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Original Article

Study of Physical Discomfort and Working Postures Related to Squatting/Kneeling Tasks Performed on Construction Sites

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A cross-sectional survey of 599 male and female workers at construction sites in Taiwan was carried out via questionnaire. Information was obtained on individual factors, job characteristics, workloads, and physical discomfort. Observational data was then collected for 23 construction workers performing six activities to obtain 1,436 observations using Ovako working posture analysis system (OWAS), to identify and evaluate harmful working postures in the construction workplace. The observational results showed that the most pronounced and prevalent complaints after prolonged squatting or kneeling relate to the knee (54.6%), upper back (53.8%), and lower back (53.3%). Female workers had higher prevalence of physical discomfort than male workers for most body areas. Multivariate logistic regression models were used to predict physical discomfort. Daily squatting or kneeling on a construction site for more than 4 hours was strongly associated with discomfort in the upper and lower extremities (odds ratio ranges from 1.74 to 2.56). Among the six job activities analyzed in this investigation, from OWAS, electrical work (50%), tile work (48%) and retaining pile work (42%) were the major contributors to poor working postures for construction workers. The results of this study can be employed to construct a workplace squatting/kneeling task design reference to improve musculoskeletal fatigue and prevent the development of relevant disorders.

Keywords: Squatting/Kneeling Task, Constructional Workers, Questionnaire, Physical Discomfort, OWAS

Introduction

Working in the construction industry generally involves awkward postures, heavy lifting, forceful exertion, vibration, and repetitive motion [1]. Many construction workers complain of discomfort in the upper extremities and lower back over the course of a workday [2-5]. Pinzke and Kopp [6] defined an awkward posture as a considerable deviation of one or a combination of joints from the neutral position. These postures typically include reaching behind, twisting, working overhead, wrist bending, kneeling, stooping, forward and backward bending, and squatting[6]. Several studies have identified a relationship between awkward postures and pain, with musculoskeletal system symptoms and injuries [7-10]. A survey of construction workers in the Netherlands indicated that about 35% experience lower back pain and other musculoskeletal complaints [11]. Goldsheyder et al. [12] identified a high prevalence (82%) of musculoskeletal disorders among stone masons. Meerding et al. [13] also reported that 59% of construction workers have musculoskeletal complaints and 41% experience low back pain. Moreover, the one-week incidences

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of lower back and knee complaints among Dutch pavers were 42% and 22%, respectively, in 2005 [14].

Epidemiologic studies have indicated that prolonged kneeling raises the risk of osteoarthrosis of the knee [15]. However, the health status of construction workers during tasks involving squatting or kneeling for long periods has not received much attention in Taiwan or elsewhere. To assess possible health risk factors connected with body postures, the actual postures involved in performing a certain task need to be determined [16]. Additionally, construction work is dynamic in nature, with the content and frequency distribution of job-related tasks varying across individuals and over time [17], making exposure to physical factors in construction work difficult to measure systematically [18]. To our knowledge, the observational method is the main approach for assessing exposure to and distribution of physical factors for specific construction tasks [19-21]. The Ovako working posture analysis system (OWAS) was developed by a Finnish steel company in 1974 [22] and is still used to identify and evaluate harmful working postures.

In this study, a cross-sectional questionnaire-based survey of individual factors, job characteristics, workloads, and health status was implemented to explore the associations among individual factors, job characteristics, and physical discomfort. Then, the OWAS method was applied to identify and evaluate harmful working postures in the construction workplace.

Methods

Study subjects

The study subjects comprised full-time and part-time construction workers in Taiwan. A total of 772 workers, aged 18 to 64, participated in the survey, providing 599 usable returns, for a response rate of 77.6%. Subjects in each selected company were responsible for various construction tasks involving squatting/kneeling.

Questionnaire

Trained interviewers delivered the self-administered questionnaire to the participants, accompanied by a letter signed by both managers and supervisors encouraging participation. All participants were informed of the study objectives prior to the survey and participated voluntarily. The employers gave the participants time during working hours to complete the questionnaire. To protect the confidentiality of the respondents and prevent managerial or employer access, the participants completed the questionnaire anonymously and returned it directly to the interviewers. The interviewers performed on-site checking to ensure that the subjects completed the questionnaire correctly. This questionnaire was used to collect demographic data and information regarding job characteristics, workloads, and health status. Therefore, participants were asked to record their gender, age, height, weight, years of employment at the current company, whether they were working full-time or part-time, number of work days per week, weekly physical exercise habits, and activities in the workplace. Activities were classified into the following thirteen categories: (1) formwork, (2) steel lashing, (3) plaster painting, (4) retaining piles, (5) tile work, (6) electrical work, (7) cleaning, (8) management and supervision, (9) renovation work, (10) concrete work, (11) air conditioning work, (12) scaffold-related work and (13) gutter work. For job characteristics, workloads and health status, participants were asked about their working conditions, shoes, squatting/kneeling aids, daily squatting/kneeling time, resting time after each squatting/kneeling task, upper extremity fatigue, lower extremity fatigue, and physical discomfort. Responses regarding upper and lower extremity fatigue were recorded on a five-point Likert scale, ranging from 1 (“never feel fatigued”) to 5 (“always feel fatigued”). Employees completed self-rated questions on whether they had experienced physical discomfort during the previous 12 months in the upper back, lower back, hip, thigh, knee, lower leg, ankle, and foot by stating “yes” or “no” for each respective body part.

Postural analysis

This study adopted extended basic OWAS to analyze working postures of construction workers.

Table 1. Definitions of postural codes of OWAS for each body position

Body part	OWAS score	Description of position
Head	1	Free
	2	Bent forward
	3	Bent to the side
	4	Turned to the side
Arms	1	Both arms below shoulder level
	2	One arm at or above shoulder level
	3	Both arms at or above shoulder level
Back	1	Straight
	2	Bent forward
	3	Straight and twisted
	4	Bent and twisted
Legs	1	Sitting
	2	Standing with both legs straight
	6	Standing with one leg straight
	4	Standing with both legs bent
	5	Standing with one leg bent
	6	Kneeling on one knee
	7	Kneeling on both knees
Force	1	Less than 10 kg
	2	Over 10 kg but less than 20 kg
	3	More than 20 kg

The positions of the head, arms, back, and legs, and the force, were each assigned a code. Each body position was expressed in terms of a five-figure code (Table 1) to describe various posture and force combinations. Codes were applied to each of the four head postures, three arm postures, four back postures, seven leg postures (extended OWAS includes three additional leg postures), and three variants of force. Considering these five code levels (head, arms, back, legs and force), OWAS has 1,008 ($4 \times 3 \times 4 \times 7 \times 3$) basic combinations. Furthermore, OWAS classifies the risk of injury based on working posture into the following four action categories (AC): (a) AC 1: postures are normal and natural with no particular harmful effect on the musculoskeletal system, requiring no action; (b) AC 2: postures have some harmful effect on the musculoskeletal system, requiring corrective action in the near future; (c) AC 3: postures have a distinctly harmful effect on the musculoskeletal system, requiring corrective action as soon as possible; (d) AC 4: postures have an extremely harmful effect on the musculoskeletal system, requiring immediate corrective action.

The construction sites were located in Taichung City, Taiwan. Based on the common activities identified by participants in the questionnaire, six activities were analyzed. Twenty-three male construction workers (5 formwork workers, 4 steel lashing workers, 4 plaster painters, 3 retaining pile workers, 4 tile workers and 3 electricians) were observed performing these six activities for periods

Table 2. Mean (standard deviation) and percentage distributions of demographic characteristics of construction workers

	Number	Percentage (%)	Mean (SD)
Gender			
Male	462	77.1	
Female	137	22.9	
Age (yrs)			43.5(11.8)
<30	81	13.5	
30~39	146	24.4	
40~49	160	26.7	
>49	212	35.4	
Height (cm)			166.7(8.1)
Weight (kg)			67.4(11.6)
BMI			24.2(3.3)
Length of employment (yrs)			10.9(10.8)
<5	257	42.9	
5~15	137	22.9	
>15	205	34.2	
Employment status			
Full-time worker	506	84.5	
Part-time worker	93	15.5	
Working days per week			5.6(1.1)
Weekly physical exercise			
Seldom	319	53.3	
Sometimes	193	32.2	
Often	87	14.5	
Activity			
Formwork	132	22.0	
Steel lashing	124	20.7	
Plaster painting	121	20.2	
Retaining piles	107	17.9	
Tile work	28	4.7	
Electrical work	20	3.3	
Cleaning tasks	19	3.2	
Management and supervision	16	2.7	
Renovation work	10	1.7	
Concrete work	7	1.2	

Air conditioning work	6	1.0
Scaffold-related tasks	5	0.8
Gutters	4	0.7

Table 3. Mean (standard deviation) and percentage distributions of work characteristics and physical discomfort among construction workers

	Number	Percentage (%)	Mean (SD)
Daily squatting/kneeling duration			
< 2 h	243	40.6	
2~4h	159	26.5	
4~6h	97	16.2	
>6 h	100	16.7	
Resting duration after squatting/kneeling			
< 5 min	140	23.4	
5~10 min	252	42.1	
10~20 min	132	22.0	
>20 min	75	35.4	
Squatting/kneeling aids			
Lean on a desk or wall	78	13.0	
Sit on the ground	300	50.1	
Sit on a chair	235	39.2	
Leg movement	110	18.4	
Others	6	1.0	
Physical discomfort			
Knee	327	54.6	
Upper back	322	53.8	
Lower back	319	53.3	
Lower leg	250	41.7	
Thigh	231	38.6	
Feet	221	36.9	
Ankle	217	36.2	
Hip	165	27.5	
Upper extremity fatigue			3.0(0.9)*
Lower extremity fatigue			3.3(1.0)*

*Responses were recorded using a five-point Likert scale, ranging from 1 (never fatigued) to 5 (always fatigued).

of at least 3 to 5 min (to provide a minimum of 3 work cycles) producing a total of 1,436 observations. Their average work experience was 13.4 years (SD 5.6). All observations were recorded manually at 5-second intervals with pen and paper on a modified OWAS data collection form, and videotaped for analysis in a laboratory.

Data Analysis

The prevalence rates of physical discomfort were estimated for male and female workers. Pearson chi-square test or Fisher's exact test was used to compare the prevalence rates of tasks causing physical discomfort associated with factor variations. Chi-square test for linear trends was applied for variables with ordered categories. Multivariate logistic regression models were employed to identify the relationships of physical discomfort with individual factors and job characteristics. Odds ratio (OR) and its 95% confidence interval (CI) were derived for each independent variable. All analyses were performed with SPSS Release 11.5.0 [23].

Results

Table 2 shows the study population characteristics. Male (462/599) and female (137/599) workers comprised 77.1% and 22.9% of subjects, respectively; males thus predominated. Mean age was 43.5 years. Among the 599 workers, 62.1% were aged over 40. Average height was 166.7 cm. Average weight was 67.4 kg and average body mass index (BMI) was 24.2. Moreover, the average length of employment was 10.9 years, with 42.9% of male and female workers with less than 5 years of employment. Full-time workers dominated, accounting for 84.5% of the study sample. The average number of working days per week was 5.6. Among the subjects, 14.5% reported engaging in physical exercise often; 32.2% sometimes, and 53.3% seldom. The most common activity was formwork, performed by 22.0% (132/599) of subjects; followed by steel lashing (124/599, 20.7%), and plaster painting (20.2%, 121/599). The frequency distributions of other activities were retaining piles (107/599, 17.9%), tile work (28 subjects), electrical work (20 subjects), cleaning tasks (19 subjects), management and supervision (16 subjects), renovation work (10 subjects), concrete work (7 subjects), air conditioning work (6 subjects), scaffold-related tasks (5 subjects), and gutters (4 subjects). Table 3 shows the mean and percentage distributions of work characteristics and physical discomfort. Overall, over 40% of the subjects reported daily squatting/kneeling time of less than two hours (40.6%), followed by 2–4 h (26.5%), 4–6 h (16.2%), and over 6 h (16.7%). Nearly two-thirds (65.5%) of the subjects reported rest times after squatting/kneeling of less than 10 minutes. Most subjects (89.3%) sat on the ground or a chair after squatting/kneeling. The highest prevalence of physical discomfort was in the knees (54.6%), followed by upper back (53.8%), lower back (53.3), lower legs (41.7%), thighs (38.6%), feet (36.9%), ankles (36.2%), and hips (27.5%). The overall fatigue level in lower extremities (3.3) was slightly higher than in upper extremities (3.0).

Table 4 shows the association between study population characteristics and upper extremity fatigue. Workers were classified as having high level, intermediate level or low level fatigue. High level fatigue was defined as always or often feeling fatigued at work. Intermediate level fatigue referred to sometimes feeling fatigued at work, and low level fatigue referred to never or seldom feeling fatigued at work. Overall, 31% of male respondents and 38% of female respondents belonged to the high level fatigue group, representing a significant difference between genders ($p<0.05$). Table 5 also shows the association between study population characteristics and lower extremity fatigue. Overall, 27.7% of male respondents and 37.2% of female respondents belonged to the high level fatigue group, representing a significant gender difference ($p<0.05$). Table 6 lists the results of logistic models that addressed multiple factors simultaneously for upper extremity fatigue. For all workers, upper extremity fatigue differed significantly only in daily squatting/kneeling ($p<0.01$) and was associated with 4–6 hours of squatting (OR=2.56, 95% CI=1.49–4.38), and more than 6 hours of kneeling in one day (OR=2.34, 95% CI=1.35–4.05). Moreover, workers who often participated in

Table 4. Demographic characteristics and upper extremity fatigue levels

Variables	Men (n = 462) n(%)	Men: Upper extremity fatigue [a] (%) Low	Intermediate	High	Women (n = 137) n(%)	Women: Upper extremity fatigue [a] (%) Low	Intermediate	High
Age (yrs)								
<30	71(15.3)	16.9	62.0	21.1	10(7.3)	0.0	80.0	20.0
30~39	120(26.0)	12.5	53.3	34.2	26(19.0)	15.4	42.3	42.3
40-49	126(27.3)	7.1	62.7	30.2	34(24.8)	8.8	55.9	35.3
>49	145(31.4)	5.5	60.7	33.8	67(48.9)	4.5	55.2	40.3
Length of employment (yrs)								
<5	220(47.6)	10.9	63.6	25.5	37(27.0)	13.5	64.9	21.6
5~15	102(22.1)	13.7	53.9	32.4	35(25.5)	8.6	42.9	48.6
>15	140(30.3)	4.3	57.1	38.6	65(47.5)	3.1	55.4	41.5
Employment status								
Part-time worker	68(14.7)	13.2	60.3	26.5	25(18.2)	8.0	40.0	52.0
Full-time worker	394(85.3)	8.9	59.4	31.7	112(81.8)	7.1	58.0	34.9
Daily squatting/kneeling (hr)								
<2	188(40.7)	13.8	62.8	23.4	55(40.1)	10.9	56.4	32.7
2~4	122(26.4)	9.0	63.9	27.1	37(27.0)	5.4	62.2	32.4
4~6	75(16.2)	8.0	50.7	41.3	22(16.1)	9.1	27.3	63.6
>6	77(16.7)	1.3	53.2	45.5	23(16.8)	0.0	65.2	34.8
Resting duration after squatting/kneeling								
<5 min	111(24.0)	9.9	61.3	28.8	29(21.2)	6.9	51.7	41.4
5~10 min	182(39.4)	7.1	61.5	31.4	70(51.1)	4.3	55.7	40.0
10~20 min	105(22.7)	15.2	50.5	34.3	27(19.7)	14.8	51.9	33.3
>20 min	64(13.9)	6.3	65.6	28.1	11(8.0)	9.1	63.6	27.3

Weekly physical exercise								
Seldom	253(54.8)	7.5	56.9	35.6	66(48.2)	4.5	53.0	42.5
Sometimes	149(32.2)	10.7	67.1	22.2	44(32.1)	9.1	61.4	29.5
Often	60(13.0)	15.0	51.7	33.3	27(19.7)	11.1	48.1	40.8

[a] "Low": never or seldom feels fatigued at work; "Intermediate": feels fatigued at work sometimes; "High": often or always feels fatigued at work.

Table 5. Demographic characteristics and lower extremity fatigue levels

	Men (n = 462)				Women (n = 137)			
	n(%)	Lower extremity fatigue [a] (%)			n(%)	Lower extremity fatigue [a] (%)		
Variables		Low	Intermediate	High		Low	Intermediate	High
Age (yrs)								
<30	71(15.3)	31.0	52.1	16.9	10(7.3)	20.0	50.0	30.0
30~39	120(26.0)	16.7	55.8	27.5	26(19.0)	3.8	57.7	38.5
40-49	126(27.3)	14.3	60.3	25.4	34(24.8)	17.6	52.9	29.5
>49	145(31.4)	11.0	53.8	35.2	67(48.9)	7.5	50.7	41.8
Length of employment (yrs)								
<5	220(47.6)	19.5	55.9	24.6	37(27.0)	13.5	64.9	21.6
5~15	102(22.1)	23.5	54.9	21.6	35(25.5)	14.3	40.0	45.7
>15	140(30.3)	6.4	56.4	37.2	65(47.5)	6.2	52.3	41.5
Employment status								
Part-time worker	68(14.7)	14.7	61.8	23.5	25(18.2)	4.0	28.0	68.0
Full-time worker	394(85.3)	16.8	54.8	28.4	112(81.8)	11.6	58.0	30.4
Daily squatting/kneeling (hr)								
<2	188(40.7)	25.0	55.3	19.7	55(40.1)	18.2	49.1	32.7
2~4	122(26.4)	11.5	61.5	27.0	37(27.0)	5.4	67.6	27.0

4~6	75(16.2)	12.0	57.3	30.7	22(16.1)	4.5	36.4	59.1
>6	77(16.7)	7.8	46.8	45.4	23(16.8)	4.3	52.2	43.5
Resting duration after squatting/kneeling								
<5 min	111(24.0)	22.5	55.9	21.6	29(21.2)	6.9	62.1	31.0
5~10 min	182(39.4)	12.6	59.3	28.1	70(51.1)	8.6	50.0	41.4
10~20 min	105(22.7)	22.0	46.7	33.3	27(19.7)	11.1	55.6	33.3
>20 min	64(13.9)	10.9	60.9	28.2	11(8.0)	27.2	36.4	36.4
Weekly physical exercise								
Seldom	253(54.8)	13.0	53.8	33.2	66(48.2)	9.1	54.5	36.4
Sometimes	149(32.2)	20.1	62.4	17.5	44(32.1)	9.1	54.5	36.4
Often	60(13.0)	21.7	48.3	30.0	27(19.7)	14.8	44.4	40.8

[a] "Low": never or seldom feels fatigued at work; "Intermediate": feels fatigued at work sometimes; "High": often or always feels fatigued at work.

physical exercise had less upper extremity fatigue than those who did not (OR=0.56, 95% CI=0.37–0.85). Table 7 shows the results of logistic models addressing multiple factors simultaneously for lower extremity fatigue, and shows similar results to Table 6. Thus, for all workers, lower extremity fatigue differed significantly only in daily squatting/kneeling ($p<0.05$ or $p<0.01$) and was associated with 4–6 hours and more than 6 hours of squatting and kneeling in one day, respectively (OR=1.74, 95% CI=1.01–3.00, and OR=2.50, 95% CI=1.44–4.35). Furthermore, workers who exercised often had lower incidence of lower extremity fatigue (OR=0.57, 95% CI=0.37– 0.88).

Table 8 presents the percentage distributions of body parts in which participants experienced physical discomfort. The most pronounced and prevalent complaints of physical discomfort following prolonged working time by construction workers were in the upper back (60.9% for female respondents and 51.7% for male respondents), knees (56.9% for female respondents and 53.9% for male respondents) and lower back (54.0% for female respondents and 53.0% for male respondents). Female operators had higher prevalence rates of physical discomfort than male workers for most body parts. The gender differences were significant for physical discomfort in the upper back and ankles (Table 8).

Table 9 shows the overall percentage distributions of postures related to the head, arms, back, and legs for construction workers performing six activities. The most frequent postures of the head, arms, back and legs were free (43.2%), both arms below shoulder level (93.9%), bent forward (51.9%), and standing with both legs straight (27.0%). The force applied in all postures was less than 10kg. Table 10 shows the percentage distributions of head, arm, back, and leg postures for the six activities. The most frequent postures of the head were free in steel lashing (55%), formwork (44%), and retaining piles (72%) and bent forward in plaster painting (48%), electrical work (50%), and tile work (71%). The most frequent posture of the arms was both arms below shoulder level for all six activities. The most frequent postures of the back were straight in steel lashing (56%) and plaster

Table 6. Associations with upper extremity fatigue on multivariate logistic regression model

	OR [a]	(95% CI)
Gender		
Male	1.00	
Female	1.26	(0.83-1.93)
Age (yrs)		
<30	1.00	
30~39	1.76	(0.90-3.45)
40~49	1.28	(0.64-2.54)
>49	1.35	(0.66-2.76)
Length of employment (yrs)		
<5	1.00	
5~15	1.60	(0.98-2.59)
>15	1.53	(0.91-2.57)
Employment status		
Part-time worker	1.00	
Full-time worker	1.04	(0.62-1.73)
Daily squatting/kneeling (hr)		
<2	1.00	
2~4	1.16	(0.72-1.86)
4~6	2.56**	(1.49-4.38)
>6	2.34**	(1.35-4.05)
Resting duration after squatting/kneeling		
<5 min	1.00	
5~10 min	1.10	(0.70-1.70)
10~20 min	1.17	(0.70-1.96)
>20 min	1.81	(0.87-2.20)
Weekly physical exercise		
Seldom	1.00	
Sometimes	0.89	(0.53-1.50)
Often	0.56**	(0.37-0.85)

[a] Workers with high level of whole body fatigue were defined as those who reported feeling fatigued at work “often” or “always” vs. “sometimes”, “seldom” or “never”.
*p<0.05;**p<0.01.

painting (54%) and bent forward in formwork (47%), retaining pile work (88%), electrical work (61%), and tile work (40%). For the legs, the most frequent postures were standing with both legs straight in

Table 7. Associations with lower extremity fatigue on multivariate logistic regression model

Variables	OR [a]	(95% CI)
Gender		
Men	1.00	
Women	1.42	(0.93-2.18)
Age (yrs)		
<30	1.00	
30~39	1.66	(0.82-3.34)
40~49	1.27	(0.62-2.60)
>49	1.70	(0.82-3.55)
Length of employment (yrs)		
<5	1.00	
5~15	1.02	(0.62-1.70)
>15	1.27	(0.75-2.14)
Employment status		
Part-time worker	1.00	
Full-time worker	0.75	(0.45-1.24)
Daily squatting/kneeling (hr)		
<2	1.00	
2~4	1.15	(0.71-1.86)
4~6	1.74*	(1.01-3.00)
>6	2.50**	(1.44-4.35)
Resting duration after squatting/kneeling		
<5 min	1.00	
5~10 min	1.28	(0.68-2.42)
10~20 min	1.49	(0.93-2.39)
>20 min	1.69	(0.99-2.90)
Weekly physical exercise		
Seldom	1.00	
Sometimes	0.94	(0.55-1.59)
Often	0.57**	(0.37-0.88)

[a] Workers with high level of lower extremity fatigue were defined as those who reported feeling fatigued at work "often" or "always" vs. "sometimes", "seldom" or "never".
*p<0.05;**p<0.01.

steel lashing (48%), formwork (35%), and plaster painting (37%); standing with both legs bent in retaining pile work (88%); kneeling on one knee in electrical works (45%); and standing with one

Table 8. Percentages of workers suffering physical discomfort

Physical discomfort (prevalence)	Men (n = 155)		Women (n = 868)		
	n	%	n	%	p[a]
Upper back	239	51.7	83	60.9	0.042*
Lower back	245	53.0	74	54.0	0.459
Hip	126	27.3	39	28.5	0.431
Thigh	181	39.2	50	36.5	0.322
Lower leg	187	40.5	63	46.0	0.147
Knee	249	53.9	78	56.9	0.299
Ankle	164	25.5	53	38.7	0.028*
Feet	175	37.9	46	33.6	0.208

[a] Pearson chi-square test.
*$p<0.05$.

Table 9. Distributions of postures of construction workers

Body part	Posture	Frames N(%)
Head	Free	621(43.2)
	Bent forward	557(38.8)
	Bent to the side	122(8.5)
	Turned to the side	136(9.5)
Arms	Both arms below shoulder level	1348(93.9)
	One arm at or above shoulder level	62(4.3)
	Both arms at or above shoulder level	26(1.8)
Back	Straight	590(41.1)
	Bent forward	745(51.9)
	Straight and twisted	76(5.3)
	Bent and twisted	25(1.7)
Legs	Sitting	57(4.0)
	Standing with both legs straight	388(27.0)
	Standing with one leg straight	221(15.4)
	Standing with both legs bent	77(5.4)
	Standing with one leg bent	311(21.7)
	Kneeling on one knee	311(21.7)
	Kneeling on both knees	104(7.1)
Force	Less than 10 kg	1436(100)

Over 10 kg but less than 20 kg	0(0)
More than 20 kg	0(0)

Table 10. Average percentage distributions of body part postures of six activities (n=23)

Activity	Head				Arms			Body part Back				Legs						
	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4	5	6	7
Steel lashing	55	16	3	26	94	4	2	56	38	4	2	2	48	3	8	25	6	8
Formwork	44	38	6	12	89	8	3	40	47	7	6	0	35	11	15	11	11	17
Retaining piles	72	10	10	8	99	1	0	9	88	0	3	0	22	77	0	1	0	0
Plaster painting	36	48	8	8	88	12	0	54	45	1	0	0	37	2	0	30	31	0
Electrical works	23	50	25	2	92	2	6	39	61	0	0	21	12	0	0	7	45	15
Tile work	29	71	0	0	100	0	0	39	40	21	0	0	9	0	10	56	22	3

leg bent in tile work (56%). Based on an OWAS review study [24], it was decided to group action categories (2 + 3 + 4) for analysis, thus identifying postures needing attention in the near future, as soon as possible, or immediately. Figure 1 depicts the percentages of poor working postures for the six activity jobs. Poor working postures were observed most frequently in electrical work (50% of all observations), followed by tile work (48%), retaining pile work (42%), plaster painting (39%), formwork (37%), and steel lashing (33%).

Discussion

Most industrialized countries emphasize ergonomic

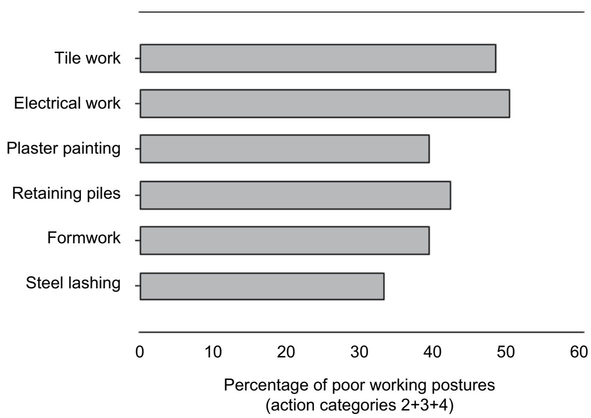

Fig. 1 Percentages of poor working postures for the six activities.

interventions to reduce worker discomfort. Since many workers squat or kneel for long periods during their work day, interventions to improve worker fitness and the work environment are essential for promoting the health, safety, and comfort of workers. Our previous investigation suggested that leg movements affect standing comfort, as quantified subjectively or by changes in leg circumference [25]. The results of that study confirmed the effectiveness of leg movement in preventing discomfort. Further research is needed to determine whether workers favor the moving of their legs and whether a change in the duration or frequency of leg movement during squatting or kneeling is favorable.

Construction workers are exposed to various physical factors, including awkward postures, heavy lifting, forceful exertion, vibration, and repetitive motion. The restriction of blood flow to lower extremities caused by long periods of squatting or kneeling can lead to venous insufficiencies and leg fatigue. The findings of this study indicated that 59.4% of construction workers in central Taiwan squat or kneel for more than two hours per day. For all workers, upper extremity and lower extremity discomfort varied significantly in association with daily squatting/kneeling durations (Tables 6 & 7). Some studies have suggested that work that entails prolonged bending of the knees increases the risk of discomfort. Cooper et al. [26] indicated that the risk of knee osteoarthritis is significantly elevated in subjects required to squat for more than 30 minutes per day (OR 6.9, 95% CI 1.8–26.4) or to kneel (OR 3.4, 95% CI 1.3–9.1). Sandmark, et al. [27] revealed that discomfort among men is associated with squatting (OR 2.9, 95% CI 1.7–4.9) or kneeling (OR 2.1, 95% CI 1.4–3.3). The findings of this study support the hypothesis that prolonged or repetitive bending of the knee(s) is a cause of musculoskeletal discomfort. They also indicated that both upper extremity fatigue and lower extremity fatigue are associated with more than 4 hours of squatting or kneeling per day. The rise in risk associated with kneeling or squatting was more marked in subjects whose jobs entailed heavy lifting or repetitive motion, but the size of the study sample did not enable precise delineation of any such interaction. Prolonged or repeated knee bending was determined to be a risk factor for musculoskeletal discomfort. Such risk may be higher for jobs that involve both knee bending and mechanical loading. However, this study is cross-sectional rather than prospective and lacks controls. Further research is required to accurately describe the work performed and ways of measuring “dose”. Prospective and well-controlled studies are also needed to accurately define the relationship between work tasks and musculoskeletal disorders.

The overall high levels of physical discomfort in this study reveal that working in construction is physically stressful. Repetitive movements of upper and lower extremities and prolonged constrained static kneeling and squatting postures contribute to physical discomfort among construction workers. Moreover, physical discomfort varies with gender, as female workers are more likely than male workers to report discomfort [28]. These findings may also be due to differences in physical capacity between men and women [29].

In this study, we observed construction workers in the field and employed OWAS to analyze their working postures to evaluate risks of occupational musculoskeletal injuries. Electrical work, (50%), tile work (48%) and retaining pile work (42%) were identified as the three principal jobs in which construction workers exhibit poor working postures. The OWAS method is a time-lapse sampling method, where the observations are performed at regular intervals [6]. A higher sampling frequency leads to a more accurate observational study. There is a recommended 30 sec time-lapse sampling for direct observations in the field. In this study, 23 male construction workers were observed performing six activities for periods of 3 to 5 min (for a minimum of 3 work cycles) and all observations were recorded at 5 sec intervals. Smaller observation intervals can be used, e.g. 5 sec, for filming tasks with a short time span [30].

Various refinements can be made to the current study. For instance, keeping of a diary and observational methods should be applied to register differences in mental, emotional, psychosocial, and environmental loads. Quantitative parameters, including duration of squatting or kneeling each working day, workplace anthropometric parameters, and energy expenditures of certain postures, should be obtained. Longitudinal studies that include hours of work and medical examination data for individual construction employees should also be performed. Other limitations of this study relate to the validity of self-reported data. As both the daily squatting/kneeling time and physical discomforts were assessed by self-reporting, negative reporting creates potential for bias. Individuals who perceive their work environment and health conditions unfavorably can generate a false correlation between daily squatting/kneeling time and physical discomfort.

Conclusion

In this study, knee, upper back, and lower back discomfort was most prevalent among construction workers who experienced prolonged kneeling or squatting. Additionally, nearly one-third of subjects reported squatting/kneeling durations of more than 4 hours, and nearly two-thirds reported rest times after squatting/kneeling tasks of less than 10 minutes. Moreover, most subjects (89.3%) sat on the ground or a chair after squatting/kneeling.

Future studies should examine the data in greater detail to more thoroughly analyze the relationships between daily squatting/kneeling duration and physical discomfort at construction sites.

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