International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958, Volume-3, Issue-2, December 2013

Quantification of the Human Postural Control Using the Nonlinear Analysis of Cop Variations during the Quiet Standing

Farshad Samaei, Maryam Daneshfar, Samane Safari Beydokhti

Abstract*—The aging is an effective factor on the quality of standing in healthy subjects. Some neural disorders, degrades the quality of standing, so that the quality of standing in young patient may be as well as the quality of standing in elderly healthy subject. So in this study, the subjects were divided to five age groups, and the age group the subject belonging to it is the measure to quantify the quality of postural control. The subjects were aged between 25-75 years old. The Center of Pressure (CoP) position variations and Center of Pressure (CoP) position velocity during the quiet standing were analyzed through the RQA (Recurrence Quantification Analysis) method. The extracted nonlinear features were fed to the nonlinear classifiers, and the output of classifiers specified the age group which each subject belongs to it. The SVM, MLP neural network, and RBF neural network were the used classifiers. In this manner, the quality of subject postural control could be quantified between1 to 5. Results show the SVM classifier with polynomial kernel reached the best performance of 97.44% accuracy.

***Index terms*—Quiet Standing, Quantification, Aging, RQA, Nonlinear classification.**

I. INTRODUCTION

Some patients with neural disorders should be continuously health monitored by a medical doctor using drugs or occupational therapy. Therefore, doctors should be able to follow-up the improving process precisely. Hence a suitable Quantified index is necessary. Quiet standing is an attractive and effective function which can be degraded through some neural disorders [4]. Nowadays, the Berg Balanced Scale is widely used for measuring the quality of balance while standing.

However this index is highly dependent on the medical doctor's viewpoint and therefore the Burg Balance Scale index of a specific person may be reported different by various doctors [6]. Since stability condition during the quiet standing can be surveyed using analyses of CoP variations, many researchers have scrutinized in dynamics of CoP to quantify the quality of standing [3].Age related changes in the central nervous system and the musculoskeletal system can influence various functions of this control mechanism, and, as a result, can reduce postural stability [2],[18]. Such age-related changes in postural stability during quiet standing have been investigated using time varying characteristics of the center of pressure (COP) and/or the center of mass (COM).[13] These measures have been associated with falling in the elderly.[4] In this study a quantification index for grading the quality of standing based on analyses of CoP variations during the quiet standing is presented.

Manuscript received December 2013.

Farshad Samaei, Department of biomedical, Mashhad Branch, Islamic Azad University, Mashhad, Iran

Maryam Daneshfar, Department of biomedical, Mashhad Branch, Islamic Azad University, Mashhad, Iran

Samane Safari Beydokhti, Department of biomedical, Mashhad Branch, Islamic Azad University, Mashhad, Iran

In the proposed approach, the nonlinear features have been extracted using recurrence maps and SVM pattern recognition classifiers have been used to quantify data with similar feature spaces.

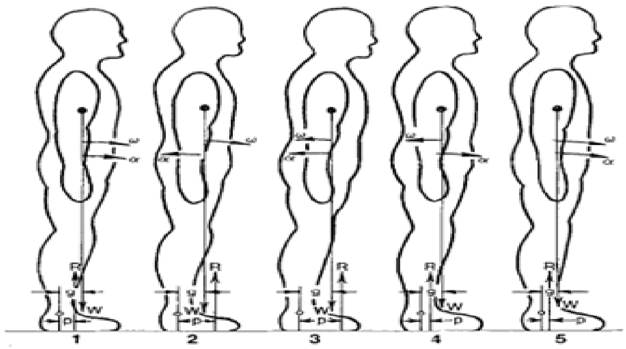

Fig. 1Keep balance during standing

II. METHODS AND MMATERIAL

A. Experimental Setup and Data Recording

The CoP can show the quality of standing solely. For classification the main criteria has been chosen to be the age of each subject. Although, the other parameters such as the length of sole or the length of leg bone could be chosen but those do not have the universality of the age. Therefore cases were chosen from 25-75 years and divided in 5 classes of ten years. The subjects included the 16 men and 9 females devoid any kind of heart, muscular and nervous disease. The body mass index of each subject has been recorded and 21 subjects had a normal BMI.

Table 1 Characteristics of participants in human experiments

Group	Sex	BMI	Age	Mean	Std
A	(3/2)5	21.16	33.2	27.4	3.78
B	(2/3)5	23.2	37.6	37.6	2.07
C	(3/2)5	27.42	51.4	51.2	3.42
D	(3/2)5	25.28	58.8	58.8	2.77
E	(0/5)5	24.5	70.6	70.6	3.50

The reason for this wide range of age was to observe the difference between classes. Subjects have been asked to stand on the force plate (AMTI) for 120 seconds while each foot was putted on a separate force plate. The subjects relaxed for 2 minutes between two consecutive trials.

Fig. 2Subject during the experiment on the force plate

The force plates each have 6 outputs containing 3 forces and 3 torques in the x, y and z directions have being recorded with 100Hz frequency sampling. The CoP variations in the anterior-posterior plane, was calculated as bellows:

$$\mathrm{CoP}(A\_P(L)) = (\mathrm{Mx1}/\mathrm{Fz1}) \quad (1)$$

$$\mathrm{CoP}(A\_P(R)) = (\mathrm{Mx2}/\mathrm{Fz2}) \quad (2)$$

Where Mx_1 and Mx_2 represent the torque in the anterior-posterior direction and Fz_1 and Fz_2 represent the force in the vertical direction in the two force plates.

B. Nonlinear Analysis of CoP

Using these recurrence maps not only has the ability to visually revise the hidden patterns but also to quantify them and find the structure variations and also the similarity between different patterns in the datasets. This ability which is known as the recurrence map analysis after calculating the mean CoPwe have extracted linear and none linear features from the datasets. The feature extraction method for the nonlinear features is the recurrence map analysis which is a nonlinear method used for information analysis in dynamic systems. The nonlinear dynamic zone is a method where the variable variations are not time dependent but dependent on other variables. assume the system has d variables [x_1 ,x_2 ,…,x_d], this relation produces a vector [x1 ,x2 ,…,xd]. In most physical and physiological systems it is only possible to measure one variable. Recurrence maps can be quantified using the recurrence quantification analysis features.

Recurrence Rate (RR)

This feature shows the recurrence points in the map as percentile and is related to the sum of correlations. For calculating this feature the black points of the recurrence map are counted.

$$RR = \frac{1}{N^2}\sum_{i,j=1}^{N} R(i,j) \quad (3)$$

Determinism (DET)

This feature shows the ratio of the points producing the diametrical lines to the whole points in the map. The diametrical lines are produced of two or more points connected in the diametrical direction.

$$DET = \frac{\sum_{l=lmin}^{N} p(l)\ln p(l)}{\sum_{i,j=1}^{N} R(i,j)} \quad (4)$$

Maximal Diagonal Line Length (Lmax)

This feature shows the length of the longest diametrical line and is calculated as followed:

$$L_{max} = \max(\{l_i; i=1\ldots,N_l\}) \quad (5)$$

Entropy (ENTR)

Entropy is a mathematical concept in quantifying nonlinear dynamics. Entropy is amount of disorder in a signal. We have calculated the entropy of the diametrical lines as followed:

$$\sum_{l=lmin}^{N} p(l)\ln p(l) \quad (6)$$

Laminarity (LAM)

To compute this feature the recurrence points in the vertical direction have been calculated as percentile.

$$LAM = \frac{\sum_{V=Vmin}^{N} Vp(V)}{\sum_{V=1}^{N} VP(V)} \quad (7)$$

Trapping time (TT)

The averages of the vertical lines have been calculated.

$$TT = \frac{\sum_{V=Vmin}^{N} Vp(V)}{\sum_{V=Vmin}^{N} P(V)} \quad (8)$$

C. Feature Selection

A statistical analysis, T-Test, is used for feature selection. The T-Test statistical approach has been used to select the features which are significantly different between the five classes. The table 1 shows the result of T-Test. According to the computed p-values, the DET, entropy, TT, L and Lmax have been selected as the most appropriate features.

Table2. The results of T-test statistical analysis utilized for feature selection

Feature	P
RR	0.001
DET	0.000
L	0.000
Lmax	0.024
ENTR	0.000
LAM	0.026
TT	0.251
K	0.018
S	0.036
M	0.125
VAR	0.763
MF	0.017

D. Quantification method

For quantification of human posture balance quality, a grading strategy is design. In the designed strategy, at first using a classification methodology, the age group which each subject belongs to it, is specified. Then, the quality of subject postural control was graded between1 to 5, depending on the specified age group. The grade one shows the best quality and the grade five shows the worst quality.

III .RESULTS

A. Classification based on feature analyses

After feature selection, the best features were used for classification. In the other hand, the age group of each person was specified through computing the difference between the computed selected feature and the obtained mean related to each selected feature and investigate if the calculated difference is less or more than the obtained standard deviation related to that selected feature. Table 3 shows the archived classification results based on selected feature analyses.

Table3.The classification accuracies related to classification based on the analyses of selected features.

Feature selection	Percent of accuracy Training	Percent of accuracy Testing
DET	81	80
ENTR	86	96
TT	80	96
L	98	88
Lmax	98	80

B. Classification using the classifiers

After classification based on analyses of the selected features, for improvement of classification accuracy, the nonlinear features have been used. SVM's are very powerful kernel based classifiers which can be adjusted to be linear or nonlinear by only making changes in the kernel function. The main concept of SVM is mapping the data to a feature space in a manner to be able to classify the data with a hyper plane. The mapping is dependent on the selected kernel function, which the scalar outputs are mapped to the feature space. SVM's have the ability to reduce the structure risks. In this study, we have used the SVM (linear and polynomial), the RBF and the MLP neural networks as the classifiers and their performances were compared. The table 4 shows te achieved results.

Table 4. The classification accuracies related to classification using the classifiers.

Group	SVM (linear)	SVM (polynomial)	MLP	RBF
A	83.60	100.00	92.22	95.00
B	82.80	99.20	94.86	100.00
C	86.00	93.60	93.00	91.70
D	84.20	95.20	95.40	92.30
E	93.20	99.20	96.64	99.00
Mean	85.96	97.44	94.42	95.00

IV. CONCLUSION

In this research a new grading methodology has been presented to quantify the quality of human posture balance during the quiet standing. The proposed methodology was based on nonlinear analyses of CoP variations through the RQA approach. Depending on the age group which the person classified in it, a specific grade, between1 to 5, is assigned. So, the accuracy of grading is significantly related to accuracy of classification. According to the results the best classification performance has been archived is related to the SVM classifier using the polynomial with mean classification accuracy as 97.44%. These promising result can be certify the performance of proposed quantification method. In the next step, the performance of proposed quantification methodology must be confirmed through the grading of standing quality in persons with neural disorder.

ACKNOWLEDGMENT

This work was supported by Neuromuscular Control Lab, biomedical department, Islamic Azad University, Mashhad branch, and also supported sport science research center of mashhad.

REFERENCES

[1] Popovic, D,Feedback Controller for Regulating the Active Albert H. Vette, K.M. Ankle Torque During Quiet Stance. Ieee transactions on neural systems and rehabilitation engineering, vol. 15, No. 2, june 2007, 2007.

[2] Vettea, K.M., Posturographic measures in Albert H. healthy young adultsdurin quiet sitting in comparison with quiet standing. Elsevier,Medical Engineering & Physics 32 (2010) 32–38, 2010

[3] Benoıˆt Seigle, S.R., Dynamica structure of center of pressure fluctuations in elderly people. Elsevier,Gait& Posture 30 (2009) 223–226, 2009.

[4] Kei Masani , A.H.V., Larger center of pressure minus center of gravity in the elderly induces larger body acceleration during quiet standing. Elsevier,Neuroscience Letters 422 (2007) 202–206, 2007

[5] Patrick D. Neuls, Usefulness of the Berg Balance Scale to Predict Falls in the Elderly, Journal of GERIATRIC Physical Therapy,2011.

[6] Elizabeth T. Hsiao-Wecksler a, K.K., Predicting the dynamic postural control response from quiet-stance behavior in elderly adults. Elsevier,Journal of Biomechanics 36 (2003) 1327–1333, 2003

[7] F.M.Birleanua,C.Gervasie,On The Recurrence Plot Analysis Method Behavior Under Scaling Transform,2011 IEEE Workshop on Statistical signal Processing,2011.

[8] Feuerbach and T.M.L.a.J.W. Mark D Grabiner, Converting Chattecx Balance System Vertical Reaction. jornal of the american physical therapy association, 1993.

[9] D A Winter, human balance and posture control, Gait&Posture: 1995; Vol. 3: 193-214, December

[10] Helene Corriveau, R.H., Michel Raˆıche, Postural stability in the elderly: empirical confirmation of a theoretical model. Elsevier,Archives of Gerontology and Geriatrics 39 (2004) 163–177, 2004.

[11] Katerina Stambolieva, Fractal properties of postural sway during quiet stance with changed visual and proprioceptive inputs, J PhysiolSci (2011) 61:123–130.

[12] ItshakMelzer a, I.K.a., Lars I.E. Oddsson, A retrospective analysis of balance control parameters in elderly fallers and non-fallers. Elsevier,Clinical Biomechanics 25 (2010) 984–988, 2010.

[13] J.Griskevicius,E.J,Evaluation of human postural balance in quiet standing by direct measurement of human body center of mass acceleration. Jornal Of Vibro enginnering,2009.

[14] Jacques Vaillant, N.V., Effect of manipulation of the feet and ankles on postural control in elderly adults. elsevier,Brain Research Bulletin 75 (2008) 18–22, 2008.

[15] Jeong-Jung Kim, T.-Y.C.a.J.-J.L., Falling Avoidance of Biped Robot using State Classification. Proceedings of 2008 IEEE International Conference on Mechatronics and Automation, 2008.

[16] Joseph,p.Zbilut,C.L, Recurrence Quantification Analysis. Wiley Encyclopedia of Biomedical Engineering,2006.

[17] K.M. Newell, S.M.S., Stochastic processes in postural center-of-pressure profiles. Springer, 1997.

[18] B.E. Maki,W.E. McIlroy, Postural control in the older adult, Clin. Geriatr. Med. 12 (1996) 635–658.

Mr. Farshad Samaie, was born in Gonbad kavous, Golestan, Iran. he received his B.E Degree in Electronic (control) Engineering from Sajad Private Institute of Higher Education in Mashhad, Iran in 2010. and completed his post graduate degree in Biomedical Engineering from Department of biomedical, Mashhad Branch Islamic Azad University, Mashhad, ran in 2013.

Ms. Maryam Daneshfar, was born in tabriz, Eastazarbayjan, Iran. she received his B.E Degree in bioelectric Engineering from azad university, dezful, Iran in 2008. and completed her post graduate degree in Biomedical Engineering from Department of biomedical, Mashhad Branch Islamic Azad University, Mashhad, Iran in 2013.

Ms. Samane Safari Beydokhti, was born in mashhad, khorasan, Iran. she received his B.E Degree in bioelectric Engineering from azad university, mashahd, Iran in 2010. and completed her post graduate degree in Biomedical Engineering from Department of biomedical, Mashhad Branch, Islamic Azad University, Mashhad, Iran in 2013.