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Changes in swimming technique and physical performance after 8 weeks of lifeguard rescue training: an exploratory study

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Abstract:

Purpose. Every lifeguard undergoes numerous tests that aim to check, among others, strength, speed, resistance, etc., which is finally verified by a rescue action without equipment. The level of mastering elements of the swimming technique and swimming kinematics is a key element to succeed in swiftly reaching the drowning person which is limited by the time needed for drowning. ~~Aim:~~ The aim of this study was two-fold: (i) analyze the variations of swimming kinematics after 8-weeks of lifeguard training; and (ii) analyze~~r~~ the relationships between changes in kinematic outcomes and swimming performance over 25 and 100 meters. **Methods.** Six lifeguard candidates (age: 21.0±~~xx~~ 1.09 years old; three female and three male students) voluntarily participated in this study. The 4x25-m freestyle test and a 100-m freestyle tests were performed twice (before and after 8-week training period). The tests were video-recorded and the following kinematic variables were calculated: swimming velocity, stroke frequency, stroke length and stroke index. **Results.** No significant changes in kinematic variables were observed. However, a strong correlation (r=0.83) occurred between the swimming velocity of the 4x25m test and the finish velocity of the 100m test. The stroke index of the 4x25 m test was strongly correlated with the swimming velocity of the 100m test (r=0.89). **Conclusions.** Although lifeguard training did not improve swimming kinematics**,** it is worthwhile using training methods to check the preparation level of a lifeguard to ensure that he/she is properly trained to help people drowning in water bodies.
Keywords: swimming technique; swimming kinematics; lifeguards

Introduction

Rescue action means providing help to people whose life or health is endangered while staying in water. Among the most important factors, there are a swift observation of the event, getting to the drowning person fast and quickly taking control over them, hauling to the land, and last but not least providing first aid swiftly. The time factor is deciding; therefore, the economics and fast swimming is helpful in ensuring the safety of the lifeguard and the drowning person. Current data show that lifeguard's fatigue caused by rapid rescue swimming may negatively affect the effectiveness of cardio-pulmonary resuscitation [3]. Therefore, rescue swimming should be optimized in terms of kinematic factors to achieve the maximal velocity at adequate energy expenditure. Swimming and other elements of rescue action (e.g. diving, towing, cardio-pulmonary resuscitation) must be trained regularly to keep the lifeguard in shape [32].

It has been long known that swimmer's technique while covering a distance is significant in achieving good results. One of the features of a good swimming technique is its stability [22]. Although the swimming stability is hard to maintain in the open water environment (waves, temperature, currents, etc.), lifeguards should keep on improving their swimming technique during pool training. The activity cannot be mechanically repeated, but it should be adjusted to the conditions both in an internal and in an external environment. Many studies show that the stroke length (SL) is a very significant factor and it constitutes a key element of the swimming technique [13,14,35]. One should increase the length of the cycle (SL) and avoid increasing the frequency of propulsive movement (SR) both during training sessions and during sporting events. The following factors contribute to prolonging the swim cycle distance: a proper body position in the water, resulting in smaller frontal drag, a proper arm entrance into the water, an increasing torque from entering an arm into the water to the maximum value at the push phase. Both the length of the cycle and the frequency of swimming depend on the distance and swimmer's individual predispositions [7,36]. Swimming kinematics is considered to have an optimal balance between SR and SL when the velocity (v_{SW}) is at its highest level with a relatively low energy cost [8]. Other studies explain the dependence of energy cost on inter-limb coordination (IdC – index of coordination). Inter-limb coordination has an impact on SR, SL and finally on v_{SW} [16]. Stroke index (SI) is one of the most important indicators of the swimming technique. It is a product of multiplying the swimming velocity (v_{SW}) and the stroke length (SL). Good swimming performance is correlated with higher SL and SI that effects higher velocity [12]. Increasing the value of these parameters is the paramount training goal while developing the swimming technique. The value of this factor can be used as a criterion which is the basis for changing the training load [26]. The research clearly shows that better swimmers are tall and they have a better swimming technique, which is significantly influenced, among others, by the length of the swim cycle distance [24]. Studies on the optimal values of the stroke length are regularly carried out by many coaches after each significant swimming competition [18]. The coaches aim to develop the optimal swimmer's SL/SF ratio to achieve the highest velocity [33].

Studies of lifeguard activities mainly focus on the effectiveness of the rescue action with a use of various equipment, e.g. fins, buoys, or life preservers [5,6]. Although numerous studies have been carried out with competitive swimmers on possible correlations between gender, training mode, anthropomorphic base, and kinematics factors, such studies have not been carried out with lifeguards [15, 17]. Therefore, the purpose of this study was two-fold: (i) analyze the variations of swimming kinematics after 8-weeks of lifeguard training; and (ii) analyze the relationships between changes in kinematic outcomes and swimming performance over 25 and 100 meters.

Materials and methods

Study design

This is a one-group observational study. A pre-posttest design was employed in the current study.

Setting and context

The study started at 14/02/2022 (baseline assessments) and ended at 11/04/2022 (post-intervention assessment). During the intervention, the participants were exposed to three training sessions/week over 8 consecutive weeks. The assessments were preceded by a 24-hour rest period, and were applied at 9:00 AM. Both assessment moments were conducted on the same day of the week (Monday) and similar conditions of rest were ensured aiming to mitigate the variability of conditions. The assessments were conducted in the same swimming pool with a water temperature of 27.8ºC, environmental temperature of 29.2ºC and relative air humidity of 68.0%.

Participants

~~A convenience sampling was used as strategy~~. A web-based calculator (ClinCalc LCC, Indianapolis, IN, USA) was utilized to estimate sample size. The calculations were based on the study in which seven collegiate swimmers were assessed in terms of swim kinematics [11]. Assuming significance at p=0.05 and the test power of 80%, a sample of 9 participants was obtained. The research involved students of the second year of full-time studies of physical education, who have applied for lifeguard training. Eligibility criteria were: (i) participate in both moments of assessment; (ii) present a minimum of 95% of adherence to the training sessions; (iii) not being injured in the week before the first assessment and during the training sessions; and (iv) not take any drug during the assessments and training period. Participants declared not to undertake any other extra-curricular physical activity during the analyzed period. Moreover, they were asked to follow the same routine in terms of eating and sleeping schedule. At the beginning of the intervention, the study group consisted of thirteen students (four females and nine males). Out of those, six students completed the lifeguard training and fulfilled all eligibility criteria. Thus, the final study group consisted of three females and three males, mean age 21 years (±1.09), body mass 71.68 kg (±11.21), stature 175 cm (±13.70). Due to the fact that the requirements for lifeguard position are equal for women and men, the results of the examined students were analyzed jointly.

Rescue training intervention

The lifeguard candidates participated in an 8-week training cycle (3 training sessions per week, 90 minutes per training unit). All training sessions were aimed at improving standard lifeguard skills according to the International Lifesaving Federation (ILS) recommendations. The subjects took part in a course for ILS pool lifeguard position. Course participants learned various methods of rescue swimming, including: lifesaving entry, freestyle swimming with head above the water, surface dive to a minimum depth of 1.5m, towing the dummy, lifting the victim out of the pool. ~~The training consisted in using only rescue swimming techniques and towing skills which should correspond to in-water resisted swim training.~~ ~~Thus,~~ No competitive strokes (e.g. butterfly, backstroke) other than freestyle were ~~used~~ performed during the training. The average volume of each training unit was 2.1 km (±0.3).

Swimming tests

Before and after the training cycle, all subjects performed two freestyle swimming tests in a 25-m pool: 4x25m step test (T_{4x25}) and 100m maximum performance test (T_{100}). The tests were preceded by a standardized warm-up protocol consisting in 15 min dryland and 1000 m swimming. Ten minutes after the end of warm-up, the participants started the tests.

In the first test, the students swam 4 times 25 m with push off starts, with progressively increasing speed. Each 25-m bout was performed in 75-sec intervals. Diagnostic properties of that test had been confirmed previously [21]. The T_{100} test consisted in swimming the distance from the starting block as fast as possible. The tests were interspaced by a 20-min rest period. The main outcome obtained for the test was the time (measured in seconds). The times of T_{4x25} and T_{100} tests were obtained using video camera recording and computer software.

Both tests were recorded using a 30 Hz digital video recorder (Panasonic HX-WA 20, Panasonic Corp. Osaka, Japan). The camera was placed on a trolley and moved along the edge of the pool following the participant's head. The start zone (15 m from the starting block), turn zone (5m approaching the wall and 10m after push-off the wall), finish zone (the last 5m of the 100-m trial), and swimming zone (10m in the middle part of the swimming pool) were marked with fluorescent tapes.

Swimming kinematics analysis and measures

Video-recorded data was transferred into Kinovea software (Kinovea 0.8.15, GPLv2 license, 2009). Kinovea is a reliable tool that enables analyzing distances, coordinates and spatial-temporal parameters [27, 34]. On the basis of data obtained by Kinovea software, mathematical calculations of the swimming velocity (v_{SW4x25}, v_{SW100}), the stroke length (SL_{4x25}, SL_{100}), the stroke frequency (SF_{4x25}, SF_{100}) and the stroke index (SI_{4x25}, SI_{100}) for both tests were made. Observed SL and SR were the mean values in each 25m in the 4x25m test and 100m test.

Calculations of kinematic variables were made according to the following formulas [24]:

$SR=60 \times 3/t_{SR}$; where "SR" is the stroke rate and "t_{SR}" is the time of three cycles. In the current study stroke rate is converted into stroke frequency (SF) according to the following formula: $SF=SR/60$ [Hz]

$v=S/t$; where "v" is velocity, "S" is distance, and "t" is time,

$SL=v \times 60/SR$; where SL is the stroke length,

$SI=v \times SL$; where SI is the stroke index

Stroke rate was measured by the Kinovea software in the swimming zone. The measurement began when the participant's hand was at shoulder level in the recovery phase of the stroke (Fig. 1.). The measurement was completed in the same moment after three full cycles.

Moreover, for the T_{100} test, the calculations of velocity in the 15m starting zone (v_S), velocity in the 15m turning zone (v_T) and velocity in the last 5m finishing zone (v_F) were additionally made [33]. Differences in kinematic parameters assessed before and after the analyzed period were marked as "Δ" (for example Δ SR).

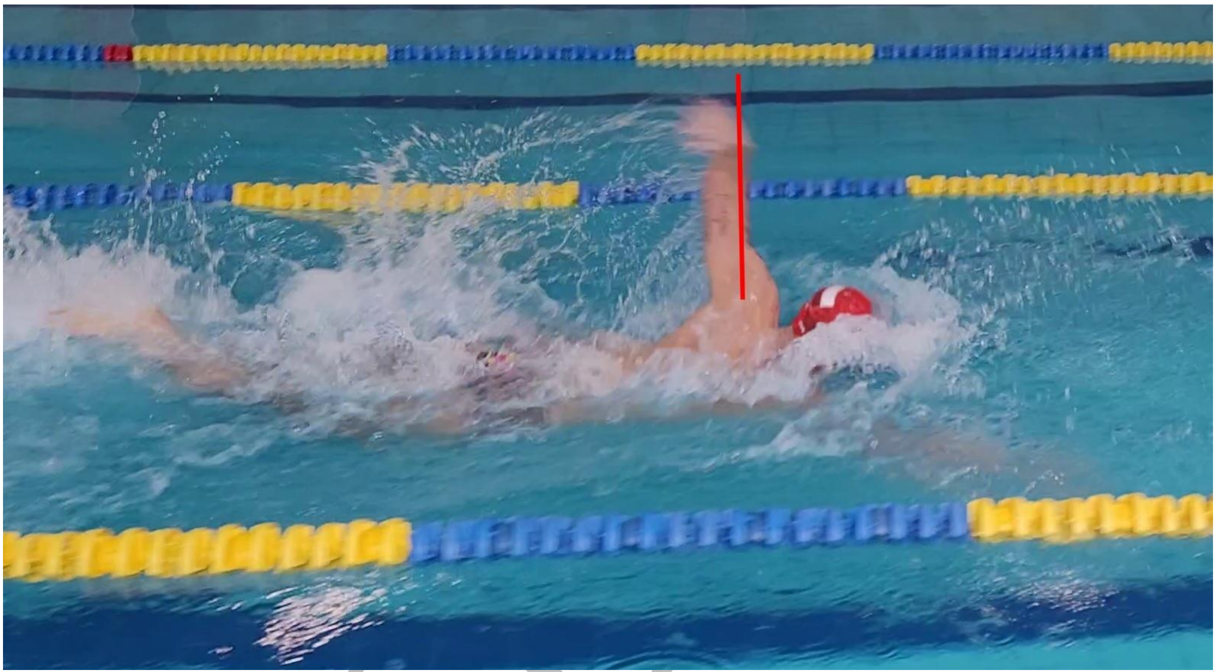

Fig. 1. The starting/finishing point of three cycles time measurement

Statistical procedures

Normality and homogeneity of the data were preliminarily inspected using the Shapiro-Wilk test and Levene's tests, respectively. Data distribution was normal according to the Shapiro-Wilk test ($p>0.05$) as well as homogeneity was confirmed ($p>0.05$). The t-paired test was used to analyze variation of population between baseline and post-intervention. The standardized effect size of Cohen (*d*) was used to estimate the effect size in the pairwise comparisons. To assess the correlation coefficient of changes (Δ) in examined kinematic values, Pearson *r* and Spearman rank order correlations tests were carried out. Ninety-five percent confidence intervals for mean values were also calculated. These statistical calculations were performed using Statistica 10.0 software (StatSoft, Tulsa, USA) for a $p<0.05$.

Results

After the 8-week period of lifeguard training, only a small improvement in the mean value of SF in the T_{4x25} was observed. Other values, i.e.: v_{SW}, SL and SI, declined. All changes were statistically insignificant (Table 1).

Table 1. Mean values of individual kinematics obtained during T_{4x25} test

Subject No	**v_{SW} (m/s)**		**SF (Hz)**		**SL (m)**		**SI (m^2/s)**	
	BT	AT	BT	AT	BT	AT	BT	AT
1.	1.55	1.43	0.74	0.90	1.83	1.69	2.84	2.42
2.	1.23	1.25	0.60	0.79	2.08	1.55	2.56	1.94
3.	1.44	1.44	0.91	0.85	1.59	1.44	2.29	2.07
4.	1.57	1.64	0.47	0.46	3.10	3.24	4.87	5.31
5.	1.29	1.25	0.72	0.79	1.73	1.59	2.23	1.99
6.	1.02	1.00	0.70	0.79	1.54	1.31	1.57	1.31
mean	1.35	1.34	0.69	0.76	1.98	1.80	2.73	2.51
SD	0.21	0.22	0.15	0.16	0.58	0.72	1.13	1.42
T-test	n/s		n/s		n/s		n/s	
Cohen's *d*	0.14		0.71		0.78		0.57	

v_{SW}-swimming velocity; SF-stroke frequency; SL-stroke length; SI-stroke index; BT-before training; AT - after training; n/s - non significant.

Table 2 presents the kinematic parameters gained during the T_{100} test. After the training, only a small improvement in SL and SI in the test was observed. All other variables decreased. The results of the *T* test did not show any significant differences between the changes before and after training in all other measurements.

Table 2. Kinematic values obtained during the T_{100} test

Subject No	**v_S (m/s)**	**v_F (m/s)**	**v_T (m/s)**	**v_{SW} (m/s)**	**SF (Hz)**	**SL (m)**	**SI (m^2/s)**

	BT	AT	BT	AT	BT	AT	BT	AT	BT	AT	BT	AT	BT	AT
1.	2.05	1.94	1.31	1.08	1.55	1.43	1.55	1.46	0.97	0.99	1.61	1.48	2.50	2.16
2.	1.78	1.74	1.00	1.04	1.23	1.25	1.21	1.14	0.96	0.93	1.26	1.22	1.52	1.39
3.	1.97	2.02	1.28	1.25	1.44	1.44	1.35	1.36	1.24	1.16	1.10	1.17	1.49	1.59
4.	2.20	2.27	1.25	1.31	1.57	1.64	1.39	1.47	0.86	0.83	1.63	1.77	2.27	2.60
5.	1.61	1.57	1.16	1.16	1.29	1.25	1.27	1.21	1.09	0.95	1.17	1.27	1.49	1.54
6.	1.53	1.41	0.98	0.86	1.02	1.00	0.96	0.94	0.88	0.78	1.08	1.31	1.04	1.23
mean	1.86	1.83	1.16	1.12	1.35	1.34	1.29	1.26	1.00	0.94	1.31	1.37	1.72	1.75
SD	0.26	0.31	0.14	0.16	0.21	0.22	0.20	0.21	0.14	0.13	0.25	0.22	0.55	0.52
T-test	n/s		n/s		n/s		n/s		n/s		n/s		n/s	
Cohen's *d*	0.35		0.36		0.14		0.45		0.93		0.45		0.13	

v_S-start velocity; v_F-finish velocity; v_T-turn velocity; v_{SW}-swimming velocity; SF-stroke frequency; SL-stroke length; SI-stroke index; BT-before training; AT - after training; n/s - non-significant.

Table 3 present substantial correlations between biomechanical variables. The strongest correlations were observed between ΔSF_{4x25} and ΔSI_{4x25} (0.94) and between Δv_{SW100} and ΔSI_{100} (0.94). Slightly weaker correlations were noticed between ΔSI_{4x25} and Δv_{SW100} (0.89) and between ΔSL_{100} and ΔSI_{100} (0.89). Even weaker correlations occurred between Δv_{SW4x25} and Δv_F (0.83), which means that the average velocity of the whole T_{4x25} test was linked to the finish velocity of the T_{100} test. The same correlation value (0.83) was noticed between Δv_F and Δv_T in the T_{100}.

Table 3. Correlation coefficient between biomechanical variables (Δ)

		ΔT_{4x25}				ΔT_{100}						
		v_{SW} (m/s)	**SF (Hz)**	**SL (m)**	**SI (m^2/s)**	**v_S (m/s)**	**v_F (m/s)**	**v_T (m/s)**	**v_{SW} (m/s)**	**SF (Hz)**	**SL (m)**	**SI (m^2/s)**
ΔT_{4x25}	**v_{SW} (m/s)**	1.00	-0.26	-0.23	0.37	0.70	0.83*	1.00	0.66	0.09	0.31	0.60
	SF (Hz)	-0.26	1.00	-0.54	-0.94*	-0.64	-0.20	-0.26	-0.83*	0.49	-0.43	-0.66
	SL (m)	-0.03	-0.54	1.00	0.71	0.49	0.26	-0.03	0.37	-0.14	0.20	0.31

	SI (m^2/s)	0.37	-0.94*	0.71	1.00	0.70	0.37	0.37	0.89*	-0.43	0.54	0.77
	v_S (m/s)	0.70	-0.64	0.49	0.70	1.00	0.75	0.70	0.64	0.03	0.03	0.41
	v_F (m/s)	0.83*	-0.20	0.26	0.37	0.75	1.00	0.83*	0.49	-0.09	0.26	0.43
	v_T (m/s)	1.00	-0.26	-0.03	0.37	0.70	0.83*	1.00	0.66	0.09	0.31	0.60
	v_{SW} (m/s)	0.66	-0.83*	0.37	0.89	0.64	0.49	0.66	1.00	-0.43	0.72	0.94*
	SF (Hz)	0.09	0.49	-0.14	-0.43	0.03	-0.09	0.09	-0.43	1.00	-0.72	-0.49
	SL (m)	0.31	-0.43	0.20	0.54	0.03	0.26	0.31	0.71	-0.71	1.00	0.89*
ΔT_{100}	**SI (m^2/s)**	0.60	-0.66	0.31	0.77	0.41	0.43	0.60	0.94*	-0.49	0.89*	1.00

v_{SW}-swimming velocity; SF-stroke frequency; SL-stroke length; SI-stroke index; v_S-start velocity; v_F-finish velocity; v_T-turn velocity; ΔT_{4x25}-differences in 4x25m step test; ΔT_{100}-differences in 100m maximum performance test; *-statistically significant ($p<0.05$).

Discussion

Analysis of the results of this study indicates that training which consisted only of specific rescue swimming and towing techniques did not substantially improve kinematic values of freestyle swimming. Moreover, swimming velocities over the distance of 25m and 100m decreased. This is in line with authors who suggest that the efficacy of the in-water swimming resisted training does not have to improve swimming performance and is yet to be confirmed [23]. On the other hand, the findings of Gulbin et al. [19] suggest that lifeguards present higher muscular strength-endurance abilities than surf lifesavers and ironman athletes.

Although there is no scientific evidence that rescue swimming may affect sports swimming performance, we assumed that the specificity of rescue techniques (e.g. higher physiological demand) could increase swimming resistance. The explanation of the decrease in swimming velocities in our study can be due to the fact that the specifics of training and testing techniques were different. In rescue swimming, the head-up front crawl technique is mostly used, whereas in sports swimming the head is kept down. Techniques used by lifeguards require more energy from the body due to the increased frontal drag caused by the towed resistance and as well as keeping head over the water surface while swimming to the drowning person than by swimmers who swim avoiding the shape resistance. Resistance training causes the increase of muscle strength [1], and, theoretically, lifeguard techniques should correspond to resisted swimming techniques. Swimming with evolving resistance is utilized both in lifeguard techniques and in resisted swimming tasks. According to Ruiz-Navarro et al. [31] that kind of training enables assessment of the ability to effectively apply force in the water. For this reason, such training should cause better swimming performance.

The strength could be improved after the training (increased SF at 4x25m), despite the SL and SI reductions. We hypothesized that lifeguard training that includes towing techniques and head-up swimming could be analogous to resisted training in sports swimming. Non-streamlined position, typical of rescue swimming, causes the increase in frontal drag and requires more strength to achieve proper velocity. Our study indicates that 8-week lifeguard training improved SF in the 4x25m test, which may have happened due to resistance increase.

In our study, a strong correlation occurred between ΔSI_{4x25} and Δv_{SW100}. Therefore, we suppose that the decrease in swimming velocity was the effect of the decline in economics of swimming strokes recorded in the 4x25m test, which could have contributed to the decrease in swimming velocity at the 100m distance. A similar relationship was observed between Δv_{SW4x25} and Δv_F for the T_{100} test. Since the decrease in swimming performance at the 25m distance highly correlated with the decrease in velocity at the last 5 meters (v_F) of the T_{100} test, then the improvement in swimming performance at the shorter 25m distance should positively affect the finishing velocity needed at the last meters of the 100m distance race [25].

A strong correlation between Δv_{SW100} and ΔSI_{100} demonstrates an increase in the stroke index value and a decrease in the swimming velocity. The explanation of this fact may be twofold: (i) the participants focused more on technical aspect of the 100m freestyle test than on achieving the maximal velocity, and (ii) the participants were not able to maintain the maximal velocity due to the accumulation of fatigue. The fatigue effect can also explain the slight decrease in v_{SW} in the 4x25m test as well as the strong correlation between ΔSI_{4x25} and Δv_{SW100}. However, the improvement in biomechanical aspects of the 100m freestyle test is displayed in the increase in SL and SI values as well as in the strong correlation between ΔSL_{100} and $\Delta SI_{100.}$ According to the literature, the increase in biomechanical variables (SL, SI) is highly correlated with swimming 100m front crawl performance [20].

During the 8-week lifeguard training, the technical skills of rescue swimming were emphasized more than the development of motor skills. Rescue swimming, diving, and towing were performed with high technical correctness, but with less physiological effort when compared to sports swimming training. As a result, SL and SI increased in 100m freestyle test, whereas SF, v_{SW}, v_F, v_T, and v_S decreased. Increase of SR values in the 4x25m test as well as increase of SL values in the 100m freestyle test may indicate more economic swimming. This assumption is confirmed by the effect size of assessed variables (d=0.71 for SF_{T4x25m} and d=0.45 for SL_{T100m}).

According to our knowledge, there is no literature concerning the kinematics aspects of rescue swimming without equipment. Therefore, it is difficult to confront the obtained results with the scientific achievements existing in this area. Some analyses of rescue action performance were done with lifeguards using fins [2,30] but no study described sports swimming kinematics and physiology in the rescue context. One study presents the comparison of the physiological cost of rescue action without equipment and with various equipment (fins, rescue tube, rescue board) [9]. In that study the swimming part of the rescue action required comparable effort, irrespective of used equipment (except the rescue board), but the swimming time without any devices was the longest one. On the other hand, authors of another study suggest using fins in rescue action, as the time spent on putting them on is fully compensated by the achieved velocity while swimming to the victim and towing him back to the shore [4]. Yet, Reilly et al. recommend sports swimming tests for lifeguards [29]. These tests should be conducted in a swimming pool without fins. The lifeguards are supposed to complete swimming 400-m test below 7.5 minutes and swimming 200-m test below 3.5 minutes. Authors suggest that meeting these time standards would assure the optimal physiological preparation for the whole recue action. Moreover, sprint swimming training and strength training affects positively sports performance in competitive lifesaving [28].

Limitations

We are aware of some limitations of the current study. We suppose that our sample size, not large enough to detect small differences, may have affected the results. On the other hand, the small group of participants followed a similar daily routine, taking part in obligatory lectures and classes as well as in lifeguard training. Therefore, we aimed to examine the participants probably presenting a similar energetic profile. The studied group took part in the standardized candidate lifeguard training, thus the competences acquired by them are comparable with any other lifeguard course. We decided not to distinguish between the results of women and men because their performance level at the beginning of lifeguard training was similar. The mean velocity of the 100m front crawl test did not differentiate between women and men. A bigger group of participants should be involved in the future studies to verify the current results. As a practical implication, we suggest more sports swimming tasks in lifeguard training in order to develop the speed ability.

Conclusions

The study shows that the 8 weeks of training consisting of swimming techniques used by lifeguards did not improve their freestyle swimming performance. There were no positive changes in the essential kinematic markers, which may be caused by different specificity of the movements used by freestyle swimmers and lifeguards. In order to reach better swimming performance by the lifeguards, we suggest using more sprint-specific swimming training. The effects of this sort of training should be beneficial both in real rescue action and in the lifesaving competitions.

Declarations

Ethics approval and consent to participate: Written informed consent was obtained from each participant. The study was conducted according to the guidelines of the Declaration of Helsinki. The study was accepted by the Bioethics Committee at the Regional Medical Chamber in Gdansk (KB-36/21).

Conflicts of Interests: The authors declare that there is no conflict of interests.

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