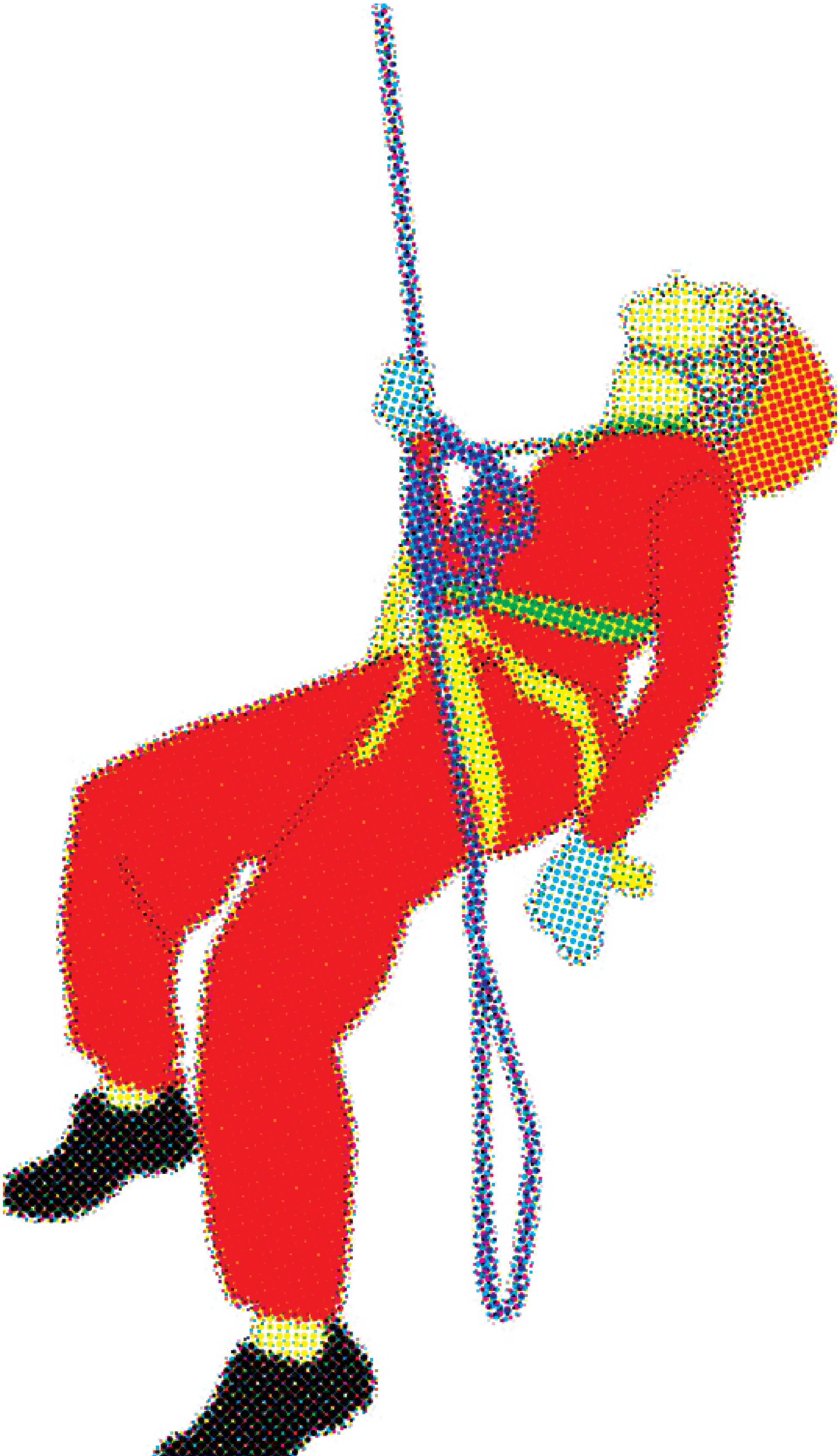
Nylon Highway

Issue #56



... especially for the Vertical Caver

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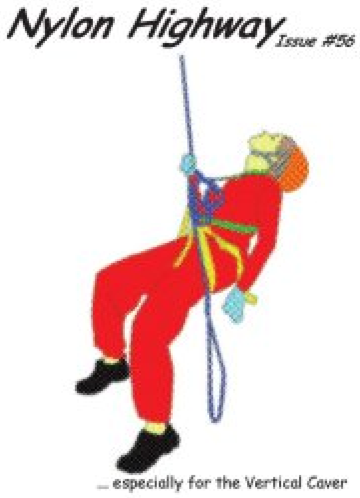

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Nylon Highway

Dick Mitchell .... Chair
14111 Sun Blaze Loop, Unit A
Broomfield, CO 80023

Terry Mitchell .... Vice-Chair
4207 Brant Drive
Springdale, AR 72762

Bill Boehle .... Secretary/Treasurer
1284 Lower Ferry Road
Ewing, NJ 08618-1408

Miriam Cuddington .... At-Large
109 Beacon St.
Moulton, AL 35650-1801

Rory Tinston .... At-Large
23 Goehring Curve
Blauvelt, NY 10913

Tim White .... Editor
2830 Olde Savannah Cove
Suwanee, GA 30024

Bruce Smith .... Education Coordinator
6313 Jan Lane Drive
Harrison, TN 37341-9419

Bill Cuddington .... Vertical Contest Chairman
109 Beacon St.
Moulton, AL 35650-1801

Terry Clark ...... Vertical Techniques Workshop Coordinator
7124 Cairo Dixie Road
Corydon, KY 42406-9735

Please send articles, art, exchange publications and other material for publication in the Nylon Highway to:
Tim White
2830 Olde Savannah Cove
Suwanee, GA 30024
e-mail: southeast@ncrc.info

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Bill Boehle
(609) 771-6969
1284 Lower Ferry Road
Ewing, NJ 08618-1408
e-mail: wfboehle2@comcast.net

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REVIEW ARTICLE

Risks and Management of Prolonged Suspension in an Alpine Harness

Roger B. Mortimer, MD

From the Department of Family Medicine, UCSF-Fresno Medical Education Program, University of California at San Francisco, Fresno, CA.

Suspension trauma is a state of shock induced by passive hanging. Those who survive passive suspension are at risk for rhabdomyolysis. In a wilderness setting, one can see this in cases of persons suspended on rope by their harness. In a conscious person, leg movements work the venous pump to return blood to the central circulation. In the person passively hanging, blood pools in the legs leading to hypoperfusion of vital organs. In the experimental setting, passive hanging has led to unconsciousness in a matter of minutes. Based on a previous series of deaths on rope that included 7 after rescue, many authors have recommended nonstandard treatment for shock including keeping rescued patients upright or squatting for 30 minutes prior to laying them down. This recommendation assumes that sudden death is a risk from acute volume overload or exposure to waste products in the returning blood. This suggestion is not supported by the original series that demonstrated sudden deaths after rescue nor by modern understandings of physiology. Search and rescue teams and party members assisting a colleague suspended unconscious on rope should follow standard resuscitation measures to restore circulation to vital organs immediately.

Key words: shock, orthostasis, vasovagal, harness, rhabdomyolysis, suspension trauma

Introduction

Harness suspension is an accepted and necessary part of rock climbing, ice climbing, mountaineering, canyoneering, and caving, and many industrial applications. The harness provides a soft interface with a life-supporting rope in actual or potential high-angle environments. In the event of a fall or loss of consciousness, the harness maintains attachment to the rope allowing the person to climb again or be rescued (see Figure 1). While remaining suspended and unconscious is preferable to falling, it has its own risks and management issues.

The idea of suspension trauma, shock leading potentially to death, induced by hanging passively in a harness, has been around for many years. It has been variously called orthostatic intolerance, harness pathology, and harness hang syndrome. Suspension trauma has become the most common name despite the lack of true trauma in most cases. Terms using the word harness ought to be avoided because, as will be discussed, it is not really the harness that is at issue.

Suspension trauma has been described independently several times. Early autopsies of persons who died on rope in Austria and Spain found minimal trauma and concluded that they had died of shock.[1–3] The medical commission of the French Federation of Speleology also studied reports of cavers who died on rope.[4] Originally they felt that the cavers died of hypothermia as 10 of 12 cases were in pits with water coming down, but several lost consciousness too quickly to have been caused just by hypothermia.[4] American caving casualties are similar.[5–11] American mountaineering cases are less clear.[12–14] The French tried to replicate the circumstances in a lab setting by instructing the participants to act as if unconscious while suspended on rope. Their first 2 participants became unconscious in 7 and 30 minutes.[4,15] They stopped to reconsider their protocol. Taking it up again 2 years later in a monitored setting in a hospital, another participant lost consciousness after 6 minutes. They concluded that hypothermia was not the sole cause of death of these cavers.[4,15]

Corresponding author: Roger B. Mortimer, MD, Department of Family Medicine, UCSF-Fresno Medical Education Program, 155 N. Fresno Street, Fresno, CA 93701-2302 (e-mail: rmortimer@fresno.ucsf.edu).

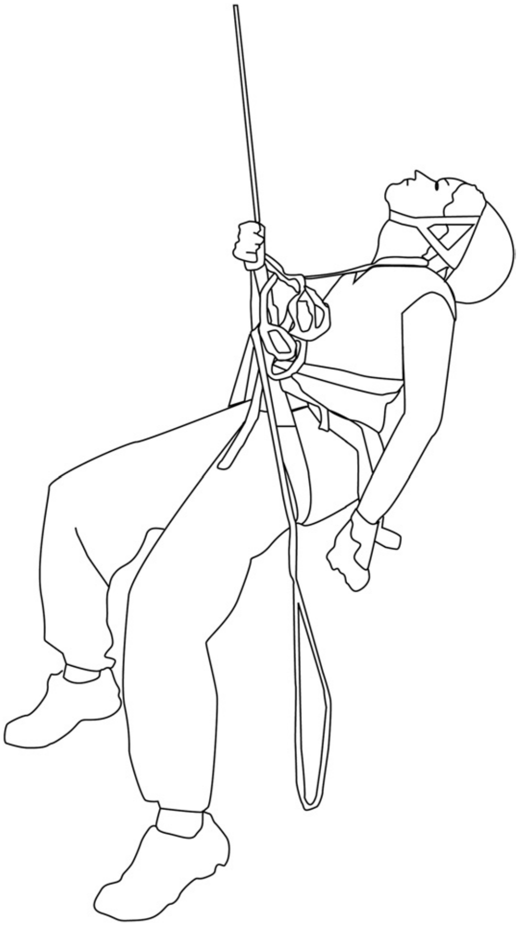

Figure 1. Passive Hanging on Rope.

Others have approached suspension trauma from a military or occupational point of view. Orzech et al, studying parachute harnesses, had 1 individual become unconscious after 6 minutes in a body harness.[16] Damisch and Schauer[17] performed 46 suspension tests in various harnesses for up to 10 minutes. No one lost consciousness but 2 wearing chest harnesses alone had to be lowered without detectable blood pressure in 5 and 9 minutes.[17] Madsen et al[18] did a series of 69 persons, not suspended in harnesses, simply lying down on a tilt table at 50°, supported by a bicycle seat. Each was instructed to abstain from movement. These participants experienced presyncopal symptoms (nausea, lightheadedness, or feeling hot) or signs (pallor, bradycardia, or hypotension) in a median of 27 minutes. This strongly suggests that passive suspension is the risk, not the harness.

Anyone roped into a harness in a vertical environment is at risk, but some have higher risks. In general, people tolerate alpine-type sit harnesses better than full-body harnesses, which are better than chest harnesses alone, which are much better than simple waist belts.[16,19–21] Intolerance of chest harnesses and waist belts is more an issue of pain and respiratory compromise than of suspension trauma per se.[19,22] Any condition that decreases central volume prior to suspension, such as dehydration or hypothermia, increases risk.[23] Support under the knees that elevates the legs seems to protect.[18] Gender does not affect risk, but increased weight has lead to decreased mean arterial pressure in the lab setting.[24] Though unlikely to be used in the wilderness environment, industrial-use full-body harnesses with attachments in the back delay suspension trauma longer but do not completely prevent it.[24] For issues related to industrial applications of harnesses, the reader is referred to the review by Seddon.[25]

Pathophysiology

At the 2nd International Conference of Mountain Rescue Doctors in 1972, the underlying physiology was first propsed.[1–3,26,27] Patscheider found little trauma in those who died on rope and concluded that they had died of shock.[1] Similarly, Toledo y Ugarte found no significant trauma but did find lower body plethora in a victim who died on rope.[3] In the normal person, venous return happens through muscular contractions forcing blood through the one-way valves of the lower extremity veins. This venous pump is disabled in the motionless patient while arterial flow continues. Subsequent work shows that suspension leads to decreased involuntary small muscle contractions normally used to maintain blood pressure when upright.[28] Failure of the venous pump leads to pooling of blood in the legs with decreasing central volume as demonstrated by enlarging thighs,[24] decreasing heart size,[27,28] decreasing stroke volume,[28] decreasing glomerular filtration rate,[26] and increasing transthoracic impedance.[18] Once capillary pressures rise, significant fluid can leak into interstitial spaces, decreasing total intravascular volume.[29] With decreasing stroke volume in a hyperautonomic state, the person becomes subject to the Bezold-Jarisch reflex, which triggers decreased heart rate and blood pressure.[30]

Adaptive reflexes can be pathological in the artificial situation of hanging motionless. In normal circumstances, acidosis from anaerobic metabolism decreases vascular resistance.[31] Decreased resistance usually leads to increased blood flow with concomitant increases in available oxygen and nutrients along with removal of waste products. In the motionless hang situation, increased flow sequesters even more blood in the periphery.

Central hypovolemia eventually leads to fainting. The vasovagal response to poor circulation normally returns one to a horizontal position, which improves blood flow

Table 1. Survivors after prolonged suspension on rope

Activity	*Age/gender*	*Time on rope*	*Outcomes*	*Reference*
Rappelling	26/M	1.5 hours	Nerve damage from chest harness, acute renal failure	34
Mountaineering	25/M	0.5 hour	Nerve damage from chest harness	34
Mountaineering	19/M	20 minutes	Nerve damage from chest harness	34
Mountaineering	28/M	2 hours	Nerve damage, acute renal failure	34
Mountaineering	31/NA	15 minutes	Nerve damage, acute renal failure	34
Mountaineering	43/NA	10 minutes	Minor trauma	34
Mountaineering	20/NA	5 minutes	Minor trauma	34
Mountaineering	36/NA	15 minutes	Minor trauma	34
Mountaineering	47/NA	1 hour	Nerve damage, hematuria	34
Mountaineering	28/NA	5 minutes	Minor trauma	34
Mountaineering	30/NA	3.5 hours	Shock	34
Mountaineering	24/NA	20 minutes	Minor trauma	34
Mountaineering	24/NA	20 minutes	Minor trauma	34
Caving	28/M	2 hours	Unknown	5
Caving	29/M	5–6 hours	Rhabdomyolysis, nerve damage	8
Caving	42/M	$<$ 5 hours	None	8
Caving	18/M	4 hours	Rhabdomyolysis	9
Mountaineering	25/M	1 hour	Major trauma	12
Mountaineering	18/M	Unknown	Nerve damage	14

N/A, not available.

to the brain. Soldiers at attention fainting on the parade ground are classic examples of this—once they are down they rapidly regain consciousness. The suspended person, however, can fall no farther—decreased heart rate and blood pressure from increased vagal tone simply results in yet more catastrophic flow reduction.

In the experimental setting, one sees evidence of increasing sympathetic tone followed by a parasympathetic response. Increased sympathetic tone leads to increased heart rate to compensate for decreasing volume. Pulse pressure narrows. Finally, blood pressure decreases either as a result of the decreased available volume, or more catastrophically from a vasovagal response including bradycardia. Symptomatically, patients report nausea, lightheadedness, and flushing.[4,16,17,19,21] Madsen et al report that half of their 69 tilt-table patients were presyncopal within 27 minutes, with pulses between 30 and 57 beats per minute.[18]

While likely multifactorial, the fainting response may be partly due to the Bezold-Jarisch reflex.[30] This reflex is mediated by receptors in the posterior left ventricle that sense volume. At normal volume, they fire tonically to control blood pressure. As volume decreases, they fire less to allow vasoconstriction. When stroke volume decreases dramatically, they fire more resulting in bradycardia, vasodilation, and hypotension. This reflex has been blamed for bouts of hypotension and bradycardia and even asystole in patients having shoulder surgery in a sitting position, not that far removed from the tilt-table experience.[32] The reflex can be demonstrated in an animal model by ligating the inferior vena cava.[33] Once volume is sequestered peripherally, receptor cells abruptly fire more and blood pressure and heart rate drop. When the occlusion is released and volume returns, the receptors fire less, and vital signs return towards normal.

Once off rope, several outcomes have been observed. Most recover uneventfully. Some have had sub-acute sequelae like rhabdomyolysis and renal failure.[34] Of 19 long-term survivors, 3 suffered from renal failure, 1 had hematuria, and 2 others had rhabdomyolysis without renal failure (see Table 1). Long-term stasis eventually leads to muscle cell necrosis with release of myoglobin, in turn leading to renal failure by a variety of mechanisms.[35]

More concerning are the reports of those who were alive after rescue but died soon thereafter. Flora and Holzl[34] accumulated a series of 10 deaths associated with prolonged suspension, of whom 7 died after rescue.[34] One survivor died 11 days after rescue from renal failure, diagnosed as a crush syndrome on autopsy. Six others died from a few minutes to 32 hours after being rescued. French and American caving accident reports document 3 other initial survivors, 1 of whom died immediately after rescue.

There may be some overlap of suspension trauma with compression asphyxia in which death is caused by inadequate ventilation from outside constriction.[36] Suspension in a chest harness alone does lead to decreases in forced vital capacity, heart rate, blood pressure, and cardiac output. These changes are not observed in participants wearing a sit harness.[22] So cases in a chest harness alone may include a degree of compression asphyxia. But as Patscheider notes, many of the victims in the Austrian series in chest harnesses alone were still able to call out while suspended.[1] Orzech et al[16] also noted breathing difficulties only in those suspended by a body belt alone and not in those suspended in a chest harness or sit harness.[16] In the 12 French cases reported by Bariod that launched their search for a cause of quicker than expected deaths on rope, only 1 was suspended in a chest harness after he undid his attachment with his sit harness.[4] Airway constriction itself is unlikely given the hyperextended position of the neck in passive hanging in a harness (see Figure 1). So restricted breathing may play a part in deaths on rope, but is unlikely to contribute much to those cases in sit harnesses.

Some have suggested that the sequestration of blood is due to a tourniquet effect from the harness.[37–39] This seems unlikely for several reasons. Orzech et al[16] found similar effects despite multiple harness types and fits, as did Nelson.[19] The phenomenon has been seen when no harness was involved.[40–42] Climbers routinely spend an entire day in a harness and can be suspended for hours at a time. Although this can be very uncomfortable, it has not proved dangerous while the climber is conscious, despite the same constriction of the harness around the legs. In the 2 cases of immediate death after rescue, neither person was using a sit harness, so removing such a harness had nothing to do with these 2 deaths. Most importantly, in alpine style harnesses with front attachments there is no compression of the anterior thighs where the femoral veins return blood to the core circulation (see Figure 2).

The pathology of suspension trauma is not absolutely clear. Other factors that can help precipitate an accident, such as drugs and alcohol, can worsen maladaptive responses. Especially in the early cases where no sit harness was used, respiratory function can also be compromised in the unconscious person on rope. What does seem clear is that passive suspension does lead to sequestering of volume in the periphery, hypotension, bradycardia, and, in the worst cases, death. Survivors are at risk for rhabdomyolysis and renal failure.

Management

The most critical part of suspension trauma management is to get the unconscious person down from the suspended position. This might mean lowering a belayed person down or raising someone up to anchors. The best approach is to rig in such a way that little rerigging is necessary to move the patient. A belayed person can usually be lowered immediately using the belay device itself, though in certain situations it may not be possible to lower them to within reach. A self-belay device prevents an unconscious rappeller from crashing but leaves them unconscious on rope. The more common scenario is someone climbing a fixed line who becomes injured,

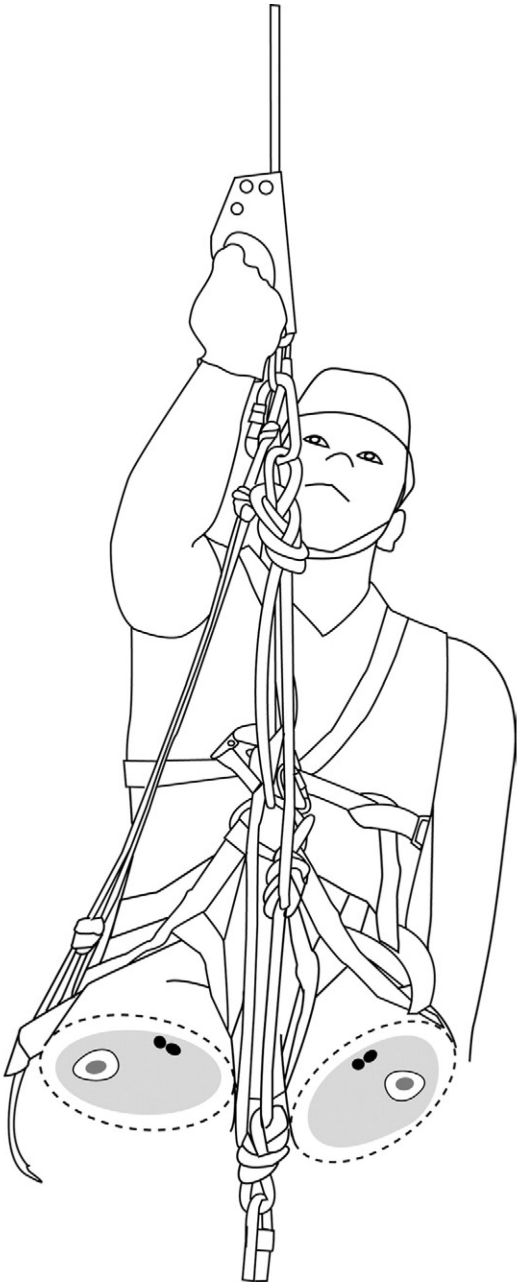

Figure 2. Leg vessels in relation to harness straps.

cold, or exhausted from poor equipment or poor technique. It is much more difficult to deal with the person stuck on a fixed line. It is best to leave adequate rope at the top of the drop to quickly create a hauling system and bring them up, or if prepared with the skill and equipment to mitigate the situation, to go down to the patient to help. For training situations, ropes should be rigged to lower anyone experiencing difficulty immediately. In extreme cases, it may be necessary to climb or descend to the person on rope, transfer them to one's own harness or to a lowering device fixed on the rope, and lower them to the ground.[43,44] This type of on-rope pick-off requires training and constant practice to do efficiently.

Once off the rope, medical management is less clear. No one disputes the standard need to address airway and breathing. Restoring pooled blood into the central circulation is more controversial. In almost all cases of shock, one ought to lay patients flat if not raise their legs to encourage blood flow to the heart and brain. This was successfully done in the lab by Orzech et al,[16] Madsen et al,[18] and Stuhlinger et al.[26] But as early as 1972, Patscheider suggested avoiding placing a patient "abruptly" in a horizontal position and other presenters at the same conference called for them to be placed in a squatting position.[1,45] This call is echoed by Seddon[25] and others citing Seddon.[38,40,46]

These authors cite a concern for what has been termed "rescue death." This seems to be in response to the Flora and Holzl's series of 10 deaths on or soon after hanging on rope.[34] At least 3 of the 7 who were rescued had a normal mental status up to the time of death.[34] Table 2 summarizes known cases of persons who survived a suspension but subsequently died. The most striking is the 23-year-old who died within minutes of being rescued. Her autopsy revealed no significant trauma.[2] She also was suspended for 4 hours in a chest harness, longer than many who died on rope prior to rescue (see Table 3), putting in question whether the timing of her death had anything to do with her rescue or simply the consequence of the long time she spent suspended.

A second concerning case comes from *American Caving Accidents*.[11] A male caver got stuck on rope. He was wearing a chest harness only. Help arrived after 4 hours; however, he died suddenly when released from his chest harness. It is unclear if he was conscious or not on rescue, or whether an autopsy was done. What is worth noting is that in both these cases of the person dying postrescue, it was after 4 hours and in both cases they wore chest harnesses only, so "releasing toxins" by removing a sit harness played no role at all.

Explaining these postrescue deaths is difficult. Pulmonary embolism fits the clinical presentation of sudden death, especially after a period of stasis, but Patschieder found no evidence of clots or other mechanical obstruction in his autopsy series.[1] Blaisdell has shown evidence of fibrin-platelet aggregates in the lungs after reperfusion of ischemic limbs, but this causes a more medium-term inflammatory reaction and not immediate death.[47] Most people have focused on cardiac dysrhythmia because of the sinus arrhythmias and premature ventricular contractions (PVCs) noted on EKG after experimental patients were laid down by Stuhlinger et al.[26] Others, however, note PVCs while the participants were suspended, making it hard to blame the act of laying down.[16,21] Cardiac arrest is a plausible cause of the sudden deaths after rescue from hanging on a rope, but the link to timing after rescue is tenuous.

Several have blamed an acute volume overload for causing cardiac arrest once someone is laid down.[25,38] Acute volume overload in healthy dog hearts increases T-wave alternans, a marker for sudden cardiac death, but so does increased sympathetic tone, which would be

Table 2. Survivors of suspension who died after rescue

Activity	*Age/gender*	*Time suspended*	*Time to death after rescue*	*Autopsy*	*Reference*
Caving	17/M	Unclear	5 hours	No	4
Caving	NA/M	"Rapidly"	20 hours	No	4
Mountaineering	25/M	3 hours	11 days	Rhabdomyolysis	34
Mountaineering	18/M	6.5 hours	1.5 hours	Unknown	34
Mountaineering	24/F	7 hours	32 hours	No	34
Mountaineering	21/M	4 hours	2 hours	No significant trauma	34
Mountaineering	33/M	3 hours	19 hours	Not available	34
Mountaineering	23/F	4 hours	"Few minutes"	Circulatory collapse	2, 34
Mountaineering	19/	8 hours	17 hours	Not available	34
Caving	NA/M	4 hours	Minutes	Not available	11

NA, not applicable.

Table 3. Deaths occurring while suspended on rope

Activity	*Age/gender*	*Time to death*	*Autopsy*	*Reference*
Training	25/M	6 minutes	No	18
Mountaineering	18/M	> ½ hour	Plethora of lower vena cava	3
Mountaineering	17/M	24 hours?	Not available	34
Mountaineering	19/M	½ hour	Not available	34
Mountaineering	25/M	2 hours	No	34
Caving	15/M	< 2 hours	No	4
Caving	NA/M	20 minutes	No	4
Caving	NA	< 1 hour	No	4
Caving	~50/M	Unclear	No	4
Caving	24/M	Unclear	No	4
Caving	NA	Unclear	No	4
Caving	NA	< 1 hour	No	4
Caving	25/M	Unclear	No	4
Caving	20/M	Unclear	No	4
Caving	23/M	Unclear	No	4
Caving	29/M	Unclear	"Hypothermia"	10
Caving	26/M	> 2 hours	"Hypothermia"	6
Caving	28/M	Unclear	No	7
Mountaineering	18/M	2–3 hours	"Asphyxia by hanging"	14
Mountaineering	16/M	35 minutes	"Suffocation caused by aspiration"	13

NA, not applicable.

present in all these patients recovering from shock.[48] Mechanical stretch in the context of regional ischemia increases arrhythmic potential, but not when hypoxia is global as would be the case in these young, healthy mountaineers.[49] Realistically, survivors of suspension will be hypovolemic or euvolemic. Laying them flat will at best reinflate shrunken ventricles back to normal size. In Oberg and Thoren's cat experiments, restoring central circulation by unoccluding the inferior and superior vena cavas stopped the Bezold-Jarisch reflex; it did not provoke it.[33] The most likely scenario is that those who died after rescue died despite rescue, not because of it.

Some blame the nature of the returning blood for sudden cardiac changes, but this seems unlikely except in extreme cases. There is no doubt that suspension trauma can lead to rhabdomyolysis and eventual renal failure (see Tables 1 and 2). In the free-hanging mountaineer there is no crushing of muscle. Muscle damage will occur from inadequate perfusion from stasis. Muscle is tolerant of 3 to 4 hours of hypoxia prior to breaking down.[47,50] This is reflected in the clinical experience of earthquake victims in whom crush syndrome is rare prior to 3 hours.[51] Table 1 demonstrates that survival was rare after 3 hours of suspension on rope. Table 2 shows much longer suspension times in those who died.

Lab data being sparse for suspension cases, it is worthwhile looking at some crush data from which one can infer issues to expect after suspension. The most concerning blood component after release from crush or suspension is potassium from muscle cell leakage. Allister reports on a case of a man with legs crushed for 8 hours who went into cardiac arrest an hour after release.[52] Prearrest his pH was 7.15 and during resuscitation his potassium 8.0 mEq/l with peaked T-waves. He was successfully treated with bicarbonate and insulin with glucose. Brown and Nicholls report 2 cases of crush with potassiums of 6.3 and 8.8 on arrival to hospital.[53] Gunal et al, however, report a series of 16 crushed patients treated with saline and bicarbonate in the field with only 1 hyperkalemic patient but 9 hypokalemic ones.[54]

Blood returning from a hypoxic leg will be acidotic. When a leg is tourniqueted for orthopedic surgery, venous pH changes to 6.9 after 2 hours.[55] While this sounds concerning, it is a common anesthetic procedure, done many times a day with no complications beyond a few minutes of hyperventilation. Moreover, while acidosis may transiently depress cardiac contractility, it has little to no effect on rhythm.[31] Thus, pH changes are not likely to be the cause of sudden death.

In crush cases, shock will complicate care soon after release. Once an ischemic limb has regained blood flow, it becomes edematous, removing intravascular volume.[50]

Studies of ischemic limbs demonstrate increasing postflow edema with worsening ischemia.[47] Restoring good circulation early will limit the further loss of volume into the interstitium.[47] This means laying the patient down as soon as possible to restore flow of oxygenated blood to damaged muscle. Keeping a suspension survivor upright will simply worsen muscle damage and worsen shock in a patient already in shock.

Seddon also recommends removing the harness slowly.[25] This is akin to the recommendations of some to place a tourniquet on crushed extremities prior to removing the crushing debris, then loosening it slowly. For the reasons stated above, it is not the harness itself that is the problem. Many have worried about the best way to remove a harness to mitigate any release of toxins to the rest of the body. Since it is not the harness itself preventing blood flow, it really matters little when it is loosened or removed. Comfort and transport issues should dictate this rather than any concern for resuscitation.

It seems likely that any risk of sudden cardiac death comes from the hypoxic damage to the heart itself. Risk from sudden volume overload is only theoretical. Myoglobin may cause medium-term renal failure, but neither it nor acidosis will cause sudden cardiac death. Elevated potassium does seem to be a real risk, but avoiding it, if it truly can be avoided, requires keeping a person in an upright position that will continue hypoperfusion of the brain and other vital organs and worsen subsequent shock once hypoxic limbs are reperfused.

The advice to keep upright for 30 minutes ignores the fact that most of Flora and Holzl's post-rescue deaths occurred much later than 30 minutes. Flora and Holzl's case in which death occurred within minutes was in the person who had a very long suspension time.[34] The caving case has fewer details but also occurred after 4 hours of suspension. The evidence of prompt resuscitation in controlled environments and a better understanding of the physiology involved argue against any recommendation to keep a victim of suspension trauma upright.

Table 4. Basics of management

1. Remove the person from the rope
   a. Be sure the scene is safe or mitigate the situation
   b. If patients can cooperate, have them move their legs and raise them up until they can be lowered
2. Lay the patient flat and start standard advanced life support protocols
   a. This should not be delayed waiting for any other supplies
   b. Airway, breathing, circulation, etc.
   c. Hypothermia prevention
3. Oxygen, monitoring, intravenous fluid as available (alternate saline and half-normal saline with added bicarbonate)
4. Remove the harness if preferable for evacuation
5. Transport. If suspended passively more than 2 hours, transport to a facility capable of dialysis

All agree that immediate rescue is critical with attention to scene safety, airway protection, and breathing (see Table 4). Once on the ground, the evidence supports standard measures to restore adequate circulation to the brain and other critical organs. Assess all patients for further injuries and then protect them from the environment. Standard advanced life support (ALS) guidelines should be followed.[56]

The original recommendations of Patschieder, Flora, Holzl, and others to avoid laying the patient down was echoed by Seddon in his extensive review of the literature.[25] Following this recommendation, though, puts the patient at continuing risk of shock from pooled blood remaining in the legs. Not laying a person down is a choice of avoiding a theoretical risk of cardiac arrest in favor of an ongoing and certain risk of hypoperfusion and hypoxia. Having an unconscious patient sitting up simply replicates the head up, feet down position that caused the problem to start with, which Madsen et al have demonstrated requires no harness.[18] Some have started to question the evidence for the original recommendation.[57] More recently, Britain's Health and Safety Executive performed an evidence review after searching multiple databases for cases or studies. After their systematic review, they concluded that there was evidence for syncope after head-up passive suspension but no evidence against standard resuscitation measures. Thomassen et al did an independent review of the issue and came to the same conclusion.[56] Health and Safety Executive has since stated that there is insufficient evidence for their original recommendation and that standard first aid practices should be followed.[58] Just as no one would recommend keeping the fainted soldier upright to keep sequestered blood from returning to his heart too soon, no one should recommend keeping the unconscious suspension victim in shock.

Once measures are available, aggressive fluid resuscitation is indicated to correct volume status and prevent renal failure from rhabdomyolysis in cases of extended passive hanging. In crush situations, one can attempt IV hydration prior to rescue. In the wilderness context, the first priority is to get the patient down. Once down, the patient should be bolused with isotonic saline as soon as feasible followed by hypotonic saline with added bicarbonate.[59] Avoid potassium use until labs demonstrate that it is needed. Anyone losing consciousness on rope should get medical evaluation, if for no other reason than to find out why consciousness was lost. Anyone suspended for a substantial time should be transported to a facility capable of dialysis.

Flora and Holzl's series,[34] with 7 out of 10 dying soon after rescue, is disturbing. Sudden cardiac death seems like a real possibility, but from previous hypoxia or current hyperkalemia, not sudden volume overload. Once available, cardiac monitoring is critical and cardiology consultation appropriate for any rhythm disturbance, with possible use of beta-blockers as prophylaxis of sudden cardiac death.[60]

Prevention

In the industrial setting, a hanging person can more easily self-rescue and is much more likely to have other workers present who can accomplish a rescue quickly. In the wilderness setting, rescue is often more difficult. The climber, caver, or canyoneer is much more likely to be in a small group with difficult access to someone isolated on rope. Having the personal ropework skills to resolve real or potential problems is primary. Rigging to avoid hazards like waterfalls or rock or ice fall zones is critical.

Another aspect of prevention is at the level of small party organization. This dynamic may vary widely depending on situation. What is the ratio of experienced to new persons on a trip? Who will climb first? Who will climb last? Does the first person to climb a fixed rope have the skills and gear necessary to effect a rescue from above if needed? What communal gear that might aid such a rescue is appropriate and who should carry it? How does one balance rest and rehydration versus risk of hypothermia while waiting to climb in a cold environment?

Once someone is stuck on rope, rescuers have the option of raising them, lowering them, or going to get them.[61] Whenever possible, one should rig in such a way that allows flexibility in response, eg, leaving extra rope at the top of a fixed line instead of lying at the bottom of a pit or canyon. This gives team members an easier way of creating a haul system to raise a stranded person or rappel down to assist. Instead of hard anchoring a fixed line, one can use a rope tied off in a rappel device so that an impaired climber can be easily lowered. Nonetheless, even with the best preparation and rescue technique, persons passively suspended on rope long enough may develop shock symptoms.

Climbers in a harness for a prolonged time should work on flexing their legs to pump venous blood.[56] An etrier will allow climbers to stand up in situations where they would otherwise be hanging for a long time such as during a prolonged rappel or for someone serving as a litter attendant during a prolonged extrication. Elevating the legs will decrease dependence on the venous pump. Madsen et al[18] found that adding a strop beneath the knees during a simulated vertical lift made suspension tolerable to 60 minutes for 8 of 9 participants.[18] Someone in a prolonged suspension situation who felt at risk could improvise something similar with available cordage.

Leg elevation and leg use are also important to avoid iatrogenic suspension trauma in patients being rescued. Rescues involving a torso strop should incorporate the under-the-knees strop as well. A patient in a litter should be kept flat as much as possible and encouraged to use leg muscles as much as is safe. In an evacuation with any chance of the litter being put into a vertical or even semivertical position, a foot loop should be supplied for each nonbroken leg for patient comfort but also to give the patient something to push against to maximize the venous pump. In an unconscious person who will need to spend prolonged time in a vertical position during rescue, shock trousers may be indicated.

Conclusions

Some have questioned the existence of suspension trauma.[39] It is clear though that persons suspended limp in a harness can die more quickly than expected and with no significant trauma. Suspension experiments demonstrate how this can happen. This is a shock syndrome in its early phase complicated by rhabdomyolysis in its late phase survivors. The shock is secondary to failure of the venous pump to return sufficient volume to central circulation in someone limp or inactive. The harness itself is not to blame.

Treatment starts with immediate rescue of a suspended person. Standard ALS procedures apply. Time suspended should not change the immediate response. Earlier recommendations to keep someone upright after rescue are not compatible with the acute need to restore central circulation. Oxygen and immediate intravenous fluid administration to prevent crush syndrome is appropriate but should not delay rescue.

Early work on this in the nonmedical and the non-English medical literature has kept it out of the medical eye. Despite this, suspension trauma and the recommendations on how to manage it have been prominent in occupational and search and rescue circles. Unfortunately, the lack of a modern medical perspective has led to a continuation of recommendations that are inappropriate. The concern for provoking "rescue death" has even led to purposeful delays in getting a person to ground and instituting treatment for shock.[8] Unless some day an appropriate animal model demonstrates the contrary, standard resuscitation measures should be used.

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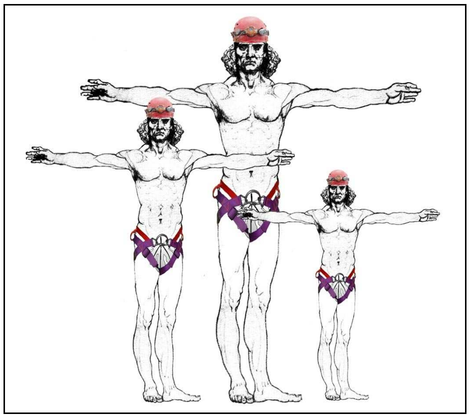
Typecasting The Vertical Caver - Part II

Preliminary results of the Mitchell Ascending System ergonomic tests

By John Woods   NSS # 10503



I began to conduct body type tests when my research failed to find significant testing that treated the human body as a mechanical part of an ascending system. My first efforts were directed at the Frog System because I felt that even a "universal" system should be reconsidered if it hindered a specific individual. A different system could increase the personal effectiveness of that individual and subsequently of any group they are with. Although it is impossible to separate the practical use of ascending systems from the types of caves where they are used, I have attempted only to test the interaction of human bodies within those systems. I treat the human body as a machine built of levers, drive trains, structural strengths and weaknesses and having a finite power source. I do NOT advocate that any particular ascending system is the best system or that my testing is in any way definitive.

The first body type tests (Typecasting the Vertical Caver Part 1)

My first tests with the Frog system indicated that certain body characteristics dramatically altered its effectiveness. These attributes of the Frog System cannot be altered without changing the system itself. The main body characteristics affecting the system are listed in *approximate* descending order:

1. Arm length plus torso length that limits potential stroke via the safety tether length.
2. Overall height and body proportions.
3. Chest depth: The distance directly through the body from sternum to backbone.
5. Weight distribution top-to-bottom (top heavy or bottom heavy people).
6. Leg length.

In short, the Frog System significantly favors tall, slender cavers with long torsos, long arms and chests of small depth. Details of these tests may be found in "Typecasting The Vertical Caver" in Nylon Highway #53 and at:
http://www.caves.org/section/vertical/nh/53/Typecasting.pdf

The Mitchell Ascending System

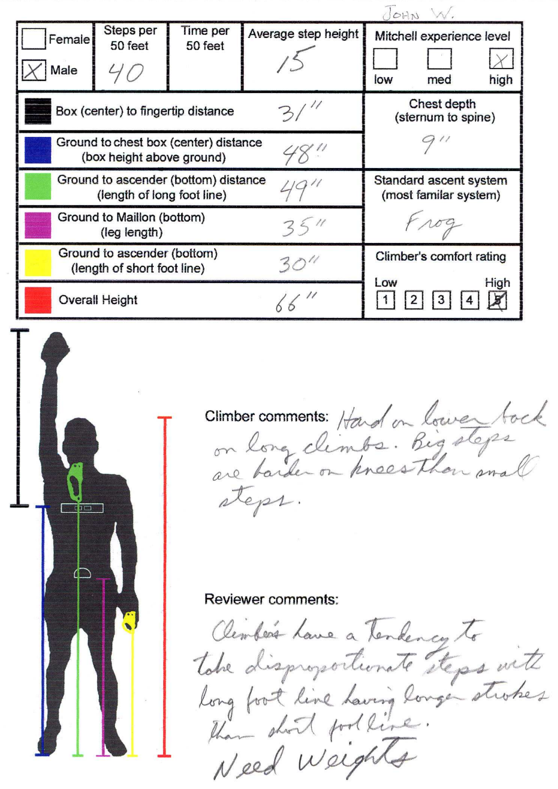
Being primarily an American ascending system, a brief description of the Mitchell may be helpful to some readers. Details on its effectiveness for Alpine SRT and a side by side comparison to the Frog system may be found in the article: "Comparisons of the Frog and Mitchell ascending systems for crossing common mid-rope obstacles" in Nylon Highway #53 and at: http://www.caves.org/section/vertical/nh/53/MitchvsFrogPart2.pdf

Fig. 1 The Mitchell ascending system, right handed setup. Sewn foot loops are shown, but rope loops may be used. This illustration shows the safety tether attached to the lower ascender, but either ascender may be used. Cowtails are not essential to ascending, but are included as essential vertical caving gear.

The Mitchell System requires two ascenders (handled or non-handled) and a double roller chest box (See Figure #1). The upper ascender is located directly above the roller box with a rope line running through one roller to the corresponding foot. The main climbing rope runs through the other roller. The lower ascender is located below the roller box at the limit of easy reach, with a rope line running to the corresponding foot. A safety tether must be used from at least one ascender to the sit harness. A ropewalking (alternating foot - stair-step) motion is used to ascend. The ascenders are moved up the rope manually.

A brief summary of test results

Since a lot of cavers insist on getting directly to the bottom line (and then arguing about it forever on Cave Chat): *The upright ropewalking motion of the Mitchell System produces a dramatically different interaction between the human body and the system compared to the sit-stand motion of the Frog System.* Arm, leg, torso length and other body proportions are relatively unrelated to climbing efficiency as indicated by the average step height. Conversely, greater overall height seems to have a very slight inverse effect with taller climbers taking smaller steps relative to their height than shorter climbers. In effect, Mitchell climbing efficiency is relatively independent of body types compared to the Frog System. Body type can however, significantly affect climber comfort (see below).



JOHN W.

☐ Female ☒ Male	Steps per 50 feet 40	Time per 50 feet	Average step height 15	Mitchell experience level ☐ low ☐ med ☒ high

⬛ Box (center) to fingertip distance	31"	Chest depth (sternum to spine) 9"
🟦 Ground to chest box (center) distance (box height above ground)	48"	
🟩 Ground to ascender (bottom) distance (length of long foot line)	49"	Standard ascent system (most familar system) Frog
🟪 Ground to Maillon (bottom) (leg length)	35"	
🟨 Ground to ascender (bottom) (length of short foot line)	30"	Climber's comfort rating Low High ☐1 ☐2 ☐3 ☐4 ☒5
🟥 Overall Height	66"	

Climber comments: Hard on lower back on long climbs. Big steps are harder on knees than small steps.

Reviewer comments:

Climber's have a tendency to take disproportionate steps with long foot line having longer strokes than short foot line.

Need Weights

Fig. 2 The actual data sheet for my personal Mitchell System test results. Measurements are in inches. The notation “Need Weights” indicates that the weight of the climber may be necessary information that was not included in the first tests.

The Mitchell body type tests

The form shown in figure #2 was used to record the test data for the first ten subjects. Additional data points (weight and femur length) were added for the second set of five subjects. Time and lack of volunteers (including the people who promised to run their own tests and then didn’t) have limited my data. At the time of writing, only 15 climbers have been tested. Larger samples may yield different results.

Even a superficial examination of the Mitchell System reveals some significant differences between the Mitchell and Frog system’s interaction with the body. The maximum Frog stroke is restricted to the Croll-to-fingertip distance (torso plus arm length) making this a prime consideration in Frog System efficiency. This is because it limits the practical length of the security tether and the adjustment of the entire Frog system is affected. Although arm and torso length also limit the total step height of the Mitchell, testing indicates that these attributes have little effect on the efficiency of normal climbing because the total step potential is seldom used. (See table #1)

While Froggers usually climb with both feet at the same time, the Mitchell System alternates full body weight between each foot. It quickly became evident that Mitchell System steps are potentially and practically disproportionate for each foot. The lower Mitchell ascender step is limited to the distance between the ascender and the bottom of the roller box. In my case it is about 18 inches. The upper ascender step is limited to the distance that the ascender can be pushed above the roller box, a distance of 31 inches for me. Without conscious effort to the contrary, most climbers take slightly disproportionate steps in practice. Right-handed climbers usually locate the upper ascender on their right as the “lead” foot. Left-handed climbers favor the left as “lead” foot. Climbers routinely took slightly longer steps with the lead foot. This tendency may be responsible for some of the lower back stress than seems to be endemic to the system.

When not conducting actual tests, I observed climbers using both the Mitchell and Ropewalker systems at N.S.S. conventions. My observations consistently showed a greater tendency to take disproportionate steps while sprinting rather than during long-distance climbs. The lead foot (upper ascender) virtually always taking a longer step than the “follow” foot. While very effective for racing, this natural tendency should be avoided during actual climbing due to the uneven stress placed on the lower back and legs. I also noticed that more experienced Mitchell users tended to equalize the step height, resulting in less back and leg stress. By inference, the longer the climb, the greater the need to retain even step height.

One dramatic difference between the Frog and Mitchell surfaced during testing. With the Frog, the maximum possible stroke is always the *desired* goal although it may not always be achievable. With the Mitchell however, the maximum step was NOT used in normal climbing, although it was occasionally used when crossing mid-rope obstacles or in special circumstances. One situation when I use the maximum step of the lower ascender is during a changeover. I bring the lower ascender into contact with the roller box. This allows me to attach my descender as high as possible on the rope without removing the ascender and violating the “two point contact” rule.

My maximum step with the lower ascender is 18 inches, but my natural average step height was calculated at 15 inches. I have never used the entire 31 inch upper ascender step and even a step of 20 inches is rarely used. This is due in part to the fact that the larger the step, the more the climber is thrown off balance to one side and also away from the rope. Disproportionate stepping increases climbing speed, but considerably decreases comfort. Most climbers quickly found a personal rhythm and their average step height, while disproportionate, remained fairly consistent during the tests.

Primary effects of overall height, torso and arm length

Overall height and body proportions such as torso, arm and leg length varied considerably between subjects. Unlike the Frog where greater height consistently meant bigger strokes, the Mitchell data is inconclusive. This suggests that overall height, torso and arm length are relatively unimportant to Mitchell System *efficiency*. Taller climbers with longer arms could take potentially bigger steps, but the maximum potential step was never used in normal climbing by any of the subjects. Table #1 shows the relationship of overall height to average step height for the first ten subjects.

Overall height and leg length

Table 1 Overall climber heights related to average step height

Overall Height (inches)	66	66	67	69	69	70	72	73	74	74
Average Step (inches)	15	13	10	12	13	10	9	13	14	14
Climber #	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*

In this small sampling, it appears that overall height and leg length have only a small effect on the average step height. Taller climbers took slightly longer average steps, but the longest average step was taken by the shortest climber. Indications are that the average step height is determined more by the personal preferences of the individual than by the literal height or body proportions. When questioned, taller climbers suggested that they were conscious of their tendency to lean away from the rope when they took larger steps and felt more comfortable taking shorter steps. Whether this is caused by overall leg length or results from upper or lower leg proportions is unclear. Further testing may provide more concrete answers.

Leg length also seems to have little effect on the average step height. Table #2 relates the climber leg length to their average step height.

Table 2 Leg length related to average step height

Leg length (inches)	35	35	35	41	41	42	40	38	42	44
Average Step (inches)	15	13	10	12	13	10	9	13	14	14
Climber #	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*

Torso length

The Frog tests required that the entire torso from the base of the neck to the abdomen be considered. This is because the Croll ascender rides at the base of the torso and its location combines with arm length to determine the maximum possible stroke. With the Mitchell System, the roller box position in relation to the lower ascender is more influential than the literal torso length. The lead foot step height is limited by the distance from the roller box to the maximum extended arm length above the box. The “follow” foot step is limited by its distance below the box. Because the relative location of the roller box varied between subjects, I decided to use the box location when measuring *effective* torso lengths.

Table 3 Roller box to lower ascender distance (effective torso)

Effective torso length in inches (roller box to lower ascender)	14	15	18	10	15	18	18	17	20	23
Average Step (inches)	15	13	10	12	13	10	9	13	14	14
Climber #	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*

As seen in table #3, this distance seems to have little effect on the average step height of the system. The location of the chest box varies as much as 3 inches between the two tallest climbers of equal height. Both climbers however, took the same average step. Climber #3 is 7 inches shorter overall than climber #9, but the effective torso length is only 2 inches less than climber #9. This is primarily due the configuration of the chest and location of the roller box in a comfortable position. Barrel chests often require the roller box to be located above the maximum depth area of the chest. Some women also prefer to wear the roller box very high to locate it above their breasts. Both situations extend the lower ascender to box distance, but may decrease climber comfort due to the chafing of the chest harness under the arms.

An extremely high roller box position also changes the amount of side load placed on the main rope by the box and the angle of the climber in relation to the rope. Tests indicate however, that these differences in climbing angle are small.

Another factor in the effective torso distance is the location of the lower ascender. This is determined by several factors:

1. Location of the roller box.
2. The length of the arms.
3. Personal comfort.
4. Leg length is of little consequence except to fix the length of the foot lines.

Once the roller box location is fixed, there is considerable tolerance for the positioning of the ascender. The main condition is that the climber be able to reach the lower ascender *cam* **easily**. Climbers wanting the maximum possible lower ascender distance will locate the cam at the limit of their reach. For racing, the maximum distance is frequently used. It is less important for practical climbing. Some climbers prefer to position the ascender higher, reducing the potential step. Smaller steps sacrifice potential speed for easier access to the lower ascender and lowers the stress on the back and knees. A higher bottom ascender position also significantly alters both the procedure and the efficiency of some rope maneuvers such as changeovers and crossing rebelays, generally making things easier.

Effect of Chest depth (front to back)

The Frog System tests clearly indicated a direct relationship between chest depth and Frogging efficiency. As the chest depth increased, the load taken by the arms during the standing portion of the cycle increased.

For the second set of five Mitchell subjects, I substituted a modified Jumar ascender to use on the lead foot (upper ascender) to measure how much relative load was being placed on it. Climbing speed was not considered and climbing times were not measured. I instructed the climbers to use the best technique possible and the climbing distance was kept at 15.3 meters (50 feet), so fatigue was a negligible factor.

Not surprisingly, the load on the arms was slight regardless of chest depth. The ideal Mitchell System climbing motion requires that each foot alternately carry the entire body weight rather than distributing between the feet and the arms. In practice, climbers with deeper chests tended to lean back against the roller box pulley when raising ascenders. Although climbers always maintained a grip on both ascenders, most of the side load was taken by the roller box, not the ascender. Leaning back (away from the rope) applies a side load to the main climbing rope and forces the box to support part of their weight. More experienced climbers and climbers with shallower chests tend to stay more vertical, increasing the load on the feet. Either way the arms carry little or no load. The lead arm however, tends to become fatigued since it is virtually always above the heart. Switching arms during long climbs is awkward, but generally relieves the problem. It was not tested, but deeper chests will probably increase lower back stress by forcing the climbing angle to increase from the vertical.

Secondary effects of overall height, torso and arm length

Although it does not directly affect climbing efficiency, the side effect of leaning away from the main rope is an increase in the load carried by the lower back. The specifics are very difficult to measure because the location of the roller box is critical to the angle at which each climber ascends. Even with the same chest depth, subjects with longer rib cages can wear the roller box at a lower position on their chests changing the upper pivot point, the climbing angle and consequently the load carried by the lower back.

Climbing angle

Even cursory observations showed me that all Mitchell climbers (Ropewalkers too) leaned away from the rope to a certain degree. Observations and test photos showed that virtually all climbers varied between 17 and 21 degrees off the vertical regardless of height (See figure #3). This was measured as the angle between the roller box pulley as a top pivot point and the lower ascender cam as the bottom pivot point. What was surprising was that the angle kept shifting as weight was shifted between the upper and lower ascenders. This effect is a large part of what causes lower back trauma with the Mitchell System. When the top ascender is loaded, the lifting force is funneled through the roller box pulley in a nearly vertical fashion. When standing up on the lower ascender however, nearly all climbers lean back into the roller box slightly. This pivots the rope at the roller box (fulcrum) to an angle between 10-20 degrees depending upon the climber's technique. This constant shifting of the pivot point (and consequently the constant shifting of the back position) during ascents seems to be the primary culprit in the lower back stress encountered by all test subjects.

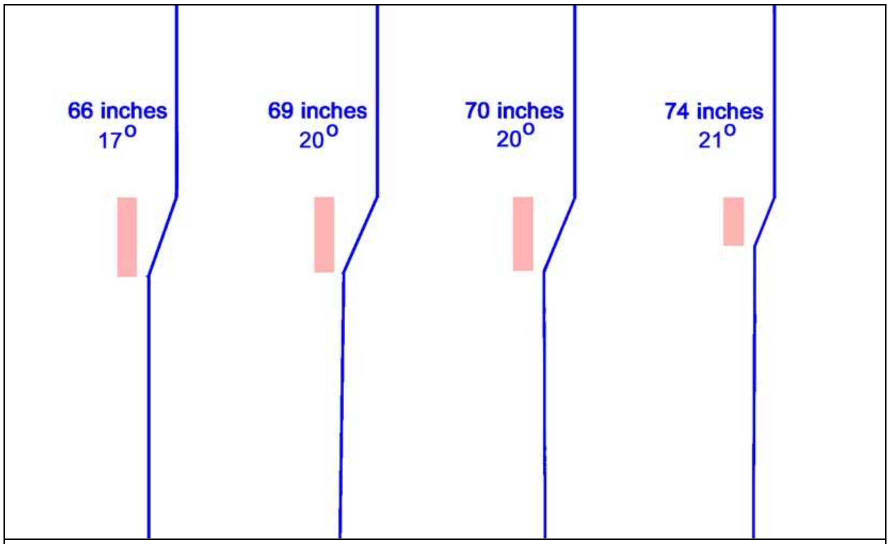


Fig. 3 The blue line represents the main climbing rope. The red area indicates the relative distances between the lower ascender and the roller box for each climber. Even the great difference between the first and last climber's lower ascender position has little effect on the climbing angle.

This effect is less pronounced with the standard Ropewalker Systems because climbers will either stay close to the rope by using their arms above the roller box as balance points or they will lean back on the roller box and use only their legs, letting the arms dangle. Because both ascenders are located below the roller box, the shifting of the climb angle between feet is greatly reduced between steps. Climbers tend to stay in either one climbing angle or the other instead of shifting their upper body position with every cycle. This also supports the notion that taller climbers take proportionately smaller steps because the literal distance between the pivot points (roller box and the lower ascender) is generally greater (greater effective torso), causing a larger potential shift between steps. It is very likely that taller climbers unconsciously reduce their step height to decrease potential back stress.

Body type test conclusions

These tests are not definitive, but they provide insight into how body type affects the Mitchell system. They suggest that unlike the Frog System, different body types have small effect on the inherent system efficiency during normal climbing. The personal preferences of each climber appear to be the mitigating factors regarding the step height. This is based on the number of steps required to ascend equal distances with varying body types.

Body type does seem to have some effect on the comfort level of the climber. The load on the lower back increases when a climber is forced off vertical either front to back or side to side, even when the step height remains consistent. This can affect climber fatigue and therefore ascent times and potentially climber safety, particularly on longer ascents. This can occur due to several factors:

1. Step height. The higher the step, the more the climber is thrown off the vertical.
2. Upper body weight and chest depth force the climber off the vertical.
3. The location of the roller box in relation to the center of gravity.
4. The tendency of the climber to shift climbing angles between each step.

The degree of discomfort varies with each climber, but the cumulative, negative effects are certain. It should be remembered however, that ALL climbing systems create physical discomfort that increases with the length of the climb. Each system stresses different parts of the body. It is also certain that continued use of a specific system will improve technique and usually (barring accidents, overuse or overstupidity), strengthen the related muscles and/or body parts that are being exercised. It is clear that off-rope exercise routines can and should be tailored to the system being used.

Yellow Spur Rope Failure Investigation

by

Rocky Mountain Rescue Group

March 6, 2011

On the morning of June 22, 2010, Joseph Miller fell while leading the second pitch of the Yellow Spur[1] route on the Redgarden Wall in Eldorado Canyon State Park[2]. During the fall the climber's rope failed, resulting in a fatal ground fall.

Due to the unusual occurrence of a climbing rope failure, the Rocky Mountain Rescue Group[3] (RMRG) conducted an accident investigation focused on the cause of the failure. This report contains the activities, findings and conclusions of that investigation. The intent of this report is to objectively determine what most likely happened during the accident. RMRG has no special relationship with any of the individuals or equipment manufacturers mentioned herein nor did RMRG receive any compensation for conducting this investigation. We encourage others to replicate our testing of this or similar scenarios.

Figure 1a shows a photo of the Yellow Spur route with the area of the accident outlined in yellow. The second pitch of the route starts from a tree and traverses to climber's left before heading up a dihedral (Figure 1b). The route was closed temporarily following the accident in order to gather on-site information in support of the initial investigation conducted by the Boulder County Sheriff's Office (BCSO). Prior to re-opening the route, a detailed inspection of the second pitch of the route was performed by RMRG, and photographs were taken of the climbing protection placed by Miller during the climb.

Interviews

Interviews with a number of nearby climbers who witnessed the events leading to the fall and/or the fall itself were conducted by RMRG. Miller's climbing partner, who was belaying at the time, was also interviewed. The primary purpose of these interviews was to understand the situation leading up to the fall and the sequence of events during the fall itself. The information provided by witnesses and the belayer were consistent with each other and allow us to present the following sequence of events:

Miller followed the first pitch, climbing it smoothly and without any difficulties. He reached the belay anchor set up by his partner at the tree in Figure 1b. During a brief discussion, he and the belayer decided that Miller would lead the second pitch. The belayer was anchored to the tree and was using an ATC-Guide (Black Diamond) in a standard belay configuration from his harness. Miller placed three pieces of climbing protection as he led the second pitch. The highest point on the route reached by Miller was in the lower portion of the dihedral in Figure 1b. The third piece of protection placed by Miller was near this high point. Miller appeared to be having difficulty with the climbing near the point where the third piece was placed and was being encouraged by the belayer. Miller fell shortly thereafter. During the fall, the third piece of

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[1] http://mountainproject.com/v/colorado/boulder/eldorado_canyon_sp/105748657

[2] http://parks.state.co.us/parks/eldoradocanyon/Pages/EldoradoCanyonHome.aspx

[3] www.rockymountainrescue.org

protection pulled out, but the first and second pieces held. Miller continued to fall straight down and past a small ledge. The speed of his fall appeared to slow very briefly as if the rope had begun to arrest the fall. However, the climbing rope then severed and Miller struck the ground near the base of the route.

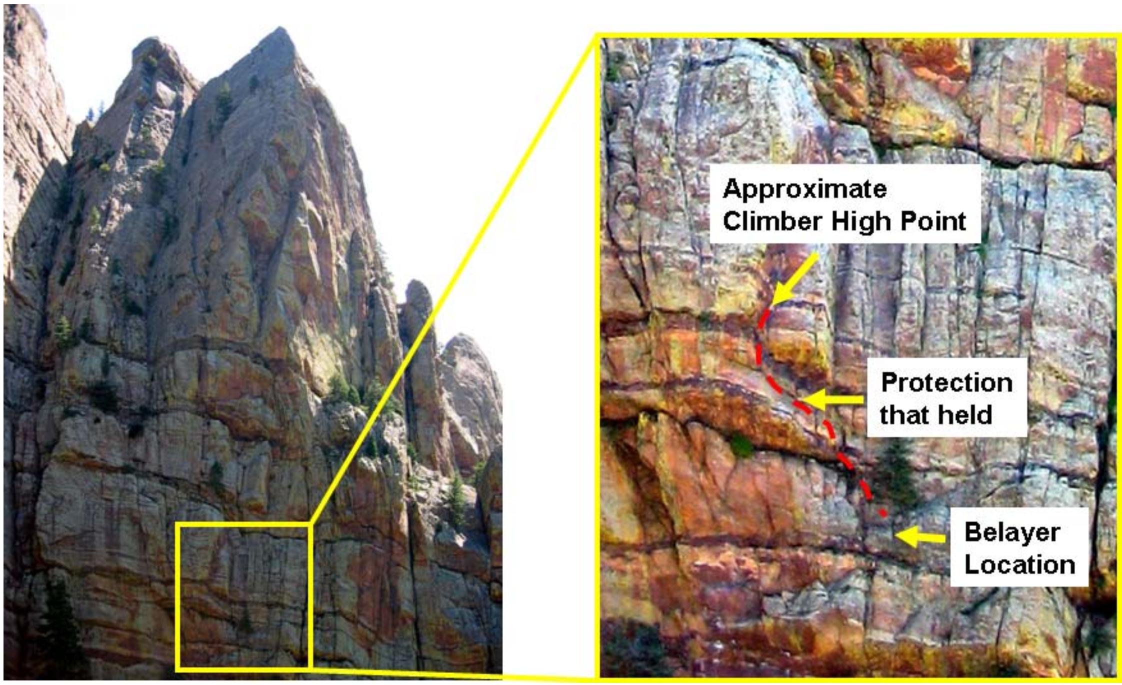

Figure 1 a) Accident location on the 2nd pitch of Yellow Spur. b) 2nd Pitch of Yellow Spur labeled with approximate climbing route (dashed line), and approximate locations of the belayer, protection and lead climber prior to the fall.

There are two additional important points from the belayer's account of the accident. First, he indicated that the initial protection placed by Miller had a long sling such that it did not cause the rope to change directions between the belayer and the second piece of protection. Second, the belayer indicated that he felt very little force on the belay from the fall. That is, he was not pulled significantly sideways or upwards by the rope as would typically be the case when catching a leader fall from this belay location. Immediately after the fall, the belayer pulled the remaining rope up to the belay and saw that the rope had been severed. He removed the first piece of protection placed by Miller before rappelling down to the base of the first pitch. The middle piece of protection (which held the fall prior to the rope failure) remained in place and was photographed during the initial investigation (Figure 2).

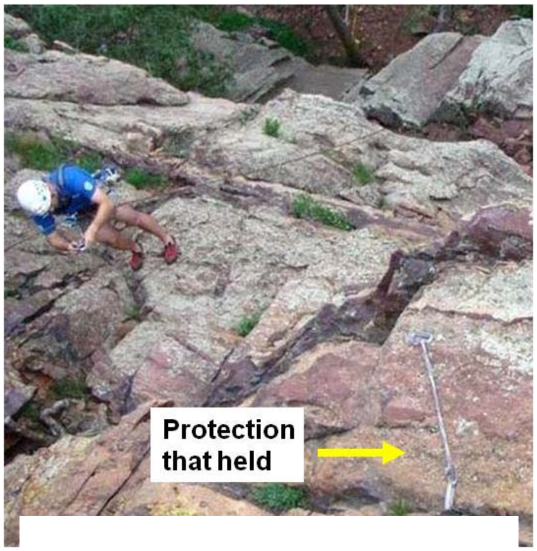

Figure 2. Protection that held during the fall (viewed from above).

Inspection of Equipment

The climber's rope was 200 feet (60 meters) in length, 9.7mm in diameter and manufactured by Beal. Three pieces of climbing protection had been placed by Miller while leading the second pitch. The highest piece was a #0.5 Black Diamond Camalot camming device that was attached with a 24-inch Dynex sling and two wire-gate carabiners. This piece pulled out during the fall. The second piece was a #0.4 Camalot, also with a 24-inch sling and wire-gate carabiners; this piece held during the fall. The lowest piece was a mid-sized stopper (unknown brand) placed a short distance from the belay.

A detailed inspection of all climbing equipment found on the route was performed. In general, the equipment appeared to be in good condition. Inspection of the #0.5 Camalot found damage to the lobes consistent with a shallow or open placement and a force considerable enough to pull the device from its placement (Figure 3). Damage to its associated carabiners and sling were also consistent with damage caused by high impact with rock. The #0.4 Camalot and its associated carabiners and sling were found to be in good condition. The climber's rope was inspected over its full length. The rope failure occurred approximately 20 feet (6 meters) from a figure-8 knot that connected the rope to the climber's harness. There were light abrasions along the rope for several feet on the climber's side of the failure. In addition, there were dark discolorations on the belayer's side of the failure consistent with a loaded rope moving across a carabiner. The remaining ~175 feet (53 meters) of rope was in good condition. During this investigation, we found no reason to suspect that there was any rope defect or that this rope was particularly susceptible to the damage that occurred.

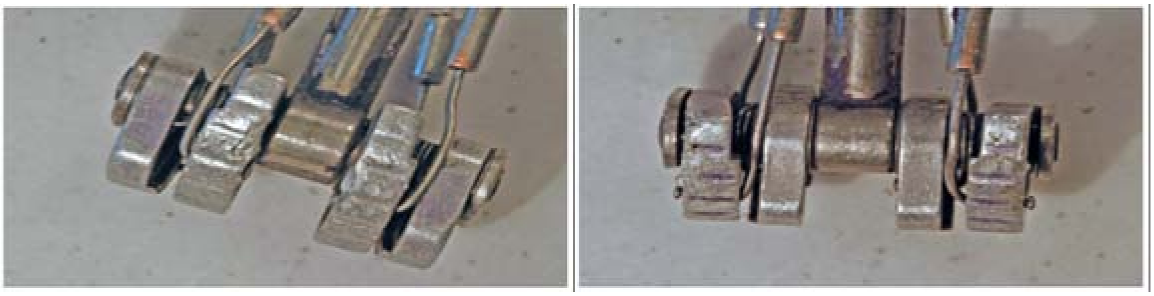

Figure 3. Close up of damage to cam that pulled out during fall.

Testing

RMRG Test Tower Facility

The majority of the testing presented in this paper was conducted on RMRG's 35-foot (10.7 m) tall steel test tower[4] (Figure 4). The tower is outfitted with a mechanical hoist and a stack of thirty 33-pound (15 kg) steel plates (for a total of 1000 pounds (455 kg)), which can be used to create a wide range of test loads. Drops are initiated using a pneumatic release mechanism (McMillan Design's "Sea Catch") and can be triggered either manually or via computer. Data is collected by a laptop computer with a National Instruments data acquisition card (Model 6251) and LabView 8.2 software. A variety of sensors collect load, temperature, and distance measurements. The load sensors have an operational range of up to 10,000 pounds (44.5 kN) and the data acquisition system allows sampling rates greater than 2500 samples per second. The

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[4] http://www.rockymountainrescue.org/randd.php

system is sufficient for capturing the critical information in the drop tests reported here. Additional details of the tower and testing equipment are available in Holden et al. 2009[5]

At any given time during the year, a number of studies are being performed at the RMRG test tower facility, including safety tests of rescue systems and new equipment. In addition, testing services are provided to other rescue organizations around the state, as time allows. Each scenario at the tower is planned in advance, and the set-up for each configuration can take several hours. The tests included in this investigation spanned seven days at the tower.

Many of the following tests involved rope-over-rock configurations. A variety of rocks with similar density, crystalline structure, and sharpness to that found on the Yellow Spur route were collected and mounted on the tower. The majority were readily available flagstone (sandstone) slabs. The ropes utilized were all commercially available climbing ropes of diameters between 9.8 mm and 11 mm. During the drop tests, load sensors were mounted on both the climber and belayer sides of the rope to measure any differences in loading. All test sequences were recorded on digital video.

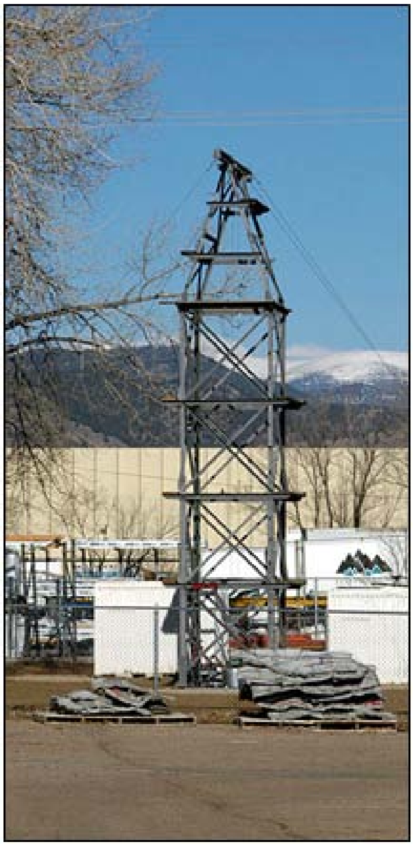

Figure 4. The RMRG test facility

Fall Forces

The estimated distance of the climber's "leader fall" (not including the distance traveled after the rope severed) was 20-30 feet (6.1-9.1 meters). Such a fall can generate forces of around 800 pounds-force (3.6 kN). This force estimate is based on previous experiments and is highly realistic for such a fall. However, the belayer reported feeling significantly less force from the fall than he would have expected. Therefore, two testing sessions were dedicated to measuring the potential forces exerted on a belayer during such a fall under a variety of configurations.

First, a 165-pound (74.8 kg) rescue mannequin was used to simulate a leader fall of approximately 25 feet (7.6 meters). The configuration was designed to replicate the general geometry of the Yellow Spur accident: a clean fall was caught by a Bluewater Enduro 11 mm dynamic climbing rope running through a carabiner and down to an anchored belayer using a standard belay device (ATC). The photo in Figure 5 shows this configuration on the testing tower.

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[5] Holden, T., May, B., and Farnham, R. (2009). "On the Utility of Rescue Randy Mannequins in Rescue System Drop Testing." International Technical Rescue Symposium, Pueblo, CO. Retrieved February 13, 2011, from www.itrsonline.org/PapersFolder/2009/Holden-May-Farnham2009_ITRSPaper.pdf.

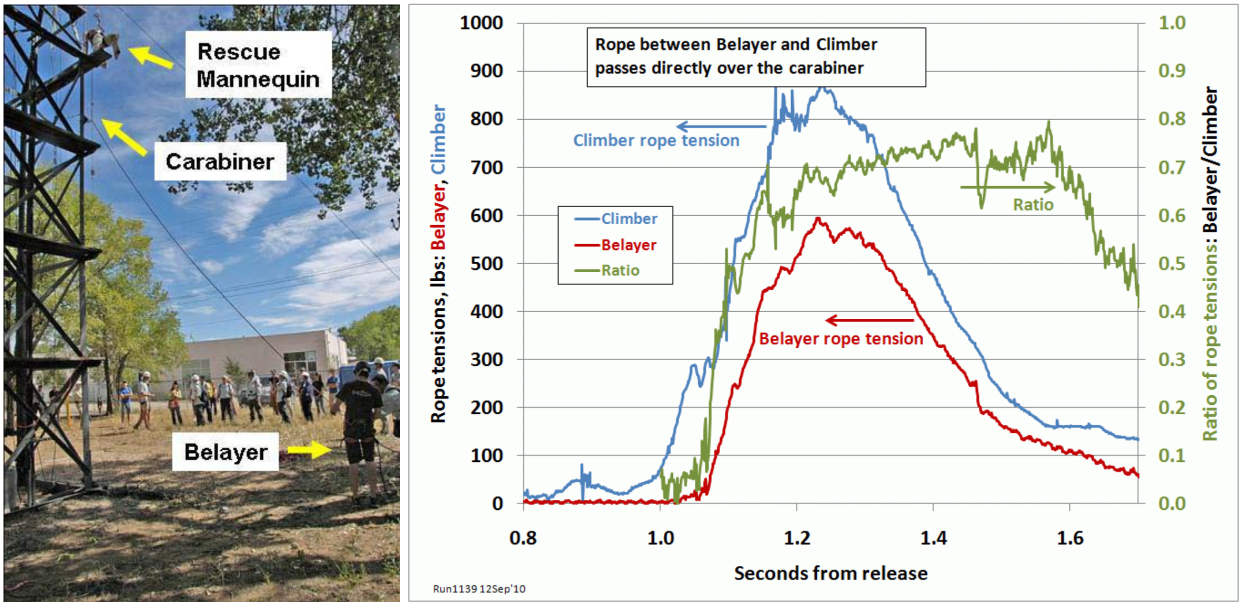

Figure 5. a) Climber and belayer forces drop test. b) Climber and belayer forces during leader fall.

Load sensors at the belayer and on the falling climber measured the resulting forces. Figure 5b shows the change in force (left vertical axis) and force ratio (right vertical axis) over time (horizontal axis). The force ratio is defined as the ratio between force experienced by the belayer to the force experienced by the climber. The force on the climber reached a peak of around 800 pounds-force (3.6 kN) at approximately 1.2 seconds. The force at the belayer was about 600 pounds-force (2.7 kN) at its peak. The ratio of the forces was approximately 0.7, consistent with the rope running cleanly through a carabiner.

The impact of 600 pounds-force (2.7 kN) lifted the belayer off the ground as the belay device caught the falling dummy during this test. Had a similar force been translated to the belayer during the Yellow Spur accident, he would have been yanked suddenly to the side (the second pitch starts with a traverse) as the rope came taught. Therefore, we can conclude that the belayer at Yellow Spur experienced a rope tension significantly less than 600 pounds-force (2.7 kN).

Fall Forces Over an Edge

The photo in Figure 2 shows the #0.4 Camalot and its associated sling and carabiners as they were found immediately after the accident. Prior to the fall, the climber's rope would have run up from the belayer, through the carabiner, and up to the climber's harness. As the climber fell past this point, the rope would have made a sharp bend through the carabiner and another sharp bend over the rock edge below the carabiner at the end of the sling. Another testing day was dedicated to measuring the resulting forces on a belayer under such circumstances. Figure 6a shows a close up of the geometry tested.

A quasi-static experiment was conducted to simulate the moment of peak loading. The belayer's end of the rope was anchored to the lower right. The rope was then run through a carabiner simulating the piece of protection that held, then back down over a rock edge. A 1000-pound (455 kg) weight was slowly lowered by a separate rope onto the climber's side of the configuration, simulating the peak tension in the rope. The rope tension on either side of the carabiner was measured separately.

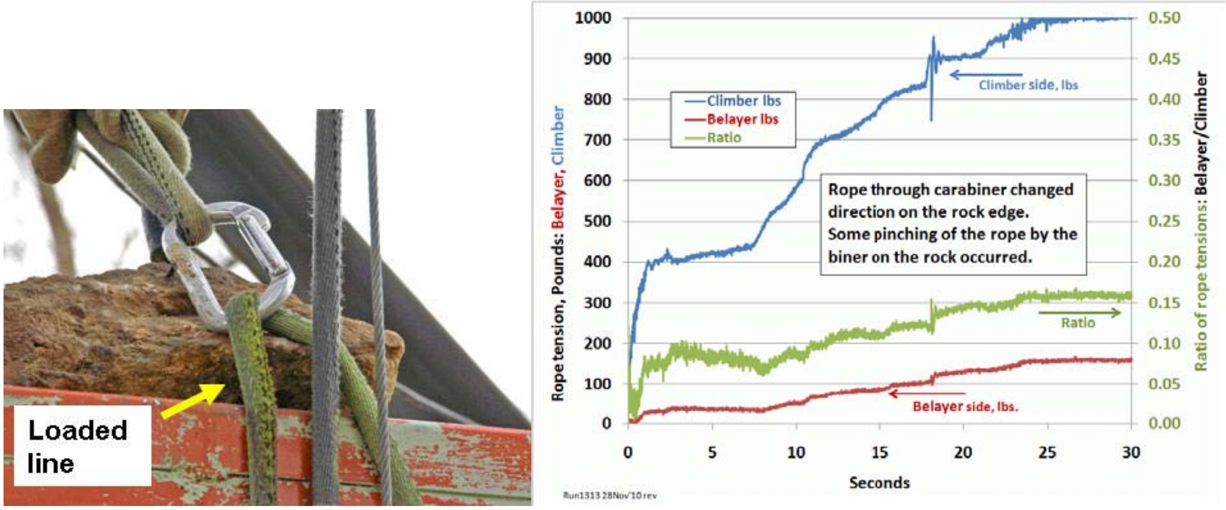

Figure 6. Rope changes direction over rock and through a carabiner:
a) testing configuration & b) forces during a direction change.

Several variations of this general configuration were tested to determine whether and to what degree the carabiner could pinch the rope against the rock, and thereby contribute to a reduction of rope tension on the belayer's side of the carabiner. The results showed that the pinching effect may have contributed to the reduction caused by the rope bending over the rock edge. Figure 6b shows the forces measured in one such test as the weight is lowered onto the system. The graph includes the entire sequence from zero force on the climber's side to a peak of 1000 pounds-force (4.4 kN). During that time, the force on the belayer's side reaches a peak of approximately 150 pounds-force (0.7 kN) for a ratio of ~0.15. The reduction in force from climber to belayer in this configuration is quite large. When the climber's side of the rope is loaded to 800 pounds-force (3.6 kN), only 100 pounds-force (0.4 kN) occurred on the belayer's side.

These tests did not include manipulating the angle at which the rope bent over rock. However, the ratio of force reduction discussed above is exponentially sensitive to the angle of bend, such that an increase in the angle of bend would further reduce the belayer load. While it is difficult to determine the exact angle of bend that occurred during the Yellow Spur accident, the angle used in these tests was based on the photo in Figure 2 and is therefore similar to the angle that occurred during the actual accident. Therefore, these findings indicate that it is very possible for a belayer to feel little of the force of such a fall, given the geometry outlined above.

Comparison of Damage in Climber's Rope to Various Cutting Methods

Figure 7 shows images of the climber's rope at both sides of the failure. The damage occurred over approximately two inches of rope. A short length of the rope's core strands were pulled out of the sheath at the point of failure during the accident.

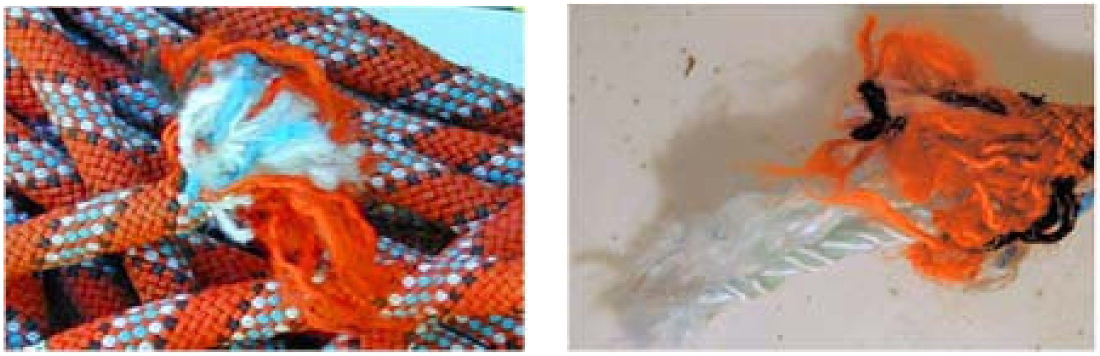

Figure 7. Climber's rope at either side of the failure.

The testing done as part of this investigation included cutting similar ropes under various conditions in order to determine the possible mechanism of failure. These tests show that ropes cut under different conditions display distinctive damage characteristics. Figure 8 shows two cuts performed under different test conditions. In each case, the rope was loaded to 800 pounds-force (3.6 kN), and the rope was cut with a sharp object. The image on the left shows the type of damage that results when a sharp knife is lightly pressed against a loaded rope. The damage occurred very quickly, and the strands showed very little elongation. The image on the right shows the type of damage that occurs when a sharp rock is used to saw across a loaded rope. The resulting damage was more uneven. Core strands near the sharp edge broke at approximately the same time as the sheath while core strands further away stretched and survived slightly longer.

Figure 8. a) Tensioned rope cut with a sharp knife. b) Tensioned rope cut with a sharp rock.

The damage characteristics of the accident rope (Figure 7) are consistent with the rock-cut test depicted in Figure 8b. These findings indicate that during the accident, the rope ran over a sharp object and failed at or near the highest point of tension.

Dynamic Drop Tests

Following the relatively static tests described above, the investigation team initiated a sequence of dynamic drop tests at the RMRG test tower. The primary purpose of these tests was to understand the combination of forces, angles, and rock structures required to cause the specific type of rope failure that occurred in this accident. The testing attempted to re-create the damage observed in the accident rope by creating fall dynamics that could have occurred during the Yellow Spur accident.

Rope Failure Test – Directly Over Sharp Edge

As mentioned previously, the photos taken on scene immediately after the accident led the investigation team to hypothesize that the climber’s rope passed over the rock edge near the carabiner connected to the sling in Figure 2. It is possible that the rope failed as it passed over this edge. Two testing days were devoted to investigating rope failures directly over similar sharp edges of rock during a leader fall sequence.

In each test, a rock with a sharp edge was mounted to a beam on the test tower. Figure 9 shows a typical pre-drop configuration with the belayer’s side of the rope attached to a load sensor. The rope then traveled through a carabiner, over a sharp edge, and down to a 200-pound (90.7 kg) weight stack on the climber’s side. The rope used in these tests was a commercially-available 9.8 mm dynamic climbing rope.

Figure 9. a) Example pre-drop configuration. b) Typical partial rope failure result.

Numerous drop tests were executed with several variations of carabiner-to-edge locations, types of rock edges, and fall line angles, such that the rope slid 1 to 3 inches along the sharp edge during the simulated fall. Each test resulted in significant damage to the rope. However, in several cases, the rope did not sever completely. Figure 9b shows the rope damage after a drop where the sheath failed but the majority of core strands survived.

Figure 10a is representative of each of the tests in which complete failure occurred. The variability in the blue trace indicates the changes in force over time as the rope ‘caught’ temporarily on the rock edge due to friction and then released. The force drops suddenly to zero shortly after reaching its peak value, indicating the point of complete failure. The maximum load reached in this case was just over 1,200 pounds-force (5.3 kN) on the climber’s side.

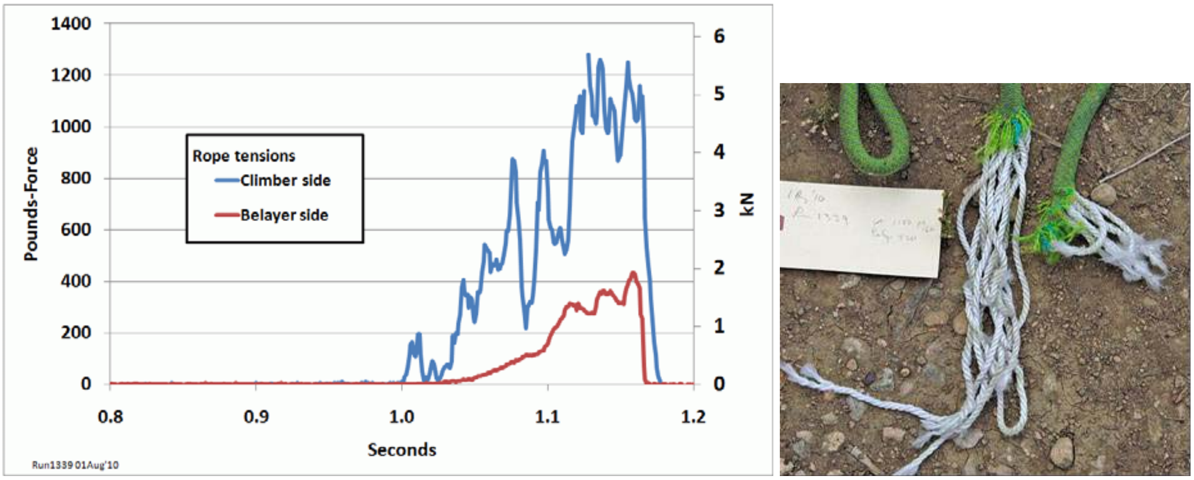

Figure 10. a) Typical loading during rope failure test. b) Typical damage caused during rope directly over sharp edge scenarios.

Figure 10b shows the type of damage done during each of the tests in which the rope failed completely. The sheath failed quickly and exposed the core strands to the edge. However, the core strands did not all fail at the same point. It is likely that as the rope is tensioned, it flattens across the edge, thereby protecting core strands that are further away, at least for a brief period of time. In addition, as the rope stretches, some of its length will become exposed to the edge and therefore the damage is spread across several inches.

While many of these tests were successful in creating complete rope failures, the characteristics of the damage were inconsistent with that of the accident rope (Figure 7). The damage to the accident rope occurs over a very short length, as if the contact point with the sharp edge did not change as the damage occurred. Therefore, it is unlikely that the accident rope failed due to the mechanisms or configurations demonstrated in this portion of the testing.

Pendulum Rope Failure Tests

Another possible mechanism for failure of the rope involves a fully loaded rope sliding sideways across a sharp rock edge. Conceptually, this is similar to the rope cut tests described above, where a sharp rock was used to saw across a loaded rope: the contact point of the rock on the rope does not change (Figure 8b). This mechanism may be present in a leader fall when the climber is not directly above the last piece of protection, introducing a sideways component to the fall. Based on previous testing at the RMRG test tower, the majority of such a pendulum movement occurs after the rope is highly tensioned. That is, a fall continues straight downwards until the rope stretches sufficiently to take a significant portion of the load, which then results in the falling object swinging from the fall line toward the last piece of protection. If there is a sharp edge between the climber and the last piece of protection, the rope will slide across it.

Two testing days were conducted to evaluate this pendulum failure theory. Figure 11a shows one of the many configurations used for the pendulum tests. The rope used during these tests was a commercially available 10.2 mm dynamic climbing rope.[6] A rock with a sharp edge was

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[6] This rope was thicker than the accident rope but it is reasonable to assume that a thinner rope could fail with the same characteristics.

mounted to the test tower. The test rope was attached to the tower approximately 3 feet (1 meter) higher than the rock and a weight stack was loaded onto the rope. In these tests, the weight was not dropped. Instead, it was allowed to swing sideways, dragging the rope along the sharp edge of the rock as indicated by the direction of the yellow arrows (Figure 11a).

The weight was pulled to the right side of the photo and attached to a release mechanism at the side of the tower. The blue piece of equipment clamped to the wooden beam is a smooth metal angle used to keep the loaded rope from rubbing on the rock edge prior to the release of the weight stack. This provided for less friction than would occur if the rope slid along the wood.

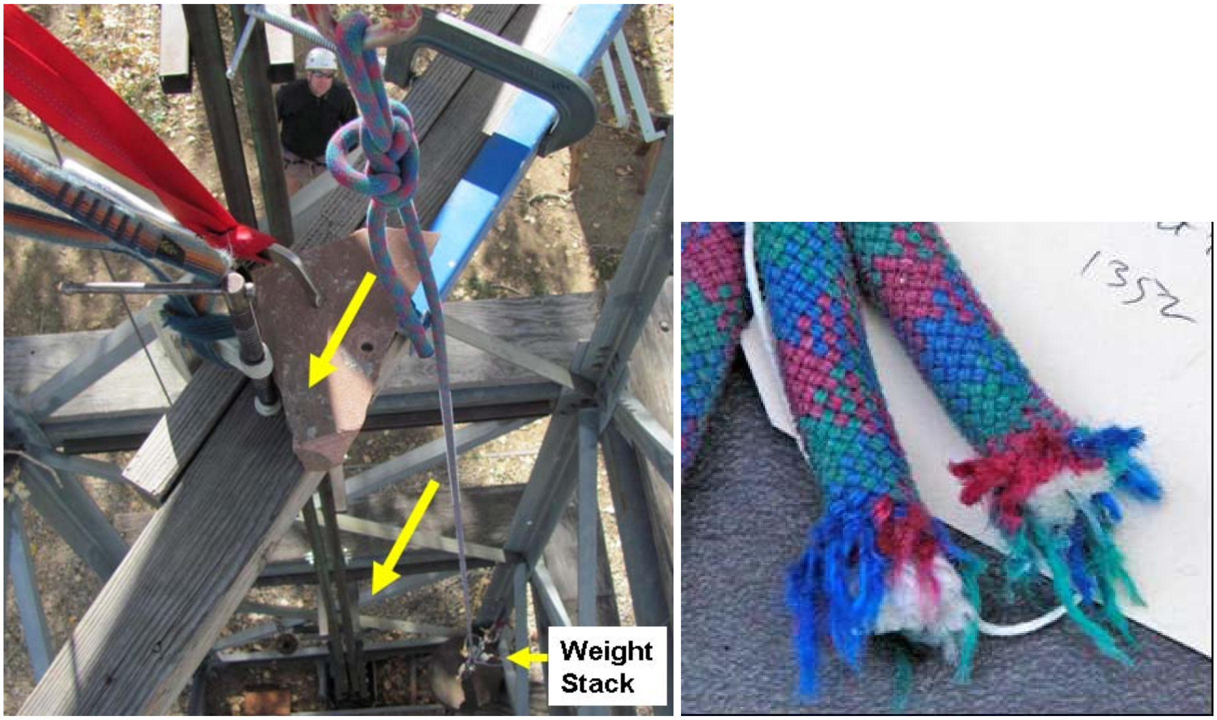

Figure 11. a) Test tower pendulum configuration. b) Pendulum test rope damage.

Different loads were used to simulate the downward force of a pendulum fall. Contact with the sharp edge of the rock during the pendulum resulted in considerable damage to the rope in each test. Using a load of 300 pounds-force (1.3 kN) caused the rope to fail, but only after sliding back and forth along the edge a number of times. However, there was no indication from witnesses to the accident that any such back and forth motion occurred prior to the rope failing. The remaining pendulum failure tests used a load of 760 pounds-force (3.4 kN). In each of these cases, the rope failed with only a single pass along the edge of the rock. Slow motion review of the video captured during the test showed that the rope passed over approximately 2 inches of the edge before failing.

Figure 11b shows the damage to the rope caused by the pendulum test with a load of 760 pounds-force (3.4 kN). The damage is isolated to a very short section of rope such that the sheath and core are cut at approximately the same location. The results of this test created a slightly cleaner cut to the rope than either the accident rope (Figure 7) or the test of the loaded rope cut by sawing a sharp rock across it (Figure 8b). In each of those cases, more of the core was exposed. Thus, it is possible that some amount of stretch occurred as the damage was occurring during the Yellow Spur accident. It is also possible that variations in the sharpness of the different rock edges could account for the different damage characteristics. However, it seems clear that this type of failure mechanism was likely responsible for the rope failure during the Yellow Spur accident.

Re-creation at Yellow Spur

As part of this accident investigation, RMRG attempted to re-create the conditions of the fall on Yellow Spur to evaluate interactions between the climber's rope and the rock during the fall. A fully-loaded fall sequence was not attempted on the route due to the time and resources required for such a recreation, the popularity of the Yellow Spur route, and the possibility of damage to the route itself. However, a simulated lead fall with a load of approximately 30 pounds-force (0.1 kN) was conducted from the climber's estimated high point in order to evaluate the pendulum characteristics of the accident, based on the best-known locations of the belayer, climber, and his protection.

The photos in Figure 12 show the start of the second pitch from the viewpoint of the belayer at the tree marked in Figure 1b. The investigator in the first photo (Figure 12a) is at the approximate location of the start of the fall. The rope (A) is an RMRG rope used by the investigators to access the route. (B) is the simulated climber's rope. The near end of the climber's rope runs through an investigator's belay device at the tree. The carabiner (C) is attached to a similar configuration of #0.4 Camalot and associated sling and carabiners that held the fall during the accident, and which have been placed according to the photo documentation in the initial investigation (Figure 2). The rope (D) connects the climber's rope and was used to provide weight during the drop.

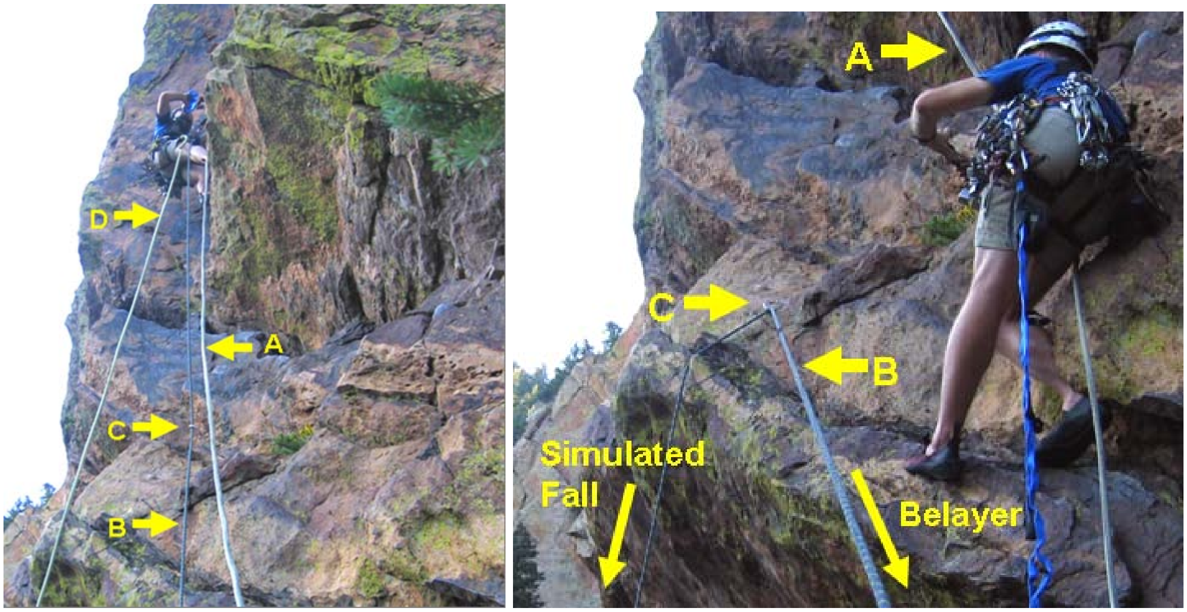

Figure 12. Re-creation configuration on Yellow Spur;
a) just prior to dropping the rope & b) just after dropping the rope.

During the interview of the belayer, it was indicated that Miller fell straight down from approximately the investigators location (Figure 12a). In this re-creation, the investigator in the image dropped the simulated climber's rope straight down without adding any outward or sideways component. While the amount of force resulting from this simulated fall is much lower than what would have occurred during the actual fall, the configuration was sufficient for estimating the general rope movement characteristics during the incident.

Figure 12b shows the resulting configuration of the simulated climber's rope after being dropped from the position indicated in Figure 12a. In the image, (A) is the investigator's access rope, (B) is the climber's rope, and (C) is the carabiner. The fall line of the drop was about 2 or 3 feet (1 meter) climber's left (into the image) from the resting location of the rope. The rope dropped straight down and then pendulumed climber's right (toward the belayer) along the edge below the carabiner, finally ending up in the notch as shown in the image. The rope between the belayer and the carabiner did not contact any rock surface and there was no obvious place along that line where the rope could have snagged. The climber's side of the rope hung in free space below the overhang at the bottom of Figure 12b. There are no other obvious edges near the carabiner other than the main edge over which the rope is draped. While there are certainly other possible rope movements that could have occurred during the actual fall, this sequence and resulting position are consistent with the available information.

Figure 13a shows the final configuration from just above the location of the #0.4 Camalot. The climber's rope pendulumed left and down along the edge to its final resting point in the notch. The location of the carabiner is consistent with the photos taken immediately after the accident. Figure 13b shows a closer image of the edge that the rope slid over before coming to rest in the notch. The notch itself is sharp and the edge just to the right of the notch along the line the rope traveled is extremely sharp.

Figure 13. Re-creation on Yellow Spur.
a) Looking down at the final configuration after simulated fall, b) Close up of the edge.

During the process of the re-creation, investigators saw no other combinations of fall characteristics and/or sharp edges that could match the known location of equipment that held during the fall and eyewitness information. If the rope movement during the actual fall followed a similar sequence as the re-creation, then nearly the full force of the fall would have been applied to the rope as it came taut over the rounded edge to the right in Figure 13a. It could then have pendulumed down along the edge toward the notch and across the very sharp edge shown in Figure 13b.

Analysis and Discussion

The purpose of this investigation was an attempt to understand the factors contributing to the death of Joseph Miller on June 22, 2010. The results indicate that a narrow set of circumstances likely led to the failure of Miller's climbing rope during a typical leader fall. Climbers may be comforted to know that it was difficult to re-create a complete failure of a standard dynamic climbing rope under realistic climbing conditions. The commercially-available climbing ropes utilized in these experiments often survived the severe tests undertaken, although with significant damage.

Non-pendulum drop tests wherein a climbing rope was loaded such that it ran for some distance over a sharp edge (without a significant lateral motion) resulted in sheath failure occurring significantly before core strands began to fail. In many cases, some of the core strands survived and ultimately held the load. This type of damage, however, was qualitatively different from the damage found in the accident rope. Therefore, it is unlikely that the failure of the accident rope was caused while elongating over a sharp edge.

Eyewitness reports indicate that the falling climber traveled straight downward and appeared to be decelerating immediately before the rope failure occurred. This is consistent with the rope failing under high tension during the maximum forces created in the fall. Furthermore, the damage found in the accident rope was consistent with results from the rock-cut and pendulum tests wherein a rope tensioned to approximately 800 pounds-force (3.6 kN) moved laterally over a sharp edge. These findings suggest that a pendulum effect contributed to the failure.

Potential Accident Sequence

While the exact alignment of the climber and the protection he placed cannot be determined with certainty, the best estimates suggest that the fall line from the climber's high point was a few feet climber's left of the #0.4 Camalot that initially held the fall. This geometry would have resulted in the climber falling straight down until the rope between the climber and the #0.4 Camalot began to stretch. The left hand pane of Figure 14 depicts the fall relative to this piece of protection (labeled 'R'). At this point in the sequence, shown in the middle pane of Figure 14, a pendulum effect would have begun, swinging the climber to his right. The rope would therefore have moved laterally across any rock edge between the climber and the #0.4 Camalot. The right hand pane depicts the potential configuration prior to rope failure from the side[7]. Re-creation of the accident events on the route itself demonstrated that such a sequence was possible and that the rope would have pendulumed across a sharp edge. It is therefore likely that Miller's rope failed under such circumstances.

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[7] This view is similar to the picture in Figure 12b taken during the re-creation.

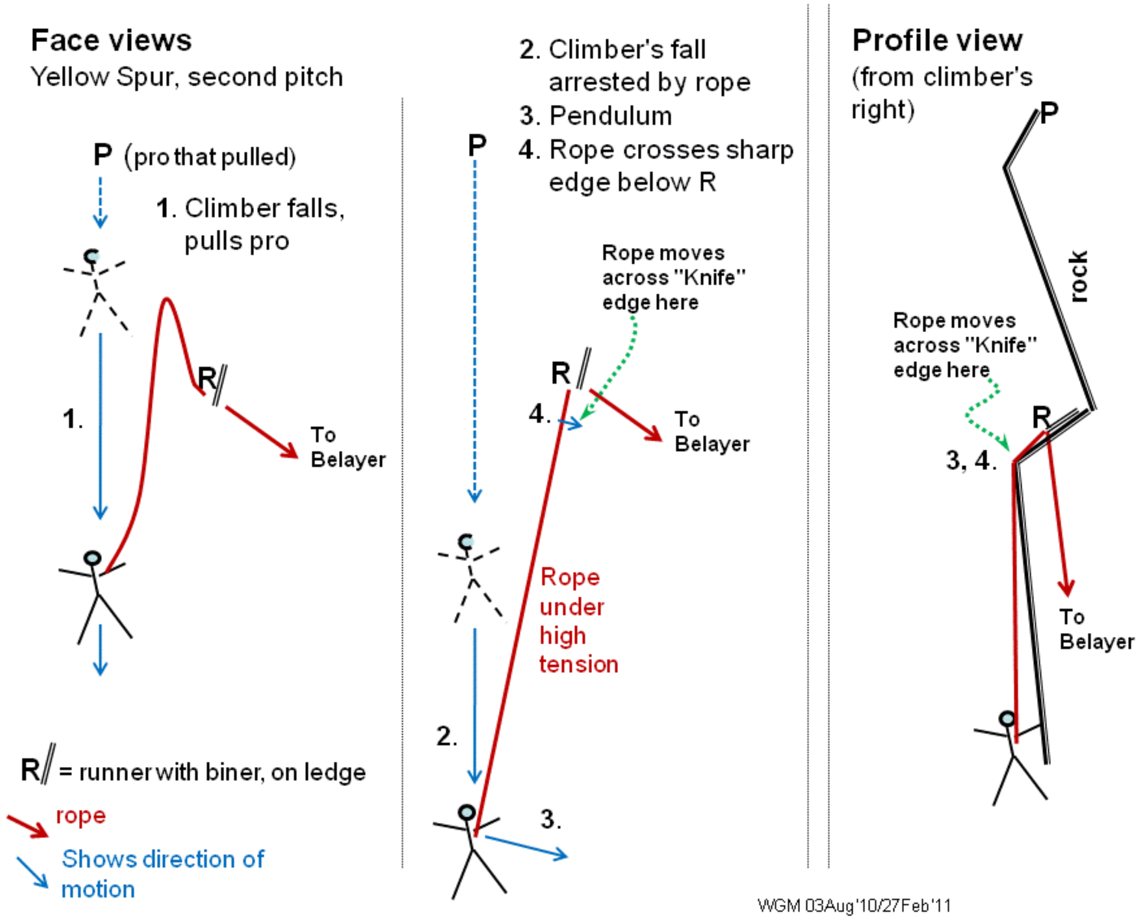

Figure 14. Potential accident sequence. Left and center pane depict sequence facing the route. Right pane depicts fall position prior to rope failure from the side.

Conclusion

There is no way to know exactly what caused the rope failure that resulted in Miller's death on Yellow Spur. However, it seems likely that a specific sequence of events occurred during this accident. First, the investigation found no indication of intrinsic (manufacturing) defect or deterioration of the rope or associated climbing equipment due to their prior use. Second, Miller appeared to be having some difficulty while climbing the route and took a typical leader fall, a fairly common occurrence among lead climbers. Third, it appears that Miller placed a piece of protection very close to his high point. Had this protection held, it is likely that the fall would have been arrested after only a very short distance. A combination of this highest piece of protection pulling out and the distance to the next piece resulted in a longer fall. Had the rope not failed, it is very likely that this longer fall would still have been stopped relatively safely. Fourth, the geometry observed during the re-creation of the accident indicated that the rope likely pendulumed across a sharp edge during the instant it was under high tension. If Miller's fall had not resulted in a pendulum, the rope may have survived running over the sharp edge (although likely with some damage). Had the fall generated a smaller force, it may also have survived the sharp edge. As with many accidents, it appears that a sequence of events rather than a single issue resulted in Miller's death.

Safety Lessons for Climbers

All lead climbers accept the possibility of a leader fall. Climbers evaluate and manage the level of risk they are willing to accept. Doing so effectively involves understanding the potential consequences of any fall. However, the general assumption among climbers is that “ropes do not fail” — or, at least, that rope failure is extremely rare. As such, climbing accidents that result in a rope failure attract considerable interest from the climbing community and may provide useful lessons for safety education. Two such lessons can be extrapolated from the current findings.

Lead climbers often place protection after passing a ledge in order to help prevent hitting the ledge during a fall. Protection may also be placed in order to prevent falling past the ledge, especially if such a fall would result in the rope running over a sharp edge. Clearly, any ledge with a sharp edge that a leader might fall past represents an extremely high risk factor. However, the rope failure tests done during this investigation suggest two additional factors to consider during such ledge transitions. First, lead climbers should attempt to visualize the geometry of a potential fall past a ledge, and consider whether a potential pendulum effect may result in a tensioned rope moving laterally across the edge. Second, climbers should consider how that geometry could differ given the failure of any piece(s) of protection along the route, possibly leading to the rope coming in contact with nearby sharp edges that may not be directly in line with the initial fall. In some cases, hazardous situations might best be managed by altering the route in order to avoid the area or even by backing off the route.

Acknowledgements

The members of the Rocky Mountain Rescue Group would like to express their condolences to the deceased’s friends and family. We would like to thank the belayer and eyewitnesses for providing invaluable information during the course of the interviews. We would also like to thank the Boulder County Sheriff’s Office for allowing the investigation team to inspect the accident rope and associated equipment that had been placed in evidence. Finally, we would like to thank the climbing community in general who expressed considerable interest in the results of this investigation and showed extraordinary patience in awaiting these results.

Minutes of the
NSS Vertical Section Executive Committee E-Meetings
July 2010 to June 2011

The NSS Vertical Section Executice Committee held a series of E-meetings on a variety of issues during the period from July 2010 to June 30, 2011. Executive Board members participated in the meeings via email, telephone and regular mail.

January 2011 - Removal of password for Nylon Highway on VS website

The VS Board has been considering removal of the password for access to the Nylon Highway on the VS website for some time. Since VS dues was reduced to zero dollars, it was decided that it was important to provide easy and unobstructed access to the educational and safety information contained in the Nylon Highway to all interested individuals. Following a vote of 7 in favor and 2 not responding, the password was removed as of January 10, 2011.

January 27, 2011 to February 21, 2011 - NSSVS Awards

The VS Board has been making efforts to formally recognize those who have made significant contributions to and otherwise served the Vertical Section over the years. In addition, the VS Board recently established criteria to guide the Awards Committee in considering nominations for the Vertical Section Lifetime Achievement Award. This award is intended for individuals who have provided a contribution to vertical caving, recognized nationally, that has benefitted the activity in terms of technique, equipment, or knowledge base.

The Awards Committee received a two nominations recommending that an award be given to Charles Gibbs: Inventor of the Gibbs Ascender and John Cole: Inventor the "Rack". On January 27, 2011, an e-meeting was called to consider these two nominations. After review and discussion, as of February 21, 2011 there was a unaniomous vote in favor of the award. NOTE: The award to Mr. John Cole was presented the evening of June 1, 2011 at a Huntsville Grotto meeting by Bill and Miriam Cuddington. The award to Mr. Charles Gibbs was presented by Bruce Smith on June 26, 2011.

June 5-13, 2011 - Approval of minutes from VSEC regular and E-meetings

The minutes from the August 1, 2010 VSEC meeting and from 2009-2010 E-meetings were approved by a majority vote of the VSEC as of the close of the E-meeting on June 13, 2011.

NOTE: There were other discussions on various topics between Executive Committee members throughout this period. None of these are recorded in these minutes since no motions were made or voted on and they did not constitute E-meetings.

Respectfully submitted,
Bill Boehle

(Rev.0)
Approved by EC e-meeting 5/20/2012

Minutes of the
NSS Vertical Section Executive Committee Meeting
July 17, 2011

The NSS Vertical Section Executice Committee held a meeting on Sunday, July 17, 2011 at a motel near the 2011 NSS Convention in Glenwood Springs, Colorado. Executive Board members present were Chair Dick Mitchell, Secretary-Treasurer Bill Boehle, At-Large Executive Members Terry Mitchell and Rory Tinston, Vertical Techniques Workshop Coordinator Terry Clark, Contest Coordinator Bill Cuddington and Education/Training Coordinator Bruce Smith. Nylon Highway Editor Tim White could not attend the convention and Bruce Smith was designated as proxy. At-Large member Miriam Cuddington was unable to attend this meeting. Vertical Section member (and rebelay course coordinator) Gary Bush was also in attendance along with Mike Rusin.

Meeting opened at 7:00 PM by Chair Dick Mitchell.

The purpose of the meeting was to discuss and deal with various issues that needed to be addressed before the annual business meeting on Wednesday.

1. Vertical Session topics. Bill Cuddington reported that there are at least two topics that will be presented at the vertical session after the business meeting on Wednesday. Bill and Miriam have a 10-15 minute presentation entitled What is the "Mitchell Upstairs"? A second presentation by Bill Cuddington will present some comments on the Mitchell System answering the question of how good it is.

2. It was recently brought to the EC's attention that an article published in the Nylon Highway (NH) on Knot Break Strength vs Rope Break Strength had some inconsistencies and inaccuracies. The EC discussed what should be done about the article and what our policy should be if something like this is discovered. Articles in the NH are put out there for discussion and comment. However, should we knowingly leave incorrect or otherwise questionable material out there without identifying the issues? It was decided to pull the article form the NH with a note stating that there were errors in the article and that it was being pulled for further review with the author.

3. Education/Training Coordinator Bruce Smith reported that several updates to the Basic Vertical Training Course are needed. He also proposed the need for a Nylon Highway article to discuss the premise that there is no "left" or "right" handed rappelling.

4. Terry Mitchell raised some issues with how the EC has been conducting e-business. It was concluded that we just need to follow the procedures established.

Adjournment - Motion to adjourn was made and carried. Time of adjournment was approximately 8:00 PM.

Respectfully submitted,
Bill Boehle

(Rev.1)
Approved by EC e-meeting 5/20/2012

Minutes of the
2011 NSS Vertical Section Meeting
July 20, 2011

The 2011 NSS Vertical Section meeting was held Wednesday, July 20, 2011 at the High School in Glenwood Springs, Colorado. Executive Board members present were Chair Dick Mitchell, Secretary-Treasurer Bill Boehle, At-Large Executive Members Miriam Cuddington, Terry Mitchell (Vice Chairman), and Rory Tinston, Vertical Techniques Workshop Coordinator Terry Clark, Education/Training Coordinator Bruce Smith, and Contest Coordinator Bill Cuddington. Nylon Highway Editor Tim White could not attend the convention and Bruce Smith was designated as his proxy. Approximately 18 additional Vertical Section members were in attendance.

I. Meeting opened at 1:00 PM by Chair Dick Mitchell.

A. Announcements - Welcome to everyone who came. Agenda, minutes, and other information available in packet. Membership/Attendance roster circulated. Introduced EC members present.

II. Minutes of the Last Meeting - were published on the website and there were no amendments or changes. A motion was made and seconded and the minutes were accepted as published.

III. Officer's Reports:

A. Secretary's Report - Bill Boehle. See attached. Accepted as presented.

B. Treasurer's Report - Bill Boehle. See attached. No further discussion. Accepted as presented.

C. VS Symbolic Items - Bill Boehle. See Treasurer's Report for sales numbers. There was some discussion about how sales of back issues of the Nylon Highway were going. Bill Boehle stated that it was just slow and steady and that sales were slightly better with bundled sets of all issues still in print as compared to individual issues. Since back issues that still have stock remaining are not posted on the website, it was asked if there is anything we can do to hasten the reduction of the stock of back issues. It was suggested that we give an issue to each participant in the Vertical Workshop as a way to use up the old stock. The group consensus was that this was a good idea and it was agreed that this is how we woulod proceed.

D. Nylon Highway Editor's Report - Report given by Bruce Smith for Tim White. There was a recent article comparing Knot Break Strength vs Rope Break Strength. There were inconsistencies in the article as well as mixed up graphics. Bruce Smith contacted the Technical Director of the Cordage Institute to resolve these problems, however he received no response to his inquiries. The EC recently voted to remove the article from the Nylon Highway pending further review and resolution of the problems with the article.

IV. Committee Reports:

A. Contest Committee - Bill Cuddington. Thanks to the Colorado convention for the nice facilities for this years contest. Thanks to PMI for donating two 600 foot lengths of EZ Bend Sport rope this year for the climbing contest. Thanks to all who help during the vertical contest, especially Ernie Coffman and the other racketteers who helped run the racks. We appreciate any help from section members and others with timing, pulling rope, running the rack, etc. Bill noted that several people inquired about the use of the spacers between the top bars of the long racks used for the climbs. He explained to them that they function to reduce heat and prevent glazing of the rope. The contest is not just a race, but also a learning laboratory to test climbing rigs and techniques. This year we had about 60 climbers over the two days. Awards will be given out at 1:00 PM on Friday.

B. Vertical Workshop - Terry Clark. This year we have 37 people signed up. Terry made a request for more help rigging and setting up the ropes on Monday mornings and for derigging on Thursdays after the workshop. It is a big job and more hands make the work easier on everyone. Thanks to PMI for their support of the vertical workshop. We are cutting up the contest ropes for use in the workshop. This way we are getting more use out of the donated ropes and have less gear to haul to the convention. Terry wants to recognize and thank Lynn Fielding (Co-Chair) who helps him run the vertical workshop. She makes his job easy. Terry pointed out that the JSS has been using some of our equipment with his permisssion for their training sessions. The JSS has a budget and has been slowly acquiring some of its own equipment. We have a good relationship with the JSS. Terry stated that the NSS has contacted him to ask if he wanted to make any changes to the $25 price we charge for the Vertical Workshop. Terry feels that the $25 is probably okay where it is but wanted to get some input from the Section. Secretary/Treasurer stated that barring some unusual expenses our budget (revenue vs. expenses) has been mostly in balance in recent years. We can always revisit the workshop fee if that situation were to change in the future. For now we will retain the $25 workshop fee. There was some discussion about equipment replacement and Terry noted that some of our older ropes were being retired. Bruce Smith pointed out that, according to the Cordage Institute, life support ropes have about a 10 year maximum life.

C. Training/Education - Bruce Smith.

Bruce stated that he is about to embark on a series of updates to the Basic Training Course. There are updates to the information on harness hang syndrome, and in response to some recent accidents there is a need to update the training to address rappelling errors made when changing the number of bars used during a descent. Problems have also been observed with people engaging too few bars when locking off the rack. The problems occur when additional load is placed on the rack and the lockoff is removed. There will also be some updates to the course testing. Bruce needs feedback for local grottoes using the course to provide input for these and future updates. The updated information will be developed, field tested, and then distributed via the website.

It has been two years since we completed the Intermediate Course and made it available via download for no charge on the website. However, we have had no students register that they are starting the course or who have filed for a certificate of successful completion. This doesn't mean the material is not being used, it just means that we are unable to gauge its use. Gary Bush said that we will try to track the downloads of the course on the website.

D. Re-Belay Course / "Dial In Your Gear" Session - Gary Bush and John Woods. This year a steady stream of people showed up all day for the rebelay training. Terry Mitchell helped out all day with Gary. As in the past, most of the time was spent with people setting up and adjusting their systems. Dick Mitchell suggested that maybe this session would be better identified as the Rebelay and System Tuning session rather than the Rebelay Course. We might see some people struggle less in the climbing contest if their systems were better tuned and adjusted for them. It was well received by all who participated.

E. Awards Committee - Dick Mitchell/Bruce Smith. This year Lifetime Achievement Awards were presented to two deserving individuals. John Cole was recognized as the inventor of the rack. The award was presented by Bill and Miriam Cuddington before the entire Huntsville Grotto. The award was a surprise to John and there was a great response from those attending as there was a 5 minute standing ovation when the award was announced. There were tears all around. The second award was presented to Charlie Gibbs for his invention of the Gibbs ascender. The award was presented by Bruce Smith at a small gathering of family and friends. The presentation was arranged as a complete surprise to Charlie. He commented that he was humbled that anyone remembered him. Needless to say it was a very emotional event.

F. Bylaws Committee - Bill Boehle and Terry Mitchell. Terry Mitchell reported that there were no new changes this year. If anyone has any suggestions for changes, they should contact either of us.

G. Web Page - Gary Bush webmaster. Gary reported that we are up-to-date and that Nylon Highway #56 should be posted shortly. He also reported that after consideration the EC voted to remove the password access to the Nylon Highway. Gary also reported that he has received many photos for the photo gallery on the website where we can display photos from past events. If anyone has photos of past meetings, contests, or other events, they should send them to Gary Bush to be included. Please identify dates, locations and people, if possible. If people have suggestions for other things they would like on the website, send Gary an email and we will see what can be done.

V. Old Business:

A. None.

VI. New Business:

A. Bill Cuddington introduced Steve Hudson who is the President of PMI who was able to join us today. The group acknowledged PMIs long time support of the Vertical Section with a round of applause.

B. Ray Sira was designated as the Section's onsite liason for the MayaCon 2012 NSS convention.

C. Dick Mitchell asked for feedback on several questions: (1) Our membership is about 250 out of over 10,000 NSS members---Should it be more and, if so, how would we get more people?; (2) Our leadership is aging---Should we be involving younger people, and how?; (3) Should we be increasing the distribution of the Nylon Highway, and how?; and (4) Should the Vertical Section try to get more publicity from means such as articles in the NSS News?

It was suggested that we use the Yahoo newsgroup as a means to alert members that new articles are available in the Nylon Highway. While not all VS members have signed up for the newsgroup, we could use it in this manner for those that choose to participate.

It was asked how do people become VS members. People can either sign our roster at an official event such as convention, send in an application that is available on the website, or to just send the Sec/Treas an email with their name and address saying they want to be a member. Membership is for 5 years and, when acknowledged, they are also given the opportunity to join our newsgroup.

Someone suggested using the NSS News as a means of notifying members that a new Nylon Highway is out. Gary Bush clarified that even IOs have to pay for notices in the NSS News.

Many organizations have aging membership. Younger people have many varied interests. Pehaps we need to sit down with some of them and talk about what would attract them to our group. What do we need to do or provide to involve them in our activities?

Can we make better use of the On Rope forum on CaveChat to promote membership and participation in our activites? Tim White is the moderator of that forum. There are more younger participants there who could be recruited for section membership. Tim needs to look into this.

It was suggested that some of the recent recognition awards would translate into a good short article for the NSS News. Bruce Smith said that was something that is being worked on.

Membership in the past was hurt by non-timely publication of the Nylon Highway. This was compounded by the lack of articles being submitted to the editor. We have an interest in our material from many people in the caving community, as well as the search and rescue community, and other users of rope. We still have a need for people to submit material to the editor.

We need to interest people in safe vertical caving. Perhaps a series of columns or articles in the NSS News on Vertical Techniques and Tips would be helpful in educating people and recruiting new members.

It was suggested that our best way to be in contact with people is through education and training. There we can influence them to be safe vertical cavers and to convince them of the benefits of paricipating in our organization.

Steve Hudson asked us who our market is. Is it cavers or all SRT practitioners? There is a big difference between the two. There is a much bigger group of people out there than just cavers.

It was suggested that perhaps we should produce a short handout on vertical caving that could be given by grottos to new members. It could educate them on the proper training necessary to safely participate in vertical caving activites and to introduce them to the Vertical Section.

VII. Elections:

A. Secretary/Treasurer (1 year term) - Bill Boehle was nominated and reelected by acclamation.

B. At-Large Board Members (2 year term, 2 to be elected) - Miriam Cuddington, Rory Tinston, Ray Sira, and Mike Rusin were nominated. A ballot of the section members present was conducted. Miriam Cuddington and Ray Sira were elected by a majority of the votes cast. [Note: Current At-Large members Dick Mitchell and Terry mitchell have 1 year remaining in their terms.]

VIII. Adjournment - Motion to adjourn was made and carried. Time of adjournment was approximately 2:35 PM.

[Additional note: Subsequent to the Meeting, the Board Members elected Dick Mitchell as Chair and Terry Mitchell as Vice Chair. The four appointed members were re-appointed to serve for another year. They are:
* Contest Committee - Bill Cuddington
* Vertical Techniques Workshop Committee - Terry Clark (Assistant: Lynn Fielding)
* Education Committee - Bruce Smith
* Nylon Highway Editor - Tim White

Respectfully submitted,
Bill Boehle

(Rev. 1)
To be approved at 2012 Convention meeting

NSS VERTICAL SECTION

SECRETARY'S REPORT

July 2011

By Bill Boehle

Number of Members (current/just expired)	......	262
Number of Members Current as of 2011	......	256
Number of Subscribers Current as of 2011	......	13
Number of Annual Volumes Paid for 2011	......	0
Number of Complementary Subscriptions	......	3

YEARS PAID:	MEMBER	SUBSCRIBER	ANNUAL VOLUME
Comps			3
2011	1	0	0
2012	0	0	0
2013	112	3	0
2014	90	8	0
2015	53	2	0
2011 Totals:	256	13	3
Expired 2010:	6	1	
Totals:	262		

NSS VERTICAL SECTION

TREASURER'S REPORT

July 2011

By Bill Boehle

INCOME:

Nylon Highway Annual Volume Sales	$0.00
2010 Convention Workshop Registrations	$650.00
Symbolic Item Sales	$349.00
Nylon Highway Back Issue Sales	$37.00
Shipping/Postage Charges	$21.93
Donations	$0.00
Bank Interest (Ally) July 2010 - May 2011	$217.18
TOTAL INCOME:	$1,275.11

EXPENSES:

Shipping/Postage Costs	$11.35
NSS - wesite hosting fees (2011)	$12.00
2010 Vertical Workshop Transportation Expense Subsidy (Terry Clark)	$309.00
2010 Climbing Contest prizes	$391.41
Vertical Workshop & Rebelay Course Supplies/Expenses	$23.29
Nylon Highway Annual Volume Production & Mailing Costs	$0.00
Symbolic Items Restocking (T-shirts, Sweats, etc.)	$0.00
Symbolic Items Restocking (VWS Instructor T-shirts)	$397.80
VS Recognition Awards	$184.62
Climbing Contest Record Boards (updates)	$0.00
Printing/Photocopying - Climbing Contest	$0.00
Photocopying/Supplies for 2010 NSS Convention administration	$41.83
Petty Cash for postage	$30.00
Training/Education Committee Printing Costs	$0.00
TOTAL EXPENSES:	$1,401.30

ACCOUNT BALANCES: (as of 6/30/2011)

TD Bank (NJ)	$2,504.62
Ally (formerly GMAC)	$10,198.74
TOTAL:	$12,703.36