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Determinants of towing effectiveness in water rescue

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Abstract

Purpose: Drownings are a societal phenomenon occurring worldwide, hence the importance of rescue skills, including directly towing a victim to a safe place. The purpose of this study was to evaluate the most effective towing techniques based on kinematic parameters, considering different types of drowning cases, for their recommendation for widespread use in water rescue.

Methods: The research involved 18 water lifeguards aged 18-25 years. The evaluation included speed tests in towing a mannequin over a distance of 50 m using the Extended Arm Tow (EAT), Double Armpit Tow (DAT), "Sailor" Technique Tow (STT), and with a rescue tube (RT), accompanied by video recording to measure in the designated measurement area the number of cyclic paddling movements by the lower limbs, angles of the body attack, towing velocity, and its decrease during towing.

Results: Number of cyclic paddling movements by the lower limbs, towing with a RT was considered the most beneficial, and least beneficial was the DAT. In the DAT, the lifeguard swam with the smallest body angle, in contrast to the STT, where this angle was the largest. The effect of the number of cyclic paddling movements and the body angle by the lifeguard was the velocity, with the highest value recorded in towing using a RT; in other techniques, velocity were similar.

Conclusions: Institutions associated with water rescue should recommend towing using a RT for direct rescue actions in the water, as its use shortens the time, while simultaneously increasing safety for both the rescuer and the victim.

Keywords: drowning, rescue tube, towing techniques, kinematic parameters

Introduction

The survival chances of a drowning person depend on many factors, including the efficient rescue operation conducted by well-trained and equipped water lifeguards . It is assumed that in case of drowning, one should reach out to the drowning person, extending a hand or an object to pull them to shore and save them. If the distance is too great, a line with a buoyancy aid should be thrown to the drowning person. If this approach proves ineffective or impossible, one should reach the drowning person by boat, and if for some reason this is not feasible, direct action in the water should be taken, namely entering/jumping into the water, swimming to the drowning person, securing/positioning them, and towing them to a safe place while keeping their mouth above the water surface. The “Reach-Throw-Row-Go-Tow” is one of the most widely accepted rescue action sequences [26].

It is difficult to precisely predict the distance a lifeguard will need to swim to reach a victim, the size of the drowning person, their emotional state and health condition, and therefore what techniques of control and towing of the drowning person will be undertaken, and most importantly, the duration of the rescue operation. The safety of the lifeguard and the associated effectiveness of the action is also of great importance [39]. Therefore, in the case of direct action in the water at swimming areas and places occasionally designated for bathing, the lifeguard should be equipped with buoyancy aids, especially a rescue tube (RT), which not only maintains the drowning person's head above the water surface but also provides effective protection for the lifeguard from drowning [6].

The physical effort and accompanying stress of a lifeguard during a rescue operation lead to a gradual loss of the lifeguard's strength [26], [27], [30], especially when towing a drowning person requires significant exertion [21]–[23]. Research and practical experiences do not clearly indicate the manner and pace at which a lifeguard should move with the victim. It is assumed that the choice of towing technique for a person at risk of drowning is conditioned by the stage of drowning and the associated level of health disturbance. This is illustrated in Figure 1.

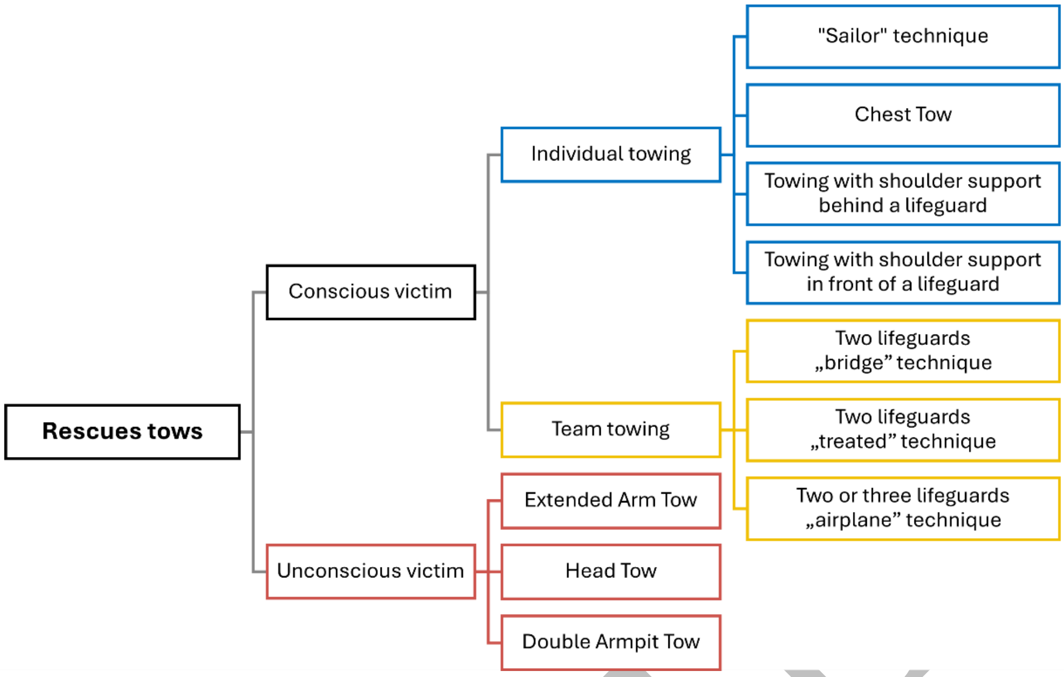

Figure 1. Typical towing approaches based on victim's state of consciousness.
Source: *Own elaboration*.

When towing a conscious, tired person who responds to the lifeguard's commands, a method involving a catch through the victim's chest is used, or with the victim supporting themselves with their upper limbs on the lifeguard's shoulders/hips behind or shoulders in front. In cases where the lifeguard is concerned about the victim's uncontrolled behavior and the risk of the lifeguard being submerged, the "Sailor's" Technique Tow (STT) is used, along with immobilizing the victim's upper limbs. Immobilization is applied because it is assumed that a drowning person, in the threat of losing the ability to breathe freely and due to emotions, will struggle for breath, treating the lifeguard as support to keep their head above water. This is a very demanding and difficult method of towing a drowning person.

In the case of towing an unconscious person, the lifeguard's primary task is to keep the victim's mouth above the water surface. Therefore, depending on the buoyancy of the injured person, techniques such as the Extended Arm Tow (EAT), the Double Armpit Tow (DAT), and the Head Tow (HT) are used. In the EAT technique, the lifeguard, while moving to a safe place, uses their hand to keep the drowning person's mouth above the water surface. In the HT technique, the lifeguard, while moving to a safe place, holds the drowning person's head with both hands under the jaw, simultaneously tilting their head back and keeping the mouth above the water surface. In the DAT, the lifeguard holds the drowning person under the armpits with both hands, also ensuring their mouth remains above the water [31]. The choice between the EAT, the HT, and the DAT techniques depends on the physical capabilities of the lifeguard, related to keeping the drowning person's mouth above the water surface. It should be noted that when assisting an unconscious person, the lifeguard is obliged to reach a safe place with the victim as quickly as possible, while with a conscious person, the towing pace can be less significant.

These towing techniques require the lifeguard to appropriately position the victim on the water surface, while simultaneously adopting a position suitable for the towing technique. When performing the HT or the DAT, the lifeguard swims on their back with cyclic propulsion from the lower limbs. In the STT, the Chest Tow, or the EAT, the lifeguard swims on their side with cyclic movement of the lower limbs and one upper limb. During towing with shoulder/hips support behind the lifeguard, the lifeguard swims on their front with cyclic movement of both upper and lower limbs.

During the provision of direct assistance in the water, the lifeguard should use a RT. The technique of towing with a RT is applied in rescuing both conscious and unconscious persons. The tube is handed or thrown to a conscious person, and in the case of an unconscious person, after reaching them, the lifeguard places and secures the RT around their chest, then tilts the head back to clear the airway and keep the mouth above the water surface to enable free breathing. In all cases of towing with a RT, a cyclic propulsion of three or two limbs is used. Equally important is the ability for the lifeguard to lean on the RT both while swimming to the drowning person and during towing. The use of a RT significantly increases the safety level of both the drowning person and the lifeguard [6], [31].

A technique to assess the effectiveness of a lifeguard in water towing is through tests with a mannequin, where towing velocity is primarily conditioned by the magnitude of propulsive forces generated from technical skills, morphological characteristics, and motor abilities. Therefore, the main research objective of this study was to evaluate the role of kinematic parameters in various techniques of lifeguard towing. The application objective was to develop and recommend to institutions responsible for training programs and safety in water areas the most effective and safest towing techniques, taking into account different types of drowning cases. Taking into account the purpose of the research undertaken, the study has formulated the following research questions:

1) How did the individual towing technique characterize in terms of the number of cyclic propulsive movements made by the lower limbs?
2) At what angle of the body relative to the horizontal plane (body angle of attack) did the lifeguards swim during towing with the techniques studied?

3) To what extent were there differences in velocity in the tested towing techniques?
4) Were there any decreases in velocity during towing with each technique, and to what extent?
5) Which towing technique is most effective and should be recommended?

Material and Methods

Participants

Eighteen male water lifeguards aged 18 to 25 years were qualified to participate in the study. The inclusion criteria were: a medical certificate confirming good health and no contraindications to work as a water lifeguard, and achieving a time of less than 1:20 (mm:ss) in a 100 m freestyle preliminary test. All participants were informed about the purpose and procedure of the study and the possibility of withdrawing without giving a reason. Participants provided written consent to participate in the study. The research project was approved by the University Bioethics Committee for Scientific Research at the Jerzy Kukuczka Academy of Physical Education in Katowice – Resolution No. 8/2018 dated April 19, 2018. The average age of the participants was 18.8 ± 1.29 years, the average tenure in water rescue was 3.0 ± 1.14 years, the average body mass was 73.2 ± 13.19 kg, and the average body height was 177.7 ± 9.57 cm.

Research procedure

The study was divided into two stages; the first consisted of anthropometric measurements (body height and mass), and the second, after a week-long break, focused on evaluating the towing of a mannequin over a distance of 50 m using the EAT, DAT, then the STT, and finally with a RT. Between each trial, participants had a minimum of 60 minutes of rest. This time was sufficient for the recovery of energy stores for the working muscles [14]. Before starting the towing, each lifeguard performed an individual warm-up consisting of basic stretching exercises on land (5 min), then swam at a slow pace for 300 m by repeating three times the sequence: 25 m freestyle, 25 m backstroke with arms along the torso and breaststroke leg kick, 25 m freestyle, 25 m sidestroke with one arm extended upwards and the other arm along the torso using a scissor kick for propulsion. Five minutes after the warm-up was completed, the participant began towing. After the measurement was finished, the participant exited the water, where they passively rested for 45 minutes and could consume only water.

During the measurement series, the participants towed a standard DLRG (Deutsche Lebens-Rettungs-Gesellschaft) mannequin [40] using the aforementioned methods over a distance of 50 m at maximum velocity at the 25-m swimming pool. In order to ensure the highest measurement accuracy, the kinematic parameters were recorded in five-meter measurement zones. The first measurement zone (1MZ) was located between 10 and 15 m distance (first length of the pool), while the second measurement zone (2MZ) was between 35 and 40 m distance (second length of the pool).

Based on video material recorded with cameras placed above and below the water surface, kinematic indicators of towing technique were identified, such as:

1) number of cyclic propulsive movements of the lower limbs (Leg Kick), which the lifeguard performed in the 1MZ (LK1) and 2MZ (LK2), measured from the moment of crossing the initial five-meter measurement zone line with the head to the moment of crossing the final line defining this zone,
2) angle of the body relative to the horizontal plane (Body Angle of Attack), measured in the 1MZ (BA1) and 2MZ (BA2) at the moment when the lower limbs of the rescuer were extended at the hip and knee joints, occurring after the completion of the propulsive movement by the lower limbs,
3) towing velocity in the 1MZ (v1) and 2MZ (v2), the measurement starting from the moment of crossing the initial five-meter measurement zone line with the head to the moment of crossing the final line defining this zone,
4) percentage velocity decrease index calculated using the formula: %decrement = (v2–v1)/v1×100.

The DLRG mannequin is used for lifesaving competitions and to conduct simulated water rescue operations. It complies with international water rescue competition regulations. Made of polyethylene, its buoyancy can be adjusted by filling it with water, simulating the weight of a human in water under real rescue conditions. Its dimensions are approximately 100 cm in length and 44 cm in width.

To ensure an accurate time-motion analysis of the towing technique in the 1MZ and 2MZ, a special trolley with one underwater video camera and one above-water video camera (Sony FDR-X3000, Japan) was used. The trolley moved along the edge of the pool at the towing speed. Reference poles of known lengths were placed at 1 m intervals along the lane where the lifeguard was towing. The video material was analyzed by two independent experts using Kinovea software (version 0.8.26, Kinovea, Paris, France), which enabled a time-motion analysis of the recorded elements. To assess the reliability of the video material analysis, 6 towing recordings were evaluated using the intraclass correlation coefficient (ICC). The ICC score ranged from 0.981 (95% CI, 0.975–0.986) to 0.993 (95% CI, 0.979–0.996).

Statistical analysis

Descriptive statistics are reported as mean ± standard deviation (SD) and range (min–max). The Shapiro-Wilk test and Levene's test were used to check the normality and homogeneity of the data variables, respectively. To compare the kinematic parameters of the tested towing methods, a one-way analysis of variance with repeated measures was conducted, where the towing technique was established as the factor of repeated measurement. Pairwise comparisons were made considering the Tukey correction. The assumption of sphericity was confirmed using Mauchly's test. In cases where the sphericity assumption was not met, the Greenhouse-Geisser correction was applied. Partial eta-squared (η_p^2) was selected as the variance effect size index and interpreted as: small (< 0.01), medium (≥ 0.01), and large (> 0.06). Effect sizes for significant pairwise comparisons were calculated using Cohen's d and interpreted as: trivial (< 0.2), small (≥ 0.2), moderate (≥ 0.5), and large (≥ 0.8) [7]. The significance level was set to $p < 0.05$ for all analyses. All calculations were performed using TIBCO Statistica, v. 13.3.0 (TIBCO Software Inc, Palo Alto, CA, USA). For graphical data presentation, the *ggplot2* [34] library in the R programming environment was utilized [20].

Results

In Table 1, the velocity obtained in the 1MZ (v1) and 2MZ (v2) during mannequin towing techniques are presented: DAT, EAT, STT, and Rescue Tube Tow (RTT). Meanwhile, Figures 2, 3, 4, and 5 depict the analysis of the recorded kinematic parameters in the 1MZ (A) and 2MZ (B), in terms of: LK1, LK2 (Figure 2), BA1, BA2 (Figure 3), v1, v2 (Figure 4), and %decrement (Figure 5).

Table 1. Characteristics of cyclic propulsive movements by the lower limbs, angles of the body relative to the horizontal plane, velocities, and velocity decrease indices obtained in the 1MZ and 2MZ by lifeguards during mannequin towing using various techniques (n = 18).

Variables	DAT	EAT	STT	RTT	ANOVA
LK1 [n]	10.64±1.34 (8.0–13.0)	8.31±1.21 (6.5–10.6)	8.68±1.68 (5.5–12.1)	7.53±1.53 (4.5–10.5)	$F_{(3,51)}$=26.82, p<0.001 η_p^2=0.61
LK2 [n]	11.75±1.61 (8.5–14.5)	9.22±1.96 (5.5–14.0)	9.47±1.40 (6.5–11.5)	8.39±1.63 (5.0–11.0)	$F_{(1.8,30.4)}$=24.21, p<0.001 η_p^2=0.59
BA1 [°]	22.62±3.60 (17.0–29.2)	36.78±6.68 (24.0–49.0)	36.06±7.26 (24.0–48.0)	26.68±5.47 (14.0–34.4)	$F_{(3,51)}$=40.46, p<0.001 η_p^2=0.70
BA2 [°]	24.94±5.00 (17.0–33.0)	39.62±5.00 (28.3–50.1)	38.61±7.87 (24.0–48.0)	29.89±5.81 (17.6–39.0)	$F_{(3,51)}$=53.17, p<0.001 η_p^2=0.76
v1 [m × s^{-1}]	0.68±0.06 (0.60 – 0.80)	0.68±0.12 (0.48 – 0.94)	0.67±0.06 (0.55 – 0.80)	0.77±0.05 (0.68 – 0.88)	$F_{(1.8,30.1)}$=8.24, p=0.002 η_p^2=0.33
v2 [m × s^{-1}]	0.56±0.04 (0.51–0.66)	0.59±0.09 (0.44–0.76)	0.58±0.06 (0.47–0.69)	0.67±0.05 (0.58–0.77)	$F_{(3,51)}$=20.41, p<0.001 η_p^2 = 0.55
% decrement	20.84±7.92 (7.5–35.8)	15.94±6.74 (5.1–26.7)	14.11±7.64 (1.2–26.2)	13.55±4.97 (4.8–22.7)	$F_{(3,51)}$=4.23, p=0.01 η_p^2=0.20

Note:

DAT: Double Armpit Tow; EAT: Extended Arm Tow; STT: "Sailor" Technique Tow; RTT: Rescue Tube Tow; LK1, LK2: number of cyclic propulsive movements of the lower limbs, which the lifeguard performed in the 1MZ (LK1) and 2MZ (LK2); BA1 BA2: angle of the body relative to the horizontal plane (Body Angle of Attack), measured in the 1MZ (BA1) and 2MZ (BA2); v1, v2: towing velocity in the 1MZ (v1) and 2MZ (v2); %decrement: percentage velocity decrease index.

In the 1MZ (Table 1, Figure 2A), lifeguards performed the fewest leg propulsive movements during mannequin towing using a RT (7.53 ± 1.53). Similar numbers of lower limb movements were recorded during towing using the EAT and the STT (8.31 ± 1.68 and 8.68 ± 1.68, respectively). The towing technique accompanied by the largest number of lower limb movements was the DAT (10.64 ± 1.34). It is noteworthy that the difference in the number of cyclic lower limb movements during towing using the DAT was 3 full cyclic movements more compared to the number of leg cycles during towing with a RT. During mannequin towing in the 2MZ (Table 1, Figure 2B), a similar trend was observed. Again, the fewest cyclic leg movements were recorded during towing with a RT (8.39 ± 1.63), and the most during the DAT (11.75 ± 1.61). Lifeguards performed a similar number of lower limb movements during towing using the EAT and the STT (respectively: 9.22 ± 1.96 and 9.47 ± 1.40). The number of cyclic paddling movements by the lower limbs during DAT towing was significantly different from the number of paddling movements during towing using the techniques: EAT ($p < 0.001$; *ES* = LARGE), STT ($p = 0.002$; *ES* = LARGE) and with a RT ($p < 0.001$; *ES* = LARGE) ($F_{(3,51)}$ = 26.82; $p < 0.001$). A statistically significant difference was also noted in the number of cyclic paddling movements by the lower limbs between towing using the STT and with a RT (p = 0.004; *ES* = LARGE).

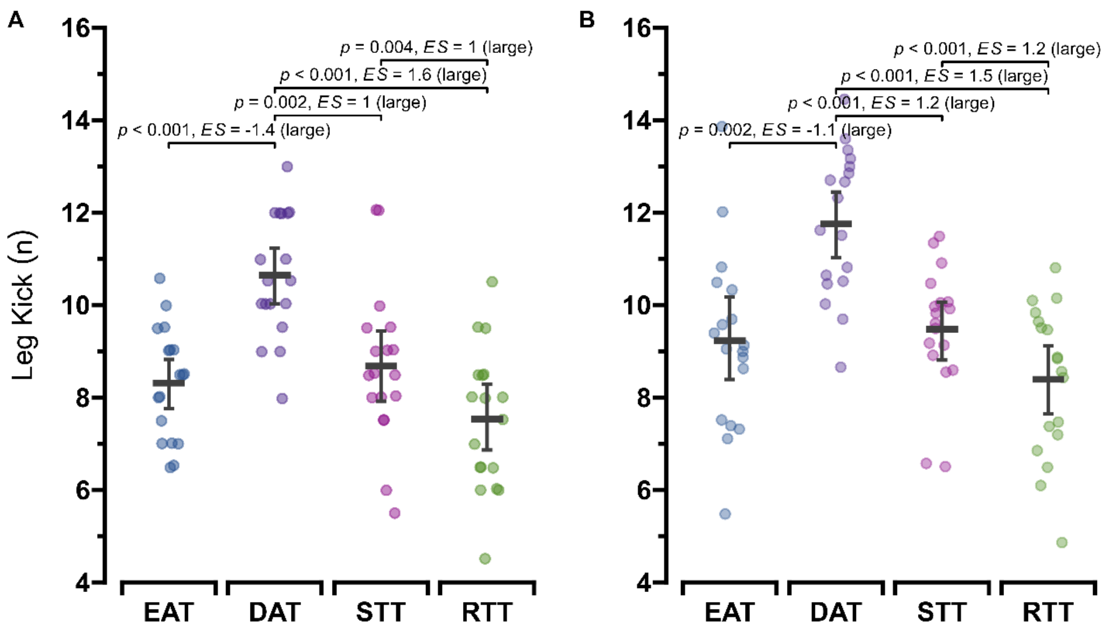

Figure 2. Characteristics of individual values of the number of cyclic paddling movements by the lower limbs of lifeguards recorded in the 1MZ (A) and 2MZ (B). Results of analysis of variance and multiple comparison tests.

The smallest body angle of attack in the 1MZ (Table 1, Figure 3A) was observed during the DAT (22.62 ± 3.60°), slightly larger when using a RT (26.68 ± 5.47°), and the largest during the EAT (36.78 ± 6.68°) and the STT (36.06 ± 7.26°) ($F_{(3,51)}$ = 40.46; $p<0.001$). In the 2MZ (Table 1, Figure 3B), the same distribution of body angle of attack values for each towing method was observed, but fatigue from the effort led to an increase in this angle in all analyzed towing techniques. During the DAT, the average values of the body angle of attack were the lowest (24.94 ± 5.00°), while the highest during the EAT (39.62 ± 5.00°). The size of the body angle of attack noted during the DAT differed significantly from the body angles of attack observed during towing using the EAT ($p < 0.001$; *ES* = LARGE), STT ($p < 0.001$; *ES* = LARGE) and with a RT ($p < 0.049$; *ES* = MODERATE). Additionally, statistically significant differences in the sizes of the body angle of attack occurred between towing the mannequin with a RT, and the techniques using the EAT and the STT (for both comparisons $p < 0.001$; *ES* = LARGE) ($F_{(3; 51)} = 53.17$; $p < 0.001$).

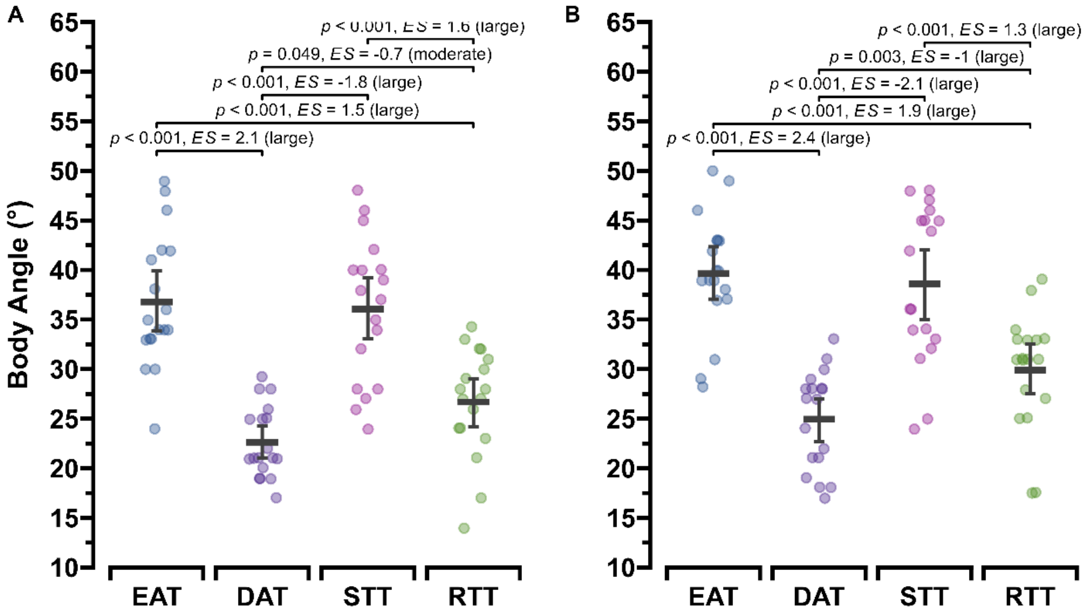

Figure 3. Characteristics of individual measurements of the angle of the body lifeguard's torso relative to the horizontal plane recorded in the 1MZ (A) and 2MZ (B). Results of analysis of variance and multiple comparison tests.

The highest velocity in the 1MZ (Table 1, Figure 4A) was achieved while towing using a RT (0.77 ± 0.05 m/s), and the lowest during the STT (0.67 ± 0.06 m/s). It should be noted that the towing pace using the EAT and the DAT was similar and slightly higher than the STT. Similar results were obtained in the 2MZ (Table 1, Figure 4B), where towing with a RT was also the fastest (0.67 ± 0.05 m/s), but a greater variation occurred between the other techniques, where the best results were achieved by lifeguards towing using the EAT (0.59 ± 0.09 m/s), and the worst with the DAT (0.56 ± 0.04 m/s). Analysis of variance revealed a significant effect in terms of the factor related to the technique of towing, both on the 1MZ and 2MZ (respectively: $F_{(1.8, 30.1)} = 8.24$; $p < 0.002$ and $F_{(3, 51)} = 20.41$; $p < 0.001$) (Figure 5). It was noted that the velocity measured, both on the 1MZ and 2MZ during mannequin towing using a RT, significantly differed from the velocity achieved during towing by other techniques, i.e.: with the EAT (p = 0.016 and $p < 0.001$; *ES* = LARGE – respectively in the 1MZ and 2MZ), DAT (respectively: $p < 0.001$ and $p < 0.001$; *ES* = LARGE), and the STT (respectively: $p < 0.001$ and $p < 0.001$; *ES* = LARGE).

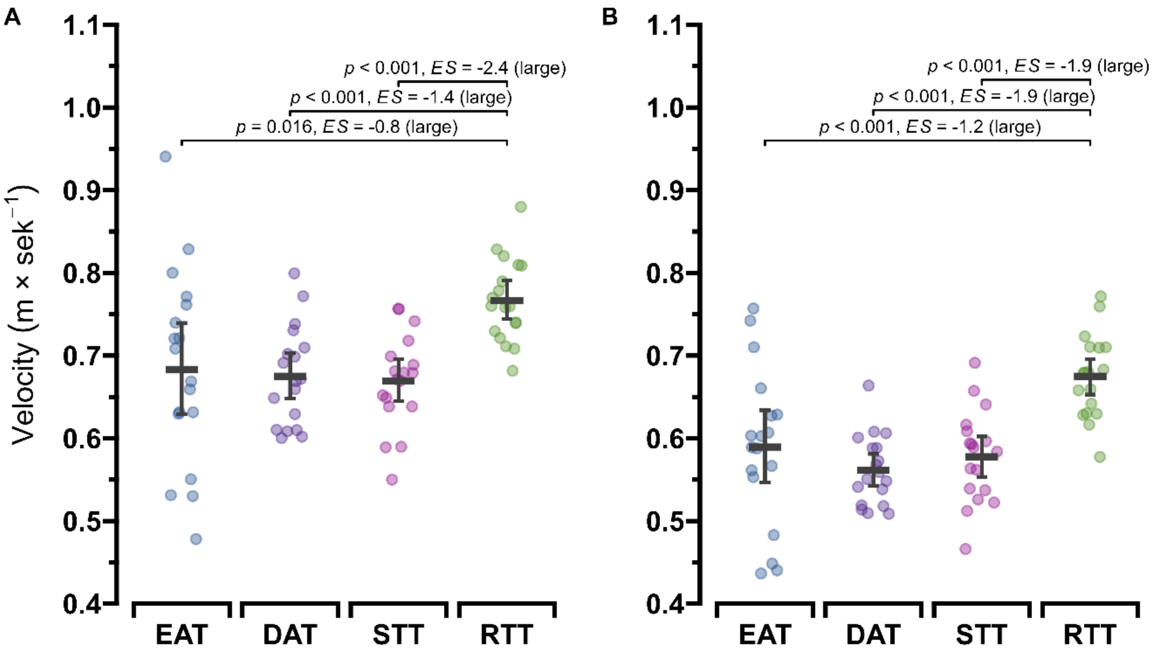

Figure 4. Characteristics of individual velocity values obtained by lifeguards in the 1MZ (A) and 2MZ (B). Results of analysis of variance and multiple comparison tests.

The calculated % decrement of towing (Table 1, Figure 6), indirectly indicating the level of fatigue, achieved the lowest value in towing using a RT (13.55 ± 4.97%), which was about 1% lower than the index obtained for the STT (14.11 ± 7.64%). The highest value of the % decrement was noted for the DAT (20.84 ± 7.92%). Velocity changed during towing over the 2MZ. Analysis of variance revealed a statistically significant difference ($F_{(3, 51)} = 4.23$; $p = 0.01$), the largest between DAT and towing using a RT (0.56 ± 0.04 m × s^{-1} vs. 0.68 ± 0.06 m × s^{-1}; $p = 0.022$; *ES* = LARGE).

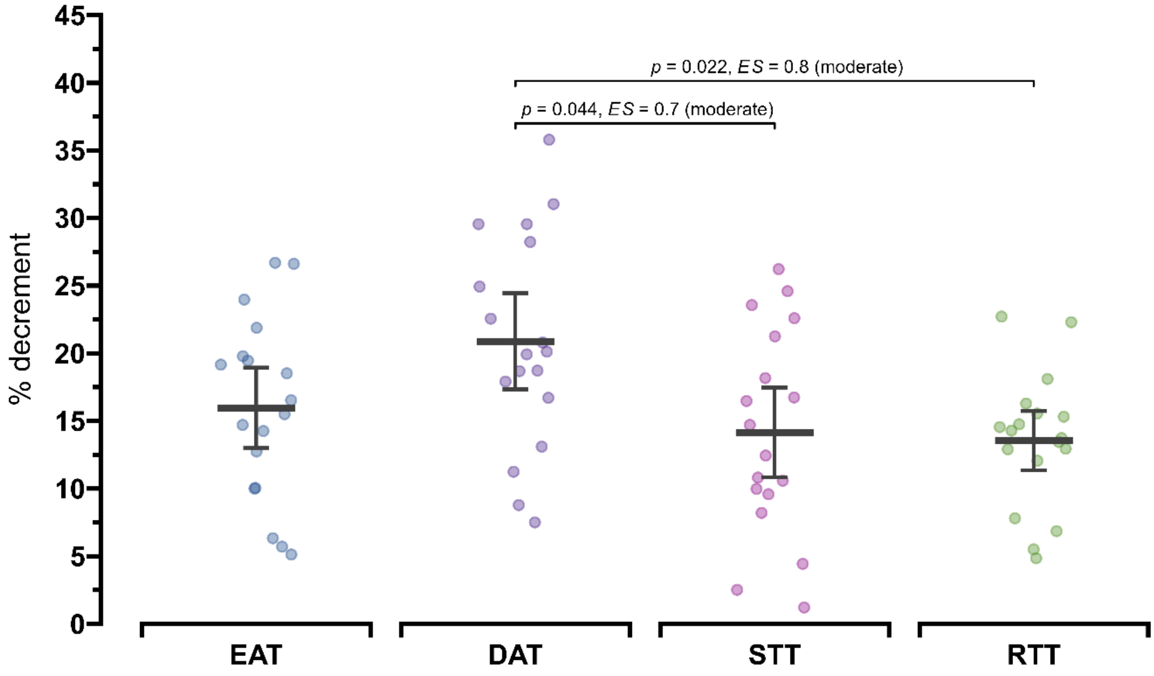

Figure 5. Characteristics of individual values of the velocity decrease during mannequin towing.

Discussion

Towing a drowning person is cited by many researchers as the most physically demanding element of a rescue operation for lifeguards [1]–[3], [6], [8], [15], [21]–[24]. Noteworthy are the results of simulated rescue actions, in which lifeguards performing the action without equipment were faster in reaching the drowning person but slower in towing compared to lifeguards using portable rescue equipment [23]. Similar results were observed based on the assessment of oxygen consumption, where rescue actions using portable rescue equipment were less burdensome on the cardiovascular and respiratory systems of lifeguards [18], [21], [22].

In these studies on the effectiveness of various towing techniques, the lifeguard swam on their side, using cyclic movements of one upper limb and two lower limbs for propulsion (EAT, STT, using a RT) or on their back, using only cyclic movements of the lower limbs for propulsion (DAT). In designated pool areas, the number of cyclic propulsive movements, the body angle of attack, and the velocity of towing were examined, based on which the velocity decrease index of towing was calculated. The conducted analysis aimed to determine the extent to which the studied kinematic parameters were determinants of towing effectiveness in water rescue.

Swimming velocity, or towing velocity, correlates with the swimming technique, including the number of limbs involved in propulsion, the swimming stroke length, the frequency of leg kicks (stroke rate), as well as body position and associated water resistance [11], [12], [29], [32], [38].

Ensuring the ability to effectively tow in water is associated with performing cyclic movements of the lower limbs. It can be assumed that the fewer cycles of limb work a lifeguard performs while maintaining a constant swimming velocity, the better, as it affects the efficiency and economy of the rescue action. In these studies, depending on the technique of towing, the lifeguard performed one movement with the lower limbs and one with a selected upper limb or only one movement with the lower limbs in each cycle. Therefore, it was considered that the analysis of the work of the lower limbs illustrates the rhythm in the entire technique of towing, which was evaluated based on the video recording analysis.

Our research reported that both in the 1MZ and 2MZ lifeguards performed the fewest leg propulsive movements during mannequin towing using a RT (7.53 ± 1.53 and 8.39 ± 1.63, respectively). The increase in the number of cycles performed in the 2MZ could be due to the high muscle load, which made the movements less efficient. The decrease in speed and the simultaneous increase in the number of movements could also be influenced by individual swimming techniques, an increasing angle of attack, which is associated with the need to overcome greater water resistance [13], [28]. It is also important to note the significantly greater number of cyclic paddling movements by the lower limbs in the DAT, where propulsion was provided by only two lower limbs. With these results, the authors recommend all towing techniques that allow for the use of upper limb propulsion, especially with the use of a rescue tube.

The effectiveness of towing is related to swimming technique, one of the measures of which is the body angle of attack, which determines the water resistance acting on the swimmer, hence the aim is to minimize it [4], [5], [9], [33], [35], [36], [38]. Therefore, the proper positioning of the lifeguard's body in the water during towing plays a key role.

Differences in the body angles of attack between the 1MZ and 2MZ were small and ranged within 2-3°. The highest velocity was observed in towing using a RT, which could be associated with the amount of resistance overcome during towing. At higher velocities, resistance increased, affecting not only the lifeguard's body but also the mannequin, which had implications for the physiological load on the subject, and ultimately led to a decrease in locomotion pace. Similar results were observed in studies by Pendergast et al. (2003) [17], Strzała, Krężałek (2010) [28] and Zamparo et al. (2006, 2011, 2020) [38], [36], [37].

The result of the number of cyclic paddling movements and the body angle of attack were the velocity achieved in the measured zones. The highest velocity both in the 1MZ and 2MZ was achieved while towing using a RT (0.77 ± 0.05 m/s and 0.67 ± 0.05 m/s, respectively). The high velocity of towing using a RT has been confirmed in studies by Prieto Saborit et al. (2010) [18] and Barcala-Furelos et al. (2016) [6]. It can be presumed that this is probably due to increased buoyancy, thereby reducing the immersion and resistance of the mannequin in water. The low velocity in towing using the STT, on the other hand, may result from the positioning of the mannequin directly above the lifeguard, causing the body angle of attack of the lifeguards' torso to average 36.06 ± 7.26°, which was reflected in the velocity. The authors emphasize the necessity of using a RT during every rescue operation. It should be mentioned that, based on unscientific but best practices, many different elements of rescue equipment have been utilized to speed up rescue operations, with the most popular being fins, RT, and rescue board, used by lifeguards as personal flotation devices for the victim, but little is known about the specific effectiveness of each piece of equipment. To fill these gaps in knowledge, scientific evidence is needed [6].

Time and the associated towing distance significantly affect the pace, which tends to decrease due to effort and fatigue. Therefore, it was decided to investigate its values using the percentage velocity decrease index of towing, taking into account the applied technique. In our research, the smallest % decrement was recorded in the case of towing using a RT (13.55 ± 4.97%). Velocity decreases in swimming with distance are increasingly significant, influenced by many factors, especially swimming technique, individual physical predispositions conditioned by body anatomy, and additional auxiliary rescue equipment [16]. It is believed that during towing, the effort of the lifeguard can even double compared to rescue swimming [10] and increasing fatigue limits the effectiveness of the rescue operation [19], [25], [33]. It should be mentioned that in all techniques, a velocity regression of $0.10 \text{ m} \times \text{s}^{-1}$ was observed, which is associated with the number of cyclic paddling movements of the lower limbs measured in the five-meter measurement zone. In the studies by Strzała, Krężałek (2010) [28], a statistically significant ($p < 0.01$) decrease in swimming speed was also observed with increasing distance.

Conclusions

The conducted studies have expanded knowledge on kinematic parameters as determinants of towing effectiveness in water rescue. Lifeguards towing with a RT performed the fewest cyclic paddling movements of the lower limbs, while the most were performed in the DAT. It should be mentioned that in the first case, lifeguards swam using an additional upper limb, and in the second case, only lower limbs. It can be inferred that assisting propulsion with an upper limb leads to fewer propulsive actions. In the next kinematic measurement concerning the body angles of attack, it was found that the most favorable angles occurred in the DAT, while the least favorable in the STT, along with the related water resistance. In drawing conclusive conclusions, differences in body positioning should be considered when towing while swimming on the back compared to swimming on the side. Additionally, it should be noted that with similar towing techniques, swimming on the side, the most favorable body angles of attack occurred with the use of a RT. The effect of the number of cyclic paddling movements and the body angles of attack by the lifeguard was the velocity, with the highest value recorded in towing using a RT. In other techniques, velocity were similar, with the greatest decrease in towing velocity noted in the DAT. It can be presumed that using only cyclic movements of the lower limbs for propulsion leads to quicker fatigue in the lifeguard. Differences in velocity between the 1MZ and 2MZ were confirmed by introducing the %decrement, which was most favorable in towing with a RT, and least in the DAT.

Among the most important achievements of this study is demonstrating the significant impact of using a RT on towing velocity. Finally, institutions related to legal acts, training, and equipment of designated water areas are advised to recommend the use of RT, which shorten the duration of towing while ensuring safety for both the rescuer and the victim, increasing the likelihood of a successful operation. The authors also recommend further research on this issue, particularly considering towing in conditions closer to real-life scenarios with victims of different morphological parameters.

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