Typecasting The Vertical Caver - Part II

Preliminary results of the Mitchell Ascending System ergonomic tests

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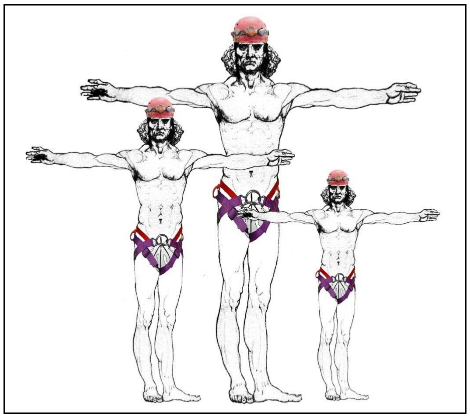

I began to conduct body type tests when my research failed to find significant testing that treated the human body as a mechanical part of an ascending system. My first efforts were directed at the Frog System because I felt that even a "universal" system should be reconsidered if it hindered a specific 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).

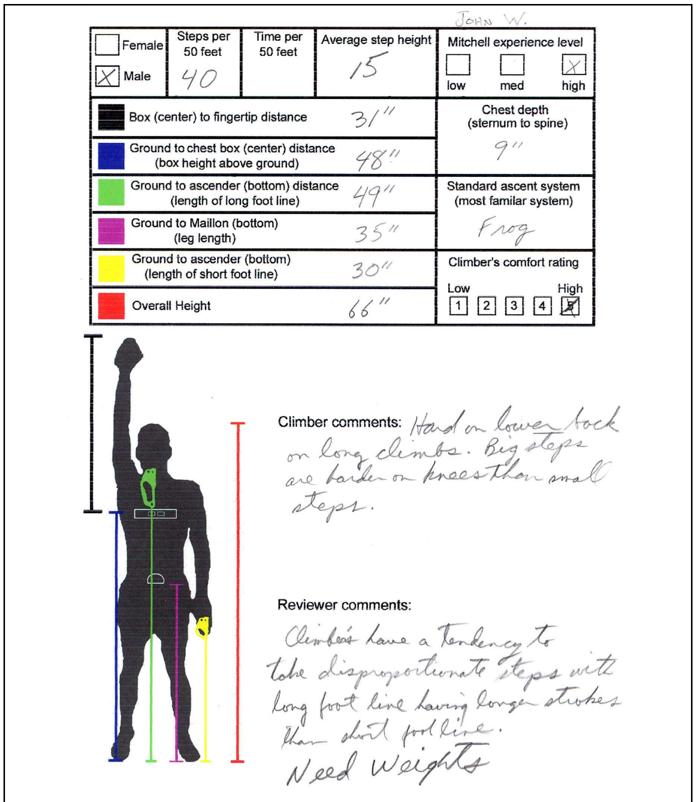

Fig. 2 The actual data sheet for my personal Mitchell System test results. Measurements are in inches. The notation "Need Weights" indicates that the weight of the climber may be necessary information that was not included in the first tests.

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.

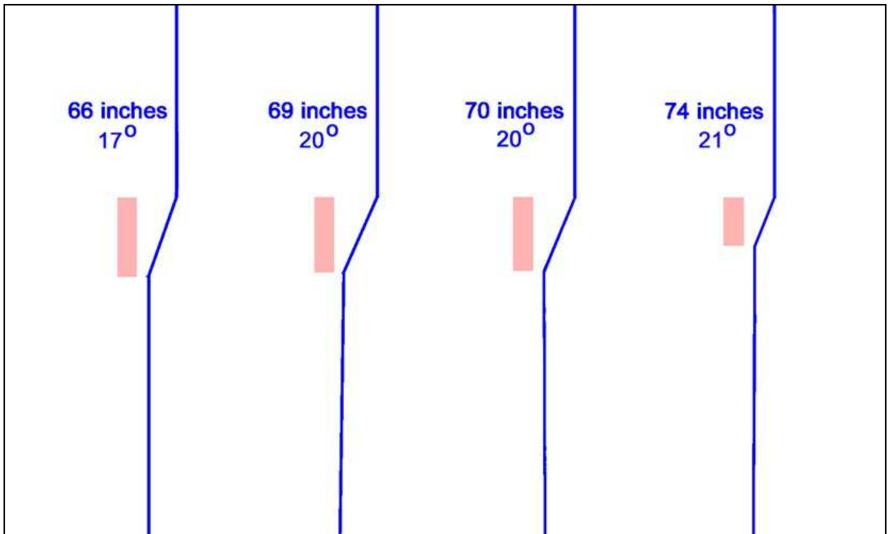

Fig. 3 The blue line represents the main climbing rope. The red area indicates the relative distances between the lower ascender and the roller box for each climber. Even the great difference between the first and last climber's lower ascender position has little effect on the climbing angle.

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.