Harness suspension and first aid management: development of an evidence-based guideline

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ABSTRACT
The possibility of a fall into rope protection and subsequent suspension exists in some industrial situations. The action to take for the first aid management of rescued victims has not been clear, with some authors advising against standard first aid practices. To clarify the medical evidence relating to harness suspension the UK Health and Safety Executive commissioned an evidence-based review and guideline. Four key questions were posed relating to the incidence, circumstances, recognition and first aid management of the medical effects of harness suspension. A comprehensive literature search returned 60 potential papers with 29 papers being reviewed. The Scottish Intercollegiate Guideline Network (SIGN) methodology was used to critically review the selected papers and develop a guideline. A stakeholders' workshop was held to review the evidence and draft recommendations. Nine papers formed the basis of the guideline recommendations. No data on the incidence of harness suspension syncope were found. Presyncopal symptoms or syncope are thought to occur with motionless suspension as a consequence of orthostasis leading to hypotension. There was no evidence of any other pathology, despite this being hypothesised by others. No evidence was found that showed the efficacy or safety of positioning a victim in a semirecumbent position. In any case of harness suspension, the standard UK first aid guidance for recovery of a semiconscious or unconscious person in a horizontal position should be followed. Other recommendations included areas for further research and proposals for standard data collection on falls into rope protection.

INTRODUCTION
Harnesses are often worn by workers for the purpose of fall protection in industrial settings. They are also used by people during rope access industrially or during climbing for sport. There are various designs of harness such as sit harnesses or full body harnesses and these may have different attachment points, for example ventral (figure 1A) or dorsal (figure 1B). A fall may result in suspension in the harness with the position of the suspended person being determined by the attachment point and anthropometric factors. In industrial fall arrest applications, the fall distance (assuming no other obstructions are encountered) depends on the deployment of a lanyard or energy-absorbing device. This limits the fall to 4 m and the arrest forces are not allowed to exceed 6 kN in order to limit injury to the worker.[1]

When a human is suspended in a vertical position and remains motionless, the physiological phenomenon of orthostatic hypotension may ensue after a variable but relatively short period.[2–4] This mechanism results in a fall of blood pressure and consequent syncope. In one experimental study using a group of 79 normal subjects, 20% developed premonitory symptoms or 'presyncope' in less than 10 min, and only 9% tolerated head-up tilt to 50° on a table for 1 h.[2] In controlled experimental conditions, and in cardiology investigations with a cardiac tilt table, subjects are recovered by laying horizontal.

Although employers are required to have rescue plans prepared under the provisions of the Work at Height regulations,[5] the time to rescue may exceed the time before a motionless person experiences syncope. Confusion regarding the best method to recover an industrial harness suspension patient has arisen, leading some authors to advocate that the casualty should not be placed in a horizontal position.[6] This advice appears to be based on papers quoted in Seddon's 2001 review of harness suspension.[7] It is not clear whether the original literature was reviewed by these authors, and it may not have been appreciated that Seddon's report was not a medical review of the literature.

Papers from a 1972 conference of Mountain Rescue Doctors in Innsbruck highlighted the medical complications arising from suspension in harnesses.[8] The term 'suspension trauma' subsequently became parlance for the orthostatic syncope that may follow motionless suspension and the postulated shock syndrome. One of the conference papers by Flora *et al* proposed that rescued suspension victims may experience adverse effects if laid horizontal, and hypothesised a pathophysiological mechanism of right ventricle overload.[9] A number of harness and rope training organisations have promulgated this advice, which is contrary to the usual UK first aid advice for unconscious victims.[10] This has led to some confusion for workplace first aiders, and first responders to potential suspension victims. In order to clarify the guidance that the UK Health and Safety Executive might give on first aid for harness suspension, a review of the medical literature was undertaken.

METHODS
The Scottish Intercollegiate Guideline Network (SIGN) methodology was the framework for the development of the guideline.[11] The guideline development group consisted of the authors who were supported by a coordinator and a project manager. The key questions to be addressed were formulated in discussion with the HSE commissioning officers (Appendix A, available online). These questions were then aligned to the

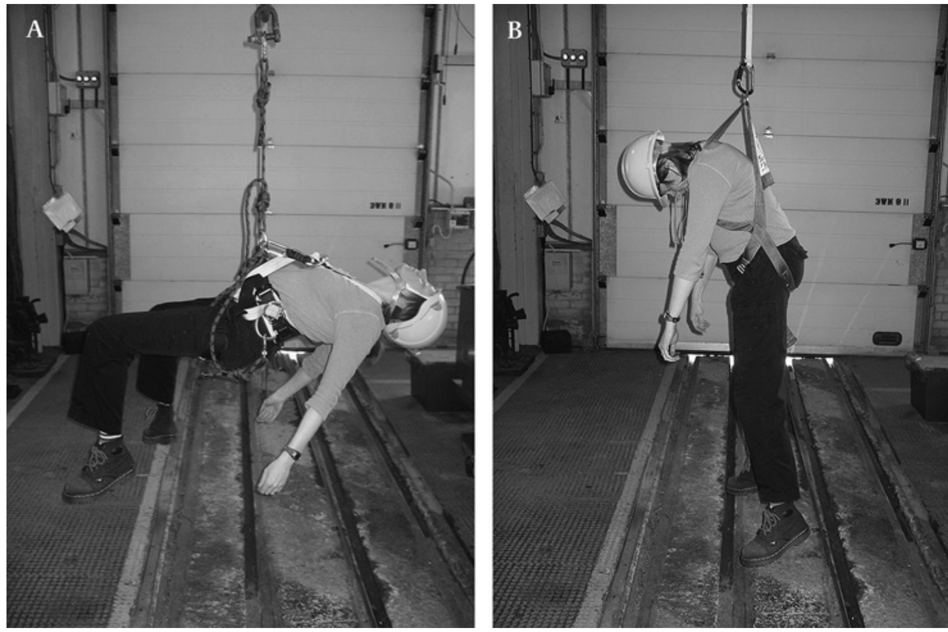

Figure 1 (A) Typical industrial sit harness with simulated post-fall suspension position. (B) Industrial full body harness with dorsal attachment point with simulated post-fall suspension position.

Population Intervention Comparison and Outcome (PICO) format to assist in the identification of relevant information. A proforma adapted from the Critical Appraisal Skills Programme was used, as one of the authors (AA) was already familiar with this appraisal tool.[12] Training was provided to CL who had not used the tool previously. Two reviewers (AA and CL) reviewed each paper independently and graded the evidence using the SIGN criteria.[11] After all the papers had been reviewed, the final gradings were agreed and discussed with KP. The group then produced the recommendations using the findings from critical appraisal. Considered judgement forms from SIGN were used to record the synthesis of the evidence and the recommendations that followed for each key question.

Data sources

The guideline group agreed a list of keywords from personal knowledge and by reference to known articles relevant to the topic. The list of keywords was passed to HSE information scientists, who ran a literature search. The databases searched included Medline (1951 to December 2007), EMBASE (1974 to December 2007), CISDOC (1987 to December 2007), Hseline (1987 to December 2007), Nioshtic and Nioshtic 2 (1977 to December 2007), OSHline (1998 to December 2007), Rilosh (1975 to December 2007), Healsafe (1981 to December 2007) and ROSPA (1980 to December 2007).

The search strategy was run without language restriction and is available in Appendix B (online), together with the numbers of papers returned for each step. When necessary, English translations of papers were obtained. The search returned a number of abstracts related to the hypotensive effects of medication and other medical causes of orthostatic hypotension. These articles were deselected at initial screening, as were other obviously non-relevant subjects. The flow of articles through the evidence review is shown in the flow chart at figure 2.

To ensure that the views of relevant parties were considered, a stakeholders' meeting was held to discuss the circumstances of harness suspension, the review methodology and the initial recommendations formulated from the work undertaken. The invitees included industrial training organisations and professional bodies concerned with fall arrest and rope access, union representatives, medical researchers and advisers, rescue services including the ambulance service and sport organisations, and colleagues from the Health and Safety Executive. A draft of the recommendations and guidance was circulated prior to the meeting. Discussion was encouraged, with feedback being actively sought from the invited stakeholders and taken into account in the production of the final recommendations and guidance.

RESULTS

The nine papers used as the basis for the recommendations in this review are listed with critical analysis in Appendix C (online). In all the papers reviewed that described experimental harness suspension, any subjects experiencing symptoms were laid in a horizontal position for recovery.[2–4 13 14] No paper described the effects of positioning a presyncopal, semiconscious or unconscious subject in a semirecumbent posture.

The harness types studied by various authors ranged from self-constructed rope chest harnesses (Desmaison harness) to body belts (a sling around the waist), sit harnesses and full body harnesses. Orzech *et al* found that the full body harness then chest harness were tolerated better than the body belt.[4] Other authors also comment on the problems of chest harnesses.[13–15] Some researchers used cardiac tilt table tests to investigate orthostatic effects in volunteers,[2 16] whereas others used motionless suspension in harnesses.[2 4 13–15 17] No papers were found that tested the effect of motionless harness suspension compared to harness suspension with the subject allowed to move.

Weber and Michela-Brundel investigated the effects of motionless suspension in three types of full body harness.[17] A regression equation was constructed, which explained 74% of the variation for duration with free hanging suspension. The most important explanatory variables were body weight, height, shoulder width and stomach girth. Madea provides a discussion of death occurring in head down suspension in a number of cases.[18] None of these were occupational, but nonetheless these illustrate that head down suspension is also a factor that needs to be remembered. It seems that head down suspension may be better tolerated than motionless head up suspension.[16 18]

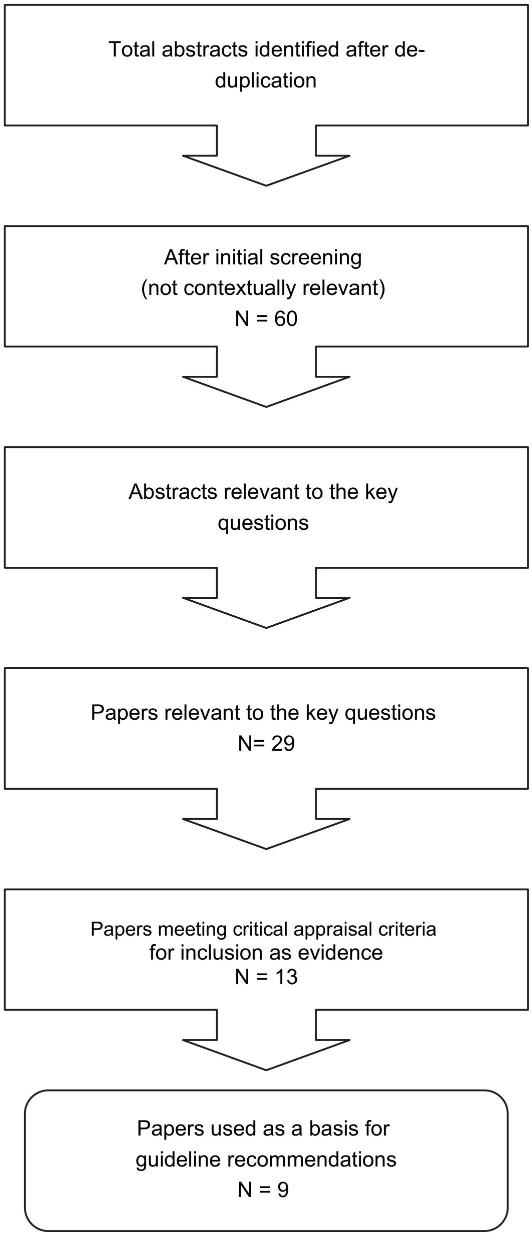

Figure 2 Flow of papers through the selection process.

Madsen *et al* demonstrated that head up suspension with the legs in an elevated position was better tolerated than with the legs dependent.[2] The symptoms most often reported by study subjects in harness suspension were lightheadedness, nausea, sensation of flushing, tingling and/or numbness of the arms or legs, and drowsiness in decreasing order of frequency with visual disturbance and anxiety in single cases.[3 4 17]

No systematic studies of the incidence of falls into rope protection were found, other than the mountaineering cases reported by Flora and Holzl in the 1950s–1970s.[8] However, in that study, information bias is likely with a more complete ascertainment of fatal than non-fatal falls. Only one death in this case series was reported to have a hanging time less than 2 h; the duration may have related to the ability of the victims to move. The majority of cases have confounding factors to account for their death that are not considered, including falls of 40 m in height before fall arrest; strangulation by the rope; and use of a rope tied around the chest, which caused paralysis of the arms and deep pressure furrows on post mortem signifying thoracic compression.

On the basis of the evidence that was currently available, the recommendations given in tables 1–4 (Appendix A, available online) were formulated to address the key questions posed.

DISCUSSION

There was no convincing evidence found of a distinct clinical entity of suspension trauma and the authors, therefore, prefer the term 'suspension syncope'. Figure 3 describes the sequence of events that may operate to result in syncope. Once syncope has occurred, the victim's airway may not be maintained and this will contribute to hypoxia, potentially being fatal. Failure to place an unconscious victim in the recovery position may result in death. The possibility of head injury or other causes of loss of consciousness must be considered and appropriate first aid provided.

There are no documented cases of syncope occurring with industrial fall protection and the available evidence suggests that supine positioning is appropriate. In practical terms this means the recovery position for non-traumatic patients, and a supine position with spinal immobilisation for those patients who have sustained traumatic injury in their fall.

If a victim were to be suspended and rescue delayed then positioning of the legs in an elevated position seems likely to be a useful measure to prolong tolerance without presyncope or syncope. Since the completion of this literature review, work has been published by Turner *et al* that examined the use of a passively deploying mechanism to elevate the legs during harness suspension.[19] Using this mechanism, suspension was tolerated for a mean of 58 min without any subjects experiencing presyncope, all withdrawals were due to discomfort. This finding, therefore, supports the recommendation to elevate the legs if immediate release of a conscious casualty is not possible.

This review of the medical evidence relating to harness suspension highlighted a number of gaps in knowledge and evidence, which may be suitable for future research. The question of the tolerance of vertical suspension in a harness while the subject is allowed to move the legs could easily be answered and is relevant to the industrial and sport settings. Further studies exploring the relationship of anthropometric data to harness suspension tolerance would build on the work of Weber and

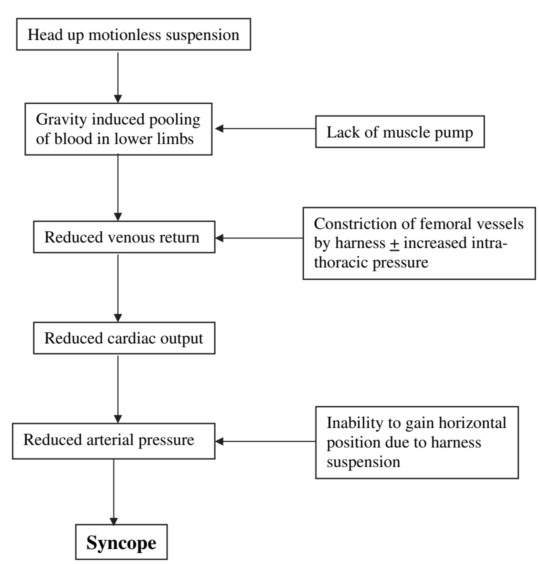

Figure 3 Proposed mechanism of suspension syncope.

Michela-Brundel,[17] and may lead to better harness design. The harness attachment point and, therefore, position on fall arrest, for example face forward or leaning back, may be important, and experiments have not assessed the physiological effect of an unexpected drop or fall into harness suspension.

The safety or the efficacy of positioning an unconscious or semiconscious victim in a semirecumbent position has never been investigated. The standard positioning for any 'fainting' or syncopal patient would be horizontal to resume venous return. Before anyone considers using a semirecumbent flexed knee posture as a recovery position for an unconscious or semi-conscious victim, the physiological effects should be studied, as the consequences of this could result in disability or death. One of the concerns that has been prevalent in the 'grey literature' and among those with an interest in the topic, has been a hypothesis that a volume of toxic pooled metabolites may re-enter the systemic circulation and overload the right heart on laying the suspension victim horizontal. The theories are akin to a crush injury or reperfusion injury post tourniquet release. This hypothesis remains speculative from the evidence obtained in the present review, but again would be amenable to study.

Finally, in view of the limited data on falls into rope protection, a standard format on a central recording system for fall events would provide incident figures that may allow a better understanding of the contributory factors.

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Contributors AA: study design, critical appraisal, main author, project lead, guarantor; CL: study design, critical appraisal, coauthor; KP: study design, coauthor.

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