Ergonomic Interventions in WMSDs Prevention – A Case Study Using 3D Twist Insoles to Reduce the Body Pain in a Tape Manufacturing Company

Wen-Lian William Lee [a b], Sai-Wei Yang [c], Keh-Tao Liu [d] and Ingrid Yuan-Ying Lin [d]

[a] School of Occupational Safety and Health
Chung-Shan Medical University
Taichung 402
Taiwan, Republic of China

[b] Occupational Medicine Department
Chung-Shan Medical University Hospital
Taichung 402
Taiwan, Republic of China

[c] Department of Biomedical Engineering
National Yang-Ming University
Taipei 100
Taiwan, Republic of China

[d] Global Action, Inc. FOOTDISC©
Taipei 100
Taiwan, Republic of China

ABSTRACT

Work-related musculoskeletal disorders (WMSDs) are becoming serious occupational safety and hygiene problem in Taiwan Industries. Overexertion, high repetition, prolonged exposure, cold and vibration are the five concerns as major WMSDs causes. The intrinsic factor, foot progression angle, should be further considered to reduce risk impact to the workers' health. The purpose of this study is aimed to demonstrate the reduction of the workers' body pain by ergonomic principles in a tape manufacturing company. The new developed 3D twist insoles with arch support are selected to help release pain. In this current study, workers with high arch and flat arch are selected as members of the study group, via a 2-step screening test to identify arch type and leg-axis. Nordic musculoskeletal questionnaires (NMQ) were further used to analyze musculoskeletal condition of the workers. Moreover, candidates with Body Mass Index (BMI) value higher than 25, age average over 42, and standing period over 8 hours each day are picked as study group using 3D twist heavy duty insoles. The control group has similar working situation in the same company, wearing the same type of safety boots without the insoles. After 20 weeks, the results suggest the study group of 14 workers have released 40% of pain.

Keywords: work-related musculoskeletal disorders, ergonomic intervention, 3D twist insoles

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INTRODUCTION

Musculoskeletal disorders (MSDs) are a major concern of work-related disability and productivity loss in many industrialized countries (Whysall et al., 2004). From the national occupational injury records of Taiwan, average 33% of total work injuries are MSDs for last decades (Wu et al., 2009). Moreover, the related medical loss of was approximately 0.67% of Taiwan's GDP, approximately NT$ 2 billion for the year 2009, the most widespread occupational disease (Wu et al., 2011, Tu et al., 2011).

MSDs include a broad range of conditions affecting the muscles, tendons, ligaments, joints, and nerves (Punnett et al., 2004). These include tendon inflammations, as well as low back pain, and other regional pain syndromes (Marras, 2000). The occurrence of MSDs is usually a result of factors such as excessive force, highly repetitive motions, awkward postures, prolonged static postures, muscle fatigue, and exposure to low temperature or vibration (Wu et al., 2009, Wu et al., 2011). The body parts most often affected by MSDs are the lower back, neck, and upper extremities (shoulder, arm, and wrist). MSDs not only affect worker's health, but also reduce their productivity. Therefore, it is crucial to lower the risk for the developing of MSDs among the workers to improve labor health and safety and increase business productivity (Taiwan IOSH, 2010). In order to minimize worker discomfort, reducing task exertions is one approach that may reduce MSDs risks as task related to work overload (Lu et al., 1999, Klussmann et al., 2010). In addition, several ergonomic interventions, such as workstation redesign, employee training, and working conditions improvement, have been reported to mitigate risk factors causing MSDs (Granata et.al., 2008, Takala et al., 2010, Tu et al., 2011). This paper presents a case study in which risk factors of MSDs in a tape manufacturing. The results demonstrate the reduction of the workers' body pain by ergonomic principles for WMSDs prevention. Especially, 3D twist insoles with arch support are selected to help the pain release.

More than 607 workers are investigated first by a 2-step screening test to identify arch type and leg-axis. Whoever with high arch and flat arch workers is further selected as members of the study group. Nordic musculoskeletal questionnaire (NMQ), were further used to analyze musculoskeletal condition of 207 workers. Moreover, based on the Body Mass Index (BMI) value higher than 25, age over 42, and standing period over 8 hours each working day, 14 candidates are picked up as study group using 3D twist heavy duty insoles interventions inside safety boots to reduce serious pain condition. On the other hand, 14 candidates are selected as control group, each one has similar working situation in the same company, wear only the same type safety boots without using 3D twist insoles inside for comparison. After 20 weeks, the results suggest the study group have released 40% of pain.

METHODOLOGY

In order to investigate human factors, on-site supervisors and safety personnel will be provided assessment tools to assess worker gait and posture, in order to reduce musculoskeletal injuries (such as backache, back pain, etc.) and, therefore, designed this questionnaire to measure degree of pain. The protective 3D twist insoles help relief pain and fatigue by using subjective questionnaires and experimental analysis amongst workers standing in prolong periods of time over 8 hours. This questionnaire investigates degree of pain and fatigue level, musculoskeletal injuries and its causation, using protective foot pads as intervention to measure effectiveness in improving musculoskeletal fatigue, as shown in Figure 1.

Self reporting questionnaire design

Musculoskeletal discomfort subjective analysis of the subjects through subjective questionnaires aims to investigate the prevalence of musculoskeletal discomfort amongst workers. Through body mass index, abnormal foot structure, and different legs axis to assess the impact on the prevalence of discomfort with further analysis. Adapted from the Nordic Musculoskeletal Questionnaire (NMQ), the questionnaire measures overall fatigue, as well as the neck, shoulders, upper back, elbows, hands, lower back, buttocks, thighs, knees, calves, ankles, feet and other body parts, measuring degree of discomfort. And finally the Mann-Whitney U test is conducted for each work area having a

significant difference in the statistical analysis.

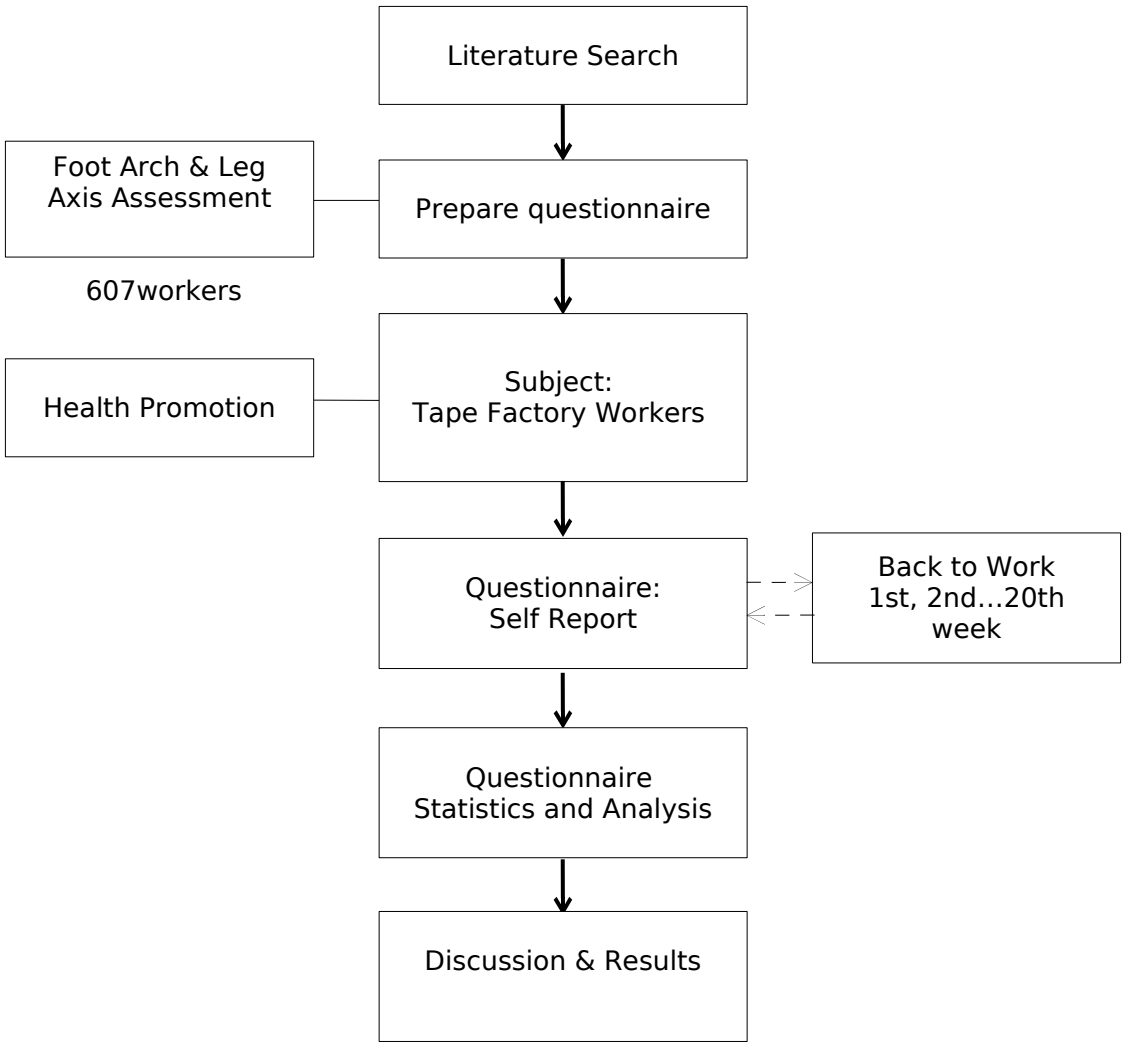

Figure 1, Research process

Subjective pain measurement

The experiment uses a questionnaire to test the subjects on discomfort or fatigue level before and after usage. Borg's Perceived Exertion and Pain Scales or Visual Analogue Scale have been used as shown in Figure 2. Upper and lower body pain, or discomfort or fatigue on the foot survey is as shown below

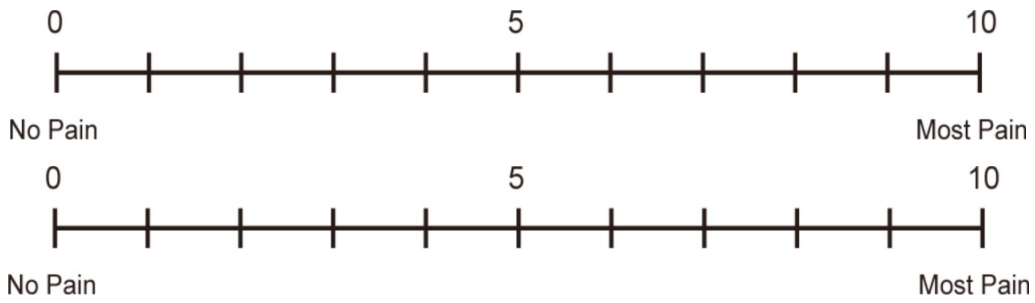

Figure2, Borg's Perceived Exertion and Pain Scales (Borg G, 1985)

0: no pain completely
1: muffled bloated
2: there is pain, but the pain does not stimulate
3: do not have a pain stimulus, but does not want to take medicine
4: pain will want to see a doctor, no medicine can live
5: pain will want to see a doctor, it will affect the lives

6: needs to see a doctor to take medicine, you can go to work
7: must eat painkillers, can work
8: must eat painkillers, may be required to leave work
9: pain, must leave work
10: need emergency treatment or hospitalization

Lower body extremity biomechanics assessment

Using thermal sensing board, the applications can detect foot arch type and according to classification can be high arch, normal arch, low arch or flat feet. To determine the type of leg axis, the subjects place their feet together to determine the distance between the legs. And according to classification can be bowl leg, knock knee leg, or straight legs.

RESULTS AND DISCUSSION

Health Promotion Activities

More than 607 workers are investigated first by a 2-step screening test to identify arch type and leg-axis. The measurement results of the foot arch and leg axis distribution are as shown in Table 1. An interesting attribution is that the high arch and flat arch are almost one- third of the samplings. Flat foot attribute 7% and high arch attribute 27%, with the totaling 34%. Whoever with high arch and flat arch workers is further selected as members of the study group. Moreover, the results of examination reveal that the majority attribute is either normal arch totaling 37%, or low arch totaling 29 %. Nordic musculoskeletal questionnaire (NMQ), were used to analyze musculoskeletal condition of 207 workers.

Table 1, Employee foot arch and leg axis attribution

Numbers (607)	Normal Arch	Low Arch	Flat Foot	High Arch
Bow Leg	65	36	12	52
Knock Leg	42	56	10	31
Straight Leg	118	83	23	79
Percentage of different arch	37%	29%	7%	27%

The objective is to reduce musculoskeletal injuries, improve work efficiency and health. Activity timeline and content are divided into three parts, subjects were required to work eight hours a day in which to stand and walk for about four hours, is currently engaged in work for more than three years, and the operator is wearing steel-toed safety shoes, and upon foot arch and leg axis inspection to determine appropriate shoe insoles (Figure 3). Discomfort conditions are measured once a week for four weeks ago, and monthly measurements thereafter for four times, with a total of five months. The questionnaire categorized foot pain and non foot pain group.

Correlation of Basic Demographic Data and Foot Pain

Plantar fasciitis is largely due to an excessive burden on the foot, or the bottom of the foot being over-stimulated, with plantar fat pad thinning with a majority of the population suffering from this. As for the effect of weight as it relates to foot arch and leg axis, they have found that age, height, weight, BMI and foot pain have a significant

weak correlation, as shown in Table 2. Twenty-eight male professional workers were selected by factory doctor for this study. The fourteen male workers for performance test with pain, average age is 42.3±9.4years old, height is 169.3±8.9 cm, weight is 77.3±16.5 kg, and body mass index 28±2.3. Subjects were classified into normal, high low arch or flat foot type according to the arch index with straight, genu varum, or genu valgum leg alignment. Three types of insoles: Although obesity can cause extra load to the foot and increase pressure to the plantar, there is no sufficient subjects to verification its correlation.

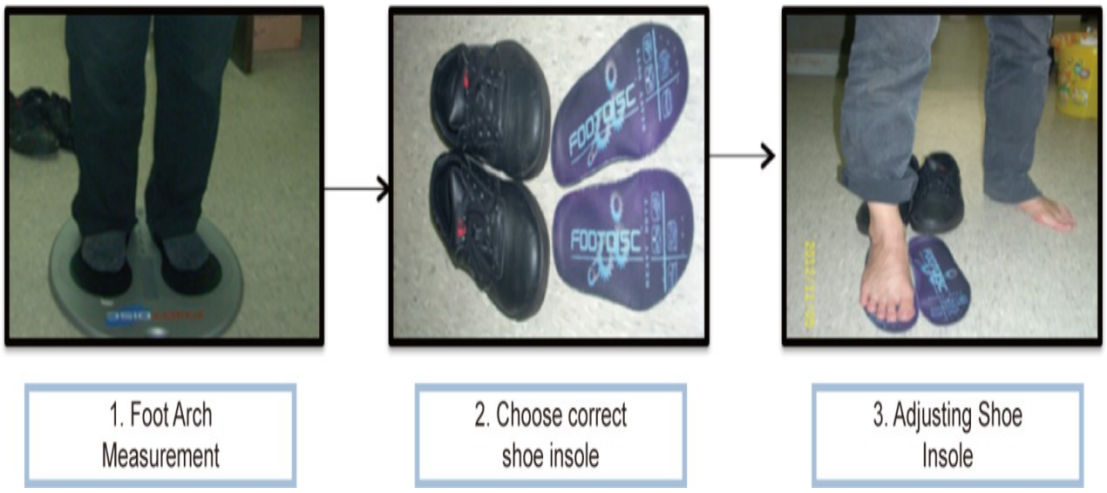

Figure 3, Insole fitting procedure (1) foot arch measurement,(2)choose correct shoe insole, and (3)adjusting shoe insole

Disproportion of workers' foot pain has high foot arch

Foot arch can provide elasticity, torque and shock absorption to accommodate a variety of terrain when walking or running. From mid stand to late stand, using the elasticity provided by the foot arch, aiding the foot move forward. In the event that the foot arch has any biomechanical abnormalities (such as flat feet or high arches and other structural abnormalities), it will result in excessive labor injury (train/ sprain) and unable to walking or running for prolong period of time. When the foot arch collapses, leading to excessive pressure on the bottom of the foot, the foot will fatigue easily. If the foot ligaments is pulled, causing chronic foot muscle strain, tendonitis, plantar fasciitis, plantar pain, knee pain, leg pain and other complications. The experiment proves that with foot pain, there are higher chances with an abnormal foot structure, compared to non-foot pain group.

Table 2, Subject information

Category	Foot pain (n=8)	No Foot Pain (n=6)	p value
Age	42.3±9.4	45.2±7.7	0.27
Height(cm)	169.3±8.9	167.0±4.0	0.28
Weight(kg)	77.3±16.5	70.7±7.6	0.19
BMI	28±2.3	25.2±4.1	0.28

Addendum：1. Number as average value ± range. 2. BMI as Body Mass Index.

Table 3, BMI categorization

< 18.5	18.5 - 24	24 - 27	27 - 30	30 - 35
Underweight	Normal	Overweight	Moderate Obese	Severely Obese

Table 4: BMI, foot arch and leg axis structure

Category	Foot pain (n=8)	No Foot Pain (n=6)	p value
BMI >25	6	4	0.21
Knock Knee Legs	2	1	0.20
Bow Legs	4	1	0.09
Flat Foot	5	1	0.001*
High Arch Foot	2	1	0.19

Addendum: 1.＊p value <0.05。 2. BMI as Body Mass Index with 24 ≦ BMI as overweight.

Upper and lower body pain survey and improvement

Causation for cumulative injury from prolong standing (Cumulative Trauma Disorder, CTD) are more common in lower back pain. Initial symptoms are lower back pain, neck pain, muscle strain, coupled with the lack of proper rest, and the need to handle heavy loads, over time will result in the lumbar spine and cervical vertebrae disc hernia. More serious complications include numbness in the upper extremity, sciatica pain and decline in muscle strength.

Using the scale of 1 to 10 to answer the degree of pain on each body part, figure 4 and 5, foot pain in the affected group are between 60% - 70%, particularly in the neck, shoulders, ankles, lower back being the most serious.,

After wearing protective shoe insoles for industrial use, found that on the first week pain has reduced 10%, while pain and discomfort after eight weeks decreased to 20%. After a 20-week observation, findings demonstrate that pain scale flattens.

The results of this study showed that although obesity and high foot arch have a higher probability of developing pain when standing for prolong period of time, however statistically it is not significant. In the future, however, with the increase of the number of study subjects statistically will be more meaningful.

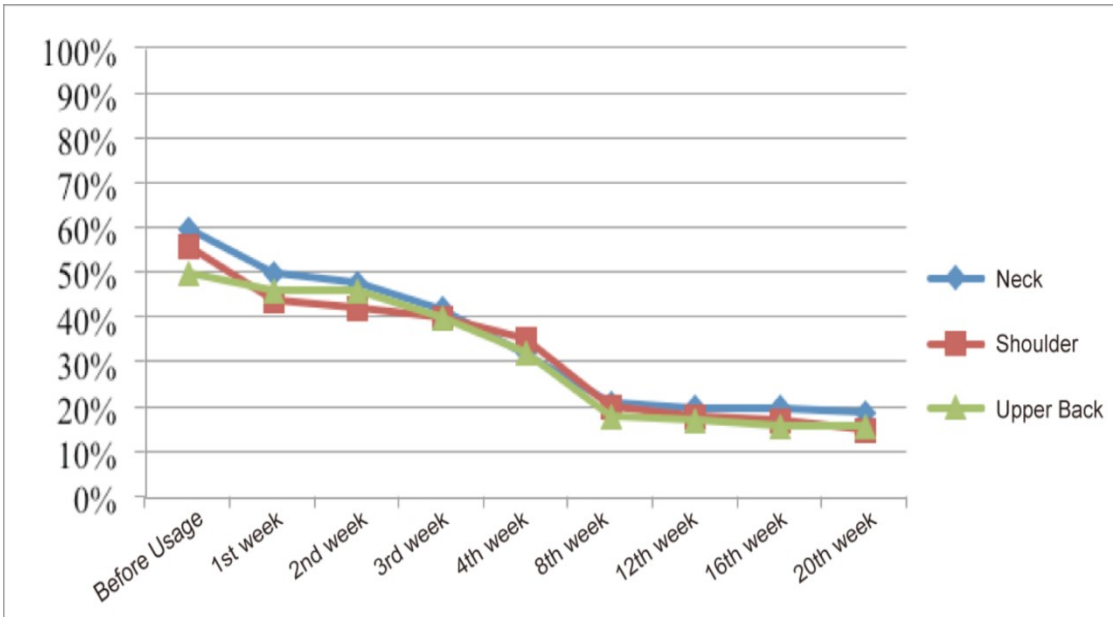

Figure 4, Upper Body Discomfort Level

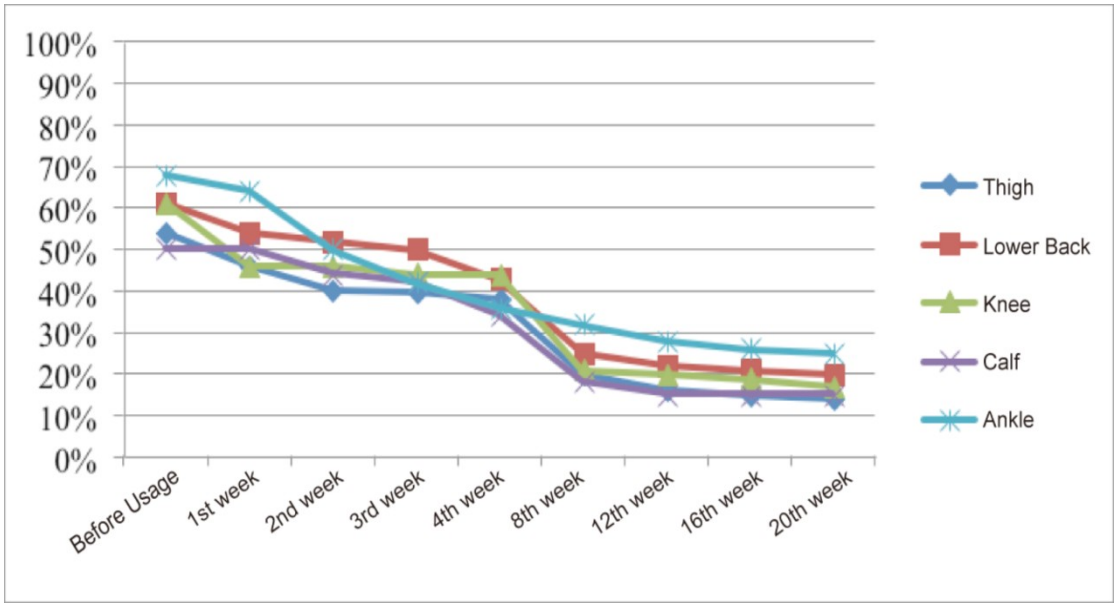

Figure 5, Lower body discomfort level

Foot pain survey and improvement

Prolong standing increases pressure to the knee, causing knee inflammation. Initial symptoms include knee joint swelling and pain, with the lack of proper rest, and the need for handling heavy objects, often results in knee joint degeneration, and even difficulty walking. In addition, coupled with poorly designed shoes, causing toe valgus and joint deformity, toe pressure under long-term pressure also result in callus and corns. Before testing, foot arch, ankle, and big toe have the highest pain scale (Figure 6), while heel discomfort is at a high 90%. Through the use of protective shoe insole, after a week of usage, the heel discomfort level dropped 20%, while after four weeks the pain scale dropped until 50%. All other parts also have significant improvement in the pain scale.

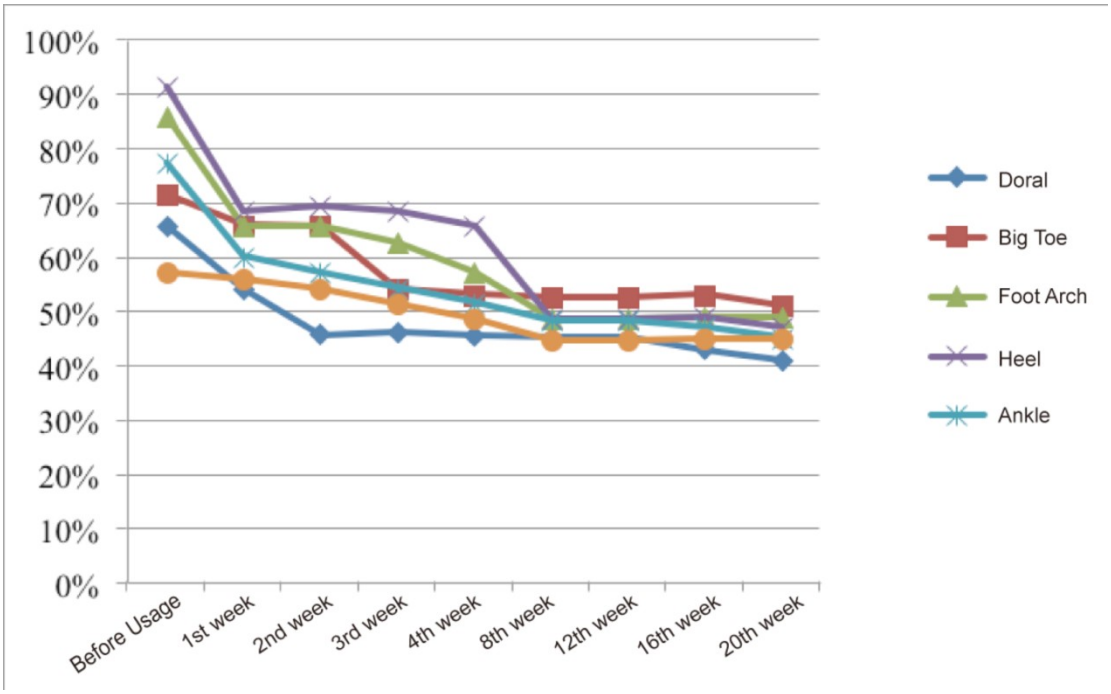

Figure 6, Foot discomfort level dropping process

CONCLUSION

Tape factory operators are at risk for developing Plantar Fasciitis, through the use of questionnaires to survey the occurrence of lower body extremity and foot pain in prolong period of time standing up. The results of this study showed that although obesity and high foot arch have a higher probability of developing pain when standing for prolong period of time, however statistically it is not significant. In the future, however, with the increase of the number of study subjects statistically will be more meaningful. In addition, this study did not analyze the complex cause of foot pain. If this measure could be taken into consideration, this samples could be of clinical and health wellness promotion significance. After wearing industrial protective shoe insoles, there is significant improvement in the pain scale after first week usage. The degree of discomfort has been reduced 5-10%. After 20 weeks of measurement, the pain scale and discomfort level has evened off, with a decrease of 40%. If operators with abnormal foot structure, can have a higher probability developing foot pain. This conclusion can provide follow up reference study for foot pain.

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