Workload Benefits of Using a Synthetic Rope Strawline in Cable Yarder Rigging in Norway

Giovanna Ottaviani, Bruce Talbot, Morten Nitteberg, Karl Stampfer

Abstract – Nacrtak

This study examined the difference in workload brought about by exchanging a 3.5 mm steel rope with a 4.0 mm synthetic fiber rope when dragging a strawline up a 300 m corridor in setting up a new cable-yarding line. Physiological workload was monitored through heart rate measurement, while the physical forces acting on the subject (rope mass and friction) were quantified using a dynamometer attached to a belt. While there was a substantial difference in force between rope types at full extent (140 N vs. 40 N), the result was less significant when seen against the total work required in moving the subjects own body mass up the slope. The direction of the resultant force vector appears to play an important role in the way that strain is experienced. It was discovered that 300 m was the maximum hauling distance for a single person using this rigging method with a steel wire strawline, whereas for the synthetic rope, the same tensile force would only be reached at 1200 m. This alone has important implications for labor saving amongst small cable logging teams.

Keywords: cable logging, workload, heart rate, synthetic rope

1. Introduction – *Uvod*

In Norway, topography and surface conditions are often challenging for ground based harvesting systems. Much of the mature timber on steep slopes is found in the coastal belt. Here, high growth rates in plantation forests (*Picea spp*.) established in the 1950s through 1970s have resulted in volumes in excess of 600 m^3 ha^{-1} which need to be harvested in coming years. Amongst forest stands mature for harvesting, around 28% (1 213 000 ha) is on slopes exceeding a gradient of 33% (classified as steep slopes), of which 43% (524 000 ha) exceed slopes of 50% (Larsson and Hylen 2007). The challenge of increasing the proportion of the annual cut from steep slopes can partly be met by increasing cable yarding activity. Given a current production of under 30 000 m^3 per year per unit, there are opportunities for tens of new cable yarding crews to enter the sector over the next 20 – 30 years.

However, the shortage of labor willing to work in cable yarding operations is considered an obstacle to further expansion. The present situation is dependent on migratory labor that has no initial skills in mountain logging, and is at high risk of being lost to other sectors after becoming established in the Norwegian labor market. The retention of such workers is a priority in the industry. Ergonomic benefits reducing work strain, danger or discomfort of working with cable yarders would likely benefit the industry through improved recruitment, productivity and retention.

Depending on the actual function being carried out, forestry workers in steep terrain work continuously at or over the endurance limit (Stampfer 1997). One infrequent but strenuous activity is rigging the yarder into a new corridor. For downhill yarding, which is most common in Norway, a strawline is manually pulled up the corridor (c. 3 – 400 m) connected through an end block and used to winch successively heavier lines up. Walking directly up the slope is one of the more strenuous activities associated with cable logging and classified as moderately heavy to heavy work (Vik 1992, Kirk and Sullman 2001, Stampfer et al. 2010).

The use of synthetic ropes (ultra-high molecular weight polyethylene) has become popular in a range of logging applications in North America (Pilkerton et al. 2004, Hartter and Garland 2006, Garland et al.

2003), and has also been adapted and tested in specific applications in Europe. Talbot (2007) found that in winching large hardwood logs, a 14 mm synthetic rope increased the working radius for a single operator and tractor setup from 15 m to 80 m as against using a 12 mm steel rope, while Stampfer et. al (2010a) showed that synthetic guylines reduced the workload from 2 to 1 person, and still reduced the heart rate for the single person by 30%. Depending on the application and dimensions required, synthetic ropes can offer a mass saving of 70 – 85% as against conventional steel cables of equivalent load capacity, while abrasion resistant covers and the absence of elastic energy ensures their technical integrity (Kirth et al. 2007, Stampfer et al. 2010b). The purchase price of synthetic ropes is 3 to 4 times that of steel ropes, while durability is application dependent and not well documented in the literature.

The goal of this study was to quantify the work strain saving that could be achieved in switching from a 3.5 mm steel wire strawline to a lightweight synthetic rope.

2. Materials and methods – *Materijal i metode*

2.1 Corridor – *Ispitna trasa*

A 300 m (59% slope) corridor on an existing harvesting site in central Norway was divided into 12 successive segments of 25 m. Each segment profile was measured separately using a Vertex IV hypsometer and rangefinder. There was a plateau in the profile at 75 m – 100 m (40%) and 100 – 120 m (20%), otherwise the slope was relatively consistent though increasing with increasing distance – i.e. concave form (Fig. 1). The profile data was used in determining the altitude (above starting point) of each of the segments. Walking conditions on the slope were generally firm with only limited interference from harvesting slash or loose rocks.

2.2 Treatments and measurements – *Postupci i mjerenja*

The experiment aimed to quantify the workload saving of switching from the steel strawline to the synthetic strawline. This was done by monitoring the force that the subject was exposed to while walking up the slope, as well as monitoring the heart rate. Three treatments were defined; (i) pulling out the 3.5 mm steel wire strawline weighing 39 g m^{-1} (STEEL, W) (ii) pulling out the 4.0 mm synthetic strawline with a braided cover weighing 11g m^{-1} (SYNTH, X) and (iii) walking the profile with no load (ZERO, Z). The ZERO treatment was designed to be the control.

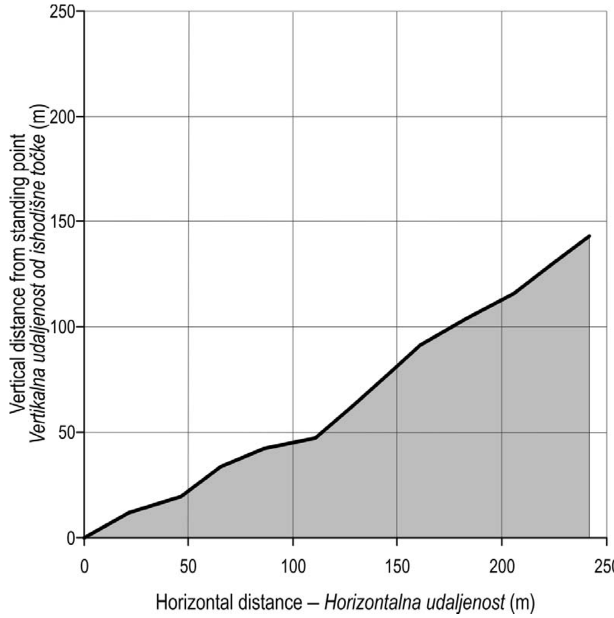


Fig. 1 Profile of the 300 m corridor (slope length)
Slika 1. *Profil ispitne trase u duljini 300 m (duljina nagiba)*

Table 1 Study layout
Tablica 1. *Postavka istraživanja*

Replication Block *Blok ponavljanja*	Subject *Radnik*	Sequence and treatment code (rep-subject-treatment) *Slijed i šifra postupka (postupak ponavljanja radnika)*			Time of day *Razdoblje dana*
		1	2	3	
1	A	1AX	1AZ	1AW	Morning *Jutro*
	B	1BZ	1BX	1BW	Morning *Jutro*
2	A	2AW	2AZ	2AX	Afternoon *Popodne*
	B	2BZ	2BX	2BW	Afternoon *Popodne*
3	A	3AW	3AX	3AZ	Morning *Jutro*
	B	3BZ	3BX	3BW	Morning *Jutro*

The trial was designed in a randomized block with each subject drawing a random sequence of the 3 treatments within each of the 3 replication blocks (Table 1). Subjects were alternated and had approximately 1 hour rest between treatments. The 3 replication blocks were carried out in the morning, the afternoon, and the subsequent morning.

The tensile force that the subject pulled (constituting the mass of the rope and friction on the ground

Table 2 Details of the two subjects included in the study
Tablica 2. *Detaljni opis dvaju radnika u istraživanju*

Subject *Radnik*	Age *Dob*	Height *Visina*	Mass *Masa*	Initial heart rate HR_r *Početni puls srca* HR_r	Body mass index *Indeks tjelesne mase*
	year *godina*	cm	kg	bpm *otkucaji/min*	-
A	26	181	88	93 (13)	26,9
B	37	186	110	75 (8)	31,8

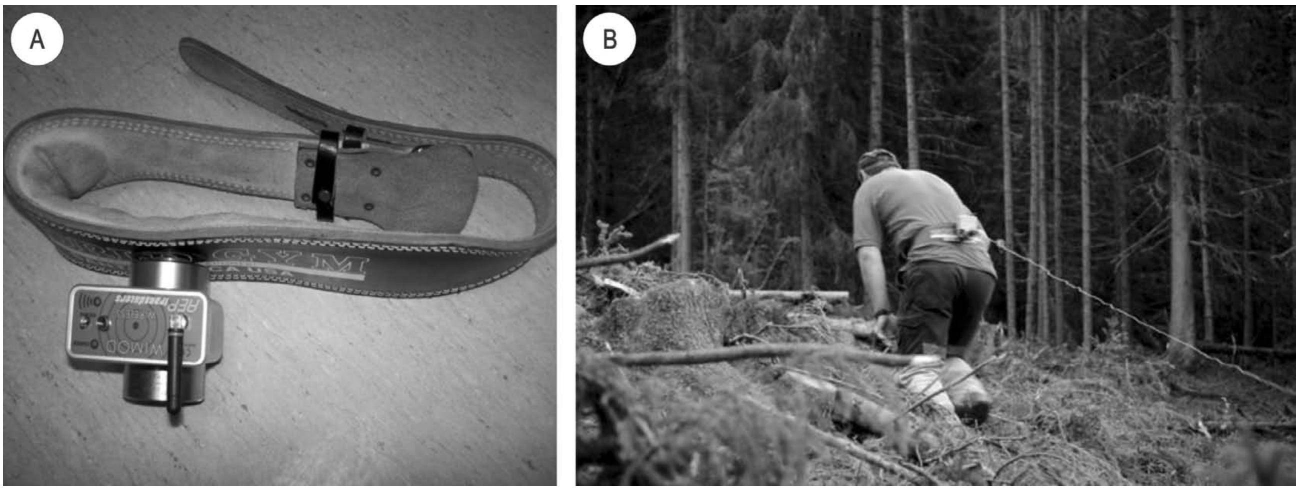


Fig. 2 Illustration of the belt, dynamometer (A) and steel strawline being pulled out (B)
Slika 2. *Prikaz remena, dinamometra (A) te izvlačenja čeličnoga pomoćnoga užeta (B)*

and in the winch drum) was measured continuously using a 3.5 kN AEP dynamometer fitted to a belt and equipped with a wireless transmitter (Fig. 2). The tensile force (N) combined with the distance (m) and height increment (m) was used to calculate the amount of work done (J) and the rate of work (W) in pulling the rope between segment endpoints and for the entire profile. The calculation of the rate of work done included lifting the subject's own body mass through 143 vertical meters. The rate of work (W) was calculated by m (kg) s·(m^2) t (s^{-3}), where m is vertical meters and s is time in seconds.

2.3 Physiological measurements – *Fiziološka mjerenja*

Two male subjects (A and B) from a 3 man logging team participated in the study. Both had been working in steep terrain for more than 2 years, were considered well experienced in yarder rigging, and accustomed to hard physical work despite their relatively high *BMI*. Heart rate was measured to assess the level of physical stress of each treatment using a Polar RS400 pulse monitor with continuous data logging and storage. Heart rate measurement included the downhill return leg, where recovery time was also monitored. Resting heart rate (HR_r) was not recorded as the no-load (zero) treatment was to be used as the benchmark for comparison. However, HR_r was estimated from the initial heart rate readings (first 5 s) from each treatment (Table 2). Percentage of heart rate reserve (%*HRR*), a measure of exercise intensity, was calculated from the mean working heart rate (HR_w), the proxy resting heart rate (HR_r) and the maximum heart rate (HR_{max}) for each subject as: $\%HRR = (HRy\text{-}HR_r)\cdot 100/(HR_{max}\text{-}HR_r)$. HR_{max} was approximated from the rule stating HR_{max} = 220-subject age.

Walking speed was monitored, but not regulated, for each of the 12 segments in the profile using SIWORK 3 time study software running on an Allegro data logger.

3. Results – *Rezultati*

3.1 Force and work done – *Sila i izvršeni rad*

The force (N) that the subjects were exposed to increased linearly for both treatments, and was made up of a mass and a friction component. At the full

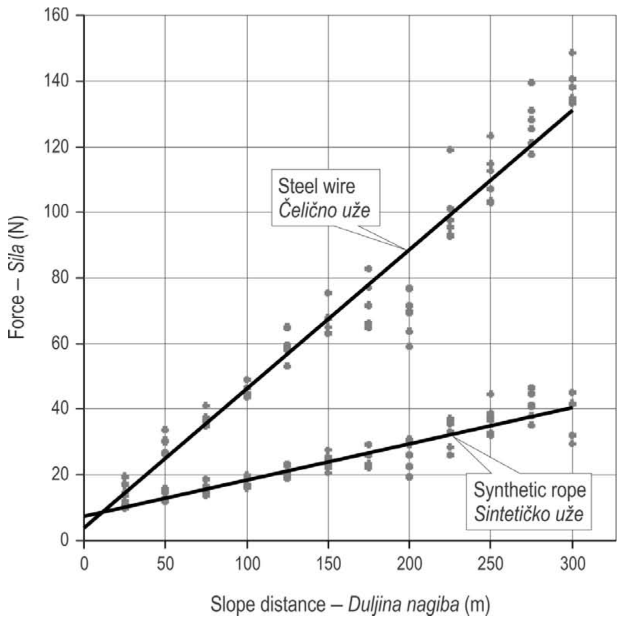


Fig. 3a The tensile force exerted on the subject for the steel wire and synthetic rope, respectively. The resistance in the drum of the steel cable was higher than for the synthetic rope at 0 m despite the linear regression indicating otherwise

Slika 3a. *Primijenjena sila radnika za izvlačenje čeličnoga i sintetičkoga užeta. Otpor bubnja kod čeličnoga užeta veći je od otpora kod sintetičkoga užeta, iako linearna regresija pokazuje obrnuto*

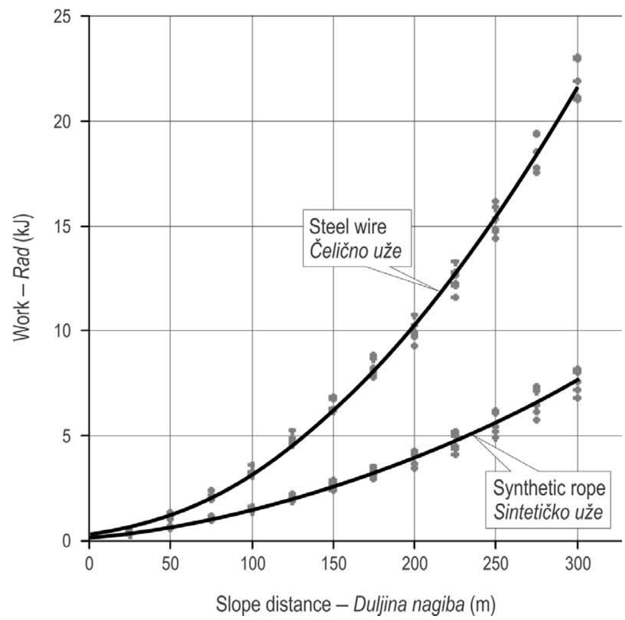
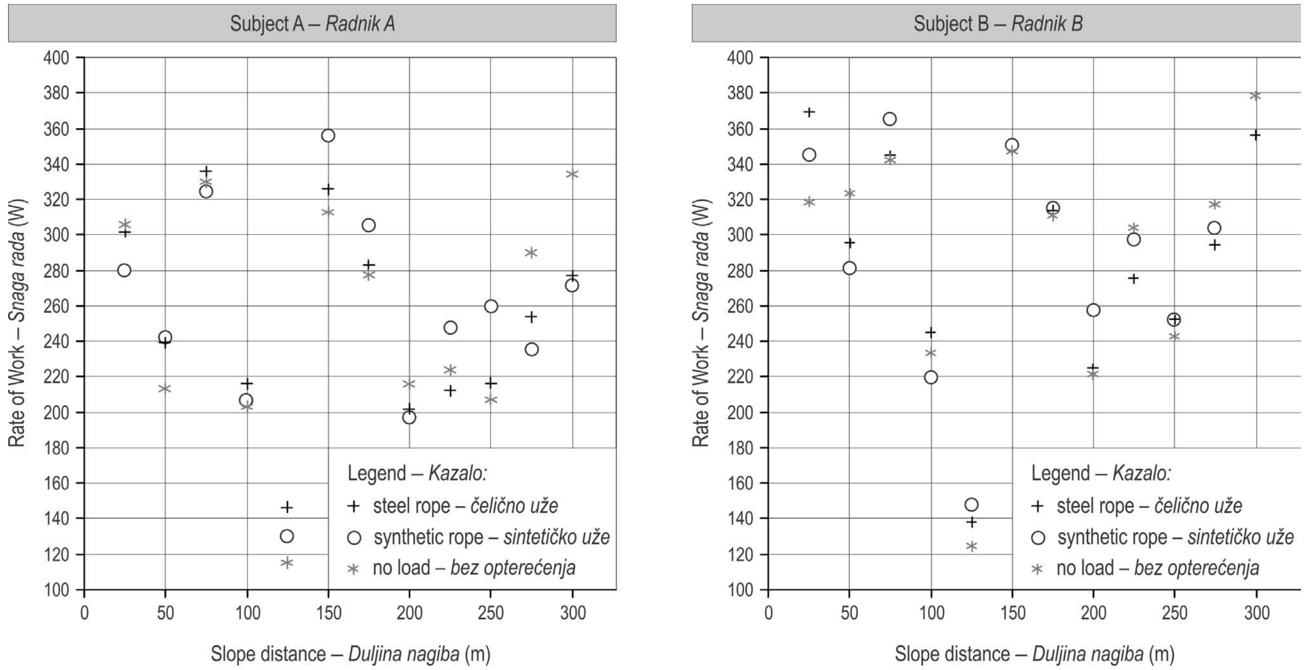


Fig. 3b The cumulative work done in pulling out the steel and synthetic ropes, net of body mass

Slika 3b. *Kumulativne vrijednosti obavljenoga rada pri izvlačenju čeličnoga i sintetičkoga užeta bez mase tijela*



Note: The 75 m to 125 m interval correlates to the plateau seen in the topographic profile (Figure 1)
Bilješka: udaljenosti od 75 m do 125 m odnose se na položeniji dio trase (vidi topografski profil na slici 1.)

Fig. 4 Mean rate of work (W) by 25 m segment for subject A (left) and subject B (right) for each treatment

Slika 4. *Srednje vrijednosti snage rada po segmentima trase od 25 m za radnika A (lijevo) i radnika B (desno)*

Table 3 Summary data on subject's heart rate response to treatments
Tablica 3. *Zbirni podaci o pulsu srca radnika ovisno o postupku*

	Weighted mean working heart rate *Vrednovani srednji radni puls srca*		Duration *Trajanje*		Percentage heart rate reserve *Postotak pričuve pulsa srca*	
	HRw		*t*		*% HRR*	
	bpm – *otkucaji*/min		s		%	
Subject – *Radnik*	A	B	A	B	A	B
Steel rope – *Čelično uže*, W	170	162	589	612	76	80
Synthetic rope – *Sintetičko uže*, X	165	157	529	548	71	75
Zero – *Bez opterećenja*, Z	166	148	497	542	72	67

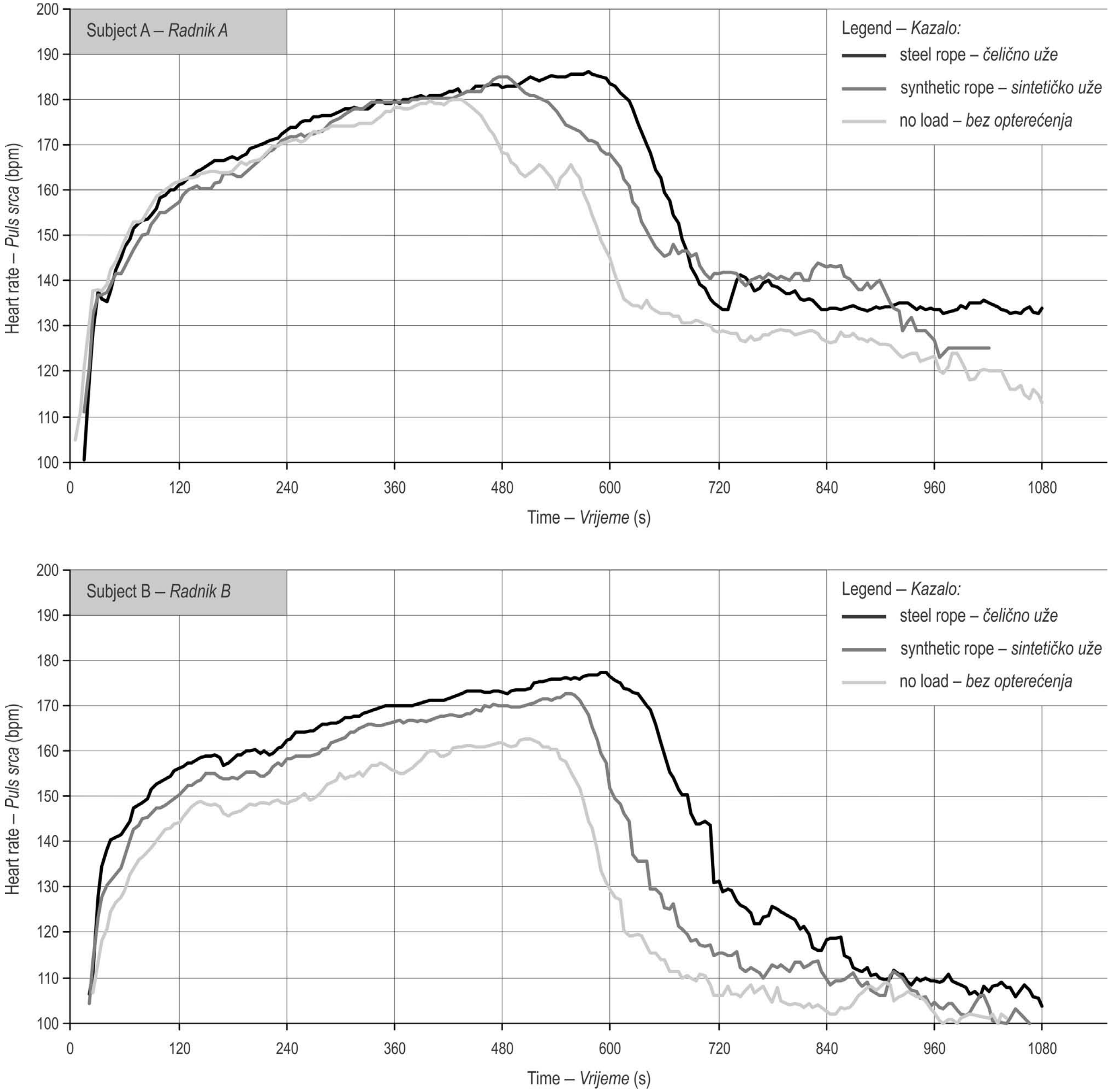
300 m, the subjects were exposed to a mean force of approximately 140 N with the steel wire and 40 N with the synthetic rope (a). On average, subjects were exposed to higher force from the steel wire for 80 seconds longer than the synthetic rope. Fig. 3a shows smoothed forces, averaged over the 25m intervals and does therefore not include all force spikes seen in the continuous measurement. The cumulative work done (due to treatments only) was 21 kJ for the steel wire and 8 kJ for the synthetic rope (Fig. 3b). In considering the rate at which work was done, both the treatment force and the subject's own body mass play a role. The lighter subject (A) worked at a mean rate of 236 W, with a minimum of 100 W and a maximum of 402 W for treatment zero (Fig. 4a). The heavier subject (B) had a mean output of 277 W with a minimum of 93 W and a maximum of 472 W (b). For both subjects and all treatments, a clear decrease in work output is seen in segments 4 and 5 (75 – 100 m and 100 – 125 m), which correlates to the plateau in the terrain profile.

The working pace was not strictly regulated, and from the heart rate measurements, subject A worked at an intensity of over 70% *HRR* for each treatment, though for differing lengths of time (Table 3). The higher working pace resulted in subject A rapidly ascending to 140 bpm and following the same trajectory for all 3 treatments (Fig. 5). Subject B, who worked at a slower pace, showed more distinct heart rate differences between treatments. Heart rate recovered more rapidly and uniformly for subject B than subject A, although the route of the descent was not monitored.

4. Discussion – *Rasprava*

Despite the 25 m intervals set up in order to regulate the working pace, this was not done carefully enough during the trial and subjects had a tendency to work toward maximum capacity, irrespective of the treatment they were subjected to. This blurred the expected result in heart rate differences and therewith the inference of the study. Due to inter-person variability, the rule of HR_{max}=220-age appears not to be specific enough for robust scientific analysis, and HR_{max} ought to be determined in laboratory conditions (Robergs and Landwehr 2002). HR_r was estimated using the initial heart rate as a proxy and is therefore not the true resting heart rate. In this study, subject A appeared to have an unnaturally high initial heart rate for his age despite the extra care taken to ensure total rest before each treatment. Also, his recovery rate was slower and more erratic than for subject B.

The dynamometer tests showed a clear difference in force required to overcome the mass and drag of the respective ropes (100 N at 300 m). The work done in drawing out the steel wire was 21 kJ as against approximately 8 kJ for the synthetic rope. In an attempt to standardize the evaluation of work by compensating for different walking speeds, we calculated the rate at which it was done (W) for the treatment only, and for the treatment including the subject's own mass. Considering the ergonomic theory that a manual worker can sustain approximately 100 W throughout a working day, with shorter spikes of up to 400 W (Witney 1988), our data seemed to fit well. The mean power output of roughly 250 W during that time equates to strenuous work and this is corroborated by the heart rate data. A similar study cites a categorization of exertion as being 'Very heavy work' for a heart rate of 131 – 150, and 'Extremely heavy work' for a heart rate of 151 – >170 for 20 – 30 year olds (Pilkerton et al. 2004). In this study, subjects worked in latter zone for much of the time. In reality, a logging crew member would likely adjust the intensity of the task to his own capacity – a tendency known as constant strain behavior – especially as this is an infrequent task carried out only a few times per week and the speed of performance would have only a limited effect on productivity. Future studies ought to be carefully planned to ensure that working pace is



Note: Curves represent mean values of 3 replications for each treatment
Bilješka: Krivulje prikazuju srednje vrijednosti triju ponavljanja za svaki postupak

Fig. 5. Heart rate monitoring of subject A (upper) and subject B (lower), respectively
Slika 5. *Izmjereni puls srca za radnika A (gore) i radnika B (dolje)*

kept constant if heart rate is to be used as an effective proxy for physiological workload.

Irrespective of the rate of work, we found that when pulling the steel wire, the load on the subject towards the end of the corridor (140 N) was the maximum load that a single person could pull on the given slope, and that completion of the final segment was exceedingly strenuous. This implies that 300 m is the maximum operational rigging length for a single person using the steel wire. Following the force gradient exerted by the synthetic rope in , such a barrier (140 N) would only be reached at 1200 m, which is three to four times normal yarding distance. Although the mass of the fully extended steel wire was only 11.7 kg, it is the resultant force vector (on a 59% slope) that contributes substantially to the effort required to overcome it. The resultant force is not transferred downwards through the muscular-skeletal structure, but backwards and downwards, and therefore requires extra compensatory effort by the person. It should also be pointed out that in this trial, no rigging equipment (end block, guy-lines, tensioners, etc.) were carried. These would normally load the subject with an additional 15 kg or more, making them more sensitive to differences in the forces they are subjected to.

Rolling resistance in the winch drum was not isolated in the analysis. Assuming 800 m of line on each drum, the initial mass of steel wire on the drum would be 31.2 kg, and for the synthetic rope only 9.5 kg. The mass of the drum itself and the resistance would add to this. The forces measured in the first segment (25 m) could be used as a proxy measure as the rope mass on the ground is relatively insignificant. The difference here is 17 N for the steel wire and 10.8 N for the synthetic rope on average. Differences in drum rolling resistance would decrease with distance.

Using a wireless transmitter on the dynamometer with a receiving computer introduced some difficulties as the full 300m range was not covered and the person had to be followed in the terrain. A smaller datalogger attached to the dynamometer and carried by the subject would likely have provided a more effective and robust solution.

Some yarder operators use a different approach to laying out the strawline. A backpack mounted drum allows the person to walk up the slope along a more natural path, connect through the end block and walk directly down the corridor. However, this method transfers the full mass of a 6 – 800 m strawline to the subject from the beginning – a shift to synthetic rope would imply a large saving in mass to be carried.

Acknowledgements – *Zahvala*

The authors wish to acknowledge the financial support from the Norwegian Research Council (grant No. 186912) and the Norwegian Forestry Development Fund (Skogtiltaksfondet) as well as assistance from colleagues Eirik Nordhagen, Helmer Belbo and Daniel Kindernay. We also express our thanks to forest entrepreneur Frivik A/S, whose logging team and equipment participated in the study.

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Sažetak

Olakšanje radnoga opterećenja primjenom sintetičkoga pomoćnoga užeta za postavljanje trase žičare u Norveškoj

Cilj je rada odrediti razliku u radnom opterećenju koja nastaje zamjenom čeličnoga užeta promjera 3,5 mm sintetičkim užetom većega promjera 4,0 mm prilikom izvlačenja pomoćnoga užeta za postavljanje nove žične linije na udaljenosti od 300 m.

U Norveškoj su reljefne značajke terena često nepovoljne za pridobivanje drva s kretnim sustavima po tlu. Većina se zrelih sastojina nalazi na strmim terenima u obalnom pojasu. Velik prirast u šumskim plantažama smreke (Picea sp.), koje su osnivane od 1950-ih do 1970-ih, rezultirao je visokom drvnom zalihom, preko 600 m^3/h, koju treba posjeći idućih godina. Među sastojinama koje dolaze na red za sječu oko 28 % (1 213 000 ha) nalazi se na nagibu većem od 33 % (označen kao strmi teren), od čega se 43 % (524 000 ha) nalazi na nagibu većem od 50 % (Larsson i Hylen 2007). Povećenje godišnjega sječivoga etata može se donekle ostvariti povećanjem upotrebe šumskih žičara. S godišnjom proizvodnošću žičare od 30 000 m^3 drva u idućih 20 do 30 godina otvara se mogućnost upotrebe na desetke novih šumskih žičara.

Ipak, smanjenje broja zainteresiranih za rad na šumskim žičarama ograničavajući je čimbenik. Trenutačna je situacija ovisna o sezonskoj radnoj snazi koja nema dovoljno iskustva u pridobivanju drva na strmim terenima te često odlazi na druge poslove koji se otvaraju na norveškom tržištu rada. Zadržavanje je takve radne snage prioritet u šumarstvu. Poboljšanje ergonomskih uvjeta, smanjenje radnoga opterećenja, opasnosti i neudobnosti rada sa šumskim žičarama vjerojatno bi povećalo zapošljavanje, proizvodnost i zadržavanje šumskih radnika.

Jedan od rjeđih, ali napornijih poslova jest postavljanje šumske žičare na novu trasu. U Norveškoj se najčešće šumskim žičarama iznose drva niz nagib. Pri tome se pomoćno uže, koje se koristi za podizanje težih užadi pri postavljanu žičare, mora ručno vući uz nagib (300 do 400 m). Kretanje okomito na slojnice terena jedan je od najnapornijih aktivnosti u radu sa žičarom. Upotreba sintetičke užadi (polietilenska užad vrlo visoke molekularne težine) za pridobivanje drva postaje sve češća u SAD-u (Pilkerton i dr. 2004, Hartter i Garland 2006, Garland i dr. 2003) te je također ispitivana na pojedinim radovima u Europi. Ovisno o vrsti rada za koji je namijenjena i dimenziji užeta, sintetička užad ima 70 – 85 % manju masu od konvencionalne čelične užadi jednake nosivosti, dok otpornost na oštećenja i elastičnost jamči tehničku ispravnost (Kirth i dr. 2007, Stampfer i dr. 2010b). Nabavna cijena sintetičkoga užeta veća je 3 do 4 puta nego nabavna cijena čeličnoga užeta, dok je izdržljivost ovisna o vrsti posla za koji se uže koristi i nedovoljno je opisana u literaturi.

Istraživanje je provedeno u središnjoj Norveškoj na već postojećoj sječini. Trasa žičare duljine 300 m (nagib 59 %) podijeljena je na 12 uzastopnih dijelova duljine 25 m. Profil svakoga dijela zasebno je izmjeren pomoć visinomjera i daljinomjera Vertex IV. Nagib je na svim dijelovima podjednak, raste s povećanjem udaljenosti, konkavnoga je oblika. Podaci su profila korišteni za određivanje visine (od početne točke) svakoga pojedinoga dijela. Dvojica od trojice radnika (A i B) na žičari sudjelovala su u istraživanju. Obojica imaju dvogodišnje iskustvo u radu na strmim terenima i smatraju se dovoljno iskusnim u postavljanju žičare, te su naviknuti na težak fizički posao unatoč svojemu visokomu indeksu tjelesne mase (BMI). Za svaki im je radni zahvat, pomoću uređaja Polar RS400, mjeren broj otkucaja srca kako bi se odredio fizički napor kojemu su izloženi.

Smanjenje radnoga opterećenja, prilikom zamjene čeličnoga užeta sintetičkim, određivano je mjerenjem sile kojom su radnici bili izloženi tijekom hoda uz nagib i mjerenjem otkucaja srca. Fizičko opterećenje mjereno je u tri postupka: 1) izvlačenje čeličnoga užeta promjera 3,5 mm, težine 39 g/m (STEEL, W); 2) izvlačenje sintetičkoga užeta promjera 4,0 mm, težine 11 g/m (SYNTH, X) i 3) hod uz nagib bez izvlačenja užeta (ZERO, Z). ZERO način rada postavljen je kao kontrolni uzorak.

Sila izvlačenja užeta (čije su sastavnice masa užeta, trenje između tla i užeta te trenje na bubnju vitla) mjerena je pomoću dinamometra 3,5 kN AEP, opremljenoga bežičnim odašiljačem, koji je bio pričvršćen na remen šumskoga radnika. Kombinacijom sile izvlačenja užeta (N), udaljenosti (m) i povećanja visine (m) izračunata je količina utrošene energije (J) i izvršena snaga rada (W) pri izvlačenju užeta između krajnjih točaka pojedinoga dijela i duž cijeloga profila. Pri računanju izvršene snage rada u izračun je uključena i masa samoga radnika dok je radnik prelazio 143 metra visinske razlike. Izvršena snaga rada izračunata je kao m (kg) s·(m^2) t (s^{-3}), gdje je visinska razlika u metrima, a vrijeme u sekundama.

Sila (N), koja se sastojala od mase užeta i sastavnica trenja, kojom je radnik bio izložen u oba slučaja se linearno povećavala. Na maksimalnoj udaljenosti od 300 m radnik je bio opterećen silom srednje vrijednosti 140 N prilikom izvlačenja čeličnoga užeta, a 40 N prilikom izvlačenja sintetičkoga užeta. Radnik je bio izložen većemu opterećenju, u prosjeku 80 sekundi, prilikom izvlačenja čeličnoga užeta. Slika 3(a) prikazuje prosječne vrijednosti sile na dijelu od 25 m te zbog toga ne prikazuje najveća opterećenja koja su se pojavljivala tijekom mjerenja. Utrošak energije bio je 21 kJ pri radu s čeličnim užetom i 8 kJ pri radu sa sintetičkim užetom (slika 3b). Uzimajući u obzir snagu rada, u oba slučaja i sila i radnikova tjelesna masa imaju utjecaj na opterećenje. Radnik (A) s manjom tjelesnom masom radio je srednjom vrijednosti snage 236 W (najmanja vrijednost 100 W i najveća 402 W) prilikom rada bez opterećenja (slika 4a). Radnik (B) s većom tjelesnom masom radio je sa srednjim vrijednostima snage od 277 W (najmanja vrijednost 93 W i najveća 427 W). Kod oba radnika u svim slučajevima, u segmentima 4 i 5 (75 – 100 m i 100 – 125 m udaljenosti od početne točke), vidljivo je smanjenje snage izvršenoga rada, što je povezano sa zaravni u profilu terena.

Mjerenja sile pokazuju očitu razliku potrebnu za svladavanje mase i izvlačenja užeta (100 N na 300 m). Utrošak je energije prilikom izvlačenja čeličnoga užeta 21 kJ nasuprot 8 kJ prilikom izvlačenja sintetičkoga užeta. U pokušaju standardiziranja procjene obavljenoga rada kompenzacijom za različite brzine kretanja izračunali smo utrošenu snagu za istraživane slučajeve uključujući i tjelesnu masu radnika. Srednja vrijednost utrošene snage od 250 W s vremenom se izjednačava, što potvrđuju i otkucaji srca. Bez obzira na intenzitet posla, zaključujemo da je prilikom izvlačenja čeličnoga užeta opterećenje radnika (od 140 N) pri kraju trase žičare bilo najveće opterećenje koje jedna osoba može podnijeti na takvu nagibu. Završetak je zadnjega dijela u profilu bio osobit napor, što pokazuje da je 300 m maksimalna operativna udaljenost prilikom koje jedna osoba postavlja žičaru koristeći čelično uže.

Provedeno je istraživanje važno zbog uočavanja ergonomskih koristi pri korištenju lakše sintetičke pomoćne užadi u usporedbi s uobičajenom čeličnom užadi. Buduća bi se istraživanja trebala usmjeriti na smanjenje radnoga opterećenja i ergonomska poboljšanja, što bi značajno pridonijelo povećanju pridobivanja drva na strmim terenima u Norveškoj.

Ključne riječi: iznošenje drva žičarama, radno opterećenje, puls srca, sintetičko uže

Received (*Primljeno*): July 26, 2011
Accepted (*Prihvaćeno*): September 5, 2011

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