Construction Ergonomics: Observations

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Abstract. Construction entails exposure to a range of ergonomics hazards and risks. The study entailed observations of activities on several construction sites. Findings include that most construction activities entail exposure to a range of ergonomics hazards and risks, and that aspects/interventions can contribute to an improvement of construction ergonomics. Conclusions include: construction is physically demanding; construction activities are hazardous in terms of ergonomics; HIRAs, if conducted, are not effective, and there is a need to implement ergonomics interventions. Recommendations include: the level of awareness relative to construction ergonomics must be raised; designers must deliberate their general design, details, and specification within the context of construction ergonomics; HIRAs must be conducted prior to the commencement of all activities; the construction process and its activities must be reengineered, and employer and professional associations, and statutory councils should develop and or promote construction ergonomics-related continuing professional development (CPD) courses.

Keywords: Construction · Ergonomics · Hazards · Observations · Risks

1 Introduction

Construction is physically demanding [1]. The nature of construction work helps to explain why injuries, such as strains, sprains, and WMSDs, are so prevalent in the industry. Execution of tasks by construction workers requires lifting heavy loads, performing repetitive tasks, frequent bending and twisting of the body, working above shoulder height, working below knee level, manual handling of heavy and irregular-sized loads, adopting awkward work postures, working in confined spaces, holding the same position for long, forceful exertion and working under hot and cold temperatures/weather, which are inherent H&S risks and unfavourable ergonomic practices [2, 3].

The South African Construction Regulations [4] require in general that contractors must identify the hazards and the risks to which persons may be exposed.

The aforementioned highlight the relevance of construction ergonomics and given that limited, if any, activity-focused construction ergonomics studies have been

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undertaken in South Africa, such an exploratory study was conducted, the objectives being to determine the:

- extent to which activities expose the worker or workers to hazards, and
- potential of aspects/interventions to contribute to an improvement in construction ergonomics during the activities.

2 Review of the Literature

2.1 Legislation and Recommendations

The Construction Regulations [4] lay down important requirements with respect to clients and designers. Designers are required to, inter alia: inform the client of any known or anticipated dangers or hazards relating to the construction work, and make available all relevant information required for the safe execution of the work upon being designed or when the design is changed, and modify the design or make use of substitute materials where the design necessitates the use of dangerous procedures or materials hazardous to H&S.

The South African Ergonomics Regulations [5] require that before an activity that may expose workers to ergonomics risks is commenced, an employer must have an ergonomic risk assessment conducted. Such a risk assessment must include: a complete hazard identification; identification of all the persons who may be affected and how they will be affected by the ergonomic risks; the analysis and evaluation of the ergonomic risks, and the prioritization of the ergonomic risks.

In terms of the South African Construction Regulations [4] contractors must identify the hazards and the risks to which persons may be exposed. They must then analyze and evaluate the hazards and the risks using a documented method, and produce a plan and applicable safe work procedures (SWPs) to mitigate, reduce, or control the hazards and risks.

2.2 Ergonomic Problems in Construction

Previous research conducted in South Africa investigated, inter alia, the frequency at which ergonomic problems are encountered in construction [6–8]. The top 10/18 problems are ranked in Table 1 based upon a mean score (MS) with a minimum value of 1.00, and a maximum value of 5.00, which in turn are based upon percentage responses to a response range ‘never’ to ‘daily’. Mean MSs computed from the MSs from the four sample strata are also presented. The * denotes the findings originate from the study [6], ** denote from study [7], and *** denote from study [8].

Table 1. Frequency at which ergonomics problems are encountered during construction.

Problem	GC*		Worker*		Worker**		BPGC***		Mean	
	MS	R	MS	R	MS	R	MS	R	MS	R
Repetitive movements	4.29	1	4.56	1	3.97	3	4.78	1	4.40	1
Climbing and descending	3.88	2	4.01	4	4.23	1	4.56	2	4.17	2
Handling heavy materials	3.63	4=	3.68	10=	4.00	2	4.44	3	3.94	3
Use of body force	3.80	3	3.82	8	3.77	5	4.00	9	3.85	4
Exposure to noise	3.53	7	3.93	6	3.65	6	4.11	6=	3.81	5
Bending or twisting the back	2.96	11	4.47	2	3.38	7	4.22	4=	3.76	6
Reaching overhead	3.61	6	3.99	5	3.00	13	4.11	6=	3.68	7
Reaching away from the body	3.41	8	4.19	3	3.03	12	3.63	12	3.57	8
Working in awkward positions	2.70	12	3.85	7	3.30	9	4.22	4=	3.52	9
Handling heavy equipment	3.03	10	3.17	13	3.87	4	3.78	10	3.46	10

2.3 Improving Construction Ergonomics

Table 2 indicates the potential of the top 10/13 aspects/interventions to contribute to an improvement in construction ergonomics during the various project phases in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. The findings emanate from a study conducted among architectural technologists in South Africa [9]. The letters inserted within parentheses denote whether the aspect/intervention is construction (C), design (D), procurement (P), or multi-phase related. It is notable that all the MSs are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the various aspects/interventions to have the potential to contribute to an improvement in construction ergonomics during the various project phases.

Table 2. Potential of various aspects/interventions to contribute to an improvement in construction ergonomics during the various project phases.

Aspect/Intervention	Response (%)						MS	R
	Unsure	Minor ..... Major						
		1	2	3	4	5		
Safe working procedures (C)	2.7	2.7	0.0	10.8	21.6	62.2	4.44	1
General design (D)	0.0	0.0	0.0	13.5	32.4	54.1	4.41	2
Awareness (C & D)	2.7	0.0	5.4	8.1	35.1	48.6	4.31	3
Constructability (general) (D)	0.0	0.0	8.3	11.1	41.7	38.9	4.11	4
Details (D)	0.0	0.0	5.6	16.7	44.4	33.3	4.08	5
Contractor planning (C)	2.7	2.7	10.8	8.1	35.1	40.5	4.03	6
Design of construction equipment (C)	5.7	0.0	11.4	14.3	37.1	31.4	3.94	7
Specification (D)	2.8	5.6	5.6	19.4	33.3	33.3	3.86	8
Reengineering (C, D & P)	19.4	2.8	11.1	16.7	22.2	27.8	3.76	9
Design of tools (C)	5.6	0.0	19.4	13.9	36.1	25.0	3.71	10

3 Research

3.1 Research Method and Sample Stratum

The sample stratum consisted of 4 projects being undertaken by the regional entity of a national general contractor, and their plant yard. The regional entity's H&S Coordinator conducted 13 observations of various activities: manual loading of rubble; fixing of drywall screens using screws; painting inside ducts by means of ladder access; tiling; demolition of ceilings and partitions; manual excavation; mechanical excavation of hard rock using a hydraulic breaker; casting concrete; painting at ground level; tree felling using an excavator with a mulcher attachment; erecting hoarding; tree felling using a chainsaw, and manually offloading of scaffold.

The mean duration of the observations was 43.5 min, the shortest was 9 min, and the longest was 87 min.

3.2 Research Findings

Table 3 indicates the extent to which activities expose the worker or workers to hazards, in terms of percentage responses to 'does not' and a scale of 1 (minor) to 5 (major), and a MS ranging between 0.00 and 5.00. Given that a 'does not' option was provided, the scale effectively consists of six points, and hence the MS range.

It is notable that only 6/17 MSs are above the midpoint of 2.50, which indicates the activities expose the worker or workers to such hazards to a major as opposed to a minor extent.

It is notable that no MSs fall within the range of $> 4.17 \leq 5.00$ - between a near major to major extent/major extent.

Only 2/17 (11.8%) MSs are > 3.34 $\leq$ 4.17, which indicates the activities expose the worker or workers to such hazards between some extent to a near major extent/near major extent - repetitive movements, and bending or twisting the back.

4/17 (23.6%) MSs are > 2.50 $\leq$ 3.34, which indicates the activities expose the worker or workers to such hazards between a near minor extent to some extent/some extent - reaching away from the body, working in humid conditions, working in hot conditions, and exposure to noise.

6/17 (35.4%) MSs are > 1.67 $\leq$ 2.50, which indicates the activities expose the worker or workers to such hazards between a minor to near minor extent/near minor extent - climbing and descending, staying in the same position for long periods, reaching overhead, working in awkward positions, use of body force, and handling heavy materials.

3/17 (17.7%) MSs are > 0.83 $\leq$ 1.67, which indicates the frequency the activities expose a worker or workers to such hazards is between does not to a minor/minor extent - vibrating equipment, working in cramped positions, and handling heavy equipment.

2/17 (11.8%) MSs are > 0.00 $\leq$ 0.83, which indicates the frequency the activities expose a worker or workers to such hazards is between does not to a minor extent - working in wet conditions, and working in cold conditions.

Seven of the top ten hazards are among the top ten identified in previous South African studies [6–8] - repetitive movements, bending or twisting the back, reaching away from the body, exposure to noise, climbing and descending, reaching overhead, and working in awkward positions.

Table 3. Extent to which activities expose the worker or workers to hazards.

Hazard	Response (%)							MS	R
	Unsure	DN	Minor ..... Major						
			1	2	3	4	5		
Repetitive movements	0.0	0.0	0.0	0.0	38.5	38.5	23.1	3.85	1
Bending or twisting the back	0.0	9.1	9.1	0.0	9.1	63.6	9.1	3.36	2
Reaching away from the body	0.0	10.0	10.0	0.0	30.0	40.0	10.0	3.10	3
Working in humid conditions	0.0	30.8	0.0	0.0	7.7	38.5	23.1	2.92	4
Working in hot conditions	0.0	30.8	0.0	0.0	7.7	38.5	23.1	2.92	5
Exposure to noise	0.0	7.7	23.1	23.1	7.7	15.4	23.1	2.69	6
Climbing and descending	0.0	23.1	7.7	15.4	23.1	15.4	15.4	2.46	7
Staying in the same position for long periods	0.0	18.2	27.3	9.1	18.2	0.0	27.3	2.36	8
Reaching overhead	0.0	27.3	9.1	18.2	9.1	27.3	9.1	2.27	9
Working in awkward positions	0.0	33.3	8.3	0.0	16.7	41.7	0.0	2.25	10
Use of body force	0.0	15.4	23.1	15.4	23.1	15.4	7.7	2.23	11
Handling heavy materials	0.0	30.0	10.0	20.0	30.0	10.0	0.0	1.80	12
Vibrating equipment	0.0	53.8	7.7	7.7	7.7	15.4	7.7	1.46	13

(*continued*)

Table 3. (*continued*)

Hazard	Response (%)							MS	R
	Unsure	DN	Minor ..... Major						
			1	2	3	4	5		
Working in cramped positions	0.0	63.6	0.0	0.0	9.1	27.3	0.0	1.36	14
Handling heavy equipment	0.0	58.3	0.0	33.3	8.3	0.0	0.0	0.92	15
Working in wet conditions	0.0	83.3	0.0	8.3	0.0	0.0	8.3	0.58	16
Working in cold conditions	0.0	84.6	0.0	0.0	7.7	7.7	0.0	0.54	17

Table 4 indicates the potential of aspects/interventions to contribute to an improvement in construction ergonomics during the activity, in terms of percentage responses to 'does not' and a scale of 1 (minor) to 5 (major), and a MS ranging between 0.00 and 5.00.

It is notable that only 5/16 (31.3%) MSs are above the midpoint of 2.50, which indicates the aspects/interventions have major as opposed to minor potential to contribute to an improvement in construction ergonomics during the activities.

It is notable that no MSs fall within the range of $> 4.17 \leq 5.00$ - between near major potential to major potential/major potential.

4/16 (25.0%) MSs are $> 3.34 \leq 4.17$, which indicates the aspects/interventions have between potential to near major/near major potential to contribute to an improvement in construction ergonomics during the activities - hazard identification and risk assessment, safe work procedures, workplace organisation, and contractor planning. It is notable that these four aspects/interventions are all construction-related and that HIRAs and SWPs feature prominently in legisation and regulations.

Only 1/16 (6.3%) MSs is $> 2.50 \leq 3.34$, which indicates awareness has between near minor potential to potential/potential to contribute to an improvement in construction ergonomics during the activities. Awareness is a multi-stakeholder aspect i.e. client, designer, and contractor-related. It is also applicable to construction project managers (CPMs), quantity surveyors, material manufacturers, and H&S inspectors.

4/16 (25.0%) MSs are $> 1.67 \leq 2.50$, which indicates the aspects/interventions have between minor to near minor/near minor potential to contribute to an improvement in construction ergonomics during the activities minor to near minor extent/near minor extent - mechanisation, general design, specification, and details. Three aspects/interventions are design-related, and one is both design and construction-related.

5/16 (31.3%) MSs are $> 0.83 \leq 1.67$, which indicates the potential of the aspects/interventions to contribute to an improvement in construction ergonomics during the activities is between does not and minor/minor - design of tools, design of equipment (construction), reengineering of design, reengineering of construction, and constructability (general). Four aspects/interventions are design-related, and one is both design and construction-related.

2/16 (12.5%) MSs are $> 0.00 \leq 0.83$, which indicates the potential of the aspects/interventions to contribute to an improvement in construction ergonomics

during the activities is between does not and minor - workshops on site, and prefabrication. One aspect/intervention is design-related, and one is construction-related.

Five of the top ten aspects/interventions among the top ten identified in a previous South African study [9] - safe work procedures (SWPs), Awareness (C, D &C), general design (D), specification (D), and design of tools (D). However, three included in the current study, namely HIRA (C), workplace organisation (C), and contractor planning (C) were npt included in the previous study.

Table 4. Potential of aspects/interventions to contribute to an improvement in construction ergonomics during the activity.

Aspect/Intervention	Response (%)							MS	R
	Unsure	WN	Minor …… Major						
			1	2	3	4	5		
Hazard identification and risk assessment (HIRA) (C)	0.0	0.0	0.0	0.0	15.4	84.6	0.0	3.85	1
Safe work procedures (SWPs) (C)	0.0	0.0	0.0	0.0	15.4	84.6	0.0	3.85	2
Workplace organisation (C)	0.0	0.0	7.7	7.7	7.7	61.5	15.4	3.69	3
Contractor planning (C)	0.0	0.0	7.7	7.7	30.8	46.2	7.7	3.38	4
Awareness (C, D &C)	0.0	0.0	7.7	15.4	23.1	46.2	7.7	3.31	5
Mechanisation (D & C)	16.7	16.7	16.7	8.3	16.7	25.0	0.0	2.20	6
General design (D)	0.0	30.8	0.0	23.1	15.4	30.8	0.0	2.15	7
Specification (D)	0.0	30.8	7.7	7.7	30.8	23.1	0.0	2.08	8
Details (D)	0.0	30.8	15.4	15.4	15.4	23.1	0.0	1.85	9
Design of tools (D)	8.3	33.3	16.7	16.7	16.7	8.3	0.0	1.45	10
Design of equipment (construction) (D)	0.0	50.0	8.3	16.7	16.7	8.3	0.0	1.25	11
Reengineering of design (D)	15.4	53.8	0.0	0.0	23.1	7.7	0.0	1.18	12
Reengineering of construction (C)	7.7	61.5	0.0	7.7	15.4	7.7	0.0	1.00	13
Constructability (general) (D)	0.0	69.2	7.7	0.0	7.7	15.4	0.0	0.92	14
Workshops on site (C)	9.1	63.6	9.1	0.0	9.1	9.1	0.0	0.80	15
Prefabrication (D)	0.0	84.6	0.0	0.0	0.0	15.4	0.0	0.62	16

4 Conclusions

Given the extent to which activities expose the worker or workers to hazards, it can be concluded that construction is physically demanding, and that construction activities are hazardous in terms of ergonomics.

Given the existence of ergonomics hazards it can be concluded that HIRAs, if conducted, are not effective.

Given that seven of the top ten hazards encountered are among the top ten identified in previous South African studies, it can be concluded that ergonomics hazards continue to persist in construction, and that there is a need to implement ergonomics interventions.

Given that five of the top ten aspects/interventions are among the top ten identified in a previous South African study, it can be concluded that ergonomics hazards can be mitigated. Furthermore, the former conclusion is reinforced by HIRA achieving the highest rank among aspects/interventions.

5 Recommendations

In general, the level of awareness relative to construction ergonomics must be raised among all project stakeholders.

Designers must deliberate their general design, details, and specification within the context of construction ergonomics, and review the former in terms of constructability.

HIRAs must be conducted prior to the commencement of all activities.

The construction process and its activities must be reengineered.

All South African statutory built environment councils and professional associations should evolve construction ergonomics practice notes, and promote continuing professional development (CPD) relative to construction ergonomics.

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