Rebar installers' fall arrest systems: part 2, the selection of the connecting link and the attachment point

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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. 4 combinations, 2 connecting links (lanyard with energy absorber or self-retracting lanyard SRL) and 2 attachment points on the harness (dorsal or sternal) were evaluated for their perceived comfort and safety by 12 subjects while doing prescribed tasks in walls. All combinations were comfortable and safe. No statistical differences were observed between the dorsal and the sternal attachment point. For the global appreciation and the rank, the 1,5m lanyard with an energy absorber is preferred to the selfretracting lanyard.

Keywords: lanyard, selfretracting lanyard 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. The part 1 concluded that a harness was acceptable.

2. Objectives

In part 2, the objectives are to select the connecting link: lanyard with energy absorber or self-retracting lanyard SRL, and the attachment point on the harness: dorsal or sternal. Many persons in fall protection consider the SRL as the preferred link because of its longer length and its retractability and the frontal attachment as equivalent to the dorsal without any proof for both.

3. Methodology

3.1 Connecting links and attachment points

4 combinations made of 2 connecting links (lanyard with energy absorber or self-retracting lanyard SRL) and 2 attachment points on the harness (dorsal or sternal) were tested. They are summarized and illustrated in Table 1. The comparison of L1 and L2 vs L3 and L4 shows the effect of the connecting link. The comparison of L1 and L3 vs L2 and L4 shows the effect of the attachment point. The SRL is a small one, a Talon manufactured by DBI-Sala. A class A harness with a positioning belt (harness H3 from part 1) and a work positioning rebar chain were used (Figure 1).

***Table 1**. Connecting link and attachment point*

Attachment point		**Lanyard with energy absorber L = 1,52m**		**SRL L_{max} = 2,43m**
Dorsal	L1 (LAD)		L3 (EDD)	
Sternal	L2 (LAS)		L4 (EDS)	

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).

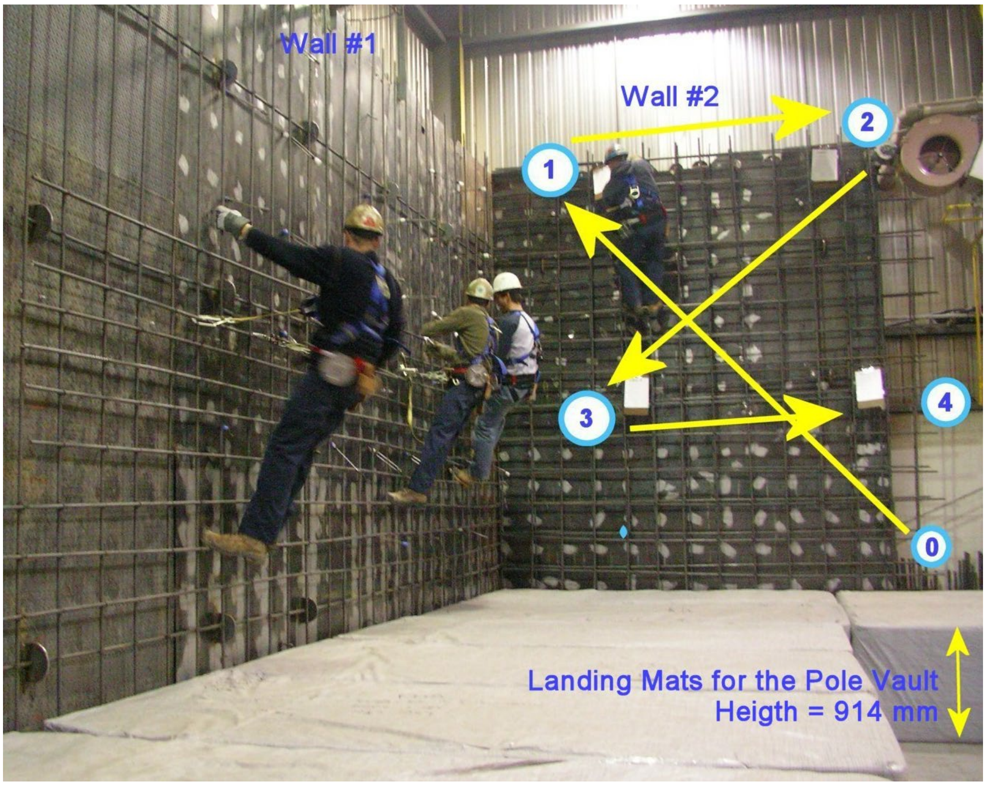

Figure 1. *Wall no.1 and wall no.2. Wall no.1: installation of horizontal rebars. Wall no.2: displacements between 4 stations.*

3.3 Tasks to be performed

Prescribed tasks similar to real tasks were performed in a controlled environment replicating a real construction site. The 1st ones are the positioning and tying of horizontal reinforcing steel bars in a vertical wall, wall#1 (Figure 1) to verify the interference between rebars and the connecting link. The 2nd 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 combinations of links-attachments were tested by all rebar installers (1) installing and splicing rebars at several heights in wall no.1 and (2) 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 combinations 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 Configurations: L1, L2, L3, L4	Wall: • Ease of use • Nuisance shoulder • Nuisance hip • Safety • Global appreciation

4. Results

The results are summarized in Table 3. In wall 1 (installing horizontal rebars) and in wall 2 (moving in the wall), all four combinations L1 to L4 are perceived equivalent for the ease of use, for the comfort at the shoulders and for the comfort at the hips. For the safety, L1 seems safer than L4 while all are considered relatively safe. In wall 1, L1 (lanyard with an energy absorber dorsal attachment) receives a global appreciation greater than L4 (SRL sternal attachment). In wall 2, L1 and L2 (lanyard with energy absorber) are clearly globally more appreciated than L3 and L4 (SRL) (Figure 2).

At the end, the subjects rank L1 to L4 from the 1^{st} to the 4^{th}. Figure 3 presents the rank. L1 and L2 are preferred. No preference is observed between the attachment point dorsal vs sternal. One of the objectives of the project was to verify a hypothetical preference for the SRL; when the wall2 global appreciation results from all stations and both attachments are regrouped in lanyard (L1-L2) vs SRL (L3-L4) a clear preference for the fixed length lanyard is observed.

Table 3. Results for wall 1 and wall 2.

Variables	Wall 1: installing rebars	Wall 2: moving
Ease of use	All equivalent: easy to very easy	All equivalent: easy to very easy
Shoulder	All little to very little harmful	All little to very little harmful
Hip	All little harmful	All little harmful
Safety	L1 safer than L4 (L1 ≡ L2 ≡ L3) (L2 ≡ L3 ≡ L4) All are safe	L1 safer than L4 (L1 ≡ L2 ≡ L3) (L2 ≡ L3 ≡ L4) All are safe
Global appreciation	L1 better than L4 All are acceptable	(L1 ≡ L2) better than (L3 ≡ L4) All are acceptable
Rank	(L1 ≡ L2) better than (L3 ≡ L4)	

5. Discussion and conclusion

Rebar installers were able to work with their traditional work positioning rebar chain attached to the work positioning belt and simultaneously anchor to the rebars by a fall arrest connecting link.

When working in a wall, rebar installers anchor their fall arrest system at the hip level because there is no anchor points at a higher level. Their anchor points are the rebars and they are installing the rebars from the floor; there is no rebars above their waist. So they work besides their anchoring at a horizontal distance and during a fall, a pendulum effect will be created.

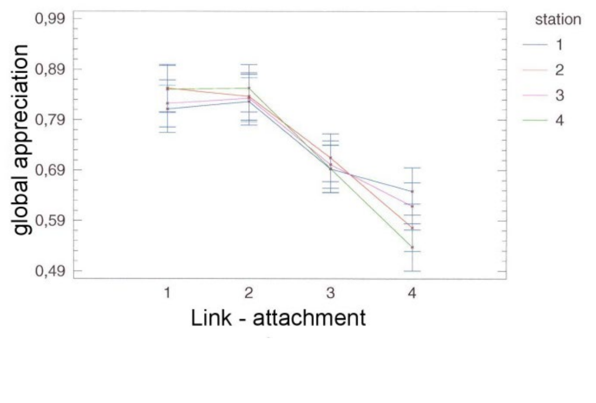

Figure 2. *Wall 2: global appreciation*

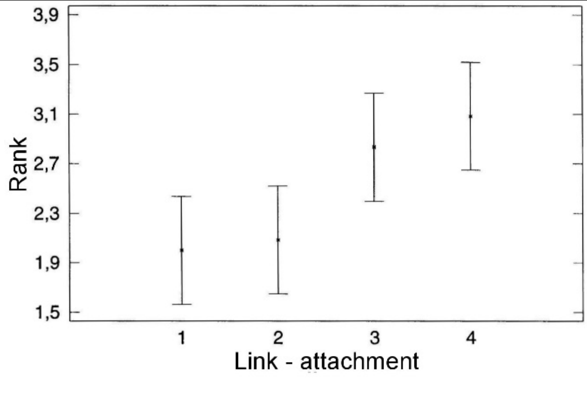

Figure 3. *Rank L1 to L4*

Means with 95% confidence intervals
L1: Lanyard with energy absorber, dorsal; L2: Lanyard with energy absorber, sternal
L3: Selfretracting lanyard SRL, dorsal; L4: Selfretracting lanyard SRL, sternal
Note: Global appreciation scale: 1 is the best; 0 is the worst.

A pendulum effect shall be avoided as possible to minimize contacts with objects. A reduced lateral horizontal distance reduces the pendulum effect. A SRL allows a greater distance (2,43m for L3 and L4). During a fall arrest, the SRLs increase the risks of injuries. To reduce the risk, the maximum length of the SRL shall be limited thus negating the advantage of the SRL. Furthermore, the SRL is heavier than the lanyard and its spring retractor exerts a tension on the harness. The SRL is not preferred by the workers and is not technically advantageous.

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