Anthropometry and selection of full body harness: beyond stature and body mass as selection criteria

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Abstract. The full body harness is a component of an individual fall arrest system made of webbings and buckles adjusted around the torso to keep the person's body from hitting the ground and to distribute the impact forces over the body. The comfort is key selection criteria after the compliance with the standards. A literature review was made. The biomechanics of the fall arrest, the positioning of the webbing on the body and the maximum deceleration were defined. Few articles discuss the sizing. Selection charts use the body mass (x axis) and the stature (y axis) to define size zones. 3 charts do not recommend the same size for a given body mass-stature combination. A harness was fitted on by volunteers. 20% of the volunteers require a larger or a smaller harness than the one selected according to the manufacturer's chart.

Keywords: harness, anthropometry, selection criteria, adjustment, comfort

1. Context

The full body harness (harness) is a component of an individual fall arrest system. The harness is made of webbings and buckles adjusted around the torso (Figure 1). Its functions are to keep the person's body from hitting the ground and to distribute the impact forces over the suitable parts of the body. After the fall is arrested, the harness should also allow a prolonged suspension without endangering the person's life. Modern harnesses are used since the development of parachutes for military purposes. In early 1990s, standards on harness for fall arrest were published (ANSI, CSA and EN) and harnesses are largely used. The selection issue could appear to be straight forward. It is not so. As part of a larger project on harness and comfort, a literature review was done by one coauthor on anthropometry, harness selection and harness comfort. The findings were surprising.

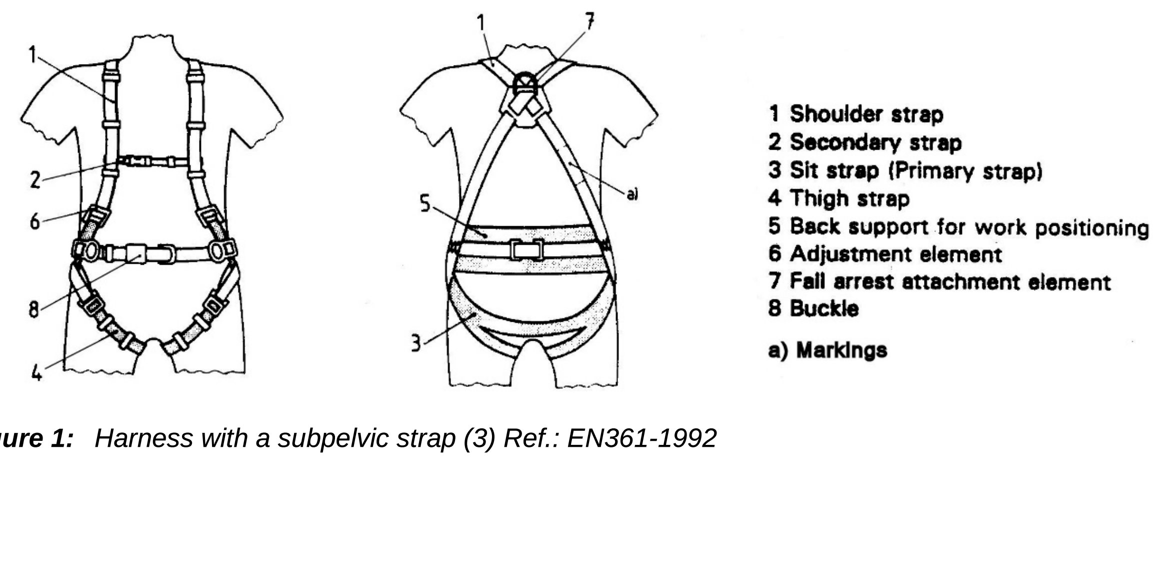

Figure 1: *Harness with a subpelvic strap (3) Ref.: EN361-1992*

2. Literature review

In the early 1980s, Amphoux and collaborators compared several arrangements of webbings for fall arrest and suspension of humans: belts, belts with thigh straps and harnesses. They addressed the biomechanics of the fall arrest defining the appropriate positioning of the webbing on the body and the maximum acceptable deceleration. They recommended a complete harness with a sub-pelvic webbing as the most suitable body gripping device for fall arrest and the subsequent suspension (Amphoux 1991). Amphoux, Bariod and Théry studied the prolonged suspension in a harness (Amphoux 1998,; Bariod 1992, Bariod and Théry 1994); then Brinkley and Orzech et al repeated similar testing. Both groups confirmed that the harness offers longer prolonged suspension duration than the belt but that duration is limited to 15 to 30 minutes. These studies were translated in the CAN/CSA Z259.10-M90, EN361-1992 and the ANSI Z359.1-1992 -standards. Seddon summarized these studies. Their concerns were the fall arrest and the prolonged suspension after the fall is arrested not the fit and the comfort during work.

The harness is in close contact with the wearer’s body. The comfort and the interference with the user’s movements are the most important selection criteria for the wearer after the compliance with the standards. The harness is worn on the torso; so torso anthropometric measures should control the size selection. Several manufacturers present graphical selection charts; these charts use the body mass (x axis) and the stature (y axis) to define size zones (extra small, small, medium, large, extra-large, double extra-large, triple extra-large) (Figures 2, 3 and 4). Hsiao and collaborators studied the anthropometry and the size of harnesses. They measured the body dimensions with 3D laser scanners, measured the comfort of humans in suspension and proposed new size selection charts; manufacturers did not adopt them. Very few articles were written on the proper sizing of harnesses (Rushworth et al).

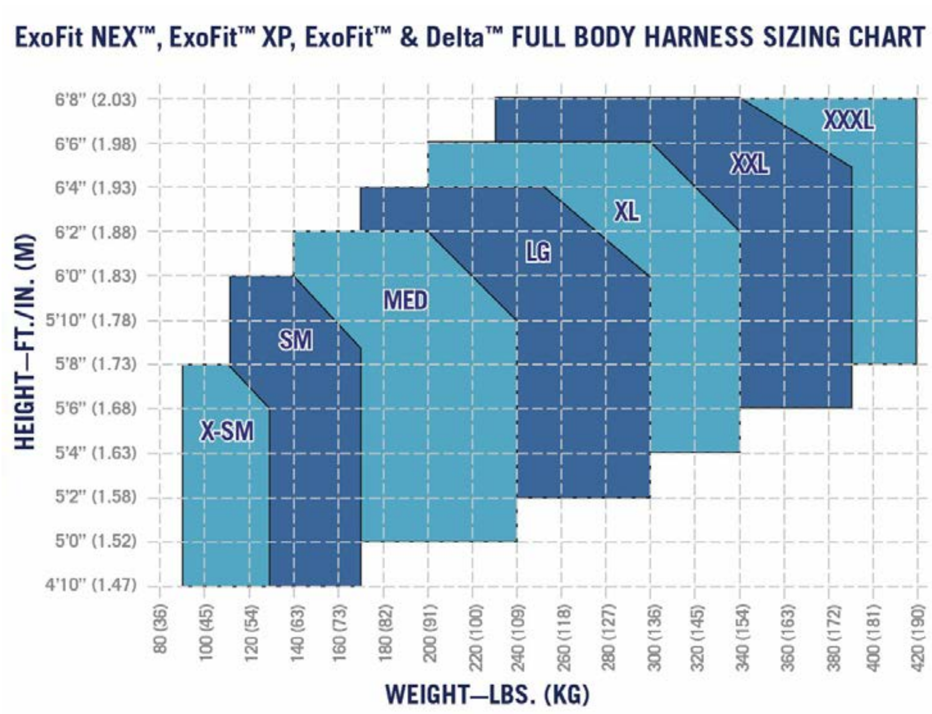

Figure 2: *3M DBI-SALA. ExoFit size selection chart. Ref.: 3M DBI-SALA Protecta*

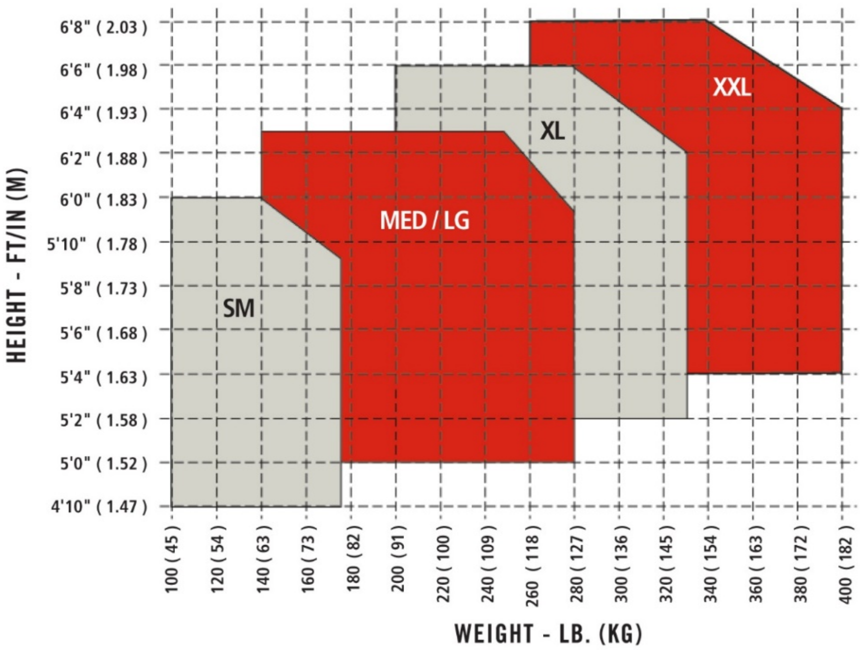

Figure 3: *3M DBI-SALA. Protecta selection chart. Ref.: 3M DBI-SALA Protecta*

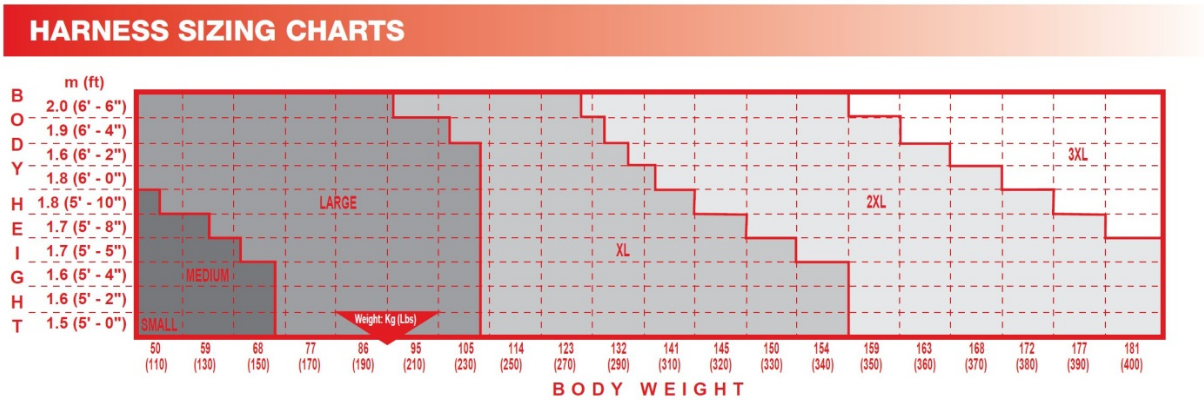

Figure 4: *Dynamic harness selection chart. Ref. Dynamic*

Random observations in real work situations had shown improperly adjusted harnesses that could lead to injuries during a fall arrest (Figures 5, 6 and 7). Workers prefer comfort and ease to work than safety (Arteau 1992).

3. Results and discussion

Manufacturers use the stature and the body mass as selection criteria. They are not the most appropriate because the harness is around the torso. The vertical circumference of the torso and the circumference of the waist belt are the most relevant measures but the vertical circumference is unknown by the users. The users know their body mass, their stature and their waist belt circumference. These three anthropometric measures could be used as selection criteria.

Figure 5: *Post-fall suspension – Real case. Ref.: Donelly*

Figure 6: *Twisted subpelvic strap. CSST private communication*

Figure 7: *Unadjusted thigh and subpelvic straps. Ref.: unknown*

The selection charts of 3 manufacturers do not select the same size for a given body mass-stature combination (Figures 8, 9 and 10). A 200lbs(91kg)-5'10"(1,78m) leeds to a medium in figure 2 and 3 while it is a large in figure 4; 130kg and 1,80m is a large in figure 2, and XL in figures 3 and 4. A medium for the A manufacturer is not a medium for the B manufacturer. The size is not transferable from one manufacturer to the other. Therefore internet purchase based on the size could lead to a misfit. One manufacturer keeps only large and extra-large harnesses on the shelf for sale. Small and medium are on special order.

Table 1: *Anthropometric data form 20 female subjects*

	Stature (cm)	**Body mass (kg)**	**Torso circumference (cm)**	**Waist belt circumference (cm)**	**Thigh circumference (cm)**
Min	150,0	48,7	82,0	70,0	43,4
Max	180,0	92,0	117,0	115,0	70,0
Avg	164,8	67,9	97,1	87,4	56,5
Std dev	8,6	13,3	10,0	12,6	8,2

A test protocol was developed to evaluate the comfort of one harness model and to test the protocol itself. 20 female volunteers were recruited by Facebook; their anthropometric measures are given in Table 1. S, M, L and XL size harnesses from the same manufacturer were available. The size of the harness was selected according to the manufacturer's chart and the harnesses were adjusted according to the manufacturer's instructions. The comfort was measured by a questionnaire. Globally 8 of 20 subjects required a smaller or a larger size (Figure 8).

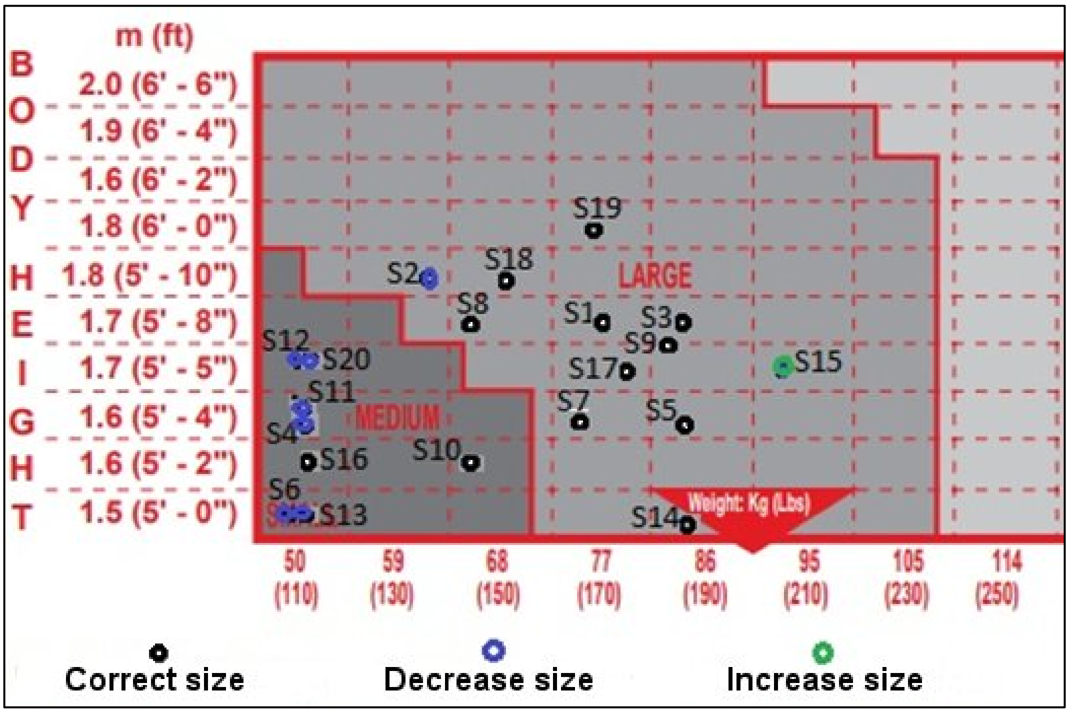

Figure 8: *Fit test results – Correct, decrease or increase harness size*

4. Conclusion

Three selection charts using the body mass (x axis) and the stature (y axis) as inputs were compared. The harness sizes identified were not the same for one specific body mass-stature combination. The sizes are not transferable from one manufacturer to the other manufacture even from one chart to another chart within subsidiaries of a manufacturing group.

One manufacturer maintains on stock only L and XL sizes; S and M sizes are special order and are manufactured only when ordered. Therefore the selection of harness according to the chart is not useful.

The tests with the volunteers show that 40 % of the volunteers require a larger or a smaller harness than the one selected according to the manufacturer's chart. The comfort issue is a key one because the users are working 100 % of the time with the harness. Selection charts should include a third anthropometric measure.

The most pertinent anthropometric measures for harness selection are the waist belt circumference and the vertical circumference of the torso. Selection charts shall use anthropometric measurements already known by the users such as stature, body mass and the waist belt circumference. We propose the development of new selection charts: (1) stature, body mass and waist belt circumference or (2) stature and waist belt circumference. The correlation between female data could help (Stirling) to select the proper combination of anthropometric measurements. Finally the sizes XS, S, M, L, XL, XXL shall be standardized.

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