Comparison between two different methods of tying a prusik knot for rope rescue: traditional triple wrap and triple wrap with a double fisherman's knot on the hitch

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Word Count:- 3765

Table Count:- 1

Figure Count:- 5

Key words: Pruisks, Rope rescue, Fisherman's knot on hitches

No Conflict of Interest

Background

Working in the Emergency Medical Services (EMS) within the pre-hospital setting, one may have to perform a rescue to save a patient's life. There are various different types of rescues that can be performed; they range from rope rescue, aviation rescue, aquatic rescue, fire search and rescue as well as urban search and rescue (USAR). Emergency care providers who engage in these rescue activities are required to be proficient and safe in a number of rescue related skills. The emergency care providers also need to be familiar with the different types of equipment available for use during the various types of rescue activities. During a rope rescue, there are many different skills inclusive of knots specialized pieces of equipment which the emergency care provider needs to be familiar with. The prusik knot being one of the most commonly utilized knots in rope rescue.

There is a paucity of literature on the tying of the triple wrap with a double fisherman's knot on the hitch prusik. In comparison, a fair amount of literature is available on the traditional triple wrap prusik knot which supports its use in the rope rescue environment. The prusik knot has many different uses within the rope rescue environment, which includes being used as a rope-grabbing device, belay device and to ascend a rope. By comparing the traditional triple wrap prusik knot on which there is literature to support its use in the rope rescue environment to that of the double fishermans knot on the hitches, the aim of this study was then to determine whether this method of tying a prusik knot was safe to use in rope rescue.

Research Design

A quantitative experimental research design was utilized. This was the perfect design for the comparison of the breaking strength, slippages and deformities of the two different prusik knots, as we were looking at numbers to compare the breaking strength and slippage of the two different prusik knots. The quantitative design was appropriate due to the fact that quantitative research is investigatory research which can be used to improve knowledge.[2]

Population and Sample

Determining the size of the study group was very important for the validity of the research**.** The minimum requirement was 15; however, it was determined that this number did not detect the differences adequately and it had a poor statistical level.

To ensure sufficient power to detect an effective size of 0.5, a power analysis for ANOVA was performed with IBM SPSS Version 23. One-way ANOVA was calculated to have a power of 0.95 in detecting an effect size of 0.5. Sample sizes of 30 of the two different prusik knots were then pulled to ensure statistical significance

Data Collection Procedure:

The 7.5mm accessory cord and the 11mm static rope were procured. Both the accessory cord and the static rope were then cut into the correct lengths of 1.5 meters each. Following which the accessory cord was used to make prusik loops and they were tied using the double fisherman's knot. The static line had

a figure of 8 on a bite tied on one end. We then tied the two different types of prusik knots (traditional and double fisherman's knot on the hitch) onto the static line. For each pull, a new piece of

static line was utilized.

The pulling of the knots was done by an electronic winch which had a capacity of 6804kg, which was securely bolted down and was powered by a deep cell battery. An electronic winch was used to ensure a more constant pull. The CAS CL-2001 A/B load cell calibrated to 2000kg was connected to the winching system via a prusik, which in turn was attached to the static line. The prusik was tensioned around the static line and the start position was then marked. The prusik was then pulled until the knot broke.
Data of the breakage was recorded by using the load cell to see how many kg/kN the rope broke at and where the prusik knot broke. Slippage was measured in centimeters using a tape measure. Slippage was measured from the starting point from when the prusik knot was under tension at which point it was marked, to where the prusik was on the static line when the knot broke.

The data was collected and captured on a data collection template. The data captured on the template was comprised of the breaking strength (kg/kN), where the knot broke and the slippage in (cm). Data was also collected through a computer program which was designed to collect the data directly from the load cell.

Validity and reliability

To ensure reliability and repeatability only newly procured 11mm static line and 7.5mm accessory cord were utilized. A calibrated CAS CL-2001 A/B load cell and proof of its calibration was used to ensure validity of the research. This was monitored visually and via video camera as well as by the program that was designed to electronically capture the data from the load cell.

Results

Breakage

Breakage in Kg

The traditional prusik after 30 pulls had a maximum breakage of 1272kg, minimum of 967kg and a range of 305kg, with a mean breakage of 1132.43kg. In comparison the prusik with the double fisherman's knot on the wraps after 30 pulls had a maximum breakage of 1272kg, minimum of 892kg and a range of 382kg, with a mean of 1145.07Kg.

Breakage in kN

The traditional prusik after 30 pulls had a maximum breakage of 12.47kN, minimum of 9.48kN and a range of 2.99kN, with a mean breakage of 11.08kN. In comparison the prusik with the double fisherman's knot on the wraps after 30 pulls had a maximum breakage of 12.22kN, minimum of 8.70kN and a range of 3.52kN, with a mean of 11.22kN.

Where the knot broke

Out of a total of 30 pulls the traditional prusik broke 29 times at the base of the wraps (96.7%) and the prusik snapped completely off the static line once (3.3%). In comparison the prusik with the double fisherman's knot on the wraps, broke at the wraps under the double fisherman's knot 26 times (86.9%) and the prusik snapped completely off the static line four times (13.3%).

Slippage

Slippage in Cm

The traditional prusik had a maximum slippage of 18cm, minimum of 1cm, a range of 17cm, with a mean slippage of 5.47cm. The prusik with the double fisherman's knot on the hitches had a maximum slippage of 30cm, minimum of 8cm, and a range of 22cm, with a mean slippage of 18.60cm.

First point of slippage KG

The first point of slippage of the traditional prusik was at a maximum of 1190kg, minimum of 564kg, range of 626 kg with a mean slippage of 873kg compared to the prusik with the double fisherman's knot on the hitches, which had a maximum of 925kg, minimum of 506kg, and range of 419kg with a mean of 671kg.

Table 1: Shows the average results of the research conducted, looking at Breakage and slippage.

Prusik	Breakage (kg)	Breakage(kN)	Slippage (cm)	Slippage (kg)
Traditional prusik	1132.43	11.08	5.46	872.9
Prusik with double fishermans on the hitches	1145.06	11.22	18.60	671.88

Discussion

A total of 60 prusiks knots were pulled during this research study as part of the data collection process; 30 traditional prusik knots and 30 prusik knots with the double fisherman's knot on the hitches. The discussion will look at the breakage in kg/kN, where the prusik knot broke, slippage distance in centimetres and at what weight did the prusik knot start to slip in relation to the literature presented.

Breakage

Breakage in Kg

The traditional prusik after 30 pulls had a maximum breakage of 1272kg, minimum of 967kg and a range of 305kg, with a mean breakage of 1132.43kg. The prusik with the double fisherman's knot on the wraps after 30 pulls had a maximum breakage of 1272kg, minimum of 892kg and a range of 382kg, with a mean of 1145.07Kg. This shows that even though the design of how to tie the knot was changed, the breakage

of the knot remained similar in strength with the prusik of the double fisherman's knot on the hitches. The average was 12.64kg stronger than the traditional prusik.

Breakage in kN

The traditional prusik after 30 pulls had a maximum breakage of 12.47kN, minimum of 9.48kN and a range of 2.99kN, with a mean breakage of 11.08kN. In comparison the prusik with the double fisherman's knot on the hitches after 30 pulls had a maximum breakage of 12.22kN, minimum of 8.70kN and a range of 3.52kN, with a mean breakage of 11.22kN. The average breaking strength of the traditional prusik from this study was lower than that which was found by Evans who made use of a 7mm accessory cord and a 11mm static line. The average breaking strength in the study conducted by Evans was 12,36kN .[4]

By comparing the breakage in the traditional prusik and the prusik with the double fisherman's knot on the hitches in this study, both the knots broke at a similar point with regards to kg and kN as seen in Table 1. This demonstrates that the prusik with the double fishermans knot breaks at a similar weight to the traditional prusik. This means that the way the knot is tied has not impeded the integrity of the prusik and the breakage depends on the accessory cord strength as they all broke around the same mean average.

Where the prusik knot broke

The integrity of a rope system depends on different factors that effects the rope, whether it be rescue devices, bends in the rope or a knot. If a rope has a bend, be it from a knot, pulley or any other rescue device it may become a concern to the emergency care provider as such bends (kinks) may cause an unequal stress to the rope. Such stresses include tensile stress on the exterior of the rope and compressive stress on the interior of the rope. A knot which contains bends will also cause stress to the rope.[5]

This is important due to the fact that in this specific study, 96.7% of the traditional prusik knots snapped at the base of the wraps (Figure 4), which is consistent with the research done by Evans who found that 96% of the failures of the traditional prusik occurred nearest to the load by the wraps under the bridge.[4]

In contrast, 86.9% of the prusik with double fisherman's knot on the wrap snapped at the wraps under the knot (figure 5). Thus this shows that the rope was weakened due to the bends made by the wraps. This reiterates to us how the bends in a rope can weaken the knot. In the traditional prusik knot, 3.3% and 13.3% of the prusiks with the double fisherman's knot on the hitches snapped completely off the static line.

Slippage

Slippage of a prusik is very important in a rope rescue system as it may indicate that the system is overloaded and warn of the impending failure of the system. Research has shown that slippage of the traditional prusik knot is not consistent or reliable therefore constant monitoring is needed.[6] In this study the traditional prusik, slipped between 1-18cm with a mean average of 5.47cm. This result compares well with the research done by Walker which showed that the traditional prusik slipped 5-8cm.[6] The first sign of slippage in kilograms fluctuated from anywhere between 564-1190kg, with a mean of 873kg. The traditional prusik knot was did not slip as constantly, which has been shown in previous research.[6] Analysis of the slippage of the prusik knot with the double fisherman's on the hitches shows that the prusik slips anywhere between 8-30cm, with a mean slippage of 18.60cm, the first sign of slippage was 506-925kg with a mean slippage of 671kg.

All of the prusik knot slipped with every single pull in this study (Figure 1). However the slippage with the traditional prusik was not continuously large enough to identify that it had slipped. Compared to the prusik with the double fishermans knot on the hitches where the knot slipped in lengths that were big enough to be noticed by the researchers. The prusik with the double fisherman's knot on the hitches, slipped at a lower, but more consistent weight, as compared to the traditional prusik.

As an example, in one of the pull tests with the traditional prusik, the traditional prusik knot slipped at 1144kg and the knot failed at 1218kg. This will reduce the time which the rope rescue technician has in order to see the impeding failure of the rope rescue system as shown in Figure 2. In one of the other pull tests, the prusik with the double fisherman's knot on the hitches slipped at a more consistent rate and at a lower weight as the prusik slipped at 587kg and the knot failed at 1044kg, therefore the rope rescue technician would easily be able to see whether the rope system was showing signs of failure.

Limitations

The limitations experienced in this study were that the computer program we used to capture the information had some errors when it came to a few of the tests. Having the video camera to record the information helped us capture what we had missed. This can be improved by rewriting the program to ensure no more errors will happen.

Conclusion

The research projects main focus was to determine whether the prusik with the double fisherman's knot on the hitches was safe to use in rope rescue. In order to determine this, the breaking strength and the slippage of the knot was determined in comparison to the traditional prusik knot.

It was found that both of the knots tested broke on a similar mean average. Thus this shows it was not breaking because of the way that the knot was tied, but down to the breaking strength of the manufactured accessory cord. This demonstrates that the prusik with the double fisherman's knot on the hitch is on par with the traditional prusik.

The slippage of both of the prusik knots tested demonstrated that there was slippage with both of the prusik knots with each pull. However the traditional prusik knot did not slip (cm) consistently, and therefore the researchers were unable to capture this. Based on this, the researchers feel that the slippage was not sufficient enough thus decreasing the chance of the rope rescue technician noticing the slippage which could indicate the impeding failure of the rope system. Whereas it was found that the prusik knot with the double fisherman's knot on the hitches, slipped (cm) more consistently and more profoundly. Thus giving the rope rescue technician time to see the slippage and to realize that the impending failure of the system is highly likely.

The prusik knot with the double fisherman's knot on the hitches breaking at a similar average of kg/kN to the traditional prusik demonstrated that it is safe for use when it comes to the strength of the knot. The constant slippage suggests that the knot could be used as a load limiter on a lowering and raising system. However more research must be done on the knot as a tandem triple wrap prusik to see if the slippage and breakage is consistent.

Conflicts of interest

There are absolutely no conflicts of interests between the authors and the co-authors in this research project.

Acknowledgement

We thank Mr. Mugen Govender for his input in the developmental phases of this research project and for his assistance in collecting the data for this project.

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