Verification of Suitable Height of Plank Seat for Improving the Health and Safety of Farmers

In Ju Jung* · Hwa Shik Jung**
*Dept. of e-Business, Dongshin University
**Dept. of Occupational Therapy, Dongshin University

농작업자의 건강과 안전 향상을 위해 적합한 작업용 좌대 높이의 검증

정 인 주* · 정 화 식**
*동신대학교 e-Business 학과 · **동신대학교 작업치료학과

Abstract

최근 들어 산업현장 뿐만 아니라 농어촌에도 자동화가 가속화 되면서 작업자의 안전성과 편리성을 높이기 위한 다양한 방안이 제시되고 있지만 여전히 농업현장에서 대부분의 작업들이 부적절한 자세로 수행할 수밖에 없는 경우가 자주 발생한다. 본 연구는 쪼그려 앉는 작업자세가 요구되는 각종 농작업에 있어서 적합한 높이의 작업용 좌대를 제공함으로써 부적절한 작업 자세를 개선하여 노동 강도를 경감시킴과 동시에 작업능률 향상과 요통 등 근골격계질환을 감소시켜 작업자의 건강과 안전을 증진시키는데 목적을 두었다. 이를 위하여 농작업에서 행해지는 쪼그려 앉는 여러 자세에 있어서 재배작물의 높이에 따라 적절한 작업용 좌대의 높이를 실험을 통하여 규명하였다.

연구결과 쪼그려 앉아 작업을 수행해야 하는 유사한 작업이라도 작업위치에 따라 쪼그려 앉는 작업용 좌대의 적합한 높이는 달라져야 한다는 것을 발견하였다. 즉 작업위치가 5cm 이하이면 작업용 좌대높이는 10cm가 적절하며 작업위치가 20cm이면 15cm, 작업위치가 40cm이면 20cm가 적절함을 알 수 있었다. 이와 같은 결과를 농작업에 적용한다면 작업조건이 향상되어 편안하고 안전한 자세로 작업을 할 수 있기 때문에 허리, 어깨, 다리 등의 근골격계 질환을 감소시킬 수 있으며 인력작업에 따른 무리한 힘의 소모를 감소시켜 노동력절감은 물론 생산성 향상을 가져올 수 있다고 판단된다.

Keywords: Farmer, Plank Seat, Squatting, Safety, Stool, Musculoskeletal Disorders

1. Introduction

Recently, musculoskeletal disorders of agricultural workers have been highlighted as a chronic health problem(Meyers et al., 1995; Chapman et al. 2000; Walker-Bone, 2002). Excessive twisting, bending and repetitive motions, which are all characteristic movements of agricultural work, are known to hike the possibility of musculoskeletal disorder development and the main symptoms respectively are reported as lower back pain, tendonitis, carpal tunnel syndrome and arthritis(Hildebrandt, 1995; NIOSH, 1997; NIOSH, 2001).

The 3 most frequently called for postures doing agricultural work are standing, stooping and squatting(Meyers et al., 1997; Newenhouse et al., 2001).

Working posture is decided according to position of work object and becomes a risk factor when work object is above elbow level while standing, between knee and elbow levels while stooping, and below knee level while squatting(Meyers et al., 1997).

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In particular, the last posture is required when sowing, cultivating and harvesting various crops.

According to Lee(2004), "When squatting, knee joints bend at an angle of 130o and pressure put on them at this time is 7.8 times that of standing," and knee arthritis is largely caused by squatting on the floor for a prolonged time or work related reasons.

These problems would be minimized by using a kind of plank seat(a kind of stool) and making work more convenient. With agricultural crops, however, working position differs according to type of crop or activity, so height of the stool would have to be adjusted. Likewise, individual body dimensions and preference require stools with different height even in the same working position. Thus, in regarding to work that require squatting posture, studies need to be conducted on proper stool height that offer comfort according to different working positions.

Chung et al.(2003) report that the optimum stool height for squatting and carrying out welding jobs is 100mm. The result, however, was found based on the supposition that work object was on the floor.

In reality, welding is done at different levels according to size of base material and position of welding patch. It would be unreasonable to unilaterally apply the result to all workers in squatting posture.

The purpose of this study was to improve inappropriate working posture and lower workload intensity by providing a support tool for work done in squatting posture.

This, in turn, would increase work efficiency and decrease the risk of musculoskeletal disorders, such as lower back pain, and ultimately enhance health and safety of workers. To this end, relation between workload and agricultural worker in various squatting postures was defined by testing suitable plank seat(hereinafter referred to as "stool") height according to different crop height.

2. Details and methodology

Forty female farmers aged from 32 to 69(mean 47.28±7.56) participated in this study. In order to estimate the proper height of squatting stool according to working position, a stool was designed for this study. Plywood was sawed to make the seat board 350(w)×250(d)×10(t)mm in size. Then each rectangular shaped wood was adhered to the bottom of each side of the seat board to make a 'Π' form.

According to Cai and You(1998), comfort height of squatting on a conventional toilet bowl without wearing any shoes is between 50.0~235.0mm and on average 109.7mm. Based on these results, 3 models were made with different stool height dimensions(from floor to seat pan) of 100, 150 and 200mm.

In general, working position below 400mm requires one to squat as work becomes difficult just by bending. Sowing and planting, transplanting, harvesting and weeding various root crop are usually work done 50mm below ground level while cultivating and harvesting leaf and stem or fruit vegetables are carried out 50 to 200mm above the ground.

In particular, red peppers, eggplants and tomatoes are cultivated and harvested anywhere from 200 to 400mm above the ground. This study established 3 different working positions at floor level of below 50mm, ankle level of 200mm and shank level of 400mm.

<Figure 1> shows an actual female farmer sitting on a stool constructed for this study and carrying out a demonstration.

<Figure 1> Exhibiting a demonstration seated on one of the constructed stool

At floor level, planting took place and at ankle and shank levels, trimming saplings of corresponding height were the tasks at hand. Subjects were asked to wear shoes that did not have high heels and as was shown in the figure, to squat naturally by opening both legs and flexing the knees within 90°.

Prior to the demonstration, work object was set up on the sagittal plane, between the two knees, and within 300mm from the front of the stool. Arms were left to move freely but elbows were not to be supported or resting on knees or thighs.

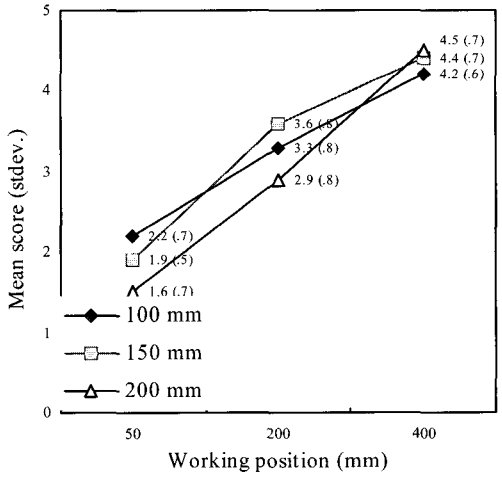
In surveying user preference among 3 different dimensions of stool height according to 3 different working positions in this study, the main standard was ease of work. Therefore, Likert summated rating method was applied with opinion scores of 'very inconvenient,' 'inconvenient,' 'average,' 'convenient' and 'very convenient.' For each working position, subjects were asked to sit on 3 different stools for 5 minutes respectively and then to write down their thoughts on a preferred stool height.

Differences in user preference were analyzed under 9 conditions according to stool height and working position. And to investigate why differences do exist, ANOVA was conducted with 2 factors of working position(ground=1, ankle=2, shank=3) and stool height(100mm=1, 150mm=2, 200mm=3) to analyze and verify main and interaction effects respectively.

3. Results

Frequency analysis, mean value analysis, ANOVA were conducted on the user preference results.

<Figure 2> shows the mean(standard deviation) preference score of 3 different stool heights in accordance with the working positions.



<Figure 2> Mean preference score of stool height

<Table 1> shows the ANOVA of convenience level according to stool height and working position. The ANOVA were first divided into 3 groups according to working position. User preference was then studied by analyzing the differences within each group under different conditions, and also by considering the 3 groups as one group.

<Table 1> ANOVA of level of convenience according to working position and stool height

Classification		Stool height (mm)	ANOVA	
Working position (mm)	50	100	$F_{2,117}=9.543^{*}$	$F_{8,351}=97.956^{**}$
		150		
		200		
	200	100	$F_{2,117}=7.842^{*}$	
		150		
		200		
	400	100	$F_{2,117}=2.184$	
		150		
		200		

**: P<0.001 *: P<0.01 n.s.: not significant

Results in 50mm and 200mm working positions under 3 different conditions indicated significant differences at 0.01 level, as seen in <Table 1>. When all 3 groups were reclassified into a single group, ANOVA results showed significant differences(p<0.001).

In order to fully investigate why preferential differences exist according to working position and stool height, two-way ANOVA was conducted to analyze main and interaction effects of the 2 factors.

Results are shown in <Table 2>.

<Table 2> ANOVA results of differences in preference according to working position and stool height

Classification		Sum of squares	DF	Mean square	F value	P-value
Main effects	(combined)	378.111	4	94.578	189.156	0.001
	Working position	371.622	2	185.811	371.622	0.001
	Stool height	6.689	2	3.344	6.689	0.001
2-way interaction effect	Working position* stool height	13.511	4	3.378	6.756	0.001
Model		391.822	8	48.978	97.956	0.001
Error		175.500	351	0.500		
Total		567.322	359	1.580		

Level of significance was 0.001 and the derived conclusion was that user preference difference, as the dependent variable of a two-way model, could be explained by the 2 main and interaction factors.

Here, working position factor showed higher scores in main effects than those of stool height factor. This means that higher working positions are preferred over lower ones in terms of convenience, as proven by all three stool height with working position of 400mm being chosen as the most preferred and conversely, all three stool height with working position of below 50mm as the least preferred.

Furthermore, analysis on how these 2 factors, working position and stool height, interact and effect user preference indicated significant results(p=0.001). That is, very high preference are shown in cases when work position is below 50mm and stool height is 100mm, work position is 200mm and stool height is 150mm, and work position is 400mm and stool height is 200mm. And when work position is low(50mm) and stool height is high(200mm), user preference(mean=1.55) plummets while work position at mid level did not show much difference regarding preference of stool height, and lastly, work position at high level mostly preferred high stools.

This finding provides a very important point in deciding how high a squatting work stool should be at the designing stage.

Additional analysis was done on preferential differences according to age by conducting an independent variable t-test. Results turned out statistically not significant($p>0.05$) for all conditions.

<Table 3> is a summary of the body dimensions of participants and these selected measurements that are assumed to be relevant to preference of stool height when in squatting posture.

<Table 3> Subjects' body dimensions(n=40)

Classification	Height (cm)	Arm reach to wall length, anterior (cm)	Body weight (kg)	Waist circumference (cm)	Thigh circumference (cm)
Range	152.2~167.5	63.7~80.4	49.2~75.6	49.4~85.6	41.8~57.9
Mean(SD)	160.1 (4.1)	70.6 (3.4)	54.1 (5.8)	70.5 (7.2)	46.6 (3.8)

It is estimated that height is related to squatting posture while arm reach to wall length(anterior) is to crop distance. Grandjean(1985), Sanders and McCormick(1992) found that motion range of joints differ in accordance to bone structure, bulk(muscle or other tissue) volume and elasticity of muscle, tendon and ligament around joint area. Squatting posture may be limited if bulk volume of abdominal area or thigh circumference is big. As such, body weight, waist and thigh circumference have been measured to analyze the correlation with preferred stool height.

Correlation of body dimension and preference of each test condition was analyzed and displayed in <Table 4>. Under work position is 50mm, when the stool height is 100mm, arm reach to wall length and waist circumferences, when the stool height is 200mm, height and arm reach to wall length showed correlation. Under work position is 200mm, some of the stool height showed correlation on the waist and thigh circumference. Under work position is 400mm, when the stool height is 100mm, body weight and thigh circumference showed correlation. However, correlation did not exist under the remaining conditions. Therefore, consideration of stool height according to body measurement seems to be not so important. ANOVA results on preferential differences according to body measurement were, as well, statistically not significant($p>0.05$) under all conditions.

<Table 4> Correlation of body dimension and preference of each condition

Working position (mm)	Stool height (mm)	Height	Arm reach to wall length	Body weight	Waist circumference	Thigh circumference
50	100	-.188	-.396*	-.067	-.498**	-.139
50	150	-.089	-.123	.246	.444	.074
50	200	-.583**	-.460**	-.232	0.232	-.140
200	100	-.237	-.170	-.275	-.273**	-.172
200	150	-.006	.048	-.366*	-.477**	-.583**
200	200	-.102	-.375*	-.363*	-.512**	-.286
400	100	-.151	-.240	-.366*	-.278	-.539**
400	150	.129	.255	.000	-.076	-.170
400	200	.171	.062	.034	-.056	.023

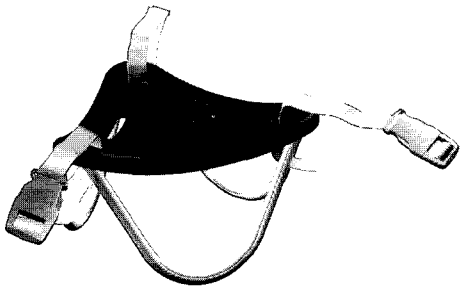
** Correlation significant at 0.01 level, * Correlation significant at 0.05 level

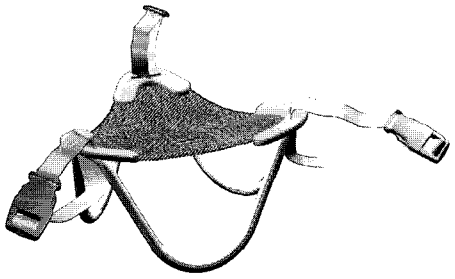
4. Design of stool for the farmers

A stool for the squatting worker has been designed in this study as a supporting work tool that could minimize the physical burden placed on various industrial and agricultural workers. In turn, this would enhance health and safety in the work environment and overall productivity by enabling workers to carry out their jobs faster and easier.

The basic design concept was to develop a simple stool with very accessible materials and little expenses that does not require special expertise or skills and training in usage. The ultimate purpose was to enhance user convenience and specific design criteria were established as follows: stool is worn by the sitting or standing worker and incorporated as one when he or she has to move to another location without having to lift and move the stool separately, thus preventing interruption in the work process; stool should not restrict posture but allow the worker to sit or stand freely; seat pan width should be wide enough and contoured seat instead of with angled corners; stool is of proper height according to different work position; stool material should be light and solid and not contaminated by dirt or water.

<Figure 3> shows the stool prototype designed in this study. It is composed of a seat pan on which the worker sits, waist belt and front belt that allow the worker to wear the body part. The stool was made to enhance user convenience. Not only does it allow the squatting worker to do various tasks in a comfortable position but also move as part of the worker's body from one place to another without having to lift and transfer the stool separately.





<Figure 3> Prototype of designed stool

The seats can be made with different height dimensions of 100, 150 and 200mm according to working position of previous tests. When trying to put on the stool, first, waist belt is tightened by the attached buckles to properly fit waist circumference of the worker. Secondly, front belt attached on front side of the seat are put together to the buckles of waist belt and adjusted as necessary. The user is now able to move freely without any limitation as the stool seat does not swing back and forth with each step. Waist and thigh belts are fastened and unfastened with plastic buckles or velcro(hook & loop) tapes for convenience.

Polypropylene, polyethylene, thermoplastic resin, nylon mesh, aluminum pipe which are comparatively light in weight, could be used to make the stool for ease of wear and movement. Weight of stool should fall under 1.5 kg. Nylon belts attached to the stool do add weight but by an almost undetectable amount.

5. Discussion and conclusion

This study sought to evaluate and make suggestions on user preference of proper stool height, at which work can be done comfortably, according to squatting work position.

In short, results showed that proper stool height differed according to working position even with similar squatting tasks. When working position is below 50mm, the proper stool height is 100mm. When working position is 200mm, the proper stool height is 150mm. When working position is 400mm, the proper stool height is 200mm.

The stool prototype was designed for squatting workers in consideration of their movement pattern.

Compared to squatting without any support tool, this prototype rids leg numbing. This prototype allows one to move easily forward and backward, left and right.

As a result, expectations are high as working conditions are improved to allow jobs to be carried out in comfortable and safe postures and thus reduce excessive consumption of labor. Not only this, but also musculoskeletal disorders of the lower back, shoulders and legs are reduced and productivity is increased.

Future studies should be deemed necessary that not only subjective tests but also objective ones, such as biomechanical and physiological methods, be introduced. Meanwhile, follow-up studies to verify practicality and effects of the stool prototype designed in this study are required.

6. References

[1] Cai, D. and You, M., "An ergonomic approach to public squatting-type toilet design." Applied Ergonomics, 29 (1998) : 147-153.

[2] Chapman, L.J., Josefsson, K., Meyer, R.H., Newenhouse, A.C., Karsh, B., Miquelon, M., "Intervention Research to Reduce Injuries on Dairy, Berry, and Fresh Market Vegetable Farms." Cooperstown, NY: NIOSH, (2000).

[3] Chung, M.K., Lee, I., and Kee, D., "Effect of stool height and holding time on postural load of squatting postures." International Journal of Industrial Ergonomics, 32 (2003) : 309-317.

[4] Grandjean, E., "Fitting the Task to the Man - An Ergonomic Approach." Taylor & Francis, London, (1985).

[5] Hildebrandt, V.H., "Musculoskeletal symptoms and workload in 12 branches of dutch agriculture." Ergonomics, 38 (1995) : 2576-2587.

[6] Lee, S.C., http://www.arthritiscenter.co.kr/, Unpublished clinical report. (2004).

[7] Meyers, J., Bloomberg, L., Faucett, J., Janowitz, I., Miles, J.A., "Using ergonomics in the prevention of musculoskeletal cumulative trauma injuries in agriculture: learning from the mistakes of others." Journal of Agromedicine, 2 (1995) : 11-24.

[8] Meyers, J., Miles, J., Faucett, J., Janowitz, I., Tejeda, D., and Kabashima J., "Ergonomics in agriculture: workplace priority setting in the nursery industry." American Industrial Hygiene Association Journal, 58 (1997) : 121-126.

[9] Newenhouse, A., Meyer B., Miquelon, M., Chapman, L., "Work Efficiency Tip Sheet: A strap-on harvest stool for field work." University of Wisconsin Healthy Farmers, Healthy Profits Project, (2001).

[10] NIOSH, "Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back." Publication No. 97-141, Cincinnati, OH : DHHS(NIOSH), (1997).

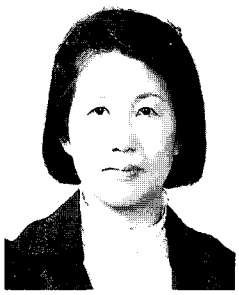
[11] NIOSH, "National Occupational Research Agenda for Musculoskeletal Disorders." Publication No. 2001-117, Cincinnati, OH : DHHS(NIOSH), (2001).

[12] Sanders, M.S. and McCormick, E.J., "Human Factors in Engineering and Design." Seventh Edition, McGraw-Hill, Inc., New York, (1992).

[13] Walker-Bone, K., Palmer, K.T., "Musculoskeletal disorders in farmers and farm workers." Occupational Medicine, 52 (2002) : 441-50.

저 자 소 개

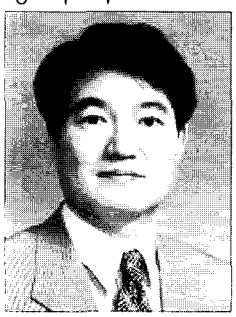
정 인 주



현재 동신대학교 e-Business학과 교수로 재직 중. 전남대학교 이학박사. 관심분야는 인터넷마케팅, 경영통계, 보건안전통계학.

주소: 전남 나주시 대호동 252 동신대학교 e-Business학과

정 화 식



현재 동신대학교 작업치료학과 교수로 재직중. Univ. of Houston 산업공학 박사. 관심분야는 인간공학, 안전공학, 작업치료학.

주소: 전남 나주시 대호동 252 동신대학교작업치료학과