A Comparison of the Trucker's Hitch, 3:1 Block and Tackle, Voodoo, and Poldo Tensioning Systems

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Introduction

In sport and rescue rigging it is sometimes desirable or necessary to produce tensioned ropes (e.g., guided rappels, highlines) or pre-tensioned anchors and back ties. These systems can be constructed in a variety of ways, and for low tension systems, the Voodoo (Evans 2015) has rapidly become a favorite for some riggers. With an expanding selection of tensioning options to work with, riggers can chose which method they prefer based on what they know, and the properties of each tensioning method. To date, however, there has not been a data-based comparison of methods riggers can use to make decisions. What is needed is a head to head comparison between methods where the properties of each tensioning system are measured objectively. Such a data set would enable more informed rigging choices in the field, hopefully improving both recreational safety and rescue response.

Presented here is a direct comparison of the Trucker's Hitch, 3:1 Block and Tackle, Voodoo, and Poldo methods of tensioning a rope. To generate the comparison each system was rigged between two stationary points using the same ropes and carabiners, recording the time needed to rig the system, required rope length, input force, maximum force generated at the anchors, and tension when completely rigged. The actual mechanical advantage of each system was determined, then each system was subjectively ranked on ease of remembering how to rig the system. Lastly, the gear required to rig each system was compared. Because all these methods can be constructed with carabiners (most common) or rope only (not compared here), the amount of equipment required is variable, but the properties of each system rigged with the same type of equipment can be compared.

This comparison will start with a brief description of each method so all readers know exactly what systems are being compared.

Brief Description of Each Method

Truckers Hitch:

Commonly used to tie down loads in industry, this is probably the most well-known of the systems compared. It is constructed by tying an inline loop knot in a rope anchored at one end, running the rope around an object, looping the running end through the loop knot, and pulling down to create tension (Figure 1A). Trucker's hitches are inline 3:1 haul systems with considerable friction within the system due to rope on rope friction and friction around whatever the rope was looped around. To hold tension the hitch must be locked off. Here I use the half hitch and overhand on a bight.

3:1 Block and Tackle:

A block and tackle is as simple as one end of a rope anchored, then the rope looped between two carabiners on anchors. The more times the rope is looped through the carabiners, the higher the mechanical advantage, but also higher the friction. To create a 3:1 haul system, one end is anchored, then the rope is passed through the carabiner at the far anchor twice, and once at the carabiner where the rope is anchored (Figure 1B). This system also requires a lock off to hold the tension, here I use a half hitch and an overhand on a bight.

Voodoo:

This system is also built starting with an inline knot in a rope anchored at one end, with the rope run around a second anchor carabiner and brought back to the inline knot. Clip a carabiner to the inline knot, pass a bight of the rope exiting the inline knot through the carabiner, and clip this new bight of rope with a carabiner connected to a knot in the rope tail (Figure 1C, and see Evans 2015b for extensive instructions).

Poldo:

Tie a loop knot in a rope, clip a carabiner into it, then clip the carabiner onto the running end of the rope forming a loop. Clip the loop into an anchor carabiner, and clip the running end of the rope into a second anchor carabiner. Pull the tail of the rope up to the loop formed with the first carabiner, tie another loop knot, and clip into this original loop with the tail of the rope. Move the carabiners to the middle of the span, then tension by pulling the two carabiners apart (Figure 1D, see Evans 2015b for extensive instructions).

Figure 1: Examples of the four tensioning systems investigated. **A)** Trucker's Hitch locked off with a half hitch and an overhand on a bight, **B)** 3:1 Block and Tackle locked off with a half hitch and an overhand on a bight, **C)** Voodoo, **D)** Poldo. All these systems can be tied in a variety of configurations; only the variant tested is shown here. For additional examples of the Voodoo and Poldo and illustrated directions on how to tie them, see Evans 2015b.

Materials and Methods

Fixed length stationary anchors were constructed on the same two immobile poles. All four systems were then tied by the author (T.E.) with lightly used 9mm PMI EZ Bend rope connected to two used aluminum HMS carabiners. Small Black Diamond locking carabiners were employed when needed. To standardize the amount of rope used, the termination knots employed were the figure 8 on the bight, and the butterfly as the inline knot, both tied tightly and with bights just large enough for a carabiner. The trucker's hitch and 3:1 block and tackle were locked off with a half hitch and an overhand. All the systems were taken apart completely, the rope length used measured, and rigged a second time as quickly as possible, not attempting to minimize the amount of rope used. The rigging time required was recorded from the time a piece of rope was picked up, to when the system was completely tightened starting with the anchors already constructed. No practice was provided before timing (other than rigging the system to measure rope length) so all values are rigging times on the first try including fumbling with knots, carabiners, etc. It is fully acknowledged that the amount of time required for rigging is partially a subjective one, because each rigger is more familiar with different systems. However, it is still useful to compare the time a single rigger takes to rig the same systems to provide an approximate baseline of how long rigging each system might take.

To calculate the Actual Mechanical Advantage (AMA) for systems, the force applied to each system and the force exerted on the anchors was measured using Enforcer load cells. The AMA was calculated as the force at the anchor divided by the input force. These measurements were inconsistent, probably due to difficulties in consistently overcoming internal friction within systems, so another proxy for system energy efficiency was also employed. The ratio of the input force to how much force remained after the system was completely built was calculated, again measured using Enforcer load cells. This is roughly an efficiency ratio of force put into the system and how much force can be expected during use.

To further investigate the internal workings of the Voodoo and Poldo, both systems were constructed and pulled as tight as possible, and the internal tension measured. They were then built with pulleys at each carabiner. The intent was to determine if internal friction keeps the Voodoo and Poldo from slipping, or if it is due to the opposite and opposed forces created by haul systems within the Voodoo and Poldo pulling against each other that keep the systems from going slack.

After all rigging was completed, each system was subjectively scored on how easy it was for the author to learn and remember them. This is also a subjective measure provided to show the relative difficulty in learning the different techniques.

The combined results are presented in a single table for ease of comparison.

Results

Nearly all systems take approximately the same amount of time to rig, between 35 and 39 seconds (Table 1). Therefore, duration of rigging is practically the same for all four systems assuming an experienced rigger.

The Trucker's Hitch, Voodoo, and Poldo require nearly the same amount of rope: in this case between 4.4m (14.5ft) and 4.7m (15.5ft) of rope (Table 1). The 3:1 Block and Tackle, however, requires considerably more rope, ~6.9m (~22.5ft) (Table 1), and thus is less rope efficient than the other three methods.

Table 1A: Results presented in metric units (centimeter, meters, and kilonewtons).

Tensioning System	Time to rig (seconds)	Rope length required (centimeters)	Rope length required (meters)	Actual Mechanical Advantage (AMA)			Input Force to Holding Tension Ratio			Tension built with only carabiners	Tension built with carabiners and pulleys	Ease of learning and remembering
				Peak force applied to system (kN)	Peak force on anchors (kN)	Calculated AMA	Peak force applied to system (kN)	Tension in static line (kN)	Calculated input to tension ratio			
Trucker's Hitch	39	447	4.47	0.98	1.72	1.75	0.979	0.489	0.500	N/A	N/A	Easy
3:1 Block and Tackle	39	686	6.86	0.62	1.28	2.06	1.068	0.623	0.583	N/A	N/A	Very Easy
Voodoo	35	443	4.43	0.69 0.77	1.60 1.33	2.34 1.71	0.979	0.409	0.418	0.376	0.615	Hard
Poldo	36	471	4.71	0.71	1.16	1.63	0.890	0.320	0.360	0.224	0.269	Hard

Table 1B: Results presented in English units (inches, feet, pounds force).

Tensioning System	Time to rig (seconds)	Rope length required (inches)	Rope length required (feet)	Actual Mechanical Advantage (AMA)			Input Force to Holding Tension Ratio			Tension built with only carabiners	Tension built with carabiners and pulleys	Ease of learning and remembering
				Peak force applied to system (lbs)	Peak force on anchors (lbs)	Calculated AMA	Peak force applied to system (lbs)	Tension in static line (lbs)	Calculated input to tension ratio			
Trucker's Hitch	39	176.0	14.67	220	386	1.75	220	110	0.50	N/A	N/A	Easy
3:1 Block and Tackle	39	270.0	22.50	140	288	2.06	240	140	0.58	N/A	N/A	Very Easy
Voodoo	35	174.5	14.54	154 174	360 298	2.34 1.71	220	92.0	0.42	84.6	138.2	Hard
Poldo	36	185.5	15.46	160	260	1.63	200	72.0	0.36	50.3	60.5	Hard

Measuring the AMA of each system was complicated. As the systems were tightened, the peak load at the anchor and the input were measured (Table 1). Because hauling on these systems is jerky and there are multiple places where internal friction must be overcome to initiate movement, it was difficult to apply the same input forces, so the results were inconsistent for a given system. For example, the Voodoo AMA was measured as both 1.71 and 2.34, a difference of 27%. These inconsistencies indicate that the numbers provided in Table 1 for the AMA, are rough approximations at best. It is likely that similar errors are associated with each system. As such, it appears the AMA of these systems appears to be somewhere between 1.6 (ish) and 2.4 (ish), less than the ideal mechanical advantage of 3:1 for the trucker's hitch and block and tackle.

A more consistent measure between systems is the ratio of input force and the amount of tension in the system when rigged (Table 1). This is a measure of how efficiently the system holds the tension applied to it during rigging. The 3:1 block and tackle was the most efficient (0.58), followed by the truckers hitch (0.50), Voodoo (0.42), and Poldo (0.36). This set of results is probably the most operationally useful because it shows that each system practically does not hold all the tension put in them, but loses between 40 to 65% of the input force through slippage and stretch, when fully rigged.

In comparing the Voodoo and Poldo constructed with and without pulleys (Table 1), it is clear that greater internal tension can be created when using pulleys, a tension that also remains when the systems are free from outside influence. This suggests that the friction within the Voodoo and Poldo inhibit tensioning the system, but the internal friction is not what holds the systems tight during use.

The tensioning methods required different amounts of time to learn, with the 3:1 block and tackle requiring the least amount of time to learn. It was learned in a matter of seconds, while the trucker's hitch took a minute or two to learn. The Voodoo and the Poldo, on the other hand, took considerably more time to learn. Both required concerted study and practice to get them right the first time every time.

The amount of equipment needed to construct these systems also varies. Ideally, in addition to a rope, it requires only two carabiners to construct the trucker's hitch and 3:1 block and tackle, three carabiners for the Voodoo, and four carabiners for the Poldo. While all four systems can be tied without any carabiners at all, having these carabiners reduces the friction in each system and reduces wear on the ropes. So the Voodoo and Poldo both benefit from consuming more equipment than the trucker's hitch or the 3:1 block and tackle. The friction within each system is also correlative to the number of carabiners each employs, except for the 3:1 block and tackle, which employs two carabiners, but the rope runs over carabiners three times, thus increasing the friction within the system relative to the trucker's hitch.

Discussion and Conclusions

Surprisingly, the four systems compared here are remarkably alike. All take nearly the same amount of time to rig, and three of the four require about the same amount of rope, though the 3:1 block and tackle requires more rope. The mechanical advantage provided by each system is not clear, but are definitely not high across the board. The tension provided by each system is nearly the same, though the truckers hitch and block and tackle do provide greater tension than the Voodoo or Poldo. For all intents and purposes, functionally the systems are quite similar, except for the greater rope demand of the block and tackle.

Where two systems seem to show improved performance is in how easy it is to learn them and how much equipment is required to build them. Both the trucker's hitch and block and tackle are simpler to learn and require less equipment than the Voodoo or Poldo (assuming carabiners at each rope deviation point). This does not mean either the Voodoo or Poldo should not be used or taught in the future, simply that the systems are slightly less efficient in ease of learning, equipment used, and tension provided.

These results, in conjunction with previous research, clarify how both the Voodoo and Poldo work. Stovall (Unknown Date) showed that, when rigged, a Voodoo retains about 50% of the input force it was rigged with. Here I measured a slightly lower value, but the results are consistent; the Voodoo, and probably the Poldo, retain about 50% or less of the initial tension imparted to the system. When both systems are rigged with pulleys in all places where ropes are

deviated, the systems can be tensioned more, indicating two things. First, the friction within both tensioning systems makes it harder for a rigger to tension them as much as systems with less friction. Second, when friction was reduced, both still held, so the internal friction in both the Voodoo and Poldo are not what is keeping the systems tight. If the internal friction held the Voodoo and Poldo tight, then the systems built with pulleys would have held a much lower tension. Because the systems built with pulleys held a higher tension, internal friction cannot be what holds the system in tension. Rather, both the Voodoo and the Poldo are haul systems hauling on themselves (Figure 1). Once tension has been added to these systems and they are static, the forces within them must be equal (e.g., nothing is moving). In other words, the forces in each haul system hauling on itself are equal, so no movement occurs because internal forces pulling against each other are equal. What this means practically is that you can tension a Voodoo or Poldo, and once rigged, it will stay taut even when subjected to failure forces (Evans 2015a). In fact, when tested in end to end pulls, the Voodoo did not slip, but rather stretched, and ultimately failed at the inline knot (butterfly in Figure 1C here, Evans 2015a). This means that the Voodoo, and probably the Poldo, are as strong as the knots used to rig them, so are just as strong as any other tensioning system investigated here.

Finally, the choice of which tensioning system you chose to use is your own. I encourage choosing the system that is most appropriate for your application(s), rather than using a system based on how novel it is or the impression it makes on those around you. These data suggest it is possible to get a tensioned line just as fast, with less equipment, and tighter using a trucker's hitch than a Voodoo. This does not mean a Voodoo is not useful, just that simpler rigging sometimes may be more functional than more complex rigging. On the other hand, sometimes the more complex rigging is more appropriate. For example, when constructing a tensioned line over a river it may be more functional to use a Voodoo or Poldo because the line can be de-tensioned and lowered into the water to allow boat traffic downstream (so watercraft do not get caught on the rigging), then the system tensioned again in a matter of seconds. Re-tensioning a slacked system rigged with the trucker's hitch or the block and tackle would be slightly more time intensive. In short, I encourage you to use the system most appropriate for the rigging conditions you face, and hope that these data sets provide the information that facilitates these decisions.

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Literature Cited

Evans, Thomas, 2015a, Strength and Failure Mode of the Voodoo Tensioning System (http://sarrr.weebly.com/sar3-original-research/strength-and-failure-mode-of-the-voodoo-tensioning-system)

Evans, Thomas, 2015b, The Voodoo and Poldo: Simple Tensioning Systems (http://sarrr.weebly.com/technique-descriptions.html)

Stovall, Paul, Unknown Date, The Voodoo tensioning system (https://drive.google.com/file/d/0B2kHROITDB1lbkFudHFQRWNobGM/view)