Quick Release Harnesses; Loads on a High Line

Simon Allfree*
Canolfan Tryweryn The national Whitewater Centre, Frongoch, Bala, Gwynedd LL23 7NU

Loel Collins
Moray House School of Education and Sport, University of Edinburgh, Edinburgh, Scotland

Chris Onions
Canolfan Tryweryn The national Whitewater Centre, Frongoch, Bala, Gwynedd LL23 7NU

Abstract

This study examines the loads associated with positioning a Rescuer on a Quick Release Harness (QRH) on a high line in moving water. Testing was conducted at water speeds of 0.6 - 2.4m/s, typical of those encountered during water related rescues. A Rescue Randy Combat Challenge Manikin (65kg) was positioned on a QRH from a high line and an in-line load cell utilised to collect force/time data. The findings identify operational water speeds for positioning Rescuers in water using a QRH. The study contributes to the work by Onions and Collins in their earlier investigations and the understanding the loads placed on high lines during rescues by the emergency services.

Key Words: Quick Release Harness, swift-water rescue, water rescue

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Introduction

Positioning as Rescuer in fast flowing water to execute a rescue is frequently both risky and time pressured. Typically, given resource and time, a suitable craft is deployed. However, a quicker but risker option exists, that of using a rescuer via a quick release harness (QRH). The use of a QRH is significantly riskier and requires the response team to be highly skilled, experienced and practiced. Consequently, we see such approaches used more readily in small teams of recreational kayakers and canoeists and highly specialised, experienced and skilled first responders.

Onions and Collins (2017) reported on the loads generated by rafts on a highline and highlighted the need for Rescuers to understand the performance of the raft being lowered from that highline (Onions & Collins, 2017). Bechdel and Ray (1997) suggests that 'any watercraft can be used for the lower' (p126.). Indeed, commercial rafts in a range of sizes, rafted canoes, semi ridged dory's both flat bottomed and rigid 'v' shaped hulled and Rescuers utilising quick release chest harness have all been proposed (Bechdal & Ray, 1997; Ferrero, 2006). This paper reports on the second of three related studies utilising a variety of techniques to position a Rescuer. This report is in effect drawing together Onions (2012); Onions and Collins, (2013), Collins and Onions, (2014); Onions and Collins, (2017). to expand understanding and inform better decision-making during emergency responses.

The aim of this work to advance the understanding of the loads generated and the practicality of a Rescuer using a QRH deployed from a highline, to consider whether quick release harness applications generate similar patterns of load to rafts when deployed from a highline and then discuss the implications for the responder.

Literature Review

Positioning a Rescuer in the flow using a QRH to retrieve a casualty or equipment is a recognised technique in swift water rescue. It is often used if the rescue is time critical, access is problematic or suitable watercraft are not readily available.

Personal Flotation Device (PFD)

A PFD is a vest or jacket suitable for water rescue, consisting of shaped, closed-cell foam sections positioned against the wearer's torso. PFD's enable the wearer to swim in a conventional facedown (front-crawl position) that would otherwise be impossible in a life jacket. The PFD also has some degree of impact protection around the torso and facilitates defensive swimming in swift water. A typical life jackets does not facilitate conventional / aggressive swimming and does not protect the spine of the user. In addition to the buoyancy of the jacket, there is typically also a webbing structure around the outside of the buoyant material that performs multiple functions including the stowage of safety equipment (knives, whistles, prusik loops, etc.). The webbing also introduces a structure and form to the PFD during a rescue, although the details of design vary between manufactures. In addition to these generic features, rescue PFD's also consist of QRH that provides an anchor point for a throw line (tethering line) via a dorsal attachment point.

Tethered Swim Rescues

The most frequent swift water rescue application for a Rescuer using a QRH is to enter the water with a throwline attached to the dorsal point of the harness, while being belayed from the shore (Figure 1), make direct contact with the casualty and then allow the flowing water to wash both parties back to the Rescuers' bank (Rescue 3 International 2018). Authors have variously described these methods as live bait (Ferrero, 2006) or tethered swim rescues (Rescue 3 International 2018). These are considered high risk rescues, however in small, experienced response teams are quick/ snatch rescue responses that generate momentary loads on Rescuer, belayer and casualty as they are recovered. They are most frequently employed as down-stream safety in rescues.

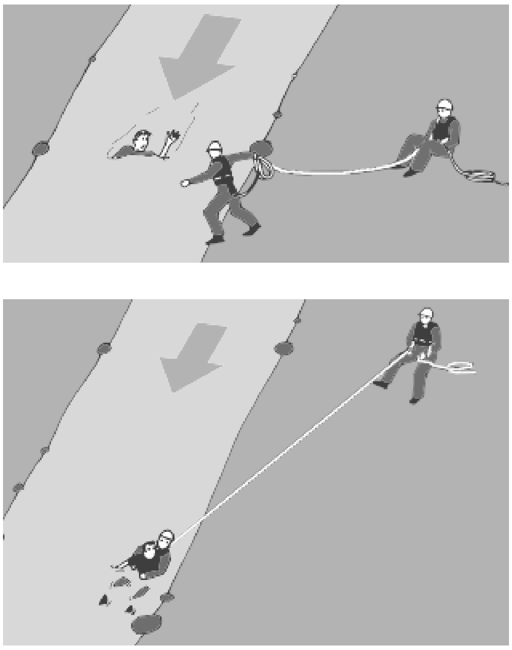


Figure 1: Tethered Swim rescue (Rescue 3 International 2018).

In has been proposed by Ferrero,(2006) and Bechdel and Ray (2009) that a QRH may also have an application in positioning a rescuer to facilitate a rescue.

Positioning Systems

Positioning a Rescuer wearing a QRH in the flow results in sustained loads being experienced by the Rescuer potentially over pro-longer periods. Positioning applications use multiple ropes on opposite banks to position the Rescuer. These systems take different forms; 'V', 'Y' and highline lowers.

V Lowers

The 'V' lower is an adaption of a two-line system used on rafts (Rescue 3 International 2018). 'V' lower systems are generally taught in the swift water context (Rescue 3 International 2018) with two lines attached to the dorsal points of the QRH (Figure 2). Each line is then belayed on either bank of the river. The Rescuer can be positioned by lowering on a single rope (moving the Rescuer both down, away from the releasing side or via lowering via both ropes which results in the Rescuer being lowered downstream (Rescue 3 International 2018).

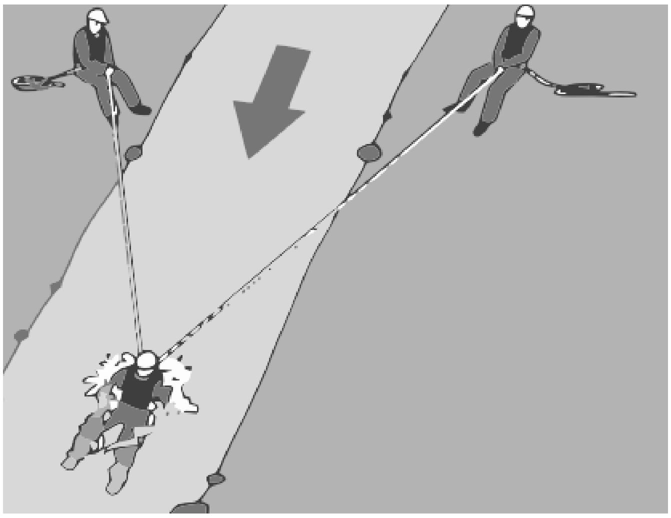


Figure 2: V Lower: (Rescue 3 International 2018).

Y Lowers

The Y lower (Rescue 3 International 2009) is a further adaptation of the two-line system. In this configuration a single line is attached to the dorsal attachment point of the QRH while being belayed to the bank, as in figure1 . A second line is then attached to the first line and belayed from the opposite bank so that a vectored load can be applied to the first, delaying the pendulum effect (Figure 3). The load on the opposite bank belayer is vectored and frequently high. The vector can also be applied actively from the same bank, to speed up the pendulum effect (figure 4). The key advantage of these ‘ Y’ approaches is that it forms a logical evolution from a typical live bait recovery. Allowing anomalies in current vectors and water features to be overcome. These have value in situations that may be at the limit of operation for a Rescuer in a QRH either because of water turbulence, current vectors on bends, complex flows or over coming low river speeds by speeding up recovery.

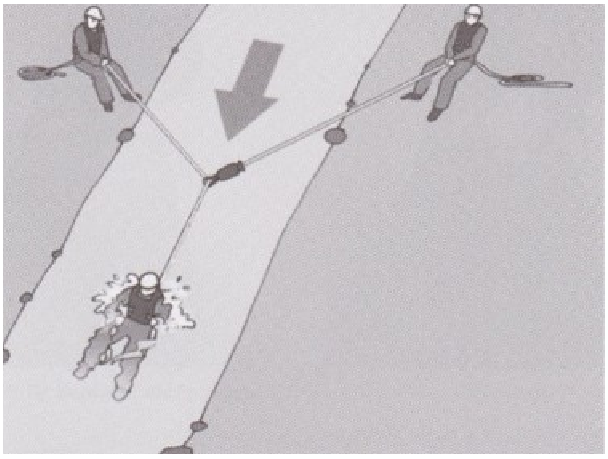


Figure 3: Y Lower, (Rescue 3 International 2009).

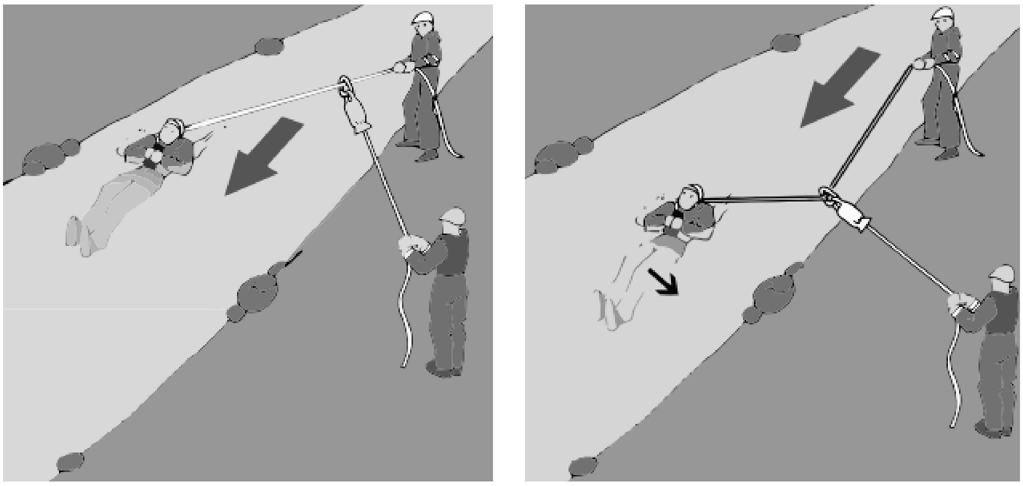


Figure 4: The set up and application of a vector pull to aid a pendulum recovery: (Rescue 3 International 2018).

Both the V and Y lowers are suitable in low river flow velocities that allow lines to be handheld. However, there are clear limitations to these ‘handheld’ approaches in higher flows as river velocity may exceed the grip threshold of the Rescuers positioned on the bank, or the capacity of the Rescuer in the water to breath duw to pressures acting on the chest. Both Ferrero (2006) and Bechdel and Ray (2009) report the limitation of quick release harness use as being determined by the flow of the water on the user's torso and arms. The loads on the torso having the potential to limit the Rescuers ability to breath and use their arms effectively.

While, load bearing, belays are possible in the V and Y techniques these place demands on equipment and importantly remove an inbuilt load limiting capacity, that of the Rescuers grip. Using direct or in direct mechanical belays consequently can subject the Rescuer in the water to unknown loads. If load holding devices or direct belay techniques are used an understanding of the loads on the Rescuer is required in order to allow safe and effective deployment. The use of load holding devices also brings with it an increased complexity in the rope systems and with it a commensurate increase in risk of entanglement.

Consequently, highline techniques become options if equipment and training allow.

Highline Lowers

Highline techniques vary depending on the force of the water, width of the river and the rope resources available. Commonly used in conjunction with a raft and increasingly with a sled, an application with a QRH represents an improvised solution in formal rescue but remains a 'last ditch' option with experienced Rescuers, team of kayakers or canoeists or if a raft or sled are not available. In selecting a QRH application it becomes important to understand the loads generated on a Rescuer.

Method

Building on the work of Onions (2012); Onions and Collins, (2013); Collins and Onions, (2014); Onions and Collins, (2017) concerning a desire for ecologically valid challenges, representative force values needed to be determined in environments in which a Rescuer might be willing to be deployed. The approach of Onions and Collins (2014) was adapted in two ways (1) utilising a more sensitive load cell, addressing the weakness highlighted by Onions, (2013) (2) varying the load on the Rescuers by positioning the rescuer in different positions within a calibrated channel in order to gather different flow rates rather than varying the flow rate by increasing the flow on an artificially pumped channel.

Qualified and experienced Rescue Technicians were used for rigging, assist help with data collection and discuss findings and the implication. Due to the duration required to be in the water a Rescue Randy Combat Challenge Manikin (65kg) dressed and trimmed to float in a defensive swimming position was used. The manakin was equipped in water rescue equipment, river shoes, wet suit, helmet and QRH PFD).

Procedure

Test site

For the purposes of this test a calibrated channel was used 100m downstream of a British standard broad-crested weir (International Standards Organisation, 2008). Flow data was recorded 50cm up stream of the Rescuer before every test to ensure accurate calibration at the site. This was done with a digital flow meter and mean flow calculated at the point of test. The site comprised of gravel beds and earth embankments with some rock armouring at key locations. Due to the nature of the channel the flow type at the test site was turbulent slow flowing being representative of the conditions in which Rescuers on a QRH may be deployed. The approach for determining the force induced by moving water on objects positioned by ropes has been established by Onions (2012); Onions and Collins, 2013; Collins and Onions, 2014; Onions and Collins, (2017). They present the case for capturing data under real world conditions using appropriate equipment in preference to mathematical modelling.

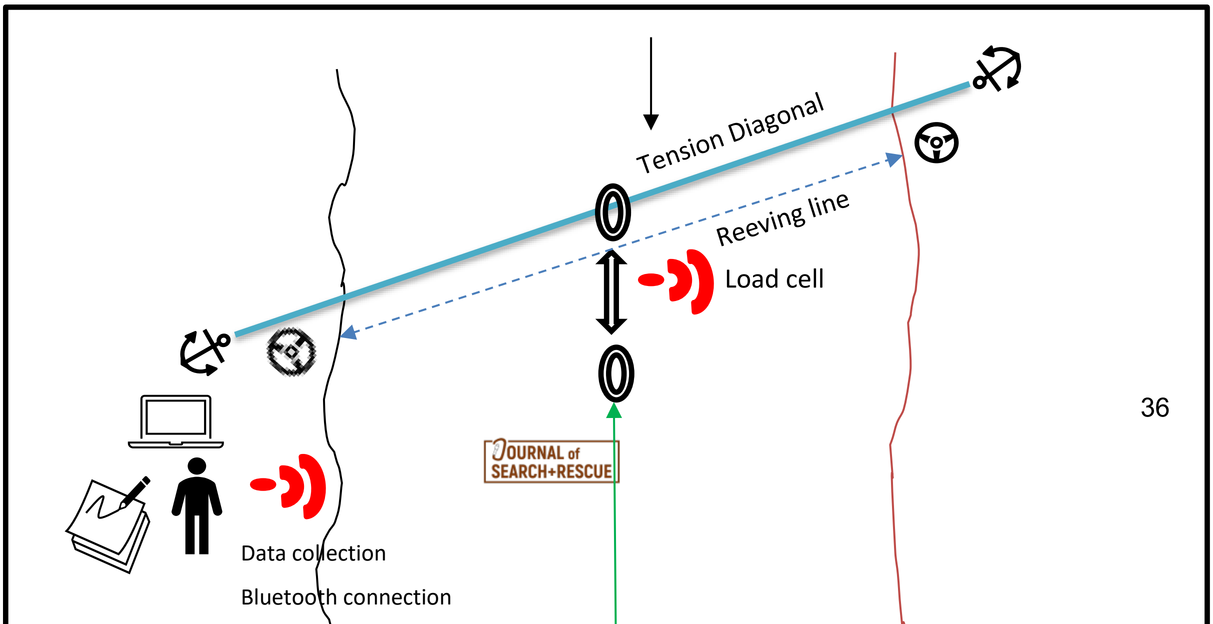
Data Collection

Flow speed data was collected via a Geopacks Advanced Stream Flowmeter and the data transferred into Microsoft Excel via a data cable. Flow speed was measured in meters per second (m/s) to 2 decimal points.

A Bluetooth Rock Exotica Enforcer load cell was connected in series with the tether at the Rescuers up stream attachment to the high line, this recorded the load in kN to 3 decimal places at a rate of 500 samples a second. Data were transmitted via Bluetooth to an iPad and managed using the Enforcer app (version 1.1.1), the data was saved and then transferred to Microsoft Excel. This was then used to produce graphs showing the relationship between mean flow and mean load.

Procedure

A highline system, as a tensioned diagonal was set up as per figure 4. This was rigged in five different locations within the calibrated channel allow the manakin to be positioned in a range of different flow rates. The Rescue Randy Manikin was then moved into positioned and the system allowed to settle for a period of at least one minute. (1) Ten flow velocity readings were then taken 50cm up stream of the manikin allowing a mean flow speed to then be calculated. (2) A minimum of one and a half minutes of force data were then collected at a sample rate of 500 samples/second. (3) The manikin was then repositioned to experience different flow rates in the channel and the procedure repeated. A total of 51 complete data sets were collected over a period of three days.



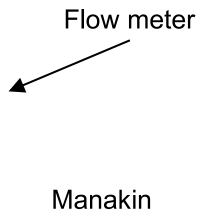


Figure 4: Test set up QRH on a high line. The box on the Rescue Technicians line indicates the position of the Rock Exotica Enforcer load cell. For clarity, the mechanical advantage rigging of the highline and reeving lines have been omitted.

Analysis

The relationship between mean flow in meters per second (X axis / explanatory variable) and the mean load in kilonewtons (Y axis / response variable) was plotted on a graph and regression lines calculated.

Results and Discussion

A strong uphill (positive) linear relationship can clearly be seen in the graph. The R value was calculated as +0.79, indicating 79% of the movement in the response variable can be explained by the explanatory variable tested. This suggets that the results are highly predictive and accurate.

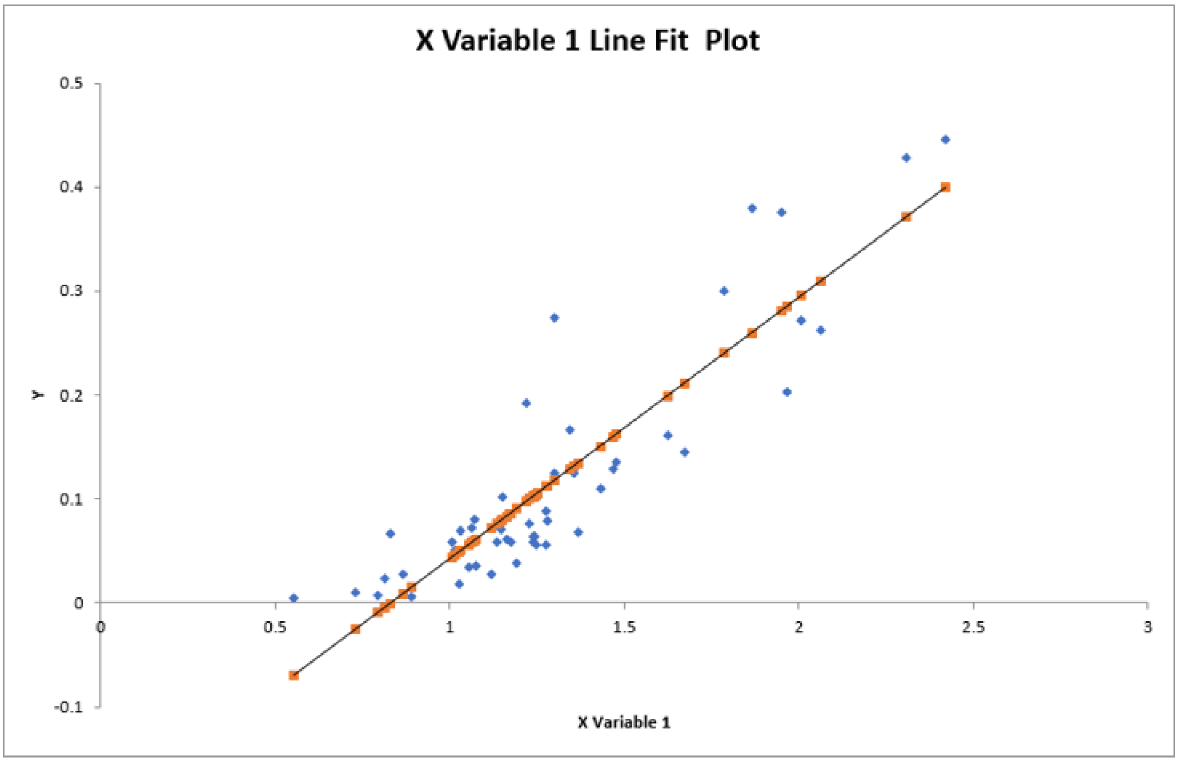


Figure 5: Graph showing mean flow in m/s (X axis) and mean load in kN.

As can be seen from the graph in Fig 5 as water speed increases there is a corresponding increase in force generated on the manikin in the water. Unlike the data collected by Onions and Collins (2017) with rafts in a similar application, the rescuer did not come up onto the plane with a subsequent drop in force. Discussions between the technicians and the research team (please see bios) led to an agreement that they had not experienced Rescuers using QRH coming up onto the plane.

However, if the expected drag force of this manikin in the water is calculated using the Rayleigh equation

$$(D = \frac{1}{2} C p A v^2)$$

In which where *C* is the drag coefficient, *A* is the area of the object facing the fluid, and *ρ* is the density of the fluid using the mean velocities of the 51 data sets obtained in this study then the blue line in Figure 6 is obtained (Benson, 2022). This line represents a rescuer whose profile to the current vector does not change as velocity increases. This line is in strong contrast to the mean loads generated by the data sets in this study. The conclusion drawn is that the Manikin/Rescuer in the water does change its profile in relation to the current vector as the velocity increases, though observation would not suggest the manakin planes as a raft does. Thus, although a linear increase in force is experienced it is not an exponential increase. These findings were borne out by the Technicians interviewed who reported experiencing a “rising up” feeling while positioned in the flow on a QRH, the diorsal attachment point ensuring the Rescuer stay in the surface water experiencing less drag.

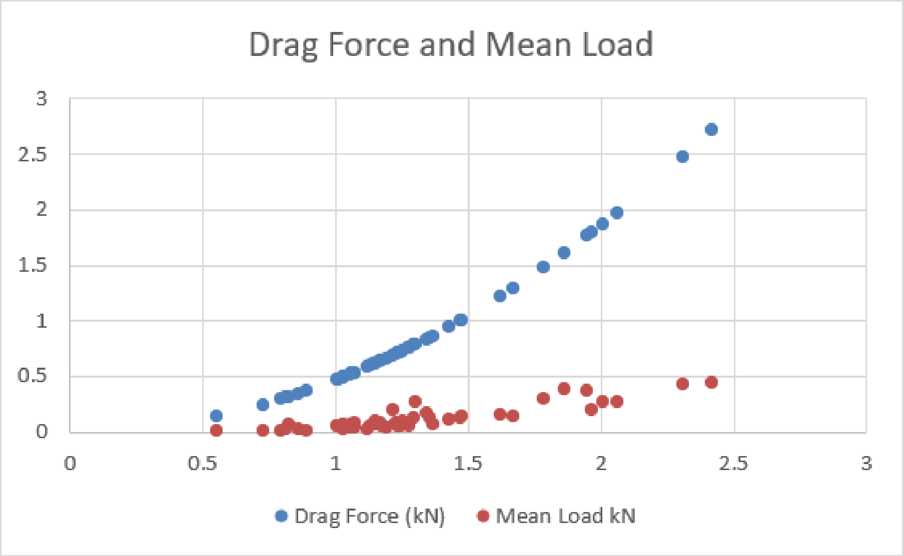


Figure 6: Graph showing Drag Force (blue) and Mean Load (Red)

Both Ferrero (2006) and Bechdel and Ray (2009) postulate that there is a point where the force of water on the Rescuer is too great for them to be able to operate effectively and that the rescuer does assume a defensive swimming position by virtue of the dorsal attachment point. The Technicians involved in the testing agreed that the higher water velocities, close to 2.5 meters per second, generating a force on the Rescuer of close to 0.5 kN experienced was towards the upper end of comfortable / effective for operation. Anything above 0.5 kN results in an unsustainable constant load on the Rescuer. This finding would align with a force of 0.623kN that has been shown to be the tolerable force for men pushed against a 100mm wide flat bar, QRH harnesses are typically 50mm although the foam of the PFD, we would expect to dissipate the load (Evans & Hayden, 1971). Tolerable forces for women were reported as being significantly less (Evans & Hayden, 1971). “These loadings are however, potentially, affected by various factors including age, gender and anatomical build” (Lee & Hughes, 2006).

Limitations of study and further research

Due to the large amounts of time required for the in-water Rescuer a manikin was used. While the use of a manakin allowed for a consistency in the tests, optimised water time, reduced risk, every effort was taken to ensure as realistic a positioning in the water as possible, it is conceivable that different results would be obtained by using a real body.

The manikin was clothed in a wetsuit rather than a dry suit, this may also have had an impact on the data. As a result of using a single manikin based on a male form the data obtained using female Rescuers may provide different results.

The highest water speed recorded in the test was 2.4 meters per second. However further research, at higher water speeds, would determine the situation in which the load on the user became unmanageable there is, however, an ethical and safety implication. It is suspected from the data obtained that the situation for the Rescuer in the water would very quickly transition from manageable to unacceptable both in terms of risk, ability to function and capacity for the Rescuer to release the QRH.

The location of the attachment point on the QRH requires further investigation. Several North American manufactured PFD's place the attachment point low on the PFD closer to the lower thoracic/ upper lumbar potion of the spine. European PFD manufacturers, position the dorsal attachment point on the PFD in the mid thoracic area. There is also variation in the attachment position following donning the PFD, some wearers preferring the PFD high on the body or low on the body, thus changing the position of the dorsal attachment point. Dorsal attachment point positioning may have an impact on the force experienced by the rescuer, their capacity to operate, and effect body position in the water. The load being spread via the PHD around the rib cage rather than across the stomach if positioned around the lumbar area. European Harnesses where used in this testing and positioned on the manakin for a mid-thoracic dorsal attachment point. Further research could be conducted to determine if there is an "ideal" attachment point, and optimum shape for the in-water Rescuer to minimise load on themselves, ensure operation and defensive positioning. Collins and Onions (2014) use of 'star' shapes to force QRH releases may offer some insight.

Conclusion

Use of a QRH from a highline represents an improvisation to a method that normally uses a raft or sled. "This is not a technique endorsed by Rescue 3 Europe" (Gorman 2020). However, this method might have application in locations with difficult bank access that would hinder deployment of large craft or the use of a V or Y lower. This method is a risky solution as it places the rescuer directly in the water, requires time to construct, high skill and judgement levels by the team. The limitation of using a QRH on a highline is the sustained loads on the rescuer. The loads generated are within SWL for the technical equipment used to construct the highline. The window of operation for the rescuer in the water is likely extremely small due to the sustained forces involved with a suggested maximum acceptable water speed of 2.5 meters per second, or loads on the rescuer that do not exceed 0.5kN even for an extremely experienced and capable rescuer. Dorsal attachment point position and height of the highline above water level may be additional factors and warrant further invetsigation. Both V and Y lowers represent simpler options that are self-limiting due to the belayers capacity to hold loads via moving, direct or indirect or body belays, this could form the focus of further studies. The implications for training and practice are that high levels of experience and judgement are required in electing to use a QRH in this manner and that use of a raft or sled are advised. This consideration was shared by our Technicians, who offered the view that, pragmatically, research time may be better employed exploring the capacity of a sled from a highline, consequently a final study of Sled on a high line is advisable.

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Abbreviations

QRH	Quick Release Harness
PFD	Personal Floatation Device

References

Bechdel, L., & Ray, S. (2009). River Rescue. Asheville: CFS Press.

Benson, T. (2022). "The drag equation". US: NASA. Retrieved June 9, 2022.

Bills , M., Edwards, B., Gillespie, K., Gorman, J., Graham, D., Hogan, M., & Turnbull, P. (2009). *White Water Rescue Technician.* Rescue 3 International.

Collins, L., & Onions, C. (2014). Improving the Performance of Swiftwater Rescue Quick Release Harnesses. *Journal of Search and Rescue*(3), 4-19.

Dudhnath, K. (2018). Whitewater Rescue Technician. Rescue 3 International.

Evans, E. J., & Hayden, F. (1971). *Tests on Live Subjects to Determine the Tolerable Forces that may be exerted by Crowd Control Crush Barriers.* Guildford: University of Surrey.

Ferrero, F. (2006). *White Water Safety and Rescue* (2nd ed.). Caernarfon: Pesda Press.

Jonkman, S. N., & Penning-Rowsell, E. (2008, October). Human Instability in Flood Flows. *Journal of the American Water Resources Association, 44*(5), 1208-1218.

Lee, S. C., & Hughes, R. L. (2006). Prediction of human crowd pressures. *Accident Analysis and Prevention*, 712-722.

Onions , C., & Collins , L. (2013). A Review of Quick-Release Harness Performance in Water Rescue. *International Journal of Emergency Services*, 141-154.

Onions, C. (2013). *Highline Rescue Boat Systems: A study of the load created by tethered rescue boats with respect to stream velocity, trim and hull size.*

Onions, C., & Collins, L. (2017). Raft on a highline: Loads and trim. *Journal of Search and Rescue, 2*(1), 1-10.