and dynamic balance function.

KEYWORDS

Balance function;
Detection and evaluation;
Sensors;
Healthy of old people.

INTRODUCTION

The health condition of the old has been paid more and more attention. In the view of medical, senium is that the structure of body and physiological function appear a series of degradation with growing older. Balance senses, such as vision, vestibule and somatosense, keep stable between 20 and 50 years old, and become instable gradually, and then decline rapidly until 70 years old[1]. In the period of becoming senium form middle to old age, some problems will appear, such as standing and walking become unstably, the range of activity of articulation gets smaller, elasticity of anadesma and power of muscle decrease. The research of Blake[2] indicated that the reason of 53 percent of trips in the old was standing and walking unstably. And trip is also a dominating reason of getting hurt and some other diseases. Trip brings extremely pain to the old and huge burden to families and society. The research of Lilley indicate that trip is the first and most important reason of deaths which is older than 75[3]. More than one third old people in older than 65 will trip once per year[4-6]. The research on dynamic balance function is meaningful for medical diagnose and national fitness.

BALANCE MECHANISM OF HUMAN BODY

Human balance ability involves the interaction of various factors, especially the elderly, which includes age-related physiological changes, and contains one or more pathological factors, and may contains joint ac-

tion of internal factors and external environment. In order to maintain the balance and stability of standing posture, the central nervous system will have to adjust the corresponding joint and muscle constantly according to sensory information provided by the visual system, ontology sense system and vestibular system.

Theoretical basis of balance mechanism

Balance function of human body is consisted of static and dynamic balance function[7]. Static balance is a kind of ability that human body keeps at a special posture. The other one is dynamic balance which is consisted of two aspects: 1): self-dynamic balance. It is an ability that human body recovers to balance when doing some self behaviors, such as transiting form sitting posture to standing posture. 2): external dynamic balance. It is an ability that human body comes back to balance when the body is affected by external environment, such as push, pull. This kind of partition includes abilities that human body keeping, getting and coming back to balance when doing serious behaviors, and it is scientific and integrated. Some scholars [8,9] use changing mode of posture when human body keeps in standing posture quietly to evaluate and study balance system of individual. But the static and dynamic balance is not relevant[10].

Now, analyzing and evaluating static balance function is achieved mainly by recording CoP. This method is built on the assumption that swing of body is a static process. However CoP track can not stand for all the evaluate pattern. This method ignores the dynamic feature during dynamic process of CoP, and can not sand for the detail of posture control. It is unreasonable to regard CoP as 'The motion of the body posture' or CoG[11]. There are two main drawbacks: 1) The control to human factors will be not taken into considerations and the control variable to the human body can not be obtained when simply recording CoP. Inverted pendulum model of human body shows that CoG is the variable controlled by the human body in maintaining equilibrium process, and CoP is just a result of human control. From the perspective of biomechanics, the CoP is just an error signal in the process of controlling horizontal acceleration of CoG. 2) There is a great limitation in the use of a single platform. It can help us identify the control mechanism when CoP moving around by recording every trounces respectively. The balance from the directions of front and back is controlled by ankle's toe flexion and plantar flexion.

The balance characters of old people

Along with the increase of age, degenerative changes of balancing sense functions such as visual and vestibular, ontology, etc, balance ability is certainly decreased obviously. Experiments show that human body movement function which is a highlight in the dynamic balance ability, such as the action agility, coordination ability, dynamic anti-jamming and keeping balance ability, will have a huge reduction with the increase of age. In other functional and comprehensive tests, abilities resisting to outside interference and keeping body balance decrease obviously with the increase of age[12].

DETECTING METHODS OF BALANCE FUNCTION

CoP balance board method which has mature technology and simple design, has been widely used, but its defects in terms of dynamic balance test; CoG measuring method has the congenital superiority in dynamic balance test, but the technology is difficult. At present only a few companies have this kind of product abroad. This paper analyses advantages and disadvantages of the two methods (CoP, CoG) respectively, and designs a comprehensive system to measure the body's ability of balance by integrating the advantages of two methods.

The CoP balance board design method

In standing state, because of the dynamic change of center of gravity, the two feet have imbalanced stress. So the changes in the body's center of gravity can be reflected through the changes of pressure center of balance board. Figure 1 is the schematic diagram of balance board. G (x, y) of CoP is calculated by four symmetrical gravity sensor values under the balance board according to the principle of moment balance. The barycentric coordinates data was transmitted to PC and center of gravity changing parameters were analyzed by software. The distribution types of body center of gravity involve the envelope area of the body center of gravity, trajectory length the body center of gravity, maximum distance in X direction and maximum dis-

FULL PAPER

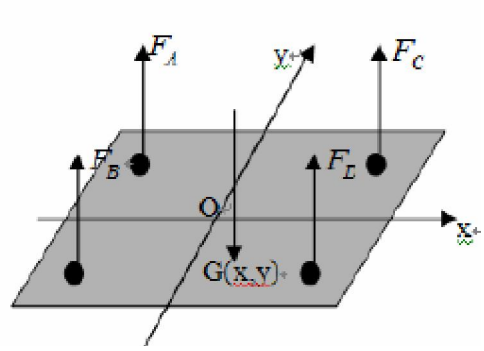

Figure 1 : Gravity balance board schematic

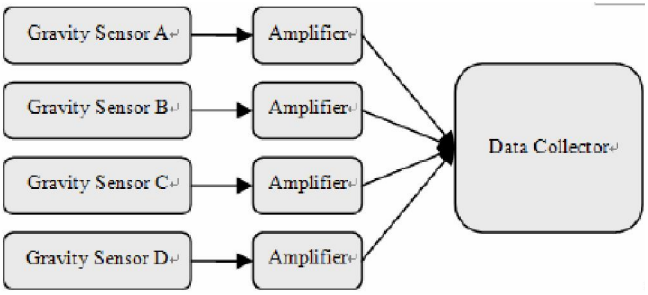

Figure 2 : Balance board weight acquisition system block diagram

tance in Y direction. Balance board weight acquisition system block diagram is shown as Figure 2.

Static balance ability of old people was evaluated according to the center of gravity changing parameters.

CoG signal detection

To measure body dynamic balance function of aging human, the dynamic information of some movement behaviors, including walking, standing, crouching, sitting down and turning around, must be detected. Referring to Figure 3, the sensors are placed in the position of center of gravity for gathering acceleration and angular velocity information during human behavior. With the experimental conditions, the variety of posture and balance ability are detected and analyzed. For example, displacement and Angle information can be obtained through the integral. On this basis, the testing and evaluation model of the dynamic balance of human behavior are gradually established and improved.

EVALUATION OF BALANCE FUNCTION

It must be divided into static balance and dynamic balance when evaluating balance function. Therefore, the evaluating basement, that is the evaluating factors or parameters, should be divided into static and dynamic evaluating factors which have similarities and different places.

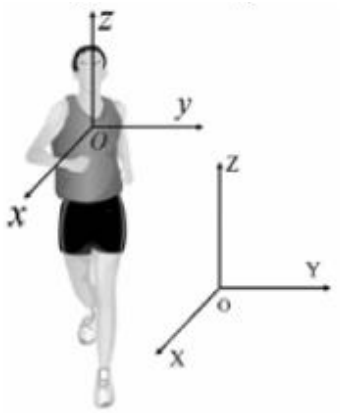

Figure 3 : Sketch map about information collection of dynamic balance

Evaluation of static balance function

At present, according to the function and meaning of each test, there are some different quantitative measuring algorithms of balance at home and abroad. The commonly used ones are divided into the following several categories[13]. The followings are the evaluating factors depending on balance board method.

(1) Algorithms of reflecting the degree of balance impairment: Because the maximum shake diameters (Dx, Dy) of X and Y directions have biggish contingency. So trajectory length (LngX, LngY) of X and Y directions have advantages than Dx and Dy. Trajectory length per unit time (Lng) is an integrated indicators of X and Y directions, and it has an average sense; Enveloping Area (Area) has a meaning of swing range, and it is more important in describing the oscillation extent; Shake Angle (Deg) is the accumulated angle of the vertical axis of center of gravity vertical projection to the ground and axis of body. Because of different height, Deg eliminates the influence to the trajectory length, envelope area.

(2) Algorithms of reflecting the shake migration and advantage direction: Sometimes CoP's migration (X, Y) of X and Y axis does not represent the location of the center of gravity, and is associated with the standing position of each evaluation. So, huge contingency is existed. Shake pendulum advantage direction and degree (Wavvol) reflects muscle tension in the trunk which is used in controlling posture. Because everyone's shake pattern is very com-

plicated, the Wavvol of individual is difficult to determine.

(3) Algorithms of reflecting energy consumption: trajectory length per unit area (Lng a^{-1}) reflects the ability of controlling posture by proprioception system; Energy consumption (Eng) which is a biomechanical index which reflects energy consumption. The energy of correcting the barycenter's position increases when the moving ability of body falls and balance ability declines. Eng can reflect the comprehensive performance of balance function.

Here are some algorithms implementations about important capability assessment factors of balance.

Shake trajectory length of center of gravity (Lng):

$$\mathbf{Lng} = \sum_{i=1}^{n-1} \sqrt{(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2} \quad (1)$$

Where n is the number of collecting.

Trajectory length of X direction LngX, and trajectory length of Y direction LngY:

$$\mathbf{LngX} = \sum_{i=1}^{n-1} \sqrt{(x_i - x_{i+1})^2} \text{ and } \mathbf{LngY} = \sum_{i=1}^{n-1} \sqrt{(y_i - y_{i+1})^2} \quad (2)$$

Average barycentric coordinates of X direction (MeanX), and average barycentric coordinates X direction (MeanY):

$$\mathbf{MeanX} = \frac{\sum_{i=1}^{n} x_i}{n} \text{ and } \mathbf{MeanY} = \frac{\sum_{i=1}^{n} y_i}{n} \quad (3)$$

Envelope area (Area):

$$\mathbf{Area} = \sum_{i=1}^{n} \frac{\pi \eta^2}{n} \quad (4)$$

Where η is the distance from coordinate of every point to the center of gravity.

Trajectory length per unit area ($Area \bullet A^{-1}$):

$$\mathbf{Area} \bullet \mathbf{A}^{-1} = \frac{\mathbf{Lng}}{\mathbf{Area}} \quad (5)$$

Shake pendulum advantage direction and degree (Wavvol):

$$\mathbf{Wavvol} = \sum_{i=1}^{n-1} \sqrt{(\mathbf{MeanX} - x_i)^2 + (\mathbf{MeanY} - y_i)^2} \quad (6)$$

Real time shake pendulum length ($Lng'i$):

$$\mathbf{Lng'i} = \sqrt{(x'_i - x'_{i-1})^2 + (y'_i - y'_{i-1})^2} \quad (7)$$

Real time shake pendulum angle (θ_i `):

$$\theta_i = \sin^{-1} \frac{\mathbf{Lng'i}}{\mathbf{H}} \quad (8)$$

Where H is the height of center of gravity.

Shake pendulum angle (Deg):

$$\mathbf{Deg} = \frac{1}{n} \sum_{i=1}^{n} \sin^{-1} \frac{\mathbf{Lng'i}}{\mathbf{H}} \quad (9)$$

Energy consumption (Eng):

$$\mathbf{Eng} = \frac{\sum_{i=1}^{n} \mathbf{M} * \mathbf{g} * \mathbf{H} |\cos(\theta_i) - \cos(\theta_{i-1})|}{1000} \quad (10)$$

Evaluation of dynamic balance function

Dynamic assessment factors contain some static balance evaluation factors and some special factors.

Dynamic evaluation factors when walking include:

Marching rhythm[14,15]: The ratio of stride frequency and stride length is called the marching rhythm. Healthy people's marching rhythm has a certain range which too big or too small will affect the stability of walking.

The ratio of acceleration between right and left pace[16]: Collect the same axial acceleration amplitude values with odd-even steps. And these values were written to (Ao, Ad) which can effectively response the body balance ability in the process of marching. The ratio of Ao and Ad is closer to 1 suggests that the body's balance ability is better.

Marching twist degree:

The twist angle in vertical axis, when walking, has a certain relationship with stride length. When their ratio is too big or too small the stability of walking will be affected.

Dynamic evaluation factors when the human body do turning around action:

Turning around time: Turning around time reflects reaction rate.

Turning around angle: Degree of accuracy of turning around angle reflects controlling ability of body.

CONCLUSION

With the theoretical analysis to balance mechanism and characteristics of old people, a new method of collecting both CoP and CoG information is putted forward to record the changes of barycenter of the human body. The method can avoid the defects caused by the CoP methods. And different algorithms were applied

FULL PAPER

respectively to evaluation of static and dynamic balance function. Combining static factors and dynamic factors, the balance function of old people can be evaluated accurately.

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