Comparison Between Rigid Climbing Aids and Rope Scramble Nets in the Effectiveness Of Rescue Operations

A Technical Report submitted to the Canada-Nova Scotia / Canada-Newfoundland and Labrador Offshore Petroleum Boards

FINAL REPORT

October 13, 2021

MARINE INSTITUTE

MARINE INSTITUTE

OSSC Document Quality Control Data Sheet

Document Title:	**Comparison between Rigid Climbing Aids and Rope Scramble Nets in the Effectiveness of Rescue Operations**
Document Type:	**Final Report**
Date:	**Draft V1 – September 27, 2021** **Final V2 – October 13, 2021**
Prepared By:	[signatures] **Robert Brown, Ph.D, P.Eng & Kerri-Ann Ennis, M.Sc (Kin)**
Project Team:	**Dave Blackmore, Damien Brazil, Robert Brown, Carl Clarke, Mike Crocker, Joanne Domino, Dan Donnelly, Dan Dwyer, Kerri-Ann Ennis, Ross Hefford, Ken Jones, Troy Nolan, John Parrell, Randy Rose, Brian White**
Final Approval:	Fred Anstey Digitally signed by Fred Anstey Date: 2021.10.14 08:49:10 -02'30' **Fred Anstey, Head, School of Maritime Studies**
Distribution:	**Robert Normore, CNSOPB** **Veronica Warren, CNLOPB**

SUMMARY

This report presents the results of a study to compare rigid and rope scramble nets used in maritime rescue situations. Participants of the study were students of Marine Emergency Duties refresher courses at the Marine Institute's Offshore Safety and Survival Centre (OSSC) in Foxtrap, NL. A total of 49 participants were involved in the study - 23 participants used the traditional rope net and 26 participants used the rigid net. All participants were male and both groups were found to be statistically similar when considering age, height, mass, previous climbing experience, comfort with heights and disabilities which might affect climbing performance. All participants were given the same basic instruction on how to climb a scramble net and proper climbing technique was demonstrated by an OSSC instructor at the start of each test session. Participants wore a fully donned Fitzwright model 9700 marine abandonment immersion suit. Both scramble nets were 5m in length with 1m below the water. The nets were mounted against a vertical wall with a platform at the top and spacers which kept the nets approximately 11 cm off the wall. All participants were video recorded during the climbing sessions so that climbing effectiveness, errors and timings could be collected during post analysis. In addition, following each climbing session, participants were asked to complete an online questionnaire (96% of participants completed the questionnaire).

Results indicate that there was a statistically significant difference between the two groups for self-rated performance and self-rated climbing difficulty, with the rigid net being rated as better than the rope net. Analysis of climbing time indicates there is a statistically significant difference between the groups, with climbing time for the rigid net (39.58 ± 9.51 s) being less than the rope net (59.58 ± 31.25 s). In addition, we observed that rope net users frequently experienced a climbing challenge whereby their foot sometimes slipped to the cell below when attempting to progress upward in their climb. In all, 70% of the rope net users slipped at least one time in their climb, with the mean slip rate being 3 times per person. Although none of the climbers fell during the research, we feel this is a significant issue because this is likely when a fall could take place, particularly if climbing in a real situation at sea where wave action and vessel motions would present an additional challenge. There were no cases of foot slipping for the rigid net group, which is likely due to two factors; (1) the lateral rigidity of the rigid net means that rung spacing is more regular than for the rope net; and (2) when a climber's weight was put on the rope net, it tended to collapse against the wall, making it difficult for a climber to get a solid foot-hold – this was not

the case for the rigid net since its lateral rigidity maintained the rung spacing off the wall even when a climber was on the net.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background and Objective

Scramble nets are passive rescue devices used in maritime rescue to enable self rescue. Scramble nets tend to be used when other preferred methods are unavailable, since they are difficult to use (Button and Gorgol, 2019). While not regularly used during maritime rescues, there have been documented cases where survivors have successfully used a scramble net during rescue (e.g. *MOL Comfort* sinking and subsequent rescue of crew by scramble net in 2013). Scramble nets can also be used during abandonment to get to the water surface when jumping from a significant height could be dangerous. Abramowicz-Gerigk & Burciu (2012), following their study of evacuation system effectiveness for large offshore installations state “There is still not enough information about the performance of life- saving appliances such as the scramble nets, ladders, or other individual means of entering the sea…”. While the present study does not attempt to understand performance parameters when using climbing aids as evacuation devices, it points to the lack of scientific knowledge of the performance characteristics of these devices in general.

Using a scramble net requires that the survivor be conscious and strong enough to perform self-rescue. Harries (1983) assessed that a freeboard of 1 m or more can be an unscalable barrier to anybody who has been in cold water for much more than 20 minutes, even if using a scramble net. Harries assessment is likely more relevant for cases in which the survivor is not wearing a fully donned immersion suit which would provide thermal protection for people in the water for significantly longer than 20 minutes. In some limited situations, it may be possible for deck crew to lift survivors once they are on the net but this becomes more difficult as the height above the water and as the number of survivors on the net increase. In some cases like this, the survivor may be able to slide their legs through the net openings (rope or rigid) and hold on while the crew lifts.

There is some published work on the use of pilot ladders when transferring from pilot boat to ship in a seaway. While this provides some insight to the problem of vertical climbing at sea, there are a number of important differences which must be considered (1) pilots are generally transferring using a rope ladder with wooden treads, (2) pilots commence their climb when warm and dry from above the water surface compared with those climbing scramble nets following marine abandonment scenarios and (3) pilot transfers take place during situations which tend to be well-controlled.

In Atlantic Canada's offshore sector, standby vessels are required to carry a scramble. Guidelines (CNL/CNS-OPB, 2018) require (Section 1.6, item c) that vessel crews demonstrate they can deploy their climbing aid (e.g. scramble net) within 5 minutes. Further, Section 2.1 (Rescue Zone), item g specifies that vessels should be fitted with either a powered survivor retrieval device (e.g. Dacon Scoop) on each side or a powered survivor retrieval device on one side and a climbing aid on the other and that the embarkation area of the rescue zone should be designed to allow deck crew to reach down and assist survivors when using the climbing aids. Section 2.2.1 of the guidelines provides specifications for acceptable climbing aids as follows:

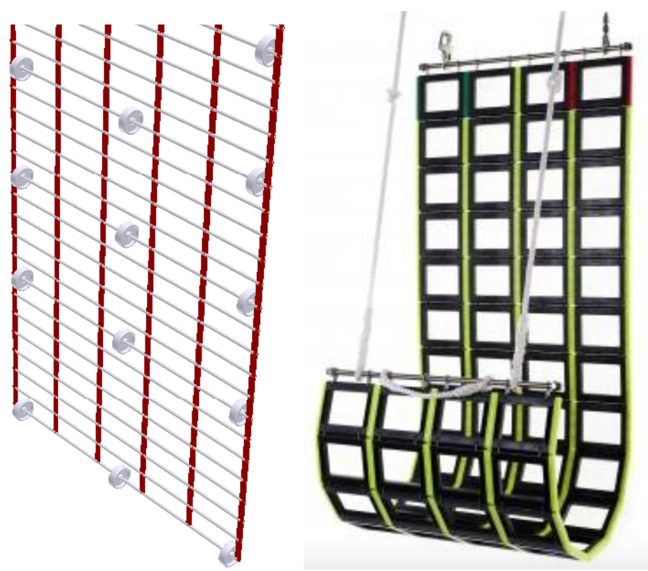
The climbing aids should be manufactured of suitable materials and with appropriate mesh size that provide a good grip for survivors. When deployed, the climbing aids should:

1. *Extend at least 3.5 metres in width along the vessel's side;*
2. *Offer a climbing distance which, measured from the waterline on the vessel's lightest operating draft during the voyage to their highest point, does not exceed 4 metres;*
3. *Extend one metre below the vessel's waterline on its lightest operating draft during the voyage;*
4. *Hang clear of the vessel's side by at least 10 cm, so as to allow survivors to have a good grip and solid footing while climbing; and*
5. *Be arranged so as to allow the vessel's crew to reach down over the vessel's side and assist survivors on board.*

Traditionally, scramble nets were made from rope (or a combination of wood and rope) and designed to provide a climbing surface reaching from the water to a vessel's deck or bulwarks (Figure 1).

Figure 1 Example of a traditional rope scramble net.

More recently, safety equipment manufacturers have developed rigid versions of the scramble net (Figure 2). Although different types of scramble nets are available, to date their effectiveness during self-rescue has not been studied. The objective of this project is to measure and compare climbing performance for rigid and rope scramble nets to determine if modern rigid designs offer an improvement for self-rescue over traditional rope nets.



(a) (b)

Figure 2 Examples of rigid scramble nets: (a) Dacon AS (b) Jason's Cradle.

1.2 Hypothesis and Research Questions

Given that rigid scramble nets offer a more stable, predictable platform for climbing (as compared with rope scramble nets), we hypothesize that users will be able to climb a rigid net (a) more quickly, (b) more easily, (c) with greater confidence, and (d) with fewer challenges as compared to users of rope scramble nets.

As such, we pose the following research questions for this study:

1. How long does it take people to climb a rigid net / rope net under the same conditions and with the same training? Are any differences statistically significant?
2. Is there a difference in self-rated performance for people climbing a rigid net/rope net under the same conditions and with the same training?
3. How difficult do users find rigid net / rope net to climb and are any difference statistically significant?
4. What types of challenges do users of rigid / rope nets experience when climbing and are they significant in terms of user safety? Is there a difference between the two net types?

2 SETUP AND METHODOLOGY

2.1 Equipment and Test Setup

Testing took place in the survival training theatre of the Marine Institute's Offshore Safety and Survival Centre in Foxtrap, Newfoundland and Labrador. The theatre contains a survival training tank which measures 12 m W x 18 m L x 4 m D, with a variety of platforms on the north and east sides, 3-4 m above the water. A traditional rope scramble net is mounted on a 4m high wall and measures 2.1 m wide x 5 m long (i.e. the bottom is 1 m below the water surface). In its original configuration, the net rested flat against the platform's vertical wall, with a 2” x 4” SPF “spreader bar” positioned approximately at the mid point between the water and the top of the platform. In order to ensure the rope net complied with CNL/CNS-OPB (2018) requirements and was in a similar configuration to that typical for offshore applications, the spreader bar was removed and a total of 6 floats with a diameter of 11 cm were secured to the net so that it would not rest on the wall.

The rigid net used for this study was manufactured by Dacon AS in Norway. It measures 1.8 m wide x 5 m long and was mounted so that the amount underwater was 1 m (the same as the rope net). The rigid net was fabricated with spacers to position it off the vertical wall by 10 cm (in keeping with the SBV guidelines and the modified configuration of the rope net). While referred to as a rigid net, it would be more accurate to describe this as a semi-rigid net, since the vertical members of the net are flexible (made from webbing) and the horizontal members rigid, providing a stable, predictable surface for climbers' feet.

2.2 Ethics, Participants and Recruitment

Students enrolled in Marine Emergency Duties (MED) refresher courses were recruited for this study, since the seafaring population is representative of who would most likely be required to climb a scramble net in the marine environment. In addition, recruiting from this population meant it was likely that the participant ages would be more representative of a seafaring population. The students in these classes must have completed at least one MED survival training course in the past and some may have undertaken one refresher course approximately 5 years ago when the refresher requirement was mandated by Transport Canada. Having prior scramble net climbing experience is not expected to bias the results from this study because none of the participants would have climbed a scramble net recently. As part of the course, students undertake a blend of theoretical and practical training related to safety and survival and any given class could be comprised of officers and ratings. During the design of the experiment, it was felt that both ratings and officers should be recruited since it is unlikely that this would be a factor affecting the results of the climbing task.

An ethics application was submitted to Memorial University's Interdisciplinary Committee on Ethics and Human Research (ICEHR) and full approval was granted by the committee on 8 June, 2021 following minor adjustments to the original application and a risk mitigation plan relating to COVID-19 and the conduct of face-to-face research.

A pre-hoc calculation was performed to estimate the expected number of participants required for the study to have statistical power of at least 80% at a 95% significance level (typically considered acceptable for most experimental setups). This was based on pilot test timings with experienced climbers (the investigators as well as OSSC instructors) using both net types.

For each class, participant recruitment took place on the practical training day of the course. One of the researchers gave a short overview of the project to prospective participants, what would be expected of them if they participated and what they would receive in return. A total of 6 classes were involved in the research and a total of 49 students were recruited out of a possible 59 (83.1% test participation rate) and 47 out 49 students completed the questionnaire (96% questionnaire participation rate).

2.3 Test Methodology

Following recruitment, the instructors delivered theoretical lectures to the students which outlined activities coming up in the pool session that afternoon. The information delivered was the consistent from class to class, regardless of the type of scramble net used. Neither the students nor the instructors knew which net would be used on each test day and the students were not told one net was better than the other. In addition, instructors did not know which students were participating in the research.

During the pool session, students performed a number of different practical exercises before proceeding to the self-rescue portion of the class. This was consistent from class to class, which eliminates any potential bias related to tiredness which could influence climbing speed and technique.

It is important to explain the climbing method which students are taught at OSSC. Instructors teach students that when climbing a scramble net, survivors may not be able to rely on their hands to be able to hold-on, which may be due, in part, to the effects of extended cold exposure and exhaustion. For this reason, students are taught that they should keep their body in a vertical position as much as possible in order to bear most of their weight on their feet and legs. They are further instructed to use larger muscle groups when holding the net by "locking" their arms through the mesh/webbing rather than use their hands/fingers when climbing (Figure 3). This is supported by the work of Armstrong et al. (2009) who stated that typical climbing force in the hands was 34-

36% of a climber's body weight and that climbing in a way that requires one to use higher levels of hand force can be dangerous in situations where friction may be low, such as in inclement weather. Although it may take a little more time, the benefit of climbing a scramble net this way is that it is expected to increase the survivor's likelihood of reaching the top. This is particularly true for situations where the exposure has been long, the survivor is cold or exhausted and when sea conditions are rough, since it would be easy for a wave and/or vessel motions to sweep climbers off the net if they are holding on with their hands alone. Thus, all climbers, regardless of the net used, were instructed to lock their arms through the net at each step.

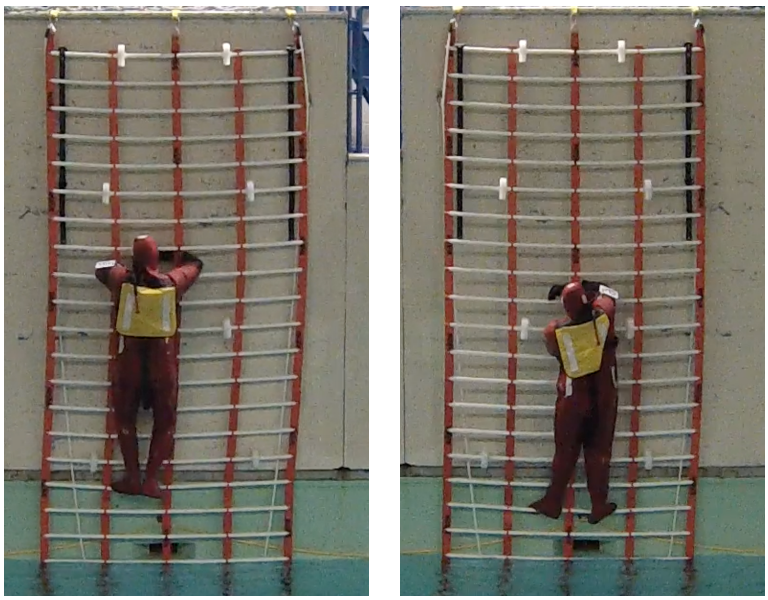


Figure 3 Still capture from video of two different rigid net climbers using their arms to grab the net rather than their hands.

All students wore a fully donned Fitzwright model 9700 marine abandonment immersion suit (including suit gloves on their hands) for the climbing exercise and all were wearing street clothing (e.g. shorts, jeans or sweat pants) under the suit. When the climbing exercise was about to begin, the in-water instructor first demonstrated proper climbing technique to all students one time. All students were then tagged with a unique number which allowed the researchers to link their climbing data with the personal data they would later provide in the questionnaires. Students were then told to enter the water one at a time and climb the net. All other students were asked to not watch the climber, since it was felt that later climbers might gain an advantage over earlier climbers, which might bias the results. Each class of students climbed one net only and only one net was used per class (either rope or rigid).

The researcher was positioned on a mezzanine above the pool deck where he/she had minimal contact with the instructors/students. A GoPro camera was mounted on the mezzanine which viewed the scramble net climbing area so that all steps in the climbing process (i.e. approach, getting on the net, beginning climbing and getting out of the water, climbing the lower half of the net, climbing the upper half of the net and getting over the top of the net) could be seen and documented in the post analysis.

As a backup, the researcher also recorded these times manually using a stopwatch, in case there was a failure in the video recording. In the end, there were no problems with the video recording and video was used as the official record for data collection purposes. A "dictionary" was developed to define the different points of interest in the climbing process and the video was analysed by one person only, to ensure consistency in the dataset and eliminate the need for inter-rater reliability testing. In addition to the timings, the analysis also included a count of the total number of steps taken by each climber and any struggles, challenges or errors made by climbers. Lastly, if any climbers were unable to make it to the top of the net, this was noted.

Following each exercise, the participants were emailed a link to a demographics questionnaire which requested the following information:

- Age
- Gender
- Weight
- Height
- Prior scramble net climbing experience
- Prior climbing experience in general (ladders or scaffolding)
- Their comfort level with heights and being in the water
- If they have a disability which could affect their climb

An additional test questionnaire requested the following information:

- How well they thought they did overall
- How difficult it was to:
    - Get onto the net
    - Climb the net
    - Get over the top of the net
    - Perform the task overall

Following completion of the questionnaires, each participant was sent an electronic (PDF) Tim Hortons gift card as a thank-you for their participation.

These procedures were developed through consultation with course instructors, OSSC management and among the research team, and were trialled during pilot testing to ensure consistency and success of the project. As a result, the actual data collection and analysis exercises were carried-out in a very consistent manner with no measurable changes from start to finish.

3 RESULTS AND DISCUSSION

3.1 Statistical Power

A statistical power calculation was performed after each test day to determine if the minimum power of 80% (at a significance level of 95%) was met. In the end, the “climbing-only” time gives a power (1- β) of 94% (with Df = 0.45 and d = 0.96 for $\alpha = 0.05$) and for the “total time” we calculated a power (1- β) of 90% (with Df = 0.45 and d = 0.87 for $\alpha = 0.05$). Thus, statistical power was sufficient in the dataset.

3.2 Demographics

From analysis of participant demographics, we see that the make-up of the rigid and rope groups is statistically similar. This gives us greater confidence in our ability to compare the climbing performance of both. A total of 23 participants used the rope net and 26 participants used the rigid net. All participants were male and details of the mean age, height and mass are shown in Table 1.

Table 1 Participant demographics – rigid and rope groups.

	Rope	Rigid
Number	23	26
Age (yrs)	43.57 ± 11.30	43.20 ± 11.49
Height (m)	1.78 ± .06	1.80 ± .06
Mass (kg)	95.61 ± 16.79	95.56 ± 12.38

All participants in both groups had experience climbing ladders and scaffolding, however, not all had prior scramble net climbing experience. This was the case for both groups (1 in the rope group and 3 in the rigid group). This does not appear to have impacted their ability to climb or their climbing time. In addition, participants' prior experience climbing ladders and scaffolding was consistent between the groups, as was their comfort level with being in the water.

3.3 Climbing Time

We divided the total rescue time per person into three distinct stages: getting onto the net, climbing and getting over the top. During video analysis, these times were delineated by specific points on the timeline:

Stage 1 - getting onto the net: time elapsed from when a participant first touched the net until they first began an upward movement of their climb.

Stage 2 – climbing: time elapsed from when a participant first began upward movement until they first touched the platform at the top.

Stage 3 – getting over the top: time elapsed from when a participant first touched the platform at the top until their body was completely on the platform.

By defining the individual points of interest on the timeline for each participant, we were able to easily determine the durations of each phase of each person's climb. In addition, this means that by adding-up all stages, we are able to determine the overall time from start to finish for each participant.

Analysis of climbing time shows that, on average, the rigid net climbers took significantly less time than rope net climbers both in stage 2 - climbing only (Figure 4 - rope: 50.68 ± 29.05 s vs. rigid: 30.35 ± 7.71 s) and the sum of stages 1 to 3 - overall total (Figure 5 - rope: 59.58 ± 31.25 s vs. rigid: 39.58 ± 9.51 s). While these differences are statistically significant, the results show an approximately 20 second gap on average between the two nets, which some may be consider to be small from the perspective of a rescue at sea. We feel this should be considered in context – less time climbing a net means there is a lower chance that a climber may fall or be swept-off. While it is important that climbers be able to reach the top, a 20 second difference in climbing time is on the scale of potentially significant vessel motions, as well as wave periods at sea where more than one wave crest may wash across the net. Therefore, we feel this is an important measure which should be considered when deciding which net type is most appropriate for use in rescue.

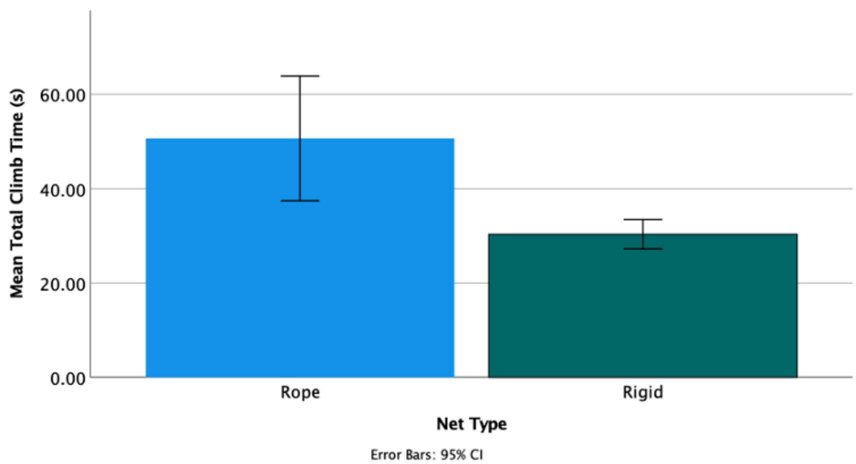


Figure 4 Mean climbing-only time for rigid and rope nets.

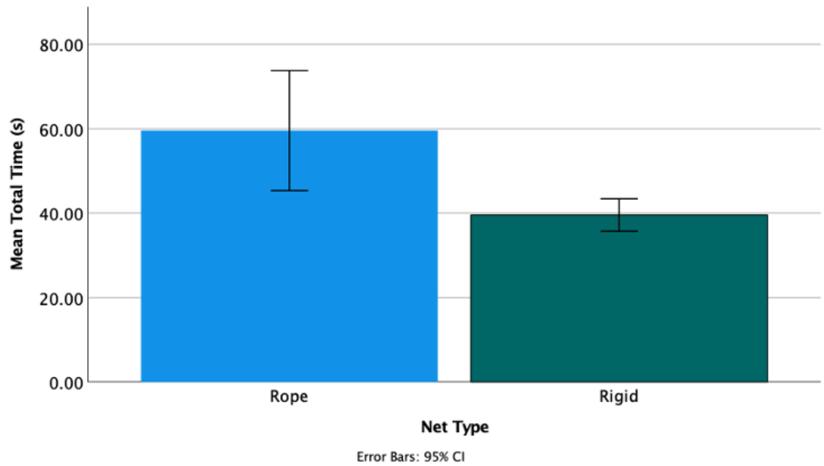


Figure 5 Mean total time for rigid and rope nets.

The mean time spent getting onto the net was not significantly different between the rigid and rope groups (Figure 6 - rope: 6.57 ± 3.57 s vs. rigid: 5.73 ± 1.95 s) and likewise, the time to get over the top of the net was not significantly different for both groups (Figure 7 - rope: 7.29 ± 3.3 s vs. rigid: 6.62 ± 2.04 s).

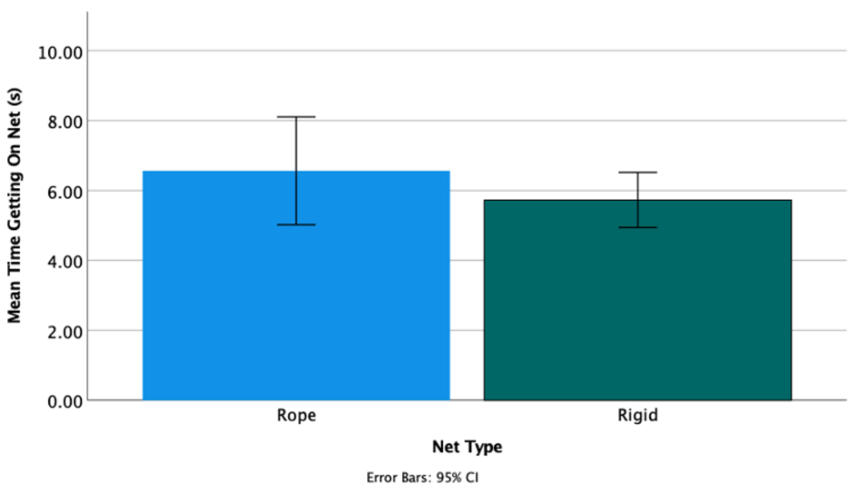


Figure 6 Mean time to get on the net for rigid and rope nets.

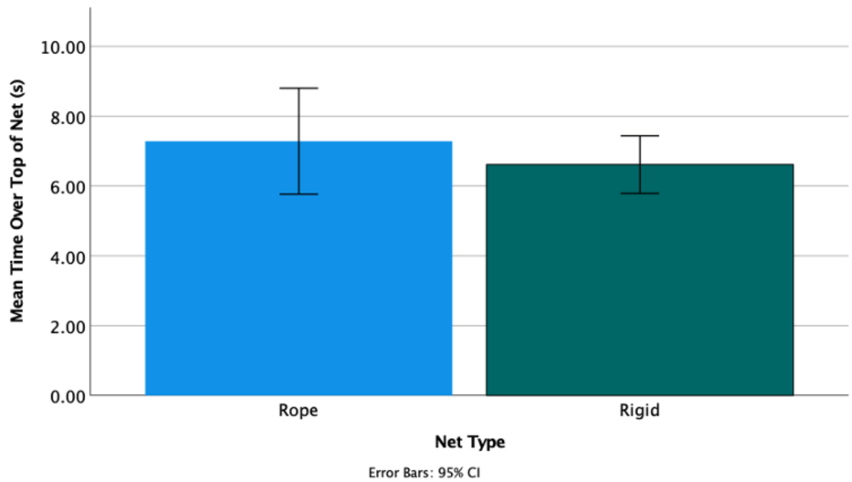


Figure 7 Mean time to get over the top for rigid and rope nets.

We also performed additional analysis to determine if there was a difference between climbing time for the bottom half as compared to the top half of the two nets (Figure 8). From the analysis, we see that for both, the climbers were faster on the top half than the bottom. While this difference was not statistically significant for the rope net, it was significant for the rigid net. This finding is a little counter-intuitive to what was expected, as we anticipated that climbers would become fatigued and slow down the longer they climbed. Reviewing the video, it appears that while some climbers were tired when they reached the top, their climbing technique and possibly confidence level improved as their climb progressed.

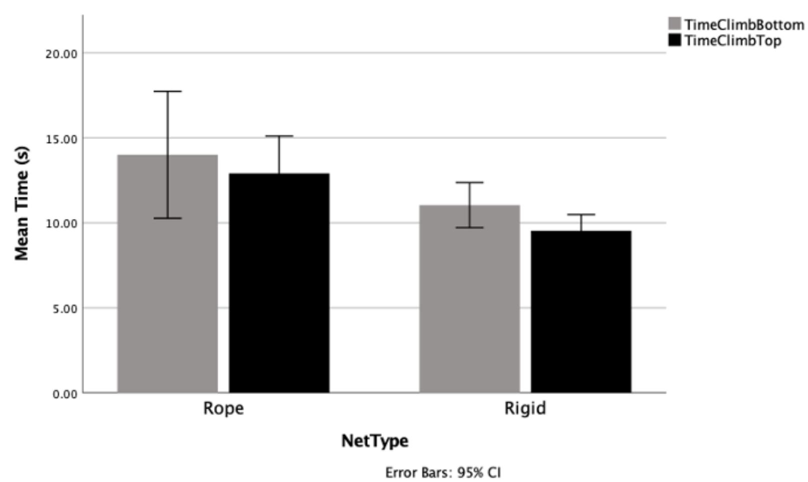


Figure 8 Climbing time for top half vs. bottom half for each net type.

In general, we see that the variability in climbing time for the rope net was significantly higher than for the rigid net, suggesting that the rigid net provides a more consistent climbing system with fewer struggles (this was observed as well).

3.4 Self-Rated Performance

The post-test questionnaire asked participants to rate how they felt they performed overall, as well as how difficult they found the different stages of net climbing.

The results for self-rated performance are presented in Figure 9. Statistical testing (Mann-Whitney U test) shows that the self-rated performance for the rope group was significantly less compared to the rigid group. This is in agreement with the observed performance of rigid net users and is important as it indicates that the rigid group felt more confident in their ability to climb when compared with the rope group.

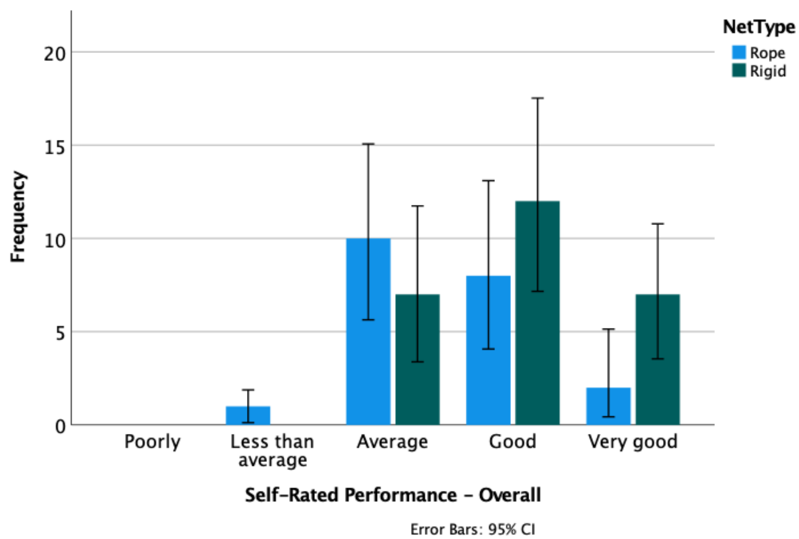


Figure 9 Self-rated performance – rigid and rope nets.

Statistical testing of participant-rated difficulty getting onto the net indicates that there is a significant difference between the rigid and the rope groups, with the rigid net rated as less difficult to get onto (Figure 10). While not consistent with the amount of time taken by both groups to get onto the net (the difference in time required for both groups was not significant), it is useful to understand that rigid users did find it an easier task to complete than rope users.

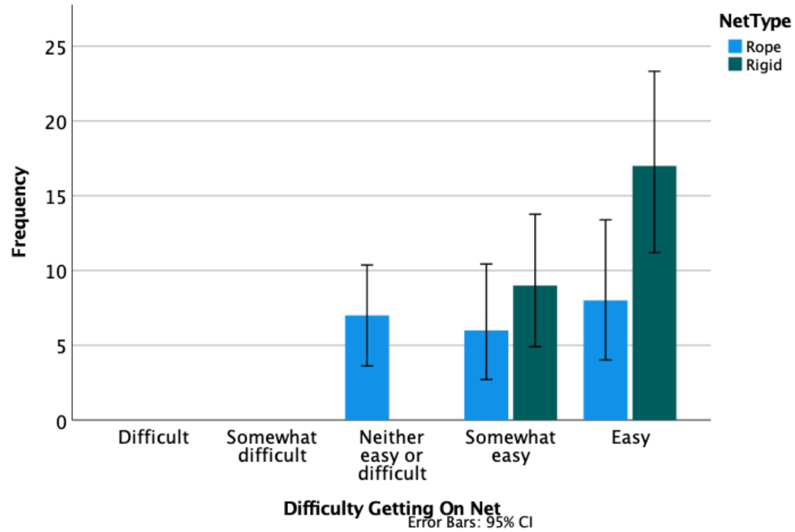


Figure 10 Difficulty getting onto the net – rigid and rope nets.

Statistical testing of the level of difficulty during climbing indicates that there is a significant difference between the rigid and the rope groups, with the rigid net rated as less difficult to climb (Figure 11) by users. This is consistent with the observed time taken by both groups to climb the net (rigid climbers required less time). While some rope climbers rated the rope net as somewhat easy and easy to climb, none of the rigid net group rated this net as somewhat difficult or worse.

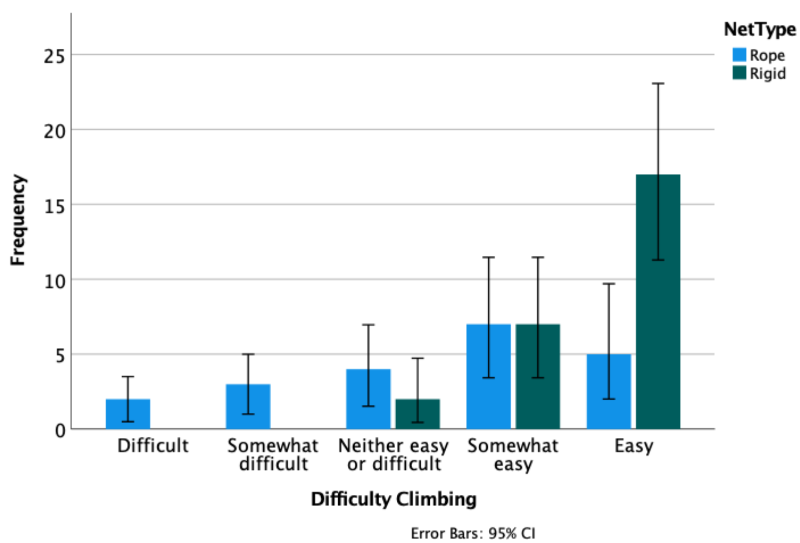


Figure 11 Difficulty climbing – rigid and rope nets.

Statistical testing of the level of difficulty getting over the top indicates that there is, again, a significant difference between the rigid and the rope groups, with the rigid net rated as less difficult (Figure 12) by users.

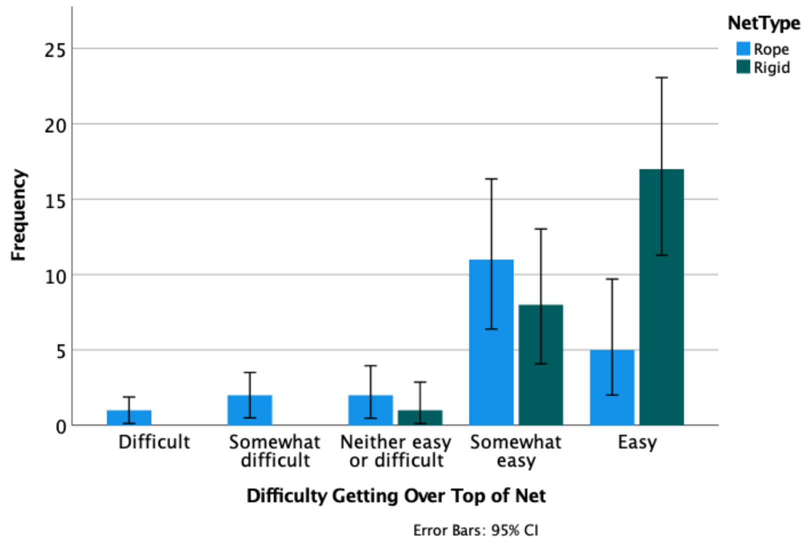


Figure 12 Difficulty getting over the top – rigid and rope nets.

Statistical testing of the overall level of difficulty indicates that there is a significant difference between the rigid and the rope groups, with the rigid net rated by users as less difficult overall (Figure 13). This is consistent with the observed time taken by both groups overall (rigid climbers required less time). A substantial portion of the rigid group reported the task as easy overall.

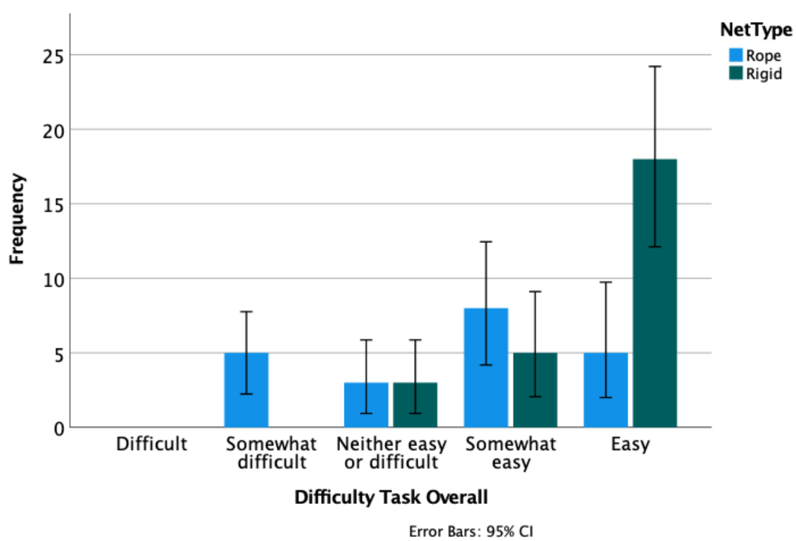


Figure 13 Difficulty overall – rigid and rope nets.

3.5 Struggles and Technique

It is worth noting that two participants in the rope group abandoned their climb before getting fully out of the water. Both individuals swam to a nearby Jacob's ladder and climbed to the top of the platform (which was a little lower at approximately 3m above the water) without significant difficulty. By comparison, all participants in the rigid group were able to climb the net to the top of the platform.

Observations from the video analysis revealed that some climbing techniques, as well as struggles were common. One technique that was common for both rope and rigid climbers was that many used their toes to feel for the climbing edge before placing their weight on that foot. This technique was not taught but seemed to be innate for the climbers since they were not always able to see where they were placing their foot. It is likely that it prevented some instances of toes slipping off completely which might result in the climber falling.

We observed that some participants climbed laterally at times rather than straight upward, which added to overall climbing time (Figure 14). This occurred more frequently on the rope net than it did for the rigid net, as climbers seemed to treat the rigid net more like a ladder and did not struggle as much with climbing.

Figure 14 Still capture of a participant climbing laterally on the rope net.

While it is difficult to assess using observation alone, it appeared that multiple participants in the rope group were very tired when they reached the top platform. We did not observe any obvious cases of tired climbers for the rigid group.

Lastly and perhaps most significantly, we observed that the majority of rope net climbers (70%) experienced at least one slip during their climb, with most experiencing multiple slips (3 slips per person on average). This is important because slips occurred when the climber(s) were attempting to place their foot (and their weight) on a lateral member of the net in order to move upward. The resulting slips were generally observed to be jarring and presented a significant opportunity for the climber to fall from the net (although none did fall). By comparison, we did not observe any slips for the rigid net group.

In reviewing the video, it appears that the slips were largely the result of how the rope net hangs against the wall while being climbed. Even though spacers on the rope net are meant to provide a toe gap between the net and the wall, when a person is climbing it (i.e. when it is in tension), the gap often closes and often found only in the immediate vicinity of the spacers. This is in contrast to the rigid net because its lateral rigidity helps ensure that the gap between the net and the wall remains in-tact across the length of each member, even when being climbed.

It is important to consider also that our test setup did not involve ship motions or waves. For a vessel in a seaway, we anticipate that roll motions would be the most challenging to a net climber. It is reasonable to assume that a scramble net would rest against the side of the vessel for roughly half the time (with it hanging freely the remainder of the time as the vessel rolls). When resting against the side of the vessel, or when pressed against the side of a vessel by wave action, it is anticipated that the rigid net would continue to provide a toe gap for climbers, whereas the rope net would be unlikely to maintain this gap.

3.6 General Discussion

It was observed that people who appear to have confidence and a reliable climbing technique are more successful than those who do not. While not statistically significant, there appears to be a negative relationship between the age/mass of the climber and total climbing time, with older and heavier climbers tending to take longer to climb.

Given that the rigid net climbers, on average (a) were faster, (b) encountered fewer challenges (slips in particular), (c) felt more confident, and (d) were always able to climb the net, it is felt that the rigid net offers a better solution for the problem of self-rescue at sea.

3.7 Limitations

While results show that we have sufficient statistical power from which to draw conclusions, it is difficult to know exactly how well climbers would perform in a real emergency at sea where vessel motions, environmental conditions and the impacts of the abandonment on each survivor are unknown. For the participants of this study, the data was collected in a well-controlled experiment where all participants experienced the same environment, climbed the same distance and had the same training and similar backgrounds. Ideally, we would be able to carry-out the same experiment in a way that more significant environmental and motion conditions could be tested but this brings with it an increased risk of injury to participants and potential for damage to equipment. We feel that the present study offers results that are still relevant for real-world situations.

4 CONCLUSIONS AND RECOMMENDATIONS

This report outlines the methods and results from an experiment conducted in a training centre to compare performance of climbers using rigid and rope scramble nets for maritime self-rescue. Participants were recruited from students enrolled in Marine Emergency Duties refresher courses during the summer of 2021. In all, 49 participants were involved - 23 used the rope net and 26 used the rigid net. Both scramble nets were 5m in length with 1m below the water. The nets were mounted against a wall with spacers meant to provide an 11 cm toe gap.

For all parameters investigates, the rigid net enabled superior performance compared to the rope net – climbing time was faster, self-rated performance was higher and self-rated difficulty was lower. We observed that 70% of rope net users had a foot slip-off when attempting to progress upward in their climb, whereas none of the rigid net climbers experienced such a slip. This is a potentially significant benefit which the rigid net offers, since having a foot slip could result in the climber falling from the net.

Given the findings and discussion presented, we feel that the rigid scramble net offers a substantial improvement for maritime self-rescue over traditional rope scramble nets and should be considered for installation on vessels which may be required to perform rescue of people from the water or life-saving appliances such as liferafts and lifeboats.

5 REFERENCES

Abramowicz-Gerigk, T., & Burciu, Z. (2012). Analysis of safety requirements for large offshore units evacuation systems. LSA safety function. *Archives of Transport, 24*(4), 429.

Button, R. and Gorgol, T. (2019). Understanding the Challenge: Mass Rescue Operations at Sea. In: *Cooperation and Engagement in the Asia-Pacific Region* (Nordquist, M. H., Moore, J. N., & Long, R. (Eds.)). BRILL.

CNL/CNS-OPB (2018). Atlantic Canada Standby Vessel Guidelines, Second Edition, Self-Published, June 18, 2018.

Harries, M.G. (1983). Medical Aspects of the North Sea Oil Industry. J Royal Society of Medicine, Vol 76, Sept 1983.