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A Study of Fall Risk Assessment in the Elderly

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ABSTRACT

Falls in the elderly can lead to many complications, which can significantly reduce the quality of life. Therefore, the research on the fall risk of the elderly has attracted extensive attention. However, little research has been done to assess the fall risk of different individuals with different symptoms combined with joint data. Based on the Kinect motion Sensor, the real-time Shift Angle of gravity center is calculated and compared with the Los Threshold, and the grade model of fall risk is obtained by defining the fall risk probability. On this basis, the paper also screened the basic information of the elderly and more than 10 common diseases, and found five factors that have a greater impact on the fall risk probability. Combining the probability grade of individual fall risk with the five factors after screening, the balance ability and fall risk of the elderly can be evaluated objectively. It also provides objective data analysis and effective fall prevention reference for the elderly.

Keywords: *Elderly, Fall Risk Probability, Multiplicative coefficient method, Kendal Correlation Analysis, Multiple Linear Regression.*

1. INTRODUCTION

Tumble is a major problem that endangers the health of the elderly. With the growth of age, the rehabilitation ability of the elderly gradually weakens. Tumble can lead to many syndromes, which can accelerate physical exhaustion. In addition, fear of tumble may impair the ability to move and contract the range of activity, which can significantly reduce the quality of life. The decline of balance ability of the elderly is one of the main reasons for their tumbles. Effective balance ability evaluation method is helpful to identify high-risk groups prone to tumble [1]. Therefore, it is of great significance to evaluate the balance ability of the elderly to maintain their movement state, helping them correct their posture and prevent them from tumble. In recent years, with the process of China's aging society, the research on the balance ability of the elderly has attracted extensive attention.

There are a lot of research results on the static assessment of the balance ability of the elderly. The evaluation methods include observation method [2,3] and scale test method [4]. The observation method is to use the body rocking situation of the evaluation object under the condition of bipedal upright and single foot upright, so as to identify the balance dysfunction group simply and intuitively. The scale test method is to identify the affected part of gait or balance item by balance and gait test scale. However, tumbles in the elderly generally occur in the process of walking. With the uncertainty of the elderly walking process, it greatly increases the difficulty of evaluation. At present, for the dynamic evaluation of the balance ability of the elderly, the reference [5] uses Kinect somatosensory equipment to collect the three-dimensional data of human joint points in real time, calculating the position of the center of gravity, calculating the relatively stable and effective angle with the time parameter, so as to obtain the effective evaluation standard. However, for different diseases of different individuals, combined with joint point data for tumble risk assessment, there are few studies. This paper uses the data of 2018 Asia Pacific University Students Mathematical Modeling Contest [6]. Considering the shift of the center of gravity trajectory of the elderly during walking, a relatively stable and effective angle is extracted as a standard to evaluate the balance and fall risk, so as to establish the probability assessment model of tumble risk. Combined with the joint point and disease history data of 80 subjects, Kendall analysis is used to screen out the diseases that can have a major impact on tumble. Finally, multiple linear regression is used to quantify the impact of basic information and disease history on the individual tumble risk, so as to give improvement suggestions.

2. PROCESSING CENTER OF GRAVITY TRAJECTORY BY MULTIPLYING COEFFICIENT METHOD

Kinect somatosensory device can get the depth information of human joints points by extracting the skeleton images of human body. In this paper, the three-dimensional coordinates of joints points of 80 elderly testers during walking are used as the data basis of the motion center of gravity trajectory of the elderly. The distribution of joints testing points is shown in Fig. 1.

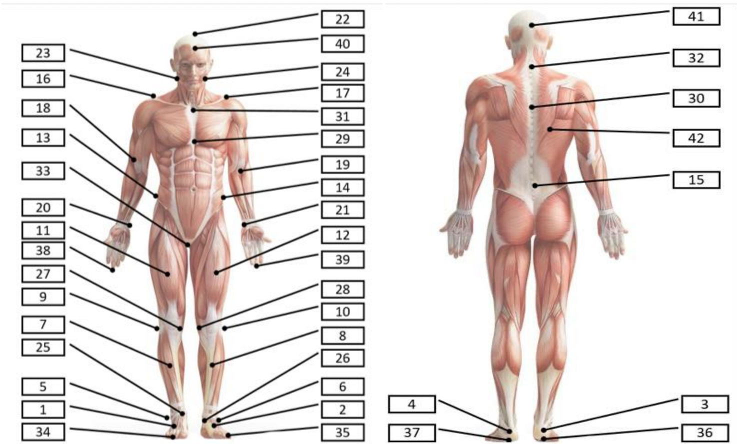

Fig.1 Distribution of Human Joints Testing Points

Since the gravity center of human body is the action point of the resultant force of gravity on the human body, the sensor can not be used for direct measurement. Firstly, the influence coefficient of some joints points of human body on the gravity center [7] obtained by German scholars Bravin and Fischer can be used to correspond the three-dimensional data obtained from joints testing points, and then the multiplication coefficient method [8] can be used to calculate, and finally the coordinates of the human body gravity center of all testers are obtained. In this paper, on the basis of the above work, the information collection of human body gravity center in dynamic motion process can be realized. Fig.2 shows the real-time trajectories of gravity center marked 42, 57, 62, 72 randomly of the selected subjects during walking.

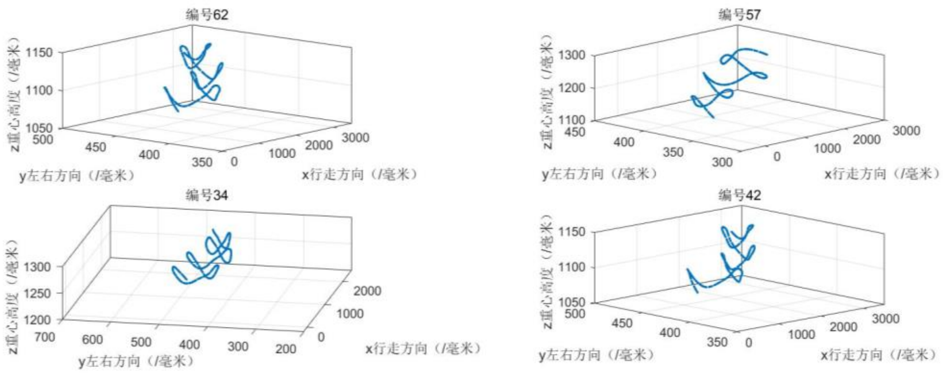

Fig. 2 Trajectories of Gravity Center of Four Testing Subjects

重心高度（毫米）Height of gravity center (mm)

编号 Number

行走方向（毫米）Walking direction (mm)

左右方向（毫米）Direction of left and right (mm)

It can be seen from Fig. 2, the real-time trajectories of gravity center of the four testing subjects were shifted left and right and up and down during walking. The deviation is large, which is consistent with the weak balance ability of the elderly during walking.

3. DETERMINATION OF TUMBLE RISK LEVEL OF THE ELDERLY

According to the dynamic balance conditions of human body in mechanics, whether the projection of the gravity center on the supporting surface is within the scope of the supporting surface determines whether the body is balanced. In the normal walking process, the position of the gravity center changes with the gait cycle. Let the maximum angle formed by the line between the gravity center and the center of the support surface and the vertical line passing through the center of the support surface is θ, which can be shown in Fig.3.

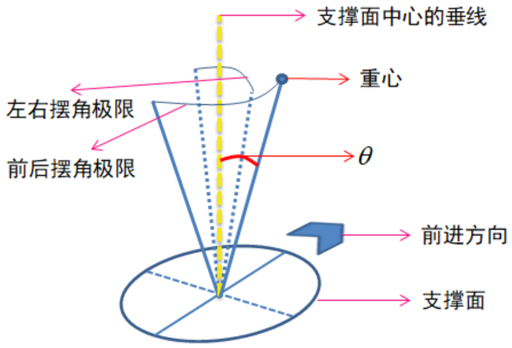

Fig. 3 The Limited Swing Range of Gravity Center

左右摆角极限 Limit of left and right swing angle

支撑面中心的垂线 The vertical line of the center of the supporting surface

前后摆角极限 Limit of front and rear swing angle

前进方向 The direction of walking

支撑面 The supporting surface

1) Quantitative Risk Assessment

During the process of human movement, if the deflection angle of the gravity center exceeds the stable threshold [9], it is regarded as having a great risk of tumble. Generally speaking, the maximum swing range of human body is 12.5 ° in front and back, 16 ° in left and right directions, and the combined swing threshold θ is 20.3 °. If the gravity center swings beyond the above threshold range during walking, the elderly can be considered to have tumble risk.

2) Construct Risk Probability

In this paper, the percentage of the frame number exceeding the maximum swing range in the gravity center offset data of each tester in the total number of frames is regarded as the risk probability of tumble p. Namely:

$$p = \frac{\text{摆动超出阈值的帧数}}{\text{总帧数}} \tag{1}$$

摆动超出阈值的帧数 Number of frames exceeding the threshold

总帧数 Number of total frames

One person was selected from the groups with the tumbling times of 0, 1, 2 and 3 respectively, and the numbers were 62, 33, 28 and 42. Using MATLAB to draw the image of the tester's gravity center deviation angle, as shown in Fig. 4.

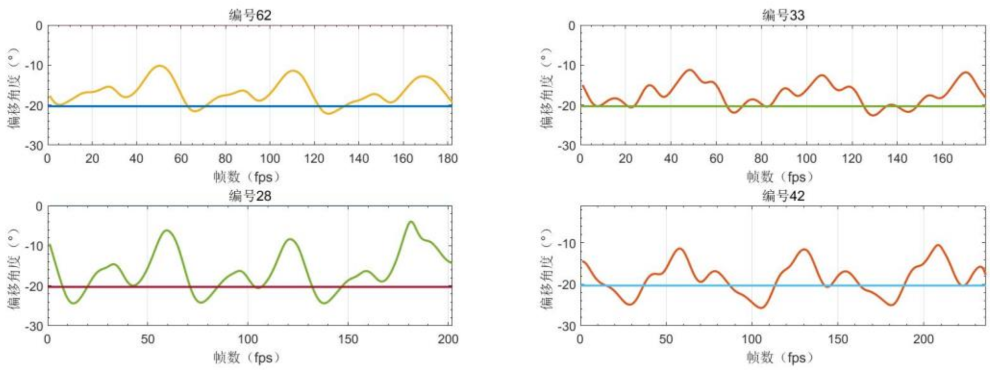

Fig. 4 Deflection Angle of Gravity Center in Motion

偏移角度 Offset angle

编号 Number

帧数 Frame number

Among them, the line represents the threshold of θ, 20.3°. From Fig. 4, we can see the fluctuation of each person's gravity center deviation angle: the number of frames in which the gravity center of subjects 62 and 33 exceeds the threshold range is less, which is basically within the threshold range, and the swing amplitude is also small; the number of frames that the gravity center of subjects 28 and 42 exceeds the threshold range is more, and the swing amplitude of gravity center is also large. The results showed that the risk probabilities of 62, 33, 28 and 42 were 9.4%, 16.3%, 20.7% and 32.6%, respectively, which were consistent with the image results.

3) Determine the Risk Level

Firstly, the risk probability of all the testers is calculated, and the arithmetic mean value of the risk probability of the testers with the tumbling times of 0, 1, 2 and 3 is taken. According to the literature [10], the average risk probability with the tumbling times of 0 can be identified as the critical value of no falling risk; the average risk probability of tumbling times of 1 is identified as the low-level fall risk threshold; and the average risk probability of tumbling times is 2, if the tumble risk probability p is greater than the critical value of moderate tumble risk, it is regarded as having high tumble risk. To determine the tumble risk assessment level, as shown in Table 1.

Table 1 Tumble Risk Assessment Level of the Elderly

Tumble risk level	Critical range of tumble risk
No tumble risk	$p \le 10\%$
Low tumble risk	$10\% < p \le 18\%$
Moderate tumble risk	$18\% < p < 25\%$
High tumble risk	$p \ge 25\%$

According to the risk probability obtained by the elderly individuals, the corresponding tumble risk level can be determined according to the critical range of tumble risk shown in Table 1.

4. SCREENING OF RISK INDICATORS OF MIDDLE-AGED AND ELDERLY PEOPLE

Tumbles in the elderly are not isolated phenomenon, not only related to their basic information, but also are affected by diseases. The following is to find out the factors which have a greater correlation with the tumble risk probability p.

The literature [6] gives the basic information, diseases history and tumble situation of 80 middle-aged and elderly people over 50 years old. The basic information includes: name, gender, age, height, weight and BMI; diseases history includes: cardiovascular disease, hypertension, drug / alcohol withdrawal symptoms, osteoporosis, fracture history, visual impairment, hypoxia, myopenia, hypotension and son on, as well as visual impairment and frontal lobe impairment.

1) Selection of Diseases Mainly Affecting Balance Ability

Because of the diversity and similarity of the diseases of the elderly, and the basic information and tumble situation are universal for different individuals, we screened the above-mentioned more than ten diseases of 80 elderly people, in order to find the ones with higher risk probability of tumble. Kendall correlation analysis in SPSS was used to calculate the significance of all etiology and risk probability values. When the significance is less than 0.05, the variable is considered to be significantly related to the risk probability. The results show that: hypertension, osteoporosis, myopenia and drug / alcohol withdrawal syndromes have high correlation coefficient and good significance value to tumble risk probability, which can be shown in Table 2.

Table 2. Correlation Analysis Result between Diseases and Risk Probability Value

Category	Hypertension	Osteoporosis	Drug / alcohol withdrawal syndrome	Myopenia
Kendall coefficient	0. 427	0. 508	0. 455	0. 402
Significance	0. 048	0. 037	0. 022	0. 044

It shows that these four diseases are more related to tumble risk probability than other diseases.

2) Selection of Tumble Risk indicators

The risk probability value is used as dependent variable, age (X_1), height (X_2), weight (X_3), BMI (X_4), four diseases: hypertension (X_5), osteoporosis (X_6), drug / alcohol withdrawal syndrome (X_7), and myopenia (X_8) were used as independent variables. The risk factors in the model can be analyzed according to the significant factors.

The Multiple Regression Model [11] is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p + \varepsilon$$

（2）

$$D(\varepsilon) = \sigma^2$$

（3）

$$E(\varepsilon) = 0$$

（4）

In the above formula, $D(\varepsilon)$ is the variance, $E(\varepsilon)$ is the mathematical expectation, β_1, β_2,...β_p is the regression coefficient, $X_1, X_2 \ldots X_p$ is the regression factor.

The results show that R square of the model is 0.86, and the fitting degree is good. The regression coefficients and significance of each parameter can be shown in Table 3.

Table 3. Multiple Regression Coefficient Table

	B	Standard error	$BETA$	t	Significance
Constant	4.605	2.900	0.01	1.588	0.143
Age(X_1)	-0.005	0.003	-0.472	-1.591	0.043
Height(X_2)	-0.024	0.017	-2.453	-1.415	0.188
Weight(X_3)	0.028	0.020	5.307	1.431	0.183
BMI(X_4)	-0.087	0.055	-4.612	-1.326	0.143
Hypertension(X_5)	0.025	0.049	0.142	0.523	0.054
Osteoporosis(X_6)	-0.007	0.048	-0.038	-0.143	0.065
Drug / alcohol withdrawal Syndrome(X_7)	-0.087	0.068	0.001	-0.002	0.001
Myopenia(X_8)	0	0.049	-0.001	-0.142	0.439

Table 3 shows that the significance of age, hypertension, osteoporosis and drug / alcohol withdrawal syndrome is less than 0.15, and the significance of other factors is greater than 0.15. Therefore, the tumble risk coefficient is related to age, BMI, hypertension, osteoporosis and drug / alcohol withdrawal syndrome, moreover the correlation is large.

4. CONCLUSION

The data in this paper are derived from 2018 Asia Pacific College Students Mathematical Modeling Contest [6]. The gravity center coordinates of human body are obtained by processing data of joint points with multiplication coefficient method. Considering the deflection angle of the gravity center trajectories of the elderly during walking, the ratio of the number of frames exceeding the stable angle threshold to the total number of frames is taken as the risk probability value. According to the average risk probability value of individuals with different tumble times in the sample, the tumble risk assessment grade is obtained. Therefore, the tumble risk level of the elderly can be determined by calculating the risk probability; in this paper, combined with the disease history data of 80 testers, from 11 kinds of diseases, Kendall analysis was used to screen out 4 kinds of diseases which had a major impact on the risk probability value. Combined with four kinds of basic information, multiple linear regression method was used to quantify the specific impact of these eight factors on the tumble risk, and five factors, namely age, BMI, hypertension, osteoporosis and drug / alcohol withdrawal syndrome were screened out.

The combination of individual risk probability grade and five factors after screening can objectively evaluate the balance ability and tumble risk of the elderly. This paper has great reference value to improve the correlation between universal diseases and tumble risk and prevent tumble in the elderly.

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