Arboriculture & Urban Forestry 2009. 35(6): 305–310

Damage Inflicted on Climbing Ropes by Handsaws

Brian Kane, Mac Cloyes, Mollie Freilicher, and H. Dennis Ryan

Abstract. Arborists frequently use handsaws while climbing, and a recent accident highlighted the danger of cutting one's rope with a handsaw. There do not appear to be any robust tests describing the ability of handsaws to cut ropes. The following study attached handsaw blades to a pendulum, which swung into a rope, bringing the blade and rope, which was under tension, into contact. The percent of the rope's diameter cut by the blade was measured, as well as the percent loss in the rope's strength after it was cut. Type of blade was a more important factor than type of rope with respect to the percent cut and percent strength loss, and there was a nearly one-to-one relationship between those response variables. The results of this study are discussed in the context of a climber's safety.

Key Words. Handsaw; Rope.

Arborists frequently use handsaws while pruning trees. Whenever they work aloft using ropes, there is a risk of the handsaw coming into contact with the rope. This is also true of chainsaws, and while the Z.133 Standard (Anonymous 2006a) clearly states that arborists shall be tied-in twice whenever they use a chainsaw, there is no such requirement when using a handsaw. It is required to use a lanyard as a second tie-in point during the work climb and Masters' Challenge events of the International Tree Climbing Championship (ISA 2008).

A recent injury highlighted the risk posed when a climber cuts his or her rope with a handsaw. In this accident, the climber completely cut his rope, fell out of the tree, and broke his neck (Georgia Arborist Association 2009). In light of this recent accident, which left the climber, who was not a novice, a quadriplegic, it became obvious that controlled testing of this type of accident was required. The objectives of this study were to determine the ease with which a climber could cut him- or herself out of the tree using a handsaw and whether a particular blade or rope (or combination thereof) was more likely to lead to rope failure.

METHODS

The study tested several common climbing lines and handsaw blades (Table 1, Figure 1). Ropes differed with respect to diameter and construction; blades differed by curvature, length, and teeth per millimeter. The study also tested one used blade and one new blade (each with conventional teeth), but did not include them in any statistical analysis because of the limited sample size. Initially, each author attempted to cut several ropes using the F3 blade, which was attached to a pole saw head. Each individual held the saw with two hands and made a single, quick pull along the rope, which was hung from a beam and loaded with a 41 kg (90 lbm) mass. The mass represents the maximum rope tension when a climber of mass 82 kg (180 lbm) is tied-in, situated with the rope running over a branch, around the trunk, and back to the saddle. Each author easily cut each rope.

Since there are many scenarios in which a climber's handsaw or pole saw might contact their climbing line or lanyard, and since it was also clear that a handsaw could easily cut through a climbing rope, an experimental protocol was developed to maintain a consistent interaction of rope and blade, with respect to impact force. Each rope was hung from the beam, as described above, and on the same beam was attached a pendulum (Figure 2), which held each blade (Figure 3) parallel to the ground when the long axis of the pendulum was perpendicular to the ground. The pendulum was raised 45° from perpendicular to the ground and released, delivering an impact force of approximately 440 N (100 lbf) at the point of contact, just before the pendulum returned to its initial position. Before cutting any ropes, the impact force was measured with a dynamometer (Dillon EDExtreme, Weigh-Tronix, Fairmont, MN) connected to the pendulum by a rope anchored to a wall. After releasing the pendulum from 45°, the rope stopped the pendulum as it reached its initial position and the dynamometer measured tension in the rope at the point of impact. The impact force of the pendulum was equivalent to the mean force (n = 10) measured when the second and

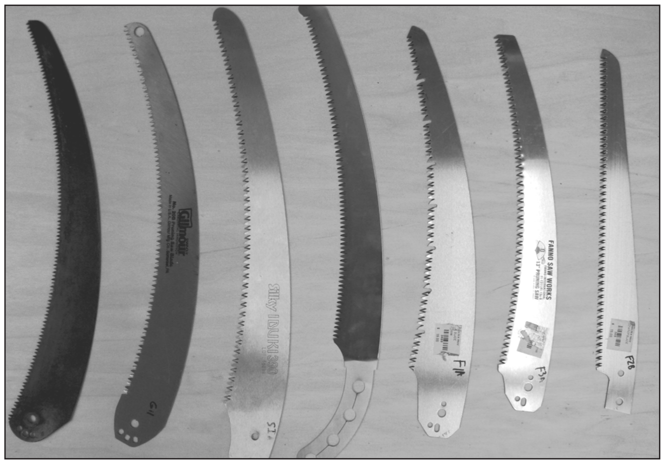

Figure 1. Blades (left to right): used (manufacturer unknown), new standard tooth (Gilmour), IB, ZU, F1, F3, F2 (abbreviations are in Table 1).

third authors applied a quick stroke with one or two hands on the handle of a handsaw that was attached to the dynamometer.

Using a digital caliper (CD-6CS, Mitutoyo, Japan), the diameter of each rope was measured (while the 41 kg mass was attached) at the point of blade impact before and after cutting. The pre- and post-cut diameters were converted to “percent cut” by dividing their difference by the pre-cut diameter. For ropes that were completely severed, percent cut equaled 100%. After cutting, ropes that were not completely severed were tested by applying an increasing tensile load [at a rate of 12.6 mm/min (0.5 in/min)] in a universal testing machine [133 kN (30,000 lbf) capacity; MTS, Eden Prairie, MN]. A piece of rope 1.0 m (3.3 ft) long was also cut past the section that was damaged during the cutting test, and its breaking strength measured as a control. Each end of the rope was tied with an anchor hitch to galvanized steel eyebolts [23.7 mm (0.93 in) diameter] attached to the testing machine. While tensile testing of climbing ropes typically follows the CI-1500 standard (Anonymous 2006b), the described setup was used because it was readily available. In reality, most attachment points (d-rings, carabiners, rope snaps) on a climber’s saddle are smaller than 23.7 mm in diameter. Since rope strength decreases with decreasing bend radius (McKenna et al. 2004), the values for rope strength are likely overestimates compared to actual field conditions. “Percent strength loss” was calculated the same way as “percent cut,” substituting breaking strength of cut and un-cut sections of rope.

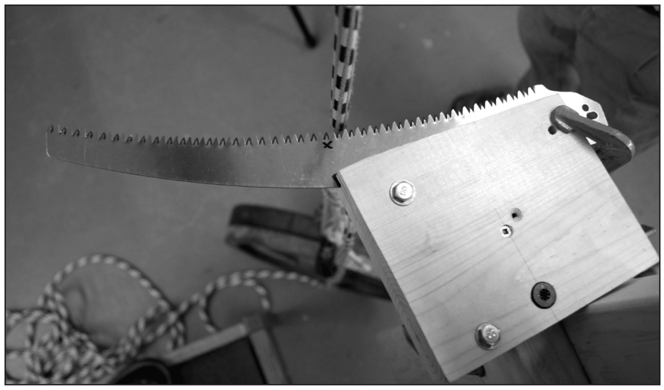

Figure 3. Blade in jig attached to pendulum. “X” marks the tooth that first made contact with the rope.

Figure 2. Pendulum attached to beam; the jig that held blades (see Figure 3) is attached to the pendulum with clamps visible just below the midpoint of the pendulum.

Aligning the blade with the same curvature in which it was attached to the pendulum during testing, the curvature of each blade was measured when traced on a piece of paper. The un-toothed edge of each blade was traced from a common starting point on the blade (opposite the first tooth closest to the handle) and on the paper. Curved blades (F1, F3, IB, ZU) contacted the rope between one-half and two-thirds of the blade length, depending on the curvature of the blade. This was not true of the straight blade (F2), for which initial contact occurred at approximately one-quarter of blade length.

The study authors expected to cut entirely through some ropes, but also measured horizontal acceleration of the pendulum (i.e., in the direction of its motion when the blade impacted the rope) throughout the test. Data were collected at 2048 Hz with a G-Link® accelerometer (Micro-Strain Inc., Williston, VT). Accelerations (m/s^2) provide an estimate of the resistance encountered by the blade as it contacted the rope. Large accelerations in the direction opposite the motion of the pendulum reflect a rope that was harder to cut with a particular blade. The study used the acceleration of greatest magnitude for analyses.

Using 3.3 m (11 ft) sections, each rope and blade combination were tested five times in a randomized complete block design, with ropes blocked in each blade. For every blade, except IB, the study randomly alternated between two individual blades; all ropes were tested on one IB blade.

A two-way analysis of variance (ANOVA) was used to investigate differences between ropes and blades for percent cut, percent strength loss, and acceleration. Levene’s test indicated the possibility of nonhomogeneous variance for each response variable, which remained after the study authors 1) removed the Zubat blade from the analysis (see following explanation), and 2) arcsine transformed the percent cut and percent strength loss data. To determine whether violating the assumption of homogeneity of variance invalidated the ANOVA, the analysis was repeated using a nonparametric permutation ANOVA (Anderson 2001). Although p-values differed slightly, significance levels from the permutation ANOVA completely agreed (to three decimal places) with the parametric ANOVA; results are presented only for the latter. An analysis of covariance (ANOCOVA) was used to determine a) the extent to which percent strength loss was due to percent cut (the covariate), and b) whether the relationship differed by blade and rope. All parametric analyses were performed in SAS (ver. 9.1, Cary, NC) and nonparametric analyses using R (ver. 2.8).

RESULTS

From the initial tests, it was obvious that a climber can easily cut through his or her rope with a handsaw. In the pendulum test, Zubat blades cut through every rope, and the study authors initially attributed the nonhomogeneous variance to this factor because the standard deviation for percent cut and percent strength loss was zero for Zubat blades. However, removing Zubat blades from the analysis only changed one result: acceleration was highly significant ($p < 0.0001$) among blades with Zubat included, but only significant ($p = 0.0477$) without Zubat blades.

For ropes, Blaze was more deeply cut than Blue Streak and Poison Ivy, Velocity was more deeply cut than Poison Ivy; and the Ibuki and F2 blades cut more deeply than the F1 and F3 blades (Table 2). Excluding tests with Zubat blades, Blaze was completely cut more frequently than any other rope (four times). Cutting reduced the strength of Blaze more than Poison Ivy, and the Ibuki and F2 blades caused greater strength loss than the F1 and F3 blades (Table 2). Cutting reduced the strength of ropes in accordance with percent cut, and while the effect was consistent among ropes, F2 and Ibuki blades more effectively reduced rope strength than F1 and F3 blades when percent cut was accounted for (Table 2). The difference between blades was also reflected in the ranges of percent cut for different blades. Although Ibuki and F2 blades cut more than 20% through all but one rope, F1 and F3 blades did not cut more than 26% through any rope. There were no differences among ropes with respect to acceleration, but acceleration was least for Zubat blades and greatest for F3 blades (Table 2). With respect to determining the percent cut and percent strength loss, differences among blades were far more important than among ropes. In the ANOVA of percent cut, the F-value for blade (62.0) was nearly 10 times greater than the F-value for rope (6.37). In the ANOCOVA of percent strength loss, the F-value for blade (283) was more than 40 times greater than the F-value for rope (6.93).

For ropes cut 20% or less, there was an almost equal chance (26/53) of failure at the point where the rope was cut or at the anchor hitch where the sample was tied to the testing machine (Figure 4). In contrast, no rope that was cut more than 31% failed at the anchor hitch. The mean breaking strength of ropes cut less than 20% was 20.5 kN (4600 lbf), only 4% less than the breaking strength of uncut ropes. Excluding ropes that were completely cut, the deepest cut that did not cause failure was 71%.

For a new pole saw blade that did not have razor teeth (Gilmour), but did have similar curvature and teeth per mm to the other blades, the average percent cut was 5.9% (standard deviation = 2.5%). The average percent cut was only 4.5% (standard deviation = 1.9%) for an old, well-worn blade without razor teeth (manufacturer unknown).

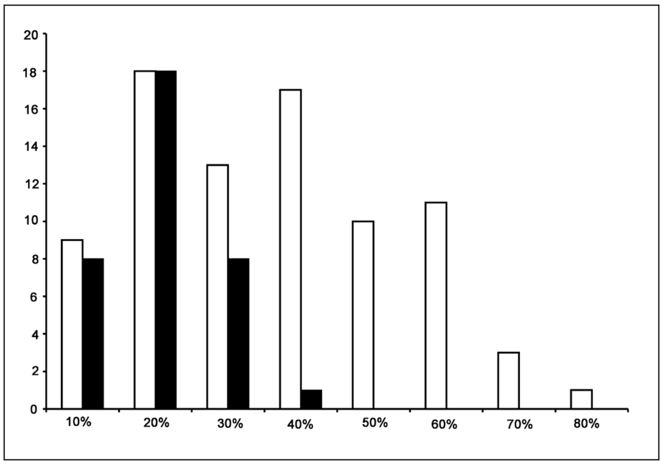

Figure 4. Frequency distribution of percent cut, categorized by type of failure: at the knot (shaded columns) or at the cut (un-shaded columns). The value on the horizontal axis is the maximum value for each category.

Table 1. Different ropes and blades used in the experiment, including means (standard deviation) for measured values as well as manufacturers' specifications. Percent strength loss (%SL) from rated tensile strength was calculated: (rated strength-knotted strength)/rated strength.

Rope (abbreviation)	Manufacturer	Mean Rated Strength[z] (kN)	Knotted Strength[y] (kN)	%SL from Rated Tensile Strength	Nominal Diameter (mm)	Diameter Under Tension[x] (mm)
Blaze	Yale	24.9	21.4 (2.24)	14%	11.0	10.3 (0.34)
Blue Streak (BS)	Samson	30.7	22.8 (1.19)	26%	12.7	11.9 (0.14)
Poison Ivy (PI)	Yale	28.9	25.4 (1.57)	12%	11.7	10.7 (0.26)
Safety Blue (SB)	New England	31.1	17.6 (1.84)	43%	12.7	11.7 (0.23)
Velocity (VEL)	Samson	26.7	19.5 (1.24)	27%	11.0	10.4 (0.31)
XTC	Yale	27.6	20.7 (1.55)	25%	12.7	12.0 (0.22)
Blade (abbreviation)	**Manufacturer**	**Blade Length (mm)**	**Teeth per mm**			
FI-K1500 (F1)	Fanno	356	0.24			
FI-1214 (F2)	Fanno	305	0.24			
FI-1311 (F3)	Fanno	330	0.24			
Ibuki (IB)	Silky	390	0.22			
Zubat (ZU)	Silky	330	0.30			

[z] As published in manufacturer's catalog.
[y] Tied with an anchor hitch.
[x] 41 kg (90 lbm).

Table 2. Means (standard deviations) for percent cut (% Cut), percent strength loss (% SL) (both in decimal form), and acceleration (m/s²) for each rope and blade (abbreviations are in Table 1). Within each classification and read down a column, means followed by the same letter are not significantly different (Tukey's HSD, $P > 0.05$).

Rope	N	% Cut	% SL	% SL LS Mean[z]	Acceleration
BLAZE	31	0.49 (0.37)a	0.48 (0.44)a	0.29 (0.024)a	2.96 (0.38)a
BS	30	0.39 (0.34)bc	0.40 (0.37)ab	0.29 (0.024)a	3.17 (0.57)a
PI	30	0.35 (0.35)c	0.35 (0.38)b	0.26 (0.025)a	2.98 (0.52)a
SB	30	0.42 (0.34)abc	0.40 (0.37)ab	0.26 (0.024)a	3.04 (0.61)a
VEL	30	0.48 (0.34)ab	0.43 (0.42)ab	0.23 (0.024)a	2.85 (0.58)a
XTC	30	0.41 (0.34)abc	0.42 (0.39)ab	0.28 (0.024)a	2.96 (0.55)a
Blade					
F1	30	0.13 (0.05)a	0.02 (0.05)a	0.15 (0.023)a	3.08 (0.33)ab
F2	30	0.47 (0.21)b	0.52 (0.23)b	0.36 (0.024)b	2.95 (0.62)a
F3	31	0.13 (0.06)a	0.03 (0.08)a	0.15 (0.023)a	3.28 (0.43)b
IB	30	0.40 (0.17)b	0.51 (0.19)b	0.41 (0.021)b	3.15 (0.54)ab
ZU[y]	30	1.00 (0.00)c	1.00 (0.00)c	n/a	2.50 (0.39)c

[z] The least squares (LS) mean for % SL is the arithmetic mean adjusted for the covariate % Cut; it is followed by the standard error (in parentheses).
[y] Zubat blades were not included in the ANOCOVA because they completely cut through every rope.

DISCUSSION

The most important finding is that there is little doubt a climber can easily cut through many climbing ropes with a handsaw, which may be more dangerous than realized. Since arborists work with many tools that are extremely dangerous (e.g., chain saws and chippers), climbers could easily underestimate the relative danger of their handsaw. It may also be true that climbers who learned to climb before the use of newer handsaws with "razor teeth" are less aware of their inherent danger. Although only limited tests were conducted on other blades, they appeared to be less likely to cut through a climber's rope.

Under the controlled conditions of the pendulum, which approximated the force a climber could apply with a sharp tug on his or her handsaw, the study did not completely cut through as many ropes as in the initial tests completed by hand, except when using Zubat blades. This was likely due to each author's ability to maintain contact of the entire blade length along the rope when cutting ropes by hand. In contrast, the pendulum mechanism maintained a fixed trajectory with respect to the rope.

Of blade characteristics that were expected to affect the efficiency of cutting (teeth per mm, blade curvature, and tooth sharpness), curvature may have exhibited greater influence than the others due to experimental protocol. For example, F2 and F3 blades shared the same number and type of teeth, but F2 blades more effectively cut ropes, presumably by virtue of their lack of curvature. The straight blade would be less likely to push the rope since each tooth needs to cut only a slightly deeper kerf in the rope. Observed, though not quantified, a large variation in the horizontal distance ropes moved at the moment of impact, the acceleration data reflect this as well. On a curved blade, each tooth must cut a disproportionately deeper kerf in the rope as the curve meets the rope. If the teeth were not able to cut through the rope quickly enough, a curved blade would eventually push the rope in addition to cutting it. Curvature may be less important than teeth per mm and inherent sharpness of a tooth, however, as demonstrated by the effectiveness of Ibuki and Zubat blades. Even though they have nearly the same curvature as F3 blades, Zubat blades have more teeth per mm and were far more effective cutting ropes. Ibuki blades, on the other hand, had fewer teeth per mm than F2 blades, but similar curvature to F1 blades, and yet they cut ropes as effectively as F2 blades. According to the manufacturer (http://www.silkysaws.com), Ibuki blades are designed for heavier cutting. They have fewer teeth per mm and lack several tooth features of Zubat blades, which cut ropes remarkably well. Regardless of the reason(s) explaining the differences among blades, those differences were much greater than differences among ropes, which highlights the overriding influence of blades with respect to percent cut and percent strength loss.

It was expected that smaller diameter ropes (typical of the 24-strand construction) would be easier to cut, especially given the alignment of the blade and the fixed trajectory of the pendulum, but the results did not support this expectation. Poison Ivy was less deeply cut than the other 24-strand ropes (Blaze and Velocity), but it is not clear whether this reflected the construction of the jacket or simply the slightly larger diameter under tension [0.4 mm [0.02 in)]. Since the cover strands for all three 24-strand ropes are polyester, and two of the 16-strand ropes (Safety Blue and XTC) were cut similarly to Blaze, the braiding process itself may produce a more cut-resistant rope.

With respect to percent strength loss, climbers can take some comfort in the finding that cutting a rope less than 20% of its diameter frequently caused no greater strength loss than tying an anchor hitch to attach rope to saddle. Cordage Institute guidelines (Anonymous 2004) suggest retiring double braid and jacketed ropes for which more than 10% of the cross-sectional area of the rope and 5% of the cross-sectional area of the core fibers, respectively, have been cut. It was interesting to observe the percent strength loss in ropes due to the knot (Table 1). Texts on rope report a general degradation in rope strength of 10%–50% when a rope is knotted (Anonymous 2004; McKenna et al. 2004), although there are few data to describe the performance of specific knots (Milne and McLaren 2006). In contrast, a spliced eye, which some climbers use on their rope, can retain 100% of the rated strength (Milne and McLaren 2006).

CONCLUSIONS

While this test did not simulate a specific situation in which a climber might cut his or her rope, it does reflect the general effectiveness of a blade to cut a rope (or a rope's resistance to cutting). In light of the many ways a blade and rope may come into contact, this study was a valuable first step in investigating the accident described in the earlier portions of this article. However, this study did not examine the effect of impact force, rope tension, blade angle, and other pertinent variables. Neither did the test regard other rope constructions (3-strand, 12-strand), which are used less often for climbing. In the interest of raising awareness of this type of injury in a timely fashion, only the initial findings are presented here. Additional studies continue to test other variables.

It is important to remember that choosing a climbing rope, handsaw, or any tool, should be made on the basis of many factors, not a single consideration such as the ease of cutting through one's rope with a handsaw. Although blade was clearly the more important factor in determining the likelihood of cutting one's rope, it does not seem prudent to require that climbers use a particular type of handsaw solely on the basis of reducing the likelihood of cutting through one's climbing rope. Since this type of accident appears to be relatively uncommon, a more judicious approach is to address this safety concern through training and raised awareness. Although there do not appear to be any specific investigations pertinent to handsaws, there is a wealth of epidemiological evidence connecting repetitive, forceful movements in the hand and wrist with carpal tunnel syndrome and tendonitis (NIOSH 1997). In light of this circumstantial evidence, and the finding that cutting productivity correlated well with the user's comfort level with a handsaw (Mirka et al. 2009), one may speculate that ergonomic injuries, such as those due to repeated strokes of a handsaw to complete a cut, would be a more likely cause of lost productivity in the industry. Future work should focus on 1) determining the field conditions under which ropes are likely to be cut between 30% and 70%, the range in which percent strength loss was greater than that caused by tying a knot in the rope but less than the point at which the rope would fail under the climber's weight; 2) developing experimental protocols to mimic such situations; and 3) which aspects of a blade (tooth design, teeth per inch, curvature) most influence cutting efficiency.

Acknowledgments. The authors thank Bartlett Tree Experts for funding our research; New England Ropes, Samson Rope, and Yale Cordage for donating ropes; Dan Pepin (University of Massachusetts) for building the pendulum; and two anonymous reviewers as well as the following individuals for helpful insights while we prepared and revised the manuscript: Jim Ackerman (Bartlett Tree Experts) Ed Carpenter (North American Training Solutions and CORErgonomics), Richard Herfurth (Bartlett Tree Experts), David Marren (Bartlett Tree Experts), Brian Maxson (Bartlett Tree Experts), and Scott Prophett (North American Training Solutions).

LITERATURE CITED

Anderson, M.J. 2001. A new method for non-parametric multivariate analysis of variance. Austral Ecology 26:32–46.

Anonymous. 2004. Fiber Rope Inspection and Retirement Criteria. Cordage Institute International Guideline CI 2001-04. Cordage Institute Wayne, PA. 67 pp.

Anonymous. 2006a. American National Standard for Arboricultural Operations–Pruning, Repairing, Maintaining, and Removing Trees, and Cutting Brush–Safety Requirements. American National Standards Institute NY, NY 32 pp.

Anonymous. 2006b. Test Methods for Fiber Rope. Cordage Institute International Guideline CI 1500-02. Cordage Institute Wayne, PA. 18 pp.

Georgia Arborist Association. 2009. Industry Incidents in Georgia. <http://georgiaarborist.camp8.org/Default.aspx?pageId=238936>.

ISA. 2008. International Tree Climbing Championship Rulebook. <http://itcc.isa-arbor.com/rules-scoring/resources/2008Rules_final_approved_022508.pdf> 33 pp.

McKenna, H.A., J.W.S. Hearle, and N. O'Hear. 2004. Handbook of Fibre Rope Technology. Woodhead Publishing Ltd., Cambridge, England. 416 pp.

Milne, K.A., and A.J. McLaren. 2006. An assessment of the strength of knots and splices used as eye terminations in a sailing environment. Sports Engineering 9:1–13.

Mirka, G.A., S. Jin, and J. Hoyle. 2009. An evaluation of arborist handsaws. Applied Ergonomics 40:8–14.

NIOSH (National Institute for Occupational Safety and Health). 1997. Musculoskeletal Disorders and Workplace Factors. US Dept. of Health and Human Services. 590 pp.

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Résumé. Les arboriculteurs utilisent fréquemment des égoïnes manuelles lors de l'ascension, et un récent accident a mis en évidence le danger de couper sa corde avec une égoïne. Il ne semble pas y avoir de tests de robustesse décrivant la capacité de l'égoïne à couper des cordes, et ce selon ce que nous avons pu découvrir. L'étude qui suit a consisté à attacher des lames d'égoïne à un pendule qui se balançait contre la corde qui était sous tension afin de les mettre en contact. Le pourcentage du diamètre de corde coupée par la lame a été mesuré tout comme le pourcentage de perte de résistance de la corde après la coupe. Le type de lame était un facteur plus important que le type de corde, et ce par rapport au pourcentage de coupe et au pourcentage de perte de résistance; enfin, il y avait une relation directe entre ces variables. Les résultats de cette étude sont discutés dans le contexte de la sécurité de l'élagueur.

Zusammenfassung. Arboristen benutzen gelegentlich Handsägen beim Klettern und ein kürzlich aufgetretener Unfall verdeutlicht die Gefahr von einem mit der Handsäge durchtrenntem Seil. Nach unseren Ermittlungen gibt es offenbar keine robusten Testverfahren, die die Fähigkeit von Handsägen, ein Seil zu durchtrennen. In der folgenden Studie wird ein Handsägeblatt an ein Pendel montiert, welches in ein unter Spannung stehendes Seil schwingt und Blatt und Seil in Kontakt bringt. Der Prozentsatz des durchtrennten Seildurchmessers wurde gemessen, ebenso wie der prozentuale Kraftverlust des Seiles nach dem Schnitt. Der Typus des Sägeblattes war wichtiger als der Seiltyp, in Relation zum Anteil der Schnitttiefe und des Kraftverlustes des Seiles. Es gab fast eine Eins zu Eins Relation zwischen diesen beiden Variablen. Die Ergebnisse dieser Studie werden im Hinblick auf die Arbeitssicherheit der Kletterer diskutiert.

Resumen. Los arboristas frecuentemente usan serrotes manuales mientras trepan y un accidente reciente alertó del peligro de cortar la propia cuerda con el serrote. Las pruebas no parecen ser suficientemente robustas para describir la habilidad de los serrotes en cortar las cuerdas, por lo cual nosotros lo investigamos. El estudio amarró hojas de serrotes a un péndulo, el cual se movía hacia una cuerda, acercando la cuerda y la hoja, lo cual fue bajo tensión y en contacto. El porciento de diámetro de cuerda cortada por la hoja fue medido, como también el porciento de pérdida de resistencia en la cuerda después que fue cortada. El tipo de hoja fue un factor más importante que el tipo de cuerda con respecto al porciento de corta y porciento de pérdida de resistencia, y la relación fue uno a uno entre estas dos variables. Los resultados de este estudio son discutidos en el contexto de la seguridad del trepador.