

A Topic Real-time training model for elderly people balance ability

Zhuojun Yao^a, Zhihong Liu, Suxin Liu

Harbin University of Science and Technology, Weihai, China

^a929063056@qq.com

Keywords: Pearson correlation factor analysis; Entropy weight method; Human body balance model; Balanced risk assessment system

Abstract: This article is about A Topic Real-time training model for elderly people balance ability. To solve the first problem, we establish the human body balance model and extracted 25 body balance characteristics. To solve the second problem, we use entropy weight method to establish a balance risk assessment system based on 25 indicators to evaluate the balance ability of the elderly. We use a series of models to evaluate the balance of the elderly, and some reasonable suggestions are put forward. Finally, we give the objective evaluation of the model and assess its practicability.

1. Problem restatement

Problem 1: First, determine the specific definition of equilibrium. From the static balance and dynamic balance, step size, center of gravity and kinematics are the three directions. Then, based on the original verification data of 76 elderly people in annex 2, we classified 42 monitoring points into 25 physical balance characteristics. To facilitate the establishment of a comprehensive body balance assessment system for the elderly population.

Problem 2: These 25 characteristics of body balance were classified to establish a comprehensive body balance assessment system for elderly population. Data from the assessment were analyzed and combined with 25 body balance characteristics. Targeted dynamic balance, static balance, as well as the characteristics of the elderly, in order to maintain their own balance, prevent falls to put forward targeted recommendations.

2. Problem Analysis

2.1 Analysis of question 1

As the topic shows that there is not a complete definition of the human body's balance, so firstly we will divide the body balance into two aspects of static balance and dynamic balance, and extracted the eight indexes in the static balance: the ability of controlling balance systems, ankle controllability, hip of controllable trajectory length, oscillation amplitude, swing, swing speed, COP envelope area, as well as the dynamic balance of the 10 indicators: walking velocity, stride length, step length, support phase, walk cycle, stride length, the dynamic state of center of gravity, rhythm, swing phase, foot Angle on foot. Through analysis in attachment 1, we put some of these factors extracted and set the rules for quantitative, characteristic parameters of the selection as we are: muscle ability, mental state, history of falls, whether to use a walker, whether cognitive state, visual acuity level, high blood pressure, bone density (osteoporosis), dysfunction (nerve damage, vestibular disorder). From this, we extracted 25 human body balance indicators. In order to verify the reasonableness of the balance index, we did Pearson priority-related factor analysis on the balance and 25 balance indexes.

2.2 Analysis of question 2

In order to quantify the balance ability of human body, problem 2 requires us to solve each characteristic value of 25 body balance characteristics in the first question, so as to comprehensively evaluate the balance ability of human body through 25 balance indicators. We chose the entropy

weight method to calculate the entropy weight of 25 balance indicators on human body balance, and obtained the weight matrix of the target. We chose several indexes with a relatively large weight as important indicators affecting human body balance, and classified the indexes and put forward reasonable suggestions for improving the elderly's own balance ability.

3. Model assumptions

Assume that the person is moving in a linear path

In data preprocessing, it is assumed that the processed data has no impact on the results

Assume that using the torque synthesis, solving the parameter of gravity balance, not to consider the influence of other factors

Assume that the evaluation matrix established is true and reliable

4. Establishment and solution of the model

4.1 Static equilibrium analysis

The influence of age on the static equilibrium ability is important. The static equilibrium ability decreases with the growth of age and is negatively correlated with age. Therefore, the relationship between COP parameters and age can indirectly reflect the correlation between COP parameters and the static equilibrium energy.

Body moving parameters reflect the static balance ability, however, a series of parameters calculated from COP data can effectively depict the static balance ability is unclear, and the lack of relative effectiveness evaluation method, the characteristics of the choice of parameters of static balance ability lack of guidance, so need to COP signal in time domain and frequency domain analysis of the influence of parameters on the static balance ability and relationship, based on the correlation degree of screening effective characteristic parameters.

Step 1 COP time-domain parameter analysis:

PCA was used to eliminate the correlation between parameters for the total length L of the swing track, the average swing displacement D, the swing velocity V and the envelope area Acop. Finally, the first principal component was obtained as a comprehensive index to evaluate the static balance ability, which was called the overall COP balance index^[2].

(a)The total length of the swing track is L

The length of the swing track, namely, the swing distance, refers to the total length of the trajectory of the pressure center in a certain period of time, which is the sum of the distance between adjacent COP points. According to different directions, this parameter can also be divided into the total length in the ML direction and the total length in the AP direction (ML AP).

$$L_R = \sum \sqrt{(X_{n+1} - X_n)^2 + (Y_{n+1} - Y_n)^2}$$

(b)Average swing displacement D

The average swing amplitude refers to the average sleeping distance from the mid-point of COP distance swing. This parameter has components in both directions of AP and ML, which are respectively called ML average swing amplitude and AP average swing amplitude

$$D_R = \sum \frac{\sqrt{X_n^2 + Y_n^2}}{N}$$

(c)Swing velocity V

Swing rate refers to the distance of COP swing in unit time, indicating the speed of body swing, which is also related to the direction. There are three derivative parameters of ML swing speed, AP swing speed and comprehensive swing speed

$$L_R = \sum \frac{\sqrt{(X_{n+1} - X_n)^2 + (Y_{n+1} - Y_n)^2}}{t}$$

(d)Envelope area A_{cop}

Envelope area refers to the area occupied by COP tracks skillfully collected at a certain time, indicating the range of body swing^[3]

Step 2 COP frequency domain feature analysis:

The control ability of balance system, ankle joint and hip joint gradually increases with age, and the relationship between hip joint controllability and age is the most sensitive. These changes endanger the stability of standing posture control and lead to the decrease of static equilibrium energy. From the following two formulas

$$R(f_i) = \frac{P(f_i)}{\sum P}$$
$$A(f_i) = \frac{\sum P(f_i)}{\sum P}$$

It is concluded that COP signal is a low-frequency physiological signal, and the main energy is concentrated in 0~ 1.5hz. According to the physiological significance of COP, three frequency domain characteristic parameters are proposed, namely, the average power of 0~ 0.5hz, 0.5-1hz and 1-1.5hz frequency bands, which respectively represent the control ability of the balance system, the controllability of the ankle joint and the controllability of the hip joint.

The relationship between age and static equilibrium is analyzed to show that these parameters can characterize static equilibrium effectively.

4.2 Dynamic equilibrium analysis

- Step size analysis

(1)Step length L_{step}

L_{step} is to point to when walking one side sufficient follows the distance between the ground to follow the ground to opposite side sufficient immediately, have individual difference, basically be concerned with the mobile range of joint of leg long, marrow and knee joint, have the cent of left and right lower limbs, computational method is like a formula, $y_{heel}(N)$ is the coordinate position of step N heel AP direction.

$$L_{step} = |y_{heel}(N) - y_{heel}(N - 1)|$$

(2)Stride length L_{stride}

Stride length refers to the distance from the coordinate position of the unilateral footprint to the AP direction of the next footprint on the same side in a gait cycle. The calculation method is 4-5, and the meaning of parameters in the formula is the same as formula 4-4.

- The center of gravity analysis

(1)The first step

The human body can be divided into three link. One is Head, neck, torso, one is upper limbs and one is lower limbs .According to the three links. we choose the hand, shoulder, head, hip, foot as the five basic points .The five basic points are based on the 42 monitoring points in the question. we need to use the 14 monitoring points marked red as follow and the relative quality P of each link . We show the selected points in the figure:

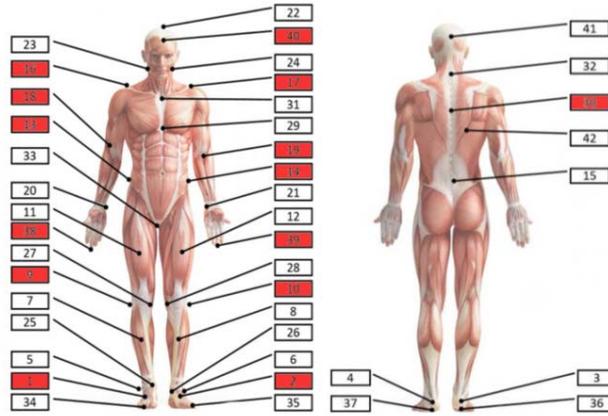


Figure 1 14 monitoring points

● the second step:

According to the three links set by the human body, the radius coefficient is calculated. Then we use the formula of definite proportion to find the coordinates of the center of gravity of each link(M,N).

$$M = \frac{x_i + \lambda x_i + 1}{1 + \lambda}$$

$$N = \frac{y_i + \lambda y_i + 1}{1 + \lambda}$$

$$\lambda = \frac{R}{1 - R}$$

The abscissa of the center of gravity of each link is calculated by multiplying the abscissa of the center of gravity of each link by its relative weight P.

$$\sum M \cdot P$$

by the same logic we can figure out the y-coordinate of the center of gravity .

$$\sum N \cdot P$$

● kinematics analysis

(1)Support phase T_{stand}

T_{stand} is the time when one side of the lower limb contacts the ground in a gait cycle. The calculation method is the time when the lower limb leaves the ground at the NTH step minus the time when the foot falls. as shown in formula(1)

(1)

(2)Swing phase T_{sway}

T_{sway} refers to the time when a single lower limb swings in the air in a gait cycle. The calculation method is the time when the single lower limb lands minus the time when the previous step leaves the ground, as shown in formula where the parameters have the same meaning as formula (2)

(2)

(3)Walk cycle T_{cycle}

T_{cycle} refers to the period from the moment of landing of one side of the lower limb to the next moment of landing in walking. The calculation method is. The meaning of parameters in the formula is the same as formula (3)

(3)

(4) Step width L_{width}

Stride Width refers to the distance between the center lines of both sides of the foot in walking. The calculation method is the distance from the center of one side of the foot to the center of the opposite side of the foot along the X-axis in a gait cycle. The formula is shown in formula(4)

$$L_{width} = x_{R-center}(N) - x_{L-center}(N) \quad (4)$$

(5) Step speed V_{gait}

Step speed refers to the distance traveled per unit time, which is used to measure the speed and speed of walking. The test method is to measure the distance and time traveled by the footpath, and then calculate the ratio. The formula is like 4-7, where the parameters have the same meaning as the formulas (5)

(5)

(6) Walking rhythm C_{gait}

The walking rhythm, also known as the step frequency or pace, refers to the number of steps per minute, represented by steps/min. It can be calculated by walking cycle, as shown in formula (6)

$$C_{gait} = \frac{60}{T_{cycle}} \quad (6)$$

(7) Foot Angle A_{toe}

Toe out angle also known as step Angle or foot Angle, refers to the Angle between the center line of the foot print and the foot line of the footprint during walking, which is related to the foot joint of the lower limb and can be divided into left and right sides

4.3 Correlation analysis of 25 factors and body balance

Pearson correlation coefficient is a method to accurately measure the degree of closeness between two variables. For the two variables x and (xi represents each body balance factor and yi represents whether to fall). A number of groups of data can be obtained through experiments, denoted as $(x_i, y_i)(i = 1, 2, \dots, n)$, and then the mathematical expression of the correlation coefficient is

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2 \sum_{i=1}^n (y_i - \bar{y})^2}}$$

● Correlation validation was performed using SPSS

We selected several old people with fracture history as the old people who might fall down. SPSS software was used to obtain the correlation between each factor and the old people's fall, and the results showed a significant positive correlation.

For reasons of length, only the correlation analysis between walking speed and old people's falls is given below.

Table 1. Correlation analysis between walking speed and old people's falls

		pace	fall
pace	Pearson correlation	1	-.842**
	Sig.(Double tail)		.000
	The case number	16	16
fall	Pearson correlation	-.842**	1
	Sig.(Double tail)	.000	
	The case number	16	16

Because $|r| \geq 0.8$ is greater than or equal to 0.8, there is a significant positive correlation between walking speed and old people's falls

4.4 Second problem solving

The index weight of 25 body balance characteristic factors extracted by the system consisting of 42 monitoring points of 76 elderly people was calculated as follows:

Single index evaluation. According to the query data, the following impact degree table is obtained:

With the help of the influence degree table in table 1, the evaluation matrix $S_{76 \times 25}$ constructed is as follows, where 2,4,6 and 8 represent the influence degree of Numbers on both sides.

$$S_{76 \times 25} = \begin{Bmatrix} 5, 7, \dots, 4, 2, \\ 7, 5, \dots, 3, 3 \\ 5, 5, \dots, 3, 5 \\ \dots \dots \dots \\ 5, 7, \dots, 3, 1 \\ 9, 3, \dots, 5, 6 \\ 2, 5, \dots, 7, 3 \\ 4, 5, \dots, 7, 9 \end{Bmatrix}$$

1) Normalization of data

For the above data, the maximum and minimum value method is adopted to normalize the data to the range, and the normalized matrix is $T_{76 \times 25}$, the single indicator normalization formula is as follows:

$$m_i = \frac{n_i - \min(n_1, n_2, \dots, n_{16})}{\max(n_1, n_2, \dots, n_{16}) - \min(n_1, n_2, \dots, n_{16})}$$

2) The results are as follows:

$$T_{76 \times 25} = \begin{Bmatrix} 0.4286 & 1.0000 & \dots & 0.2500 & 0.1250 \\ 0.7143 & 0.5000 & \dots & 0 & 0.2500 \\ 0.4286 & 0.5000 & \dots & 0 & 0.5000 \\ \dots \dots \dots \\ 0.4286 & 1.0000 & \dots & 0 & 0 \\ 1.0000 & 0 & \dots & 0.5000 & 0.6250 \\ 0 & 0.5000 & \dots & 1.0000 & 0.2500 \\ 0.2857 & 0.5000 & \dots & 1.0000 & 1.0000 \end{Bmatrix}$$

To calculate the weight of the index value, use the following formula:

$$u_{ij} = \frac{n_{ij}}{\sum_{i=1}^{16} n_{ij}}$$

The results are as follows:

$$U_{76 \times 25} = \begin{Bmatrix} 0.1304 & 0.2500 & \dots & 0.0909 & 0.0455 \\ 0.2174 & 0.1250 & \dots & 0 & 0.0909 \\ 0.1304 & 0.1250 & \dots & 0 & 0.1818 \\ \dots \dots \dots \\ 0.1304 & 0.2500 & \dots & 0 & 0 \\ 0.3043 & 0 & \dots & 0.1818 & 0.2273 \\ 0 & 0.1250 & \dots & 0.3636 & 0.0909 \\ 0.0870 & 0.1250 & \dots & 0.3636 & 0.3636 \end{Bmatrix}$$

3) Calculate index entropy:

We pretreat it, and we get v_{ij} , the calculation formula is as follows:

$$v_{ij} = -n_{ij} \times \ln n_{ij}$$

The results are as follows:

$$V_{76 \times 25} = \begin{pmatrix} 0.2657 & 0.3466 & \dots & 0.2180 & 0.1405 \\ 0.3318 & 0.2599 & \dots & 0 & 0.2180 \\ 0.2657 & 0.2599 & \dots & 0 & 0.3100 \\ \dots & \dots & \dots & \dots & \dots \\ 0.2657 & 0.3466 & \dots & 0 & 0 \\ 0.3620 & 0 & \dots & 0.3100 & 0.3367 \\ 0 & 0.2599 & \dots & 0.3679 & 0.2180 \\ 0.2124 & 0.2599 & \dots & 0.3679 & 0.3679 \end{pmatrix}$$

The calculated result of index entropy is $E_n = [e_1, e_2, \dots, e_{76}]$,

The calculation formula of a single index e_j is as follows:

$$e_j = \frac{1}{\ln^n} \sum_{i=1}^{76} V_{ij}$$

4) Calculate index entropy weight:

The calculation results of entropy weight of all indexes are as follows:

$$W_n = [w_1, w_2, \dots, w_{25}]$$

The calculation formula of a single index w_j is:

$$w_j = \frac{(1 - e_j)}{\sum_{i=1}^{16} (1 - e_j)}$$

Then, the calculation formula of the body's balance ability is obtained by combining various factors:

$$x_i = \frac{\sum_{i=1}^{25} W_i \cdot \sum \text{value}}{n + 8}$$

5) Conclusion:

Us through 42 monitoring data of 25 feature extracting, after we will data obtained through calculation of entropy method for dimension reduction calculation formula of the human body balance ability, this formula can be evaluated according to characteristics of each old man 25 data to integrated computation body balance data, thus the balance to the body by means of quantitative evaluation.

4.5 To the high risk indicators for the elderly to put forward reasonable Suggestions to prevent falls

We have put forward some reasonable Suggestions on the indicators with the highest weight as important indicators affecting the balance of the elderly.

4.5.1 Bone density (osteoporosis)

Early improvement of self-care consciousness and active scientific intervention can delay and prevent osteoporosis. Diet should have enough minerals and vitamin D, maintain a low salt and low fat diet, should not be partial to food or rely too much on supplements and health care products. Develop good living habits. There are two effective ways to prevent osteoporosis: aerobic endurance exercise and strength training. The elderly should combine their specific circumstances, strengthen physical exercise and appropriate activities, maintain the flexibility of bone and joint and prevent muscle atrophy and weakness and osteoporosis, especially to strengthen the exercise of the muscles and joints of the lower limbs.

4.5.2 Muscle ability and foot deflection with frequency swing speed

Foot declination Angle, gait frequency and swing speed can be divided into gait analysis, and muscle ability is closely related to whether gait is normal or not.

Gait in the elderly is characterized by degeneration or functional impairment of muscles, bones, joints and ligaments. This leads to slow walking, shorter stride length, lower foot lift, and poor stride continuity and stability. Strengthen leg muscle exercise, improve muscle strength and gait performance to prevent falls; In daily life, we should pay more attention to our cognitive level and strengthen the training of dual tasks, such as listening to music while doing taijiquan, singing and walking, etc., so as to improve cognitive coordination and balance. Medical staff should realize the importance of gait in the risk assessment of falls, attach importance to the assessment of gait in elderly patients, and strengthen its functional exercise to improve the walking ability of elderly people.

4.5.3 Dysfunction (nerve injury, vestibular disorder)

Any disease of the central nervous system affects the body's ability to stabilize. The drug that ACTS on central nerve, can affect the stability ability of human body. In addition, certain acute infectious diseases make people prone to fall while standing upright. Slow down your pace of getting up and out of bed to avoid leaving the bed alone when no one is around.

While static exceptions disappear in a short period of time, dynamic imbalances can persist for a long time. Dynamic balance disorder requires targeted vestibular rehabilitation training, which is helpful to improve vestibular compensation. Vestibular rehabilitation treatment is conducted in patients with dizziness and balance the dysfunction of a physical treatment, it is traumatic, not drugs, not different from general movement, has a highly specialized training methods, including peripheral and central rehabilitation, alternative healing, visual conflict and fall prevention rehabilitation. Through vestibular rehabilitation treatment, patients can achieve the state of vertigo and balance disorder improvement, spontaneous nystagmus and collapse disappearance. Vestibular functional training can be carried out, such as tai chi is a very good way of training.

4.5.4 Whether to use a walker

Walking AIDS can effectively maintain the balance of the body, support weight, increase muscle strength, assist walking, choose the right walking AIDS can greatly reduce the probability of falls in the elderly.

5. Advantages of the modelmodel

1) Simple and accurate moment synthesis method is used to calculate the center of gravity of dynamic balance. The human body 42 monitoring points were dimensionally reduced

2) Many original data are preprocessed to reduce the complexity of the algorithm. Eliminate redundant information of data and improve data processing efficiency.

3) We used PCA to identify the main characteristic values, find out the most important direction in a dry data, retain the principal components and discard other irrelevant components.

4) We analyzed COP signal in time domain and frequency domain to remove the fuzziness of parameters' description of static equilibrium capability.

5) We used the accuracy of Pearson's correlation coefficient to measure the relationship between 25 balance factors and whether older people fall. Finally, we verified with SPSS, and the results showed a positive correlation.

6) Entropy weight method can be ranked according to the degree of its impact on the target. If the judgment on the relative importance of indicators and the ability of candidate schemes to meet the optimization objective are accurate and effective, the calculation results of entropy weight method are objective and reasonable results derived from those judgments.

References

[1] Yu mei, ma yuanzheng, tang wen. Research progress on prevention of falls in elderly with osteoporosis in communities [J]. Chinese journal of osteoporosis,2012,18(12):1157-1160.

[2] Wang li, yu weihua, xu zhongmei. Research on gait characteristics of elderly people walking at

normal speed and dual tasks in communities and their relationship with falls [J]. Chinese general medicine, 2008,21(04):420-425.

[3] Zhang li, urn changshui, wang qiuhua, et al. Analysis of factors influencing vestibular sensation, proprioceptive sensation and visual function on the risk of falls in the elderly [J]. Chinese rehabilitation theory and practice,2010,16(1):16-18. DOI:10.3969/j.issn.1006-9771.2010.01.007.

[4] Wang bomin. Research on human body balance ability evaluation and fall risk prediction effect based on balancer [D]. Northeast normal university,2018.

[5] Wang shao-hui, liu kun-jiu, tan xiao-cong, hu guilin, tu da-chang. Determination and calculation of the moving point of the center of gravity of human body [J]. Guizhou sports science and technology,1986(02):30-36.

[6] Wang wei, feng ya-qin, Yang zai-xing, wang xiao-yan. Calculation method of human center of gravity based on somatosensory interaction device [J]. Data collection and processing, 2008,33(04):595-602

[7] Jia guifeng. Study on quantitative assessment method of human balance ability [D]. Zhejiang University, 2015.