Study on Optimizing the Comfort of Long-standing Crowds

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Abstract Because of the flexibility and freedom of legs, standing posture can improve the efficiency of workers, so standing posture is a common working condition, and standing for a long time will lead to workers' physical discomfort and muscle fatigue. Working in this condition for a long time may lead to occupational injury. Because standing for a long time has many negative effects, we should study some methods to solve or reduce the harm to the body. Many studies have shown that floor mats and insoles are effective ways to improve physical comfort and occupational health when standing for a long time. Nelson et al. found that standing on an inclined platform significantly reduced the discomfort of the waist and back of subjects and attributed this phenomenon to the reduction of lumbar protrusion at the end of the lumbar spine and the increase of movement posture. However, up to now, few studies have considered standing platform as an intervention to reduce long standing muscle fatigue. Therefore, this paper takes the long-standing worker as the research object, studies the comfort effects of different tilt angle platforms on the long-standing worker, uses plantar pressure, surface muscle power and skin temperature to analyze and test the physiological changes of the long-standing worker in the experimental process, and uses subjective methods such as visual analogue scale to measure their psychological fatigue, from the material of the tilt platform, soft and hard. The optimum design scheme of inclined platform is discussed by changing the parameters of degree and inclination angle, which provides an effective scheme and theoretical basis for solving the comfort of long-standing crowd.

Keywords: Long Standing; Tilt Angle; Physiological Changes; Psychological Fatigue; Comfort

1 Introduction

Standing work can be a more important work posture because the legs have great flexibility. This work posture allows workers to perform process operations in a simple and efficient manner, thereby making workers more productive. However, when workers are standing for a long time during working hours, they may feel uncomfortable and fatigued, causing occupational injuries for a long time. If a worker spends more than 50% of the total working time of working hours, then it is considered to be standing for a long time [1]. Long-term work is considered to be an important factor in reducing the efficiency of industrial workers, often leading to occupational injuries, reduced productivity, increased treatment and medical costs, and low worker mood. When the worker works for a long time, the back and legs are statically contracted, resulting in weakened function of the calf muscles [2]. This situation can cause discomfort and muscle fatigue to workers, so employers will lose income due to workers' compensation and medical expenses [3]. For example, standing for a long time causes back pain, which can affect the worker's bending posture in the next work, which may adversely affect the productivity of the worker. In addition, injured workers must go to the hospital for treatment, resulting in a large amount of medical expenses.

Standing in the workplace for a long time can cause discomfort and muscle fatigue, especially at the end of work. Discomfort or subjective fatigue can be associated with mental fatigue, which is considered a factor of alertness, concentration of mind, and decline in positivity [4, 5]. Under normal circumstances, subjective evaluation of psychological fatigue caused by prolonged standing is conducted through questionnaire survey [6], Borg scale [7], body part symptom questionnaire [8] or using visual analogue scale [9]. On the other hand, muscle fatigue can be technically identified by observing changes in the amplitude and frequency of the electromyogram (EMG) signal over time [10]. When the amplitude of the signal increases and the power frequency decreases, it indicates that the muscle being evaluated is in a fatigue state [11]. sEMG (surface electromyography) is one of the most well-recognized techniques for evaluating muscle fatigue in many studies [12].

A number of studies provide a strong argument that research on long-standing work is important to workers, industry owners and the entire national economy. Many studies have investigated the effects of floor types on long-term populations, which are thought to be related to standing discomfort. Nelson et al. found that standing on a sloping platform significantly reduced the subject's feeling of lower back discomfort and attributed this phenomenon to a reduction in end lumbar lordosis and an increase in exercise posture [13]. However, to date, few studies have used the use of tilting platforms as an intervention to reduce long-term muscle fatigue, and the specific effects of using tilting platforms to reduce long-term physical discomfort have not been fully explored. Therefore, the main content of this paper is to study the specific impact of inclined platforms from different angles on the long-standing crowds.

2 Experiment

The study completed two main tasks: determining the psychological fatigue experienced by production workers when they were engaged in long-term standing; measuring and analyzing muscle activity in the legs and waist. The following sections provide procedures and methods for applying STEM to determine muscle fatigue, as well as the fatigue time experienced by workers in locations where they need to stand for long periods of time. Eight college students were recruited as subjects, and all subjects were healthy. Each subject participated in data collection for four working days, each working day required to stand on the inclined platform at the same angle for 80 minutes, except 0°, there are 5°, 10°, 15° three different angles of inclined platform, as shown in Figure 1, Figure 2 and Figure 3.

Fig. 1. 5 °inclined platform

Fig. 2. 10°inclined platform

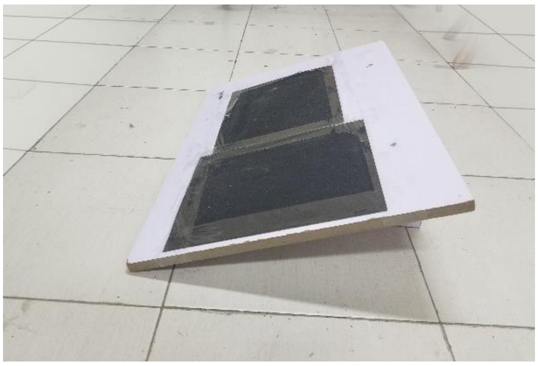

Fig. 3. 15°inclined platform

2.1 Data Collection

All data on the muscle activity of the subject were recorded, stored and analyzed using the sEMG and Mangold-10 wireless Bluetooth multi-channel physiology instrument, as shown in Figure 4. The Mangold-10 Wireless Bluetooth Multi-Channel Physiology System is equipped with electrodes to detect the subject's EMG signal. The electrodes were attached to the subject's skin and the activity of the three muscles during standing work was measured: left erector spinae, left and right gastrocnemius muscles. Figure 5 shows the location of the SEMG electrode used to measure the selected muscle fatigue.

Fig. 4. Mangold-10 wireless Bluetooth multi-channel physiology system made in Germany

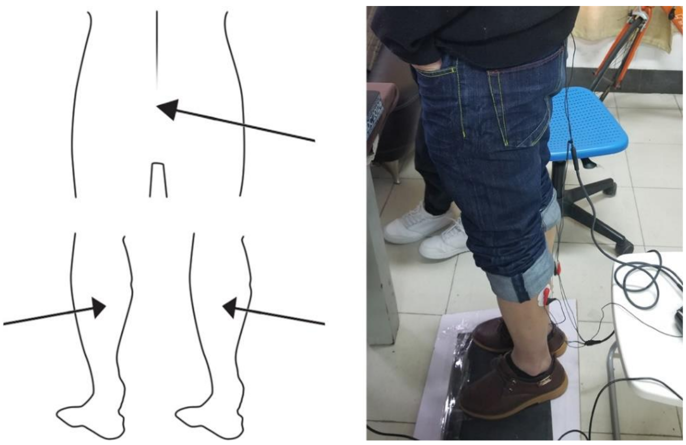

Fig. 5. Surface Electrode Patch Position

In this experiment, the muscle electrical signal data of 80 minutes was continuously measured on the inclined platform of each angle, and the data points of 5 minutes were collected every 20 minutes for analysis, and a total of 5 times were collected. After the collected raw EMG signals were processed, the amplitude-frequency comprehensive analysis method was used to analyze the fatigue changes of the muscles. As shown in Figure 6, the amplitude-frequency analysis method divides the sEMG signal into four quadrants through iEMG and MF spectrum changes to determine the increase or decrease of muscle strength, and the generation and recovery of fatigue.

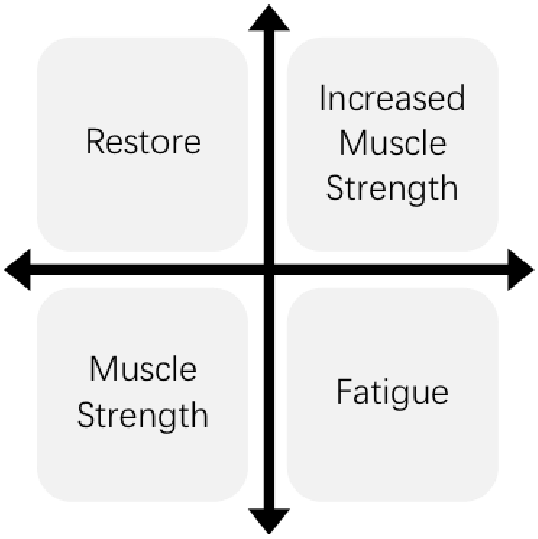

Fig. 6. Schematic Diagram of the Amplitude-Frequency Joint Analysis Method

2.2 Data Processing Results

1）The primordial EMG signals of the gastrocnemius muscles of 8 subjects in the 4 groups of experiments were evaluated, and the iEMG values of the patients' intestinal muscles were obtained, and standardized treatment and significant difference test were performed. The results are shown in Figure 7.

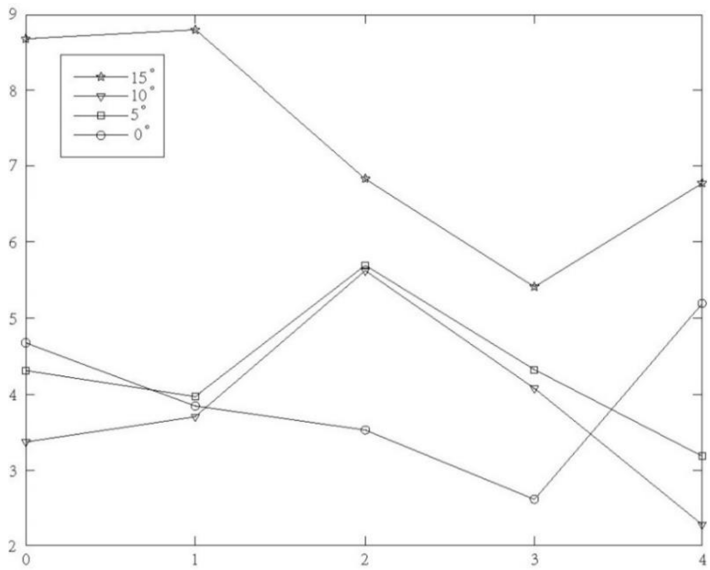

Fig. 7. Changes in the Intestinal Muscle iEMG at Different Angles of the Inclined Platform

Table 1. Significance Analysis of iEMG Signals of the Intestines Muscles at Different Angles

	T1	*T2*	*T3*	*T4*	*T5*
	0°	0°	0°	0°	0°
5°	0.13	0.360	0.025*	0.037*	0.027*
10°	0.715	0.356	0.021*	0.038*	0.042*
15°	0.002*	0.008*	0.013*	0.006*	0.015*

As shown in the above table, there is a significant difference between the data marked with'*', that is, the intestinal muscle iEMG value standing on the 0° platform is 5°, 10°, 15° in the T3, T4, T5 time period. There was a significant difference ($p < 0.05$).

2) Next, the MF values of the intestinal muscles of the subjects were normalized and the significance difference test was performed, and the results are shown in Figure 8 and Table 2.

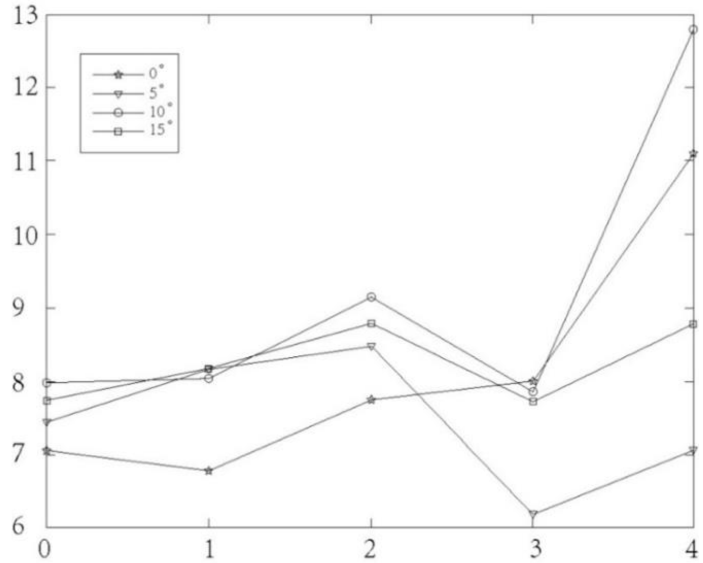

Fig. 8. Changes in MF Values (%) of the Intestines of Inclined Platforms at Different Angles

Table 2. Significance Analysis of Migrating Muscle MF Signal at Inclined Platforms with Different Angles

	T1	*T2*	*T3*	*T4*	*T5*
	0°	0°	0°	0°	0°
5°	0.25	0.80	0.83	0.88	0.023*
10°	0.10	0.52	0.11	0.96	0.046*
15°	0.30	0.37	0.22	0.92	0.041*

As shown in the above table, there is a significant difference between the data marked with '*', that is, the EF value of the gastrocnemius standing on the 0° platform and 5°, 10°, 15° in the T4-T5 time period. Significant difference ($p < 0.05$).

3) Standardized treatment and significant difference test were performed on the iRGG values of the erector spinae of the subjects. The results are shown in Figure 9 and Table 3.

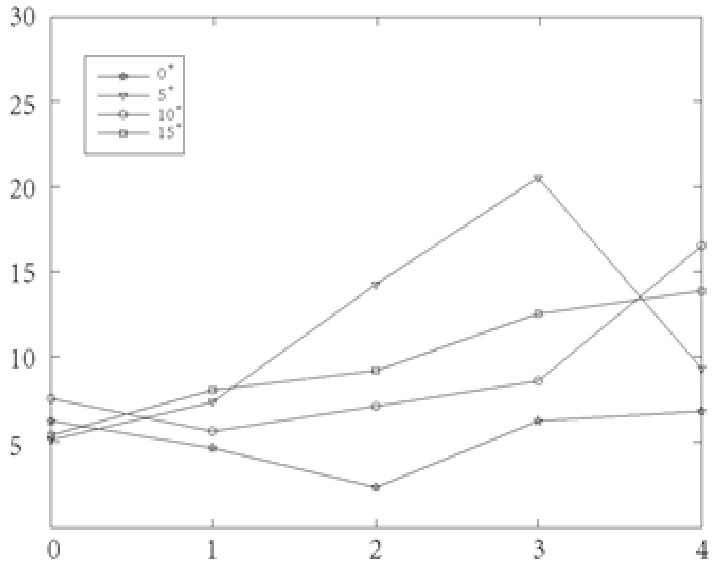

Fig. 9. Changes in iEMG Values of Erector Spinae at Different Angles of Inclined Platform

Table 3. Significance Analysis of iEMG Signals of Erector Spinae at Different Angles

	Sum of Squares	*df*	*Average Squared*	*F*	*Significance*
Between Groups	8.23	3	2.743	1.691	0.192
Within the Group	45.43	28	1.623		
Total	53.663	31			

From the above analysis of variance table, it can be seen that the erector spinae iEMG value signal standing under different inclined platforms has a significant p=0.192>0.05, that is, the iEMG signal of the gastrocnemius muscle standing on different inclined platforms is not significant. Sexual differences.

4) Standardized treatment and significant difference test were performed on the vertebral muscle MF values of the subjects. The results are shown in Figure 10 and Table 4.

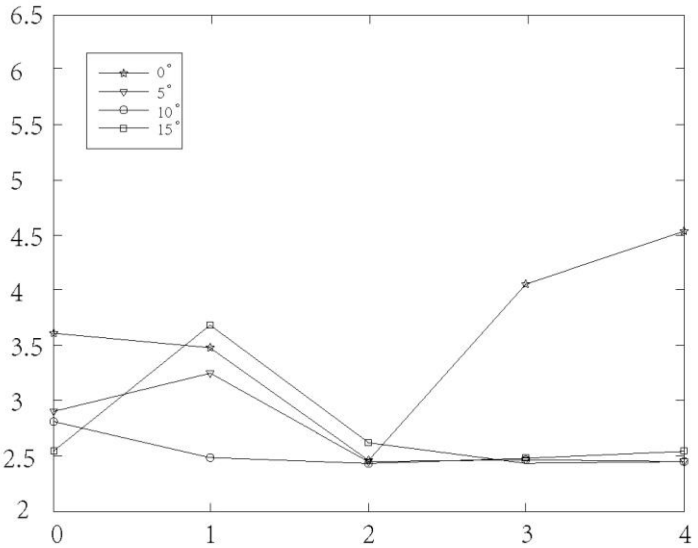

Figure 10. Changes in MF Value (%) of Erector Spinae at Different Angles of Inclined Platform

Table 4. Significance Analysis of MF Signals in Erector Spinae of Inclined Platforms at Different Angles

	Sum of Squares	*df*	*Average Squared*	*F*	*Significance*
Between Groups	3.617	3	1.206	0.285	0.836
Within the Group	118.37	28	4.228		
Total	121.98	31			

From the above analysis of variance table, it can be seen that the MF value of the erector spinae muscles standing under the inclined platform at different angles is p=0.836>0.05, that is, the MF signal of the gastrocnemius muscle standing on different inclined platforms is not significant. Sexual differences.

3 Conclusion

This experiment simulates the long-term standing situation and analyzes the muscle and electric data of the legs and the waist when different people stand at different tilt angles and draws the following conclusions.

When standing on a 15° tilting platform, the leg's self-adjusting ability is worse, and the body fatigue is large, which is not suitable for long standing. Standing on the inclined platform at different angles, the muscle fatigue of the human waist does not change much, that is, standing at different inclination angles has no significant influence on the waist. It can be known from the analysis of the EMG signal data of the leg that when the subject stands for about 40-60 minutes, the objective data of the leg muscles of the body will reach a maximum value, after 40-60 minutes. The leg muscles are slowly in a state of recovery, and the leg muscle self-regulating effect of standing on inclined platforms at different angles is: 10°>5°>0°>15°. When standing between 0-40 minutes, standing on a platform with an inclination angle of 0°, the leg muscle fatigue is relatively small.

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References

1. Ryan G A. The prevalence of musculo-skeletal symptoms in supermarket workers[J]. Ergonomics,1989, 32(4):359-371.
2. Cham R, Redfern M S. Effect of flooring on standing comfort and fatigue.[J].Human Factors, 2001,43(3):381.
3. Montoya D. Labour force trends in Greater Sydney[J]. Nsw Parliamentary Library Research Service,2014.
4. Karen J. John W. Boudreau. (2010). Retooling HR. Boston, MA: Harvard Business School Publishing. 200 pages[J]. Human Resource Management, 2011, 50(3):445-448.
5. Statistics B O L, Washington. Report on the Youth Labor Force. Revised.[J]. 2000,11(4):83.
6. Waehrer G M, Dong X S, Miller T, et al. Costs of occupational injuries in construction in the United States[J]. Accident Analysis & Prevention, 2007,39(6):1258-1266.
7. Tomei F, Baccolo T P, Tomao E, et al. Chronic venous disorders and occupation[J].American Journal of Industrial Medicine, 2010, 36(6):653-665.
8. Welford A T. Psychological Aspects and Physiological Correlates of Work and Fatigue. Edited by ERNST SIMONSON. (Springfield, Illinois: Charles C. Thomas,1976.) [Pp. xxii + 445.[$3850.[J]. Ergonomics, 2007, 21(7):579-579.
9. Van Dieën J H, Oude Vrielink H H. Evaluation of work-rest schedules with respect to the effects of postural workload in standing work[J]. Ergonomics, 1998,41(12):1832-1844.
10. Miedema M C, Douwes M, Dul J. Recommended maximum holding times for prevention of discomfort of static standing postures[J]. International Journal of Industrial Ergonomics, 1997,19(1):9-18.

11. Isa H, Omar A R, Saman A M, et al. Analysis of Time-to-Fatigue for Standing Jobs in Metal Stamping Industry[J]. Advanced Materials Research, 2012,12433-440:2155-2161.
12. Lafond D, Champagne A, Descarreaux M, et al. Postural control during prolonged standing in persons with chronic low back pain.[J]. Gait & Posture, 2009,29(3):421-427.
13. Nelson-Wong E, Callaghan J P. The impact of a sloped surface on low back pain during prolonged standing work: A biomechanical analysis[J]. Applied Ergonomics,2010, 41(6):787-795.