

A Method of Measuring and Analyzing the Regularity of Human Gait

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Abstract—There are differences between normal and abnormal gait performance. Gait analysis can help clinicians to evaluate the rehabilitation of disease. The aim of the paper is to establish a method of measuring gait features based on the optical motion capture device. This experiment was conducted on a young healthy male, who was asked to walk in the walkway back and forth in routine walking speed, so that the body data of walking in a natural state can be obtained. The motion trajectories of three markers (waist, knee and heel) were measured and the data were processed in MATLAB with the geometric mean. The results show that these gait curves have strong regularity, so that the human gait rule was obtained, which can be used for reference in clinical gait analysis.

Keywords—gait regularity; gait analysis; joint measurement; motion capture

I. INTRODUCTION

Walking is a kind of periodic movement, which is one of the most repetitive movements in the daily life of the human body [1]. The gait performance has a strong regularity during natural walking, and it plays an important role in clinical practice, bionics, machine interaction etc. [2]. Zheng analyzed the gait characteristics of patients with sciatica, and the abnormal gait features were clearly reflected [3]. Elbaz et al. investigated the effect of a biomechanical therapy of patients after TKA through gait patterns analysis [4]. Dance movements system has been built by Shinoda et al. [5], and a full-body database of human gesture was proposed by Hwang et al. [6].

Regarding kinematic gait analysis, there are several motion descriptions (basically the temporal-spatial parameters), such as the gait cycle, step length, walking speed, as well as the various joint angles of the body. Human gait measurement can not only help doctors assess disease or rehabilitation process [7], but also provides means for diagnosis and evaluation for clinical science [8]. Therefore, gait analysis plays a significant role to the understanding of human movement regularity and the rehabilitation of medical treatment [9-13].

Although experiments conducting in some literatures on a treadmill at specified speeds have many advantages, there are also shortcomings. The walking posture of human body on the treadmill is not as completely natural as on the ground, which may have some influences in measurements. Therefore, this experiment allows the subject to walk on the ground at routine speed, and the walking trail was stipulated with arrows so that the deviation of the data caused by swing route was reduced. In

this research, a healthy male aged 22 was participated, and the trajectories of three markers (waist, knee and heel) were measured. The purpose of this study is to summarize and analyze gait regularity of lower limb at routine walking speed, which can provide guidance and reference to clinical gait analysis.

II. METHOD

A. Subject

One young healthy male aged 22 with no current pain or history of major lower extremity injury was participated in this study, whose height is 170 cm and weight is 60 kg, respectively.

B. Apparatus and Measurements

Kinematic data are acquired by using the active optical motion capture system composed of multiple CCD cameras (PhaseSpace, USA), which could scans 480 frames per second for each LED. The motion range and speed of lower limbs are larger and faster than the upper. Hence, it has great value to the measurement and analysis of gait regularity of lower extremities. Considering the symmetry of the left and right side gait performance [14], the experiment here was designed to study the right side of lower limb. The motion markers measured here include the waist, knee and heel. Before the experiment, the subject was asked to walk in a walkway assisted by arrows at natural and customary posture and speed to warm up for several times (Figure. 1).



FIGURE I. EXPERIMENTAL SCENE

Then, the subject continued to walk on the 4 meters walkway back and forth for about six times maintaining almost the same walking speed.

III. DATA ANALYSIS

The measurement datas of X, Y, Z coordinates for three markers can be obtained by modifying in the MATLAB software. Figure 2 (a, b, c) depicts the X, Y, Z trajectories of three markers during the whole motion process respectively. X (red line) represents the walking trajectory, and Y (blue line) expresses the lift height, as well as the swing is denoted by Z(black line). These graphs all exhibit obvious periodic motion trajectories. By comparison of them, the gait curve of the waist is the smoothest, especially the X, which indicates that the waist motion is much more stable during walking. In contrast, the trajectory of heel fluctuates greatly, and the step shapes of its periodic curve (X) show the landings of the footsteps. Additionally, the trajectory of Z in each figure also shows periodic comparatively large fluctuations, which indicates that the subject took a turn around at each end of the walkway.

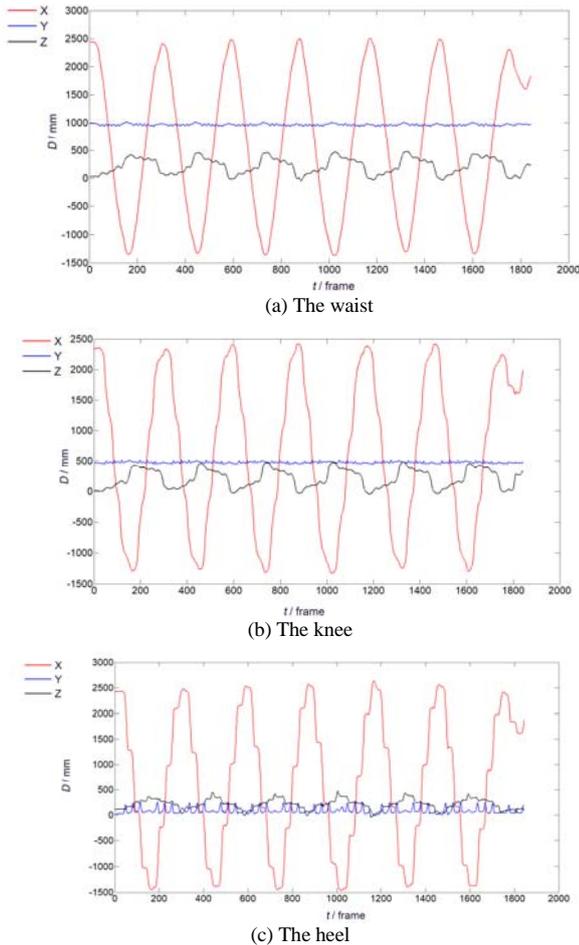


FIGURE II. THE TRAJECTORIES OF X, Y, Z DURING THE WHOLE MOTION PROCESS

The figures above were generated by about 30 steps from the subject. Here, 15 steps were chosen in the same walking

direction, and the 15 curves were fitted by using geometric mean in formula (1). Then, the regularity in one gait cycle can be observed in a specific view.

$$G_n = \sqrt[n]{\prod_{i=1}^n x_i}, \quad n=1, 2, 3... 15 \quad (1)$$

Figure 3, 4, 5 show the changes of X, Y coordinates of three markers in sagittal plane during the experiment, respectively. The red solid line of each figure is the average trajectory fitted by formula (1), and the horizontal axis represents the number of frames.

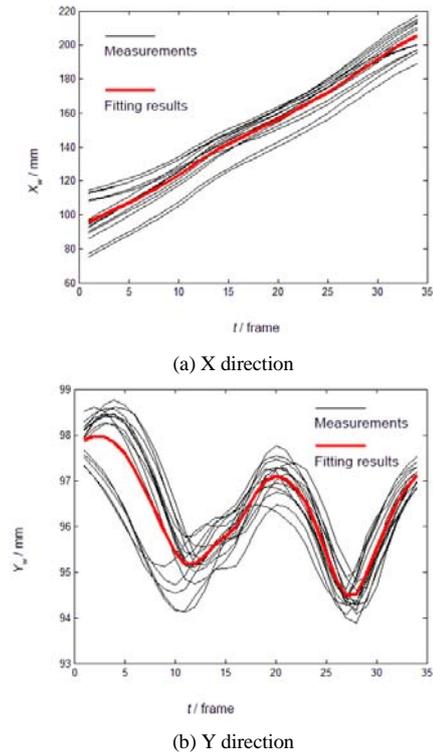
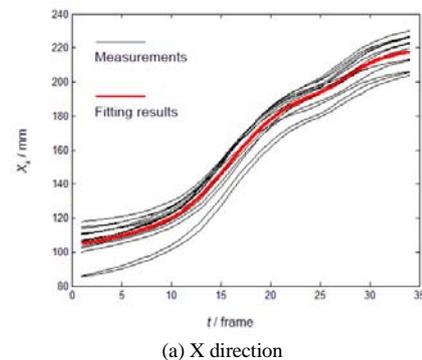
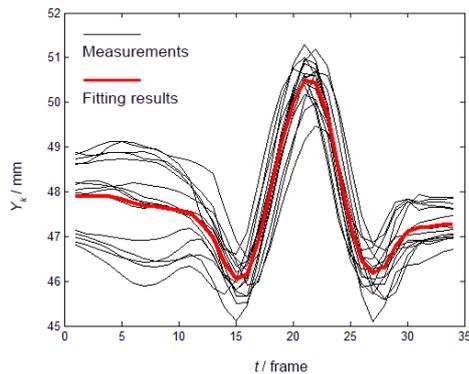


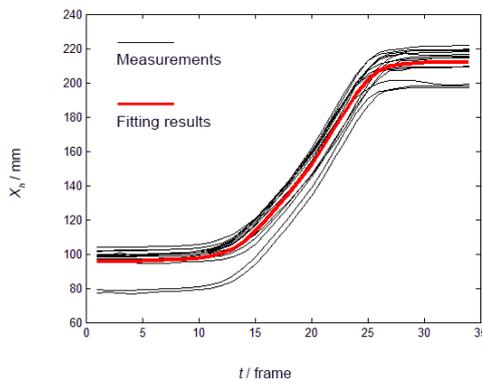
FIGURE III. THE TRAJECTORIES OF WAIST IN A GAIT CYCLE



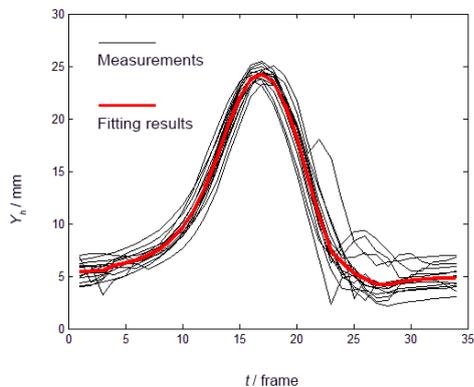


(b) Y direction

FIGURE IV. THE TRAJECTORIES OF KNEE IN A GAIT CYCLE



(a) X direction



(b) Y direction

FIGURE V. THE TRAJECTORIES OF HEEL IN A GAIT CYCLE

These figures display that the gait performance is becoming more coherent from the heel to the waist, and the fluctuation around the foot is greatly influenced by the walking action. The step length was about 550mm, and the value 1.28 m/s of the speed was calculated.

It should be noted that the peak numbers of Y trajectory for the waist is more than one than the corresponding ones of knee and heel. This shows that the frequency of the up and down vibrations of the waist is larger in a gait cycle.

IV. CONCLUSION

This work presented a method to measure the human gait data: the characteristics in the natural speed and posture, which is based on the motion capture device.

From the experimental results, it can be concluded that:

(1) The gait trajectories show obvious regularity with periodicity;

(2) The waist motions are more comparatively stable during walking, while the ranges of fluctuation of footsteps trajectories are larger because of the physiological characteristics of human walking;

(3) In one gait cycle, frequency of the up and down vibrations of the waist is larger but stable.

It needs to be highlighted that the gait parameters have great value in diagnosis and treatment of disease. So the research will continue to expand the number of samples in the future, which contains the measurement of joint ranges of motions and the dynamics parameters, in order to establish a method that can be applied to the gait characteristics of the rehabilitation evaluation of the fracture patients.

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REFERENCES

- [1] Y. W. Song, J. R. Teng, X. Y. Zhang, Effects of soles with different hardness on human lower extremity kinematics during walking [J]. *Journal of Medical Biomechanics*, 2013, 28 (4):388-396. In Chinese.
- [2] F. W. Cai, R. C. Wang, G. Q. Li, M. B. Wang. Development of low cost human gait analysis system [J]. *Chinese Journal of Rehabilitation Medicine*, 2008, 23(1):49 -53.
- [3] C. F. Zheng, Y. C. Liu et al. Gait characteristics of patients with sciatica [J]. *Journal of Medical Biomechanics*, 2016, 31(1):73-77.in Chinese.
- [4] Avi Elbaz et al. New approach for the rehabilitation of patients following total knee arthroplasty [J]. *Journal of Orthopaedics*, 2014, 11(2):72-77
- [5] Y. Shinoda, Y. Mito, T. Ozawa et al. Consideration of classification of dance movements for Nihon Buyo using motion capture system [C]. *Proc of SICE Annual Conference*. 2012:1025-1028.
- [6] B. W. Hwang, S. Kim, S. W. Lee. A full-body gesture database for human gesture analysis [J]. *International Journal of Pattern Recognition and Artificial Intelligence*, 2007,21(6):1069-1084.
- [7] P. Worsley, G. Whatling, D. Barrett, C. Holt, M. Stokes, M. Taylor, Assessing changes in subjective and objective function from pre- to post-knee arthroplasty using the Cardiff Dempster-Shafer theory classifier [J]. *Computer Methods in Biomechanics and Biomedical Engineering*,19 (4) (2016) 418-427.
- [8] I. D. Siasios et al. The Role of Gait Analysis in the Evaluation of Patients with Cervical Myelopathy: A Literature Review Study. [J]. *World Neurosurgery*, 2017, 101:275-282.
- [9] T. A. L. Wren, G. E. G. Iii, S. Öunpuu, C. A. Tucker. Efficacy of clinical gait analysis: A systematic review [J], *Gait & Posture*, 2011, 34(2)149-153.
- [10] R. Debi, A. Elbaz et al. Knee osteoarthritis, degenerative meniscal lesion and osteonecrosis of the knee: Can a simple gait test direct us to a better

- clinical diagnosis [J]. *Orthopaedics & Traumatology: Surgery & Research*, 2017, 103(4):603-608.
- [11] Avi Elbaz, A. Mor et al. Lower Extremity Kinematic Profile of Gait of Patients after Ankle Fracture: A Case-Control Study [J]. *The Journal of Foot and Ankle Surgery*, 2016, 55(5):918-921.
- [12] O. Suci, R. R. Onofrei, A. D. Totorean, S. C. Suci, E. C. Amaricai. Gait analysis and functional outcomes after twelve-week rehabilitation in patients with surgically treated ankle fractures [J]. *Gait & Posture*, 2016,49:148.
- [13] J. H. Tang et al. Characterisation of dynamic couplings at lower limb residuum/socket interface using 3D motion capture [J]. *Medical Engineering and Physics*, 2015, 37(12):1162-1168.
- [14] P. Huang, H. M. Zhong et al. Three-dimensional gait analysis in normal young adults: temporal, kinematic and mechanical parameter [J]. *Chinese Journal of Tissue Engineering Research*, 2015,19(24):3882-3888.