Development of Human Balance Assessment System with Continuous Center of Gravity Tracking

Ben-Yi Liau[1], Chi-Wen Lung[2], and Yih-Kuen Jan[3]

[1] Department of Biomedical Engineering, Hungkuang University, Taichung, Taiwan, ROC
[2] Department of Creative Product Design, Asia University, Taichung, Taiwan, ROC
[3] Departments of Kinesiology & Community Health and Computational Science & Engineering, University of Illinois at Urbana-Champaign, Champaign, IL, USA
byliau@sunrise.hk.edu.tw

Abstract. Fall is the second leading cause of injures for older adults in Taiwan. If fall risk can be prevented or decreased, fall and its complications could be reduced effectively. The purpose of this study is to develop the human balance assessment system with LabVIEW program interface. 10 healthy adults were enrolled in this study. They were evaluated under four kinds of postures while standing on a 2-axis force platform for 20 seconds. The results showed the displacements in both X and Y directions were smaller during stand with two legs and open eyes ($p<0.05$). Balance index results also revealed balance ability become lower while standing with one leg and closed eyes ($p<0.05$) In conclusion, different postures would affect balance. These differences can be assessed by this system. It is hope fall can be prevented in advanced and decrease the medical burden in older adults by the system in the future.

Keywords: fall risk, balance, force platform.

1 Introduction

With the progress of modern medical technology, life of human becomes longer and longer. However, healthy problems and nursing would be a huge burden with aging population. One of important topic in older people is "fall". Fall is the second leading cause of injures for older adults in Taiwan. In 1987, the definition of a fall was provided by Kellogg International Working Group. Fall is "unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in stroke or an epileptic seizure" [1]. Fracture is one of the serious complications resulted from fall. Injures of fall in older adults might be not only the high prevalence but also the high susceptibility to injury and co-morbid disease. It makes mild fall lead to serious condition. Lacking strength of lower extremity, difficult gait and balance would increase fall risk. Injure of fall would make limb can not be controlled properly and self-care would be more difficult. Therefore, they might need long term care or rehabilitation. All of them can be a huge burden for medical resource. Fall could be fatal in the healthy of older adults. For these reasons, if fall risk can be prevented or decreased, fall and its complications could be reduced effectively. Falls are a major threat to the health of older persons. In 1996, Nevitt et al. evaluated potential risk factors for falls. They found

V.G. Duffy (Ed.): DHM/HCII 2013, Part I, LNCS 8025, pp. 332–337, 2013.

the proportion of subjects with two or more falls per year increased from 0.10 for those with none or one of these risk factors to 0.69 for those with four or more risk factors. Among older persons with a history of a recent fall, the risk of multiple non-syncopal falls can be predicted from a few simple questions and examinations [2]. Previous studies also applied some gravity sensor to develop assessment system [3-4]. Recently, Wii balance board was adopted to evaluate balance ability [5]. Also, several physical approaches were compared and used to assess balance [6]. Due to fall risk is highly related to balance ability [7-9]. Therefore, the purpose of this study is to develop a multi-parameters balance assessment system with applying average center location, balance index, base area, and center location displacement for evaluating the human balance ability with LabVIEW program interface. Average center of gravity location can indicate the final displacement during the period of standing. Balance index may evaluate balance ability according to the change of center of gravity. Base area can calculate the region of total track. Center location displacement can indicate the displacement of center of gravity in both 2-axis. Integrate these results, it is expected that a noninvasive, low cost, reliable, simple and quantitative biomedical signal assessment system can be developed in this research for effective assessment and prevention of fall in older adults.

2 Methods

2.1 Participants

There are 10 healthy adults were enrolled in this study. They were evaluated under four kinds of postures (stand with two legs and open eyes, stand with two legs with closed eyes, stand with one leg and open eyes, stand with one leg and closed eyes) while standing on a 2-axis force platform (PASCO PS-2142) for 20 seconds. The data sampling rate were set to be 250 Hz.

2.2 Balance Signal Measurement

The balance system was based on the 2-axis force platform (PASPORT, PS-2142, USA). The force platform continuously measures force applied to it in two separate directions: normal to its surface (up to 4400 N) and along an axis parallel to its surface (up to 1100 N). Each of the four feet is connected to a beam with a strain gauge, through which the platform's electronics measure the force. As well as the sum of the normal forces applied to the four beams, the platform can be set to output the separate normal force measured by each beam. The size of the platform is 29 x 29 cm as shown in figure 1.

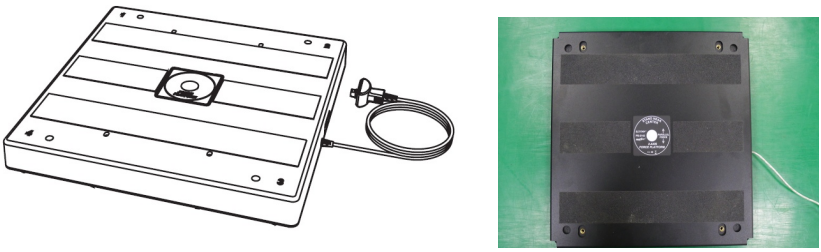
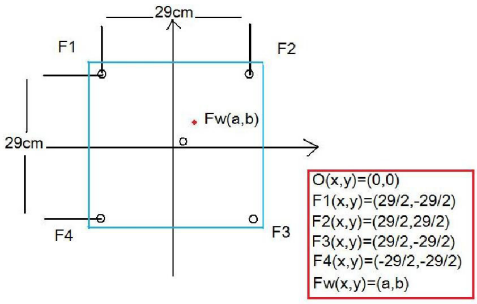


Fig. 1. The force platform was used to collect the normal force signals while standing

2.3 Data Analysis and Interface

ASCII files with data from the four sensors were processed by LabVIEW codes to estimate balance parameters. The force was determined in a defined area [29 ×29 cm^2] around the sensors. A average location of gravity center on the force platform may be calculated by the signals of normal forces. The location of gravity center is estimated as equation (1).



$$F_1 + F_2 + F_3 + F_4 = F_w$$

$$a = \frac{14.5(-F_1 + F_2 + F_3 - F_4)}{F_w}, \quad b = \frac{14.5(F_1 + F_2 - F_3 - F_4)}{F_w} \tag{1}$$

Where $F_1 \sim F_4$ is the force in each sensors, F_w is sum of normal forces, a and b is coordinates in x-axis and y-axis.

Balance Index (BI) can quantify the balance ability of human body. The value of balance index is estimated as equation (2). Due to larger value means far away more from aver age center of gravity, larger BI value, less balance ability [10].

$$BI = \sqrt{\frac{(\sum (O_x - X)^2 + \sum (O_y - Y)^2)}{N}}, \quad N \text{ is sample size} \tag{2}$$

Where O_x and O_y is the continuous coordinates of gravity center in time domain. X and Y is the average center of gravity. N is sample size.

3 Results and Discussion

The operation interface of this assessment system programmed by LabVIEW can show the track of center of gravity (COG), average position of COG, balance index and other parameters as showed in figure 2.

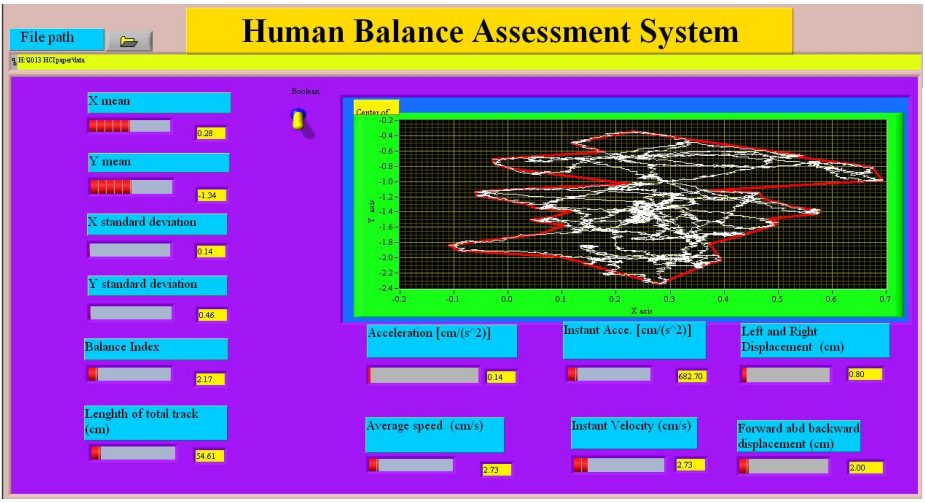


Fig. 2. The interface of human balance assessment system

Fig. 3 and 4 showed the displacements in both X and Y directions were smaller during stand with two legs and open eyes ($p<0.05$). Balance index results also revealed balance ability also become lower while standing with one leg and closed eyes ($p<0.05$) as showed in Fig. 5. Integrate these results, it indicated human balance ability was better during stand with two legs and open eyes ($p<0.05$) according to these comparison of parameters. On the other hand, stand with one leg and closed eyes will decrease balance ability.

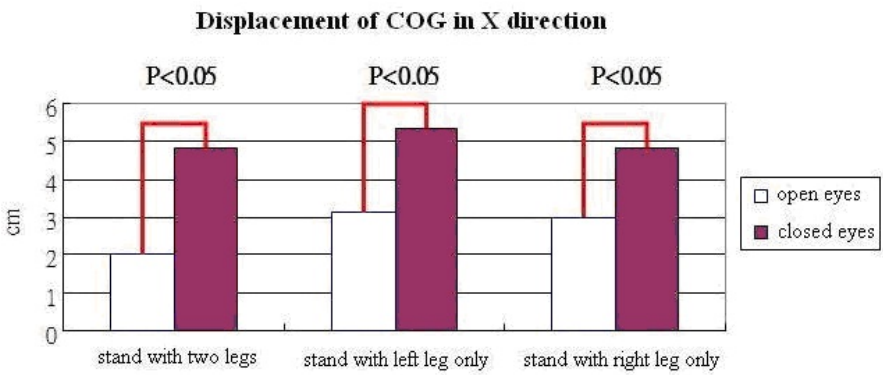


Fig. 3. Displacement of COG in X direction

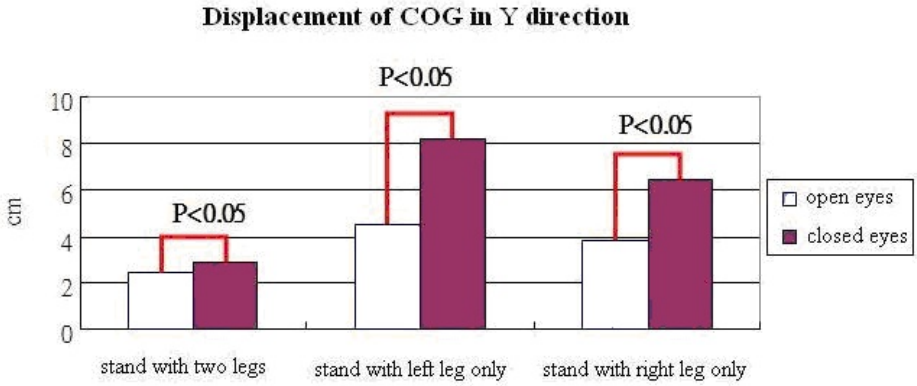


Fig. 4. Displacement of COG in Y direction

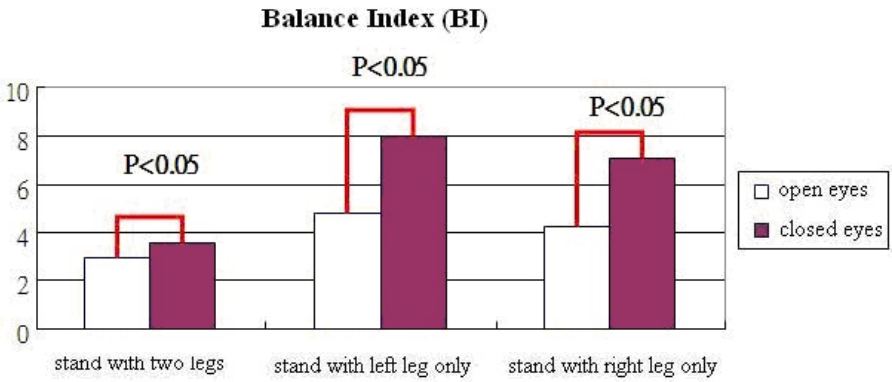


Fig. 5. Balance index (BI) results

4 Conclusions

According to the results, different posture would affect balance sense and ability. It can be assessed by this system with these parameters. Therefore, this system with easy test can provide fast and effective evaluation and these parameters can be adopted to assess fall risk, too. It is hope fall can be prevented in advanced and decrease the medical burden in older adults by the system in the future.

Acknowledgements. The authors would like to thank the National Science Council, Taiwan, and Hungkuang University for supporting this research under Contract No. NSC 101-2221-E-241 -009 and HK-CCGH-100-06.

References

1. Gibson, M.J.S., Andres, R.O., Kennedy, T.E., Coppard, L.C., et al.: Kellogg International Work Group on the Prevention of Falls by the Elderly, The prevention of falls in later life: a report of the Kellogg International Work Group on the Prevention of Falls by the Elderly (1987)
2. Northridge, M.E., Nevitt, M.C., Kelsey, J.L.: Non-syncopal falls in the elderly in relation to home environments. Osteoporosis International 6(3), 249–255 (1996)
3. Persson, L., Karberg, M., Magnusson, M.: "Effect of different treatment on postural performance in patients with cervical root compression. Journal of Vestibular Research 6(6), 439–453 (1996)
4. Uimonen, S., Sorri, M., Laitakari, K., Jamsa, T.: A comparsion of three vibratiors in static posturography: the effect of vibration amplitude. Medical and Enginering Physics 18(5), 405–409 (1996)
5. Clark, R.A., Bryant, A.L., Pua, Y., McCrory, P., Bennell, K., Hunt, M.: Validity and relability of the Nintendo Wii Balance Board for assessment of standing balance. Gait & Posture 31(3), 307–310 (2010)
6. Lafond, D., Duarte, M., Prince, F.: Comparison of three methods to estimate the center of mass during balance assessment. Journal of Biomechanics 37(9), 1421–1426 (2004)
7. Rubenstein, L.Z.: Falls in older people: epidemiology, risk factors and strategies for prevention. Age and Ageing 35(2), i137–i141 (2006)
8. Fuller, G.F.: Falls in the elderly. American Family Physician 61(7), 2159–2168 (2000)
9. Salminen, M., Vahlberg, T., Sihvonen, S., Sjosten, N., Piirtola, M., Isoaho, R., Aarnio, P., Kivela, S.-L.: Effects of risk-based multifactorial fall prevention on postural balance in the community-dwelling aged: A randomized controlled trial. Archives of Gerontology and Geriatrics 48(1), 22–27 (2009)
10. Lin, B.C., et al.: Sports Biomechanics. Wagner Publishing Co., Taiwan (2008)