Rebar installers' fall arrest systems: part 1, belt vs harness and the selection of the harness (PPE)

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Abstract. Rebar installers are exposed to fall hazard when installing reinforcing steel bars (rebars) in walls. They shall use fall arrest system composed of a harness and a connecting link. The belt was traditionally used. 4 types of belts and harnesses were evaluated for their perceived comfort and safety by 12 subjects while doing prescribed tasks in walls and on the ground. One harness is as comfortable as the work positioning belt and as a belt with a subpelvic strap. The model of harness with a subpelvic was less comfortable at the shoulder level. The subpelvic strap was not adding comfort in suspension compared to a floating work positioning belt. A basic full body harness with a floating work positioning belt is a simple and affordable solution. The use of a fall arrest system with a harness is acceptable to the workers.

Keywords. harness, psychophysical evaluation, safety, comfort, rebar installer

1. Context

During the construction of reinforced concrete structures, reinforcing round steel bars (rebars) are placed before the concrete is poured in the form. Rebars could be heavy; their masses vary from 0,25 kg/m (diameter 6,35mm) to 20,25 kg/m (diameter 57,33mm). Rebar installers could move 1000 kg during a working day (Nadeau et al); therefore musculoskeletal disorders (MSDs) are very frequent. Rebar installers are placing rebars on floors and in vertical walls. In walls, they climb in the rebar lattice and are exposed to fall hazards. The regulation imposes the use of fall protection made of a harness and an energy absorbing lanyard when exposed to a 3m fall or exposed to a fall on dangerous parts such as vertical rebars. Despite the obligation from the regulation, the traditional equipment in use was the belt and a rebar positioning chain which are not fall protection equipment as required by the regulation. There was a consensus between the employers and the workers' union to move to fall protection systems as required by the regulation. The employers' expectations were that the selected equipment will be the correct one the first time and they will not have to pay again and again for inappropriate equipment. The workers' expectations were that equipment will be as comfortable as the belt and will not interfere with the tasks.

Several equipment and systems were available. But the combinations are so numerous that the selection becomes a challenge. The same research team had leaded a research project to select the appropriate fall arrest and work positioning systems for arborists (Arteau et 2007, Arteau et al 2015). A research protocol was developed in collaboration with the employers and the workers' union.

2. Objectives

In part 1, the objectives are to demonstrate that a full body harness is at least as comfortable as the belt, that a subpelvic strap is increasing the comfort in suspension and that the same equipment could be used on a floor and in a vertical wall.

3. Methodology

3.1 Harnesses

Four types of harness combining belt or subpelvic strap and with or without braces were tested. They are summarized and illustrated in Table 1. The comparison of H1 and H2 vs H3 and H4 shows the effect of the braces namely belt type vs full harness. The comparison H1 and H3 vs H2 and H4 shows the effect of the subpelvic strap. In conventional harness, there is no subpelvic strap for support during the work. The subpelvic strap was added to verify if the comfort in suspension is increased. The harness and the work positioning chain were used during the tests.

Table 1. *Harnesses combining belt, subpelvic strap and braces*

	Belt (Lumbar support)	Belt + subpelvic strap (sit harness)
Without braces (without harness)	H1 	H2 
With braces (full harness)	H3 	H4 

3.2 Test site

The site used for the tests was a school for rebar installers CFMA *Centre de formation des métiers de l'acier*. The main difference with the real work is to be inside; this allows the tests to be performed during the winter when rebar installation activities are at the lowest and workers are available. Wall no. 1 was 8,5m by 4,6m; wall no.2 was 4,6m by 4,6m (Figure 1). The work height was limited to 3m above the landing mats. In order to protect the participating workers if a fall occurs, the floor was covered by landing mats for the pole vault jump; the thickness was 914mm for a fall height of 3m exceeding the 800mm minimum thickness for a fall of 6,50m required by the IAAF (IAAF 2008).

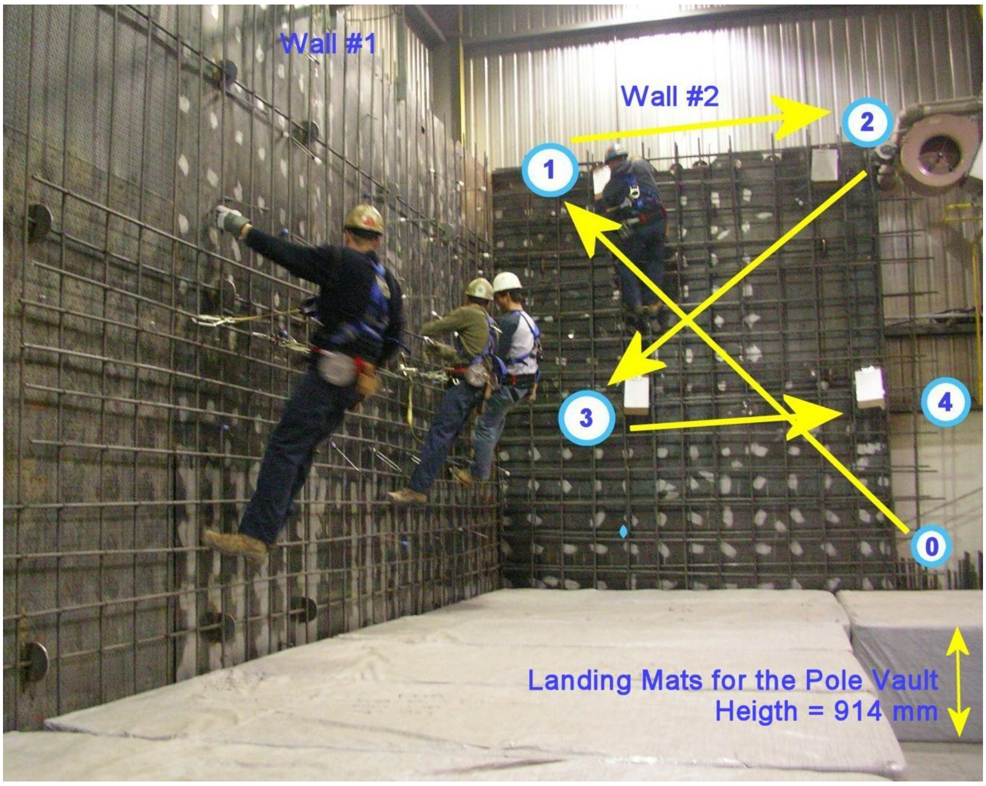

***Figure 1**.* *Wall no.1 and wall no.2. Wall no.1: installation of horizontal rebars.*
Wall no.2: displacements between 4 stations.

3.3 Tasks to be performed

Prescribed tasks similar to real tasks were performed in a controlled environment replicating a real construction site. A 1st group of tests are movements on the ground (simultaneous flexion of shoulders, torso flexion, torso abduction and adduction to the right, knees flexion) to verify the comfort in extreme body positions. The 2nd ones are the positioning and tying of horizontal reinforcing steel bars in a vertical wall, wall#1 (Figure 1) to verify the pressure on the bottom of the back by the belt or on the buttocks by the subpelvic strap. The 3rd are displacements in a vertical wall, wall#2 (Figure 1) to verify the comfort in extreme body positions.

3.4 *The subjects*

Twelve rebar installers are required to assure statistical power; this number is based on a previous study where the psychophysical variables were used to compare three fall arrest systems used for climbing wood poles (Arteau et al, 1997; Beauchamp et al, 1996). One extra rebar installer is on site distributing rebars to the three workers in wall no.1.

All rebar installers meet the following criteria:

- Representative of the population and able to verbalize their impressions.
- Having a proficiency card and a minimum of 5,000 worked hours.
- Living in the Great Montreal area where half the population is living.
- Each rebar installer was free to participate or not.
- The work conditions were those of their collective contract in the construction industry in the province of Quebec and were not influencing their free consent.

Before the tests, the objectives were explained to each and their comprehension was verified. A consent formula was signed.

The selected workers varied in experience, 4 to 25 years (avg. 14,4 years). They also varied in age (min. 24; avg. 36,8; max 52), anthropometry (stature cm: min. 170; avg. 179,5; max. 192) (mass kg: min. 65; avg. 87,1; max. 122). Their shape was recorded by photos in front of a vertical panel calibrated with horizontal and vertical lines.

3.5 Test procedures

The four harnesses were tested by all rebar installers (1) doing movements on the ground, (2) installing and splicing rebars at several heights in wall no.1 and (3) moving and reaching the four stations in wall no.2. The experiment scheme was balanced. After each group of test, the rebar installers self-answered a questionnaire on their perceptions of comfort and safety; then interviews were done. All psychophysical perceptions were collected on a visual analog scale by marking an X. At the end, rebar installers ranked the harness 1st, 2nd, 3rd and 4th choice. All data were analyzed with an ANOVA. A similar test procedure was used for arborists (Arteau et al 2007; Arteau et al 2015). The variables are presented in Table 2.

Table 2. *Variables.*

Independent variables	**Dependent variables**
Tasks: • Install rebars in wall 1 • Move in wall 2 • Movements on ground Configurations: H1, H2, H3, H4	Wall: • Safety • Nuisance shoulder • Nuisance hip • Global appreciation Ground: • Nuisance at each movement

4. Results

In wall 1 (installing horizontal rebars), all four harnesses are perceived equivalent for the comfort at the hips, for the safety and for the global appreciation; H4 a full body harness with a subpelvic strap is less comfortable than H1, H2 and H3 at the shoulders. When the arms are raised above the shoulders, the shoulder straps exert pressure because the subpelvic strap rigidifies the harness. Meanwhile H3 a full body harness without a subpelvic strap is as comfortable as a belt; therefore the design of the harness influences the comfort. A full body harness could be used.

In wall 2 (moving in the wall), all four harnesses are perceived equivalent for the comfort at the hips, for the safety and for the global appreciation; H4 a full body harness with a subpelvic strap is significantly less comfortable than H1, H2 and H3 at the shoulders. H4 is less comfortable moving upward in diagonal (station 1) than the 3 other stations. The conclusion in wall 1 is confirmed in wall 2.

On the ground, the results are presented in Table 3. All harnesses are not harmful. H1 the belt is more comfortable in lateral flexion and in squat.

Table 3. *Results for the movements on the ground.*

Tasks on the ground	Results
Raise both arms	No significate difference. All not very harmful
Torso flexion	No significate difference. All fairly harmful
Torso lateral flexion	H4 (subpelvic strap) more harmful then H1 (belt) H1, H2 and H3 not very harmful; H4 fairly harmful
Knees flexion (squat)	H1 less harmful then H3 H1 not very harmful; H2, H3 and H4 fairly harmful
Walking over an obstacle	No significate difference. All fairly to not very harmful

When the harnesses are ranked, some differences appear (Figures 2 and 3). Ranking obliges a choice by the subjects. When working in the walls where fall hazards are present, they prefer the full body harnesses H3 and H4 instead of the belt H1 and H2. When working on the ground, they prefer H1 the belt. But on the ground they are not exposed to fall hazards therefore a harness is not required.

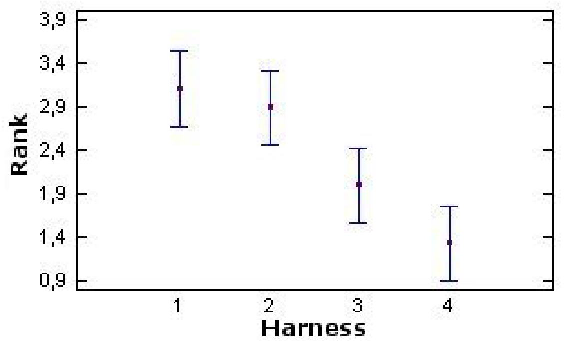

Figure 2. *Harness ranking for walls 1 and.2.*

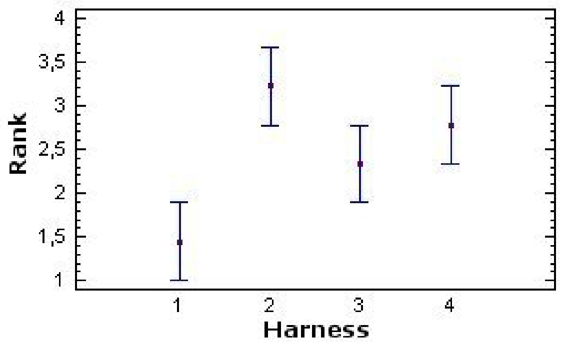

Figure 3. *Harness ranking on the ground.*

H1: work positioning belt; H2: belt with subpelvic strap (sit harness);
H3: full body harness with work positioning belt; H4: full body harness with subpelvic strap .

Note: Rank = 1 is the preferred harness; rank = 4 is the less preferred.

5. Discussion and conclusion

The shoulder straps: H4 a full body harness with a subpelvic strap is less comfortable than H1, H2 and H3 at the shoulders in the walls. The full body harness H3 is as comfortable as H1 and H2 belts without shoulder straps. Therefore shoulder straps are not the problem but the specific construction of H4. On the ground, 5 of 12 subjects add conventional braces to the belt in order to support the tools.

The subpelvic strap: the subpelvic strap was added in order to give more body support when working in the wall. No conclusion is reached. Some participants were using it but many others were reaching a good buttocks support by moving down the belt. A floating work positioning belt could be the simplest solution.

The use of a full body harness is possible and is as comfortable as the traditional belt. The simplest and less expensive solution is a basic class A harness CSA Z-259-10 with a floating work positioning belt over the harness. The worker could adjust the height of the belt and lower it to sit on the belt when working in a wall.

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