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The Effect of Fin Use on the Speed of Lifesaving Rescues

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The authors analyzed how using 2 types of fins altered the velocity (v) and fatigue indexes (FI) of lifeguards during mannequin carries. Ten participants performed 3 trials of 25-m mannequin carries at maximal v while barefoot and while wearing flexible and fiber-type fins. A swim-sensor speedometer was used to measure v. Mean v during 2-s periods was computed in the beginning, middle, and end of the event. The slopes of v and FI were computed for the first and second halves of each trial and for the total time required. After it had been established that the data distributions were normal, repeated-measures ANOVAs were calculated for each dependent variable. Results confirmed that mannequin carries while barefoot at each point had significantly slower v than when using either type of fin. Declines in v across the 25 m tended to be greater when the lifeguards did not use fins, and the slopes tended to be smoother when they used flexible fins. Using fiber fins enabled participants to maintain the same v from the beginning to the end of each trial. No significant differences were found across conditions for the v slopes and FI.

Key Words: swimming, velocimetry, fatigue, mannequin carries

The rescue of a drowning person should be accomplished as quickly and safely as possible. This is true not only for lifeguards (lifesaving rescue professionals) in real lifesaving situations but also for lifesavers (competitive lifesaving rescue athletes) in simulated lifesaving situations. The literature on lifesaving includes some physiological and biomechanical contributions (Daniel & Klauck, 1992; Juntunen, Louhevaara, & Keskinen, 2001a, 2001b) including economy and efficiency assessment (Prieto, Egocheaga, González, Montoliu, & Alameda, 2001; Zamparo, Pendergast, Termin, & Minetti, 2002, 2006) and movement analysis of propulsive (Colman, Persyn, Zhu, & Ungerechts, 1996) and carrying techniques (Hay, McIntyre, & Wilson, 1975; Juntunen, Leskinen, Louhevaara, & Keskinen, 2006). The use of such equipment as fins is essential in many rescue situations, because fins increase displacement velocity (v) both while approaching the victim and during victim transportation (Abraldes, 2004, 2006).

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Nowadays we have at our disposal a large variety of fin types, with different designs and characteristics. Each fin type presents its own advantages, considering the activity for which each has been designed. These same advantages might be transformed into disadvantages if the fin type is not the most appropriate for a particular aquatic activity. To our knowledge, until now no one has identified the most specific or best fin type for lifesaving activities, despite some works that have studied the use of monofins or other types of fins.

Rejman (1999) described the dynamic criteria involved in single-fin technique evaluation. Subsequently, his research team developed a method for the kinematic and dynamic evaluation of single-fin movements (Rejman, Colman, & Persyn, 2003). The same group has studied the intracyclic v fluctuation during swimming with monofins (Rejman, 2006). The monofins, however, are not very interesting or useful for lifesaving purposes, because they do not facilitate rescues or necessary direct interactions with the victim, even though they might produce greater swimming v.

Zamparo et al. (2002, 2006) studied economy and efficiency of aquatic displacement with fins. Their 2002 article established the higher efficiency and economy of fin propulsion compared with barefoot kicking. Their 2006 study compared barefoot leg and foot displacements with those assisted not only between different types of normal fins (small flexible fins [also known as zoomers] and large stiff fins) but also in comparison with monofins. These authors found differences in swimming economy and efficiency between barefoot leg kicking and all the assisted conditions (fins of different stiffness and monofins), as well as between normal fins and monofins. It is interesting that no differences were found between small flexible "zoomer" fins and large stiff fins.

Despite these published studies, the remaining literature on fin use does not provide other relevant results to allow us to conclude what the best fin type is for lifesaving activities. Only a few nonrefereed works have been published, and those mostly only assessed time performances. This suggests the need for our current study.

Paredes, Losada, and Gesteiro (1996) compared the use of stiff fins with barefoot kicking during a simulated rescue performed in a swimming pool with victims located 12.5–25 m away from the starting wall. Those authors found significant differences in favor of using fins, even after considering the time spent putting them on before swimming.

In 2003, members of the aquatic research team of the National Institute of Physical Education of Galicia (Spain) compared the use of two fin types (short and large, both stiff) in an open-water competition (Villar et al., 2003). These authors found better performances for lifeguards when they used larger stiff fins.

The first author (Abraldes, 2004) did not find significant differences in crawl swimming performance between wearing fins (donning time included) of three different types (short and stiff, long and flexible, and long and stiff) and barefoot kicking for distances of 25 m. This was attributed to the time spent putting on the fins. Differences became evident, however, for 25-m carrying efforts, irrespective of the fin types. In this condition, the time spent to put on the fins was not considered. No differences were found between fin types.

In another article the first author (Abraldes, 2005) compared swimming barefoot with swimming wearing four types of fins (short and stiff, long and flexible, long and stiff, and fiber long fins) in different 25-m maximal tests: crawl swimming, snorkel underwater swimming, and mannequin-carry swimming. In all tests he found differences in performance between barefoot and fin swimming, irrespective of the fin type considered. The use of stiff long fins, compared with all the other fin types, led to better performances by university students ($p < .05$), but only for the mannequin-carry event. In contrast, no differences were observed between different fin types in crawl swimming and underwater snorkel efforts.

The first author (Abraldes, 2006) returned to the comparison of fins (short and stiff, long and flexible, long and stiff, and fiber long fins) with barefoot swimming, but this time over 50-m distances, considering also the 25-m lap time (i.e., halfway point). Comparisons were conducted for two different tasks: crawl swimming (including time required to put on fins) and mannequin carry (not considering the donning time). As with his previous results in 2005, the crawl-swimming performance time was not significantly different wearing and not wearing fins because of the time it took to put them on. For the mannequin-carry test (no donning time included) fin wearing enabled faster times than barefoot swimming (both for the 25-m lap and for the final 50-m time). Swimming wearing the long stiff fins was faster than while wearing the flexible long fins, which produced the slowest times of all fin conditions.

In a more recent study, the same author (Abraldes, 2007) investigated the same topic over distances of 25 m, but now with elite lifesavers of both sexes. He found, in contrast to his previous conclusions, that long stiff fins and the fiber fins produced similar results, although there was a tendency for a slight superiority in times for the fiber type, and both long stiff and fiber fins produced faster times than the other two types of fins for both men and women. These most recent results were attributed to the higher capacity of the elite lifeguards to use the apparent hydrodynamic properties of the fiber-type fins. In this most recent study, the short stiff fins were once again the fins that produced the longest times and thus slowest velocities.

Abraldes and Avilés (2005) found significant differences in 50-m-crawl performance time in favor of efforts performed by barefoot swimmers compared with fin-wearing (flexible large and stiff large fins) swimmers, including the time taken to put on the fins. Otherwise, these differences were not significant for 100-m swimming considering the same effort conditions. In this longer event, the higher swimming speed obtained with fins compensated fully for the time spent putting them on. Therefore, it might be concluded that wearing fins is recommended for rescues requiring a distance of at least 100 m of total swimming. If one considers the advantages of fin use associated with transporting the victim back to shore or poolside, the minimum recommended distance, in fact, is probably shorter.

In all of the previously mentioned studies, the proficiency of each fin type was assessed only through performance times. None of the works was able to show the velocimetric behavior of the swimmers during total effort time. Cyclic v-variation studies have been done mainly in research on competitive swimming, using speedometers, swim meters, or swim sensors as evaluation methods (Costill, Lee, & D'Aquisto, 1987; Craig & Pendergast, 1979; Lima et al., 2006; Pedersen & Kjendlie, 2006). Light-trace photography (e.g., Vilas-Boas, 1993) and videograms (e.g., Klauck & Daniel, 1990) also have been used.

The purpose of this article was to compare differences in the fatigue effect between swimming with barefoot kicking and swimming while using two types of fins (long flexible and long fiber fins). In the current case, we used a distance of 25 m and participants towed a mannequin while swimming as fast as possible. We measured the fatigue effect based on instantaneous *v* records, considering the beginning, middle, and end of the 25-m distance. We also measured fatigue using mean *v*, slope of the *v*(*t*) decline (*v* decay), and fatigue index in the first and second halves of the time spent in each 25 m and during the entire distance.

Method

The participants were 10 certified male lifeguards with a mean age, weight, height, and body-mass index of 27.44 ± 10.79 years, 76.22 ± 11.92 kg (167.7 ± 26.2 lb), 179.33 ± 7.45 cm (70.60 ± 2.93 in.), and 23.56 ± 2.14 kg/m^2, respectively. All the tests were performed on a short-course indoor (25-m) swimming pool with a mean depth of 2 m. Water temperature was 27.5 °C (81.5 °F).

The protocol consisted of 3 × 25-m maximal swim trials carrying a mannequin (Swedish model; Figure 1) with a minimum recovery time of 30 min between trials (*SE* for *v* was 0.04). The mannequin was made of a closed PITET plastic type and had a total height of 1 m. This mannequin was totally filled with water in order to have a total mass on land of 80 kg.

Of the three trials, one was performed barefoot (i.e., without fins) and one of two other with flexible fins (Gabbiano Francis) and the other with fiber fins (Special Films), model Sebak Saber 140 Hard M. The order of the trials was randomized for each lifeguard. Flexible fins (Figure 2) were 45 cm in length and 20 cm in width. The shoe part of the fin was closed, with a small opening near the phalanges of the toes. Fiber fins (Figure 3) were rectangular on their tail and were 65 cm long and 22 cm wide. Their rigidity was created both by two spines that fixed the shoe part to the tail of the fin and by one lateral spine that reinforced the edge of the fin.

Figure 1 — Mannequin.

Figure 2 — Flexible fins.

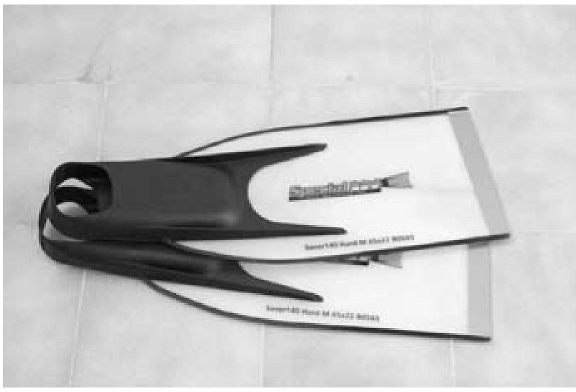


Figure 3 — Fiber fins.

The shoe part of the fin was only open at the heel and was fixed to the lifeguard's foot by an adjustable strap.

Each 25-m trial started in the water with the lifeguards in contact with the end wall of the pool and holding the mannequin in a carrying position. They started with their faces out of the water. They used their arms to help the start. The carry position was lateral-dorsal (Figure 4).

A cable speedometer (Figure 5) called the Swim Sensor (Lima et al., 2006) was connected to the mannequin in order to measure instantaneous v during the total 25-m-trial duration. The Swim Sensor uses an incremental sensor with 500 points resolution per revolution. A brake engine allows the full system inertia to be insignificant, keeping the line always taut.

During the data analysis, the first 2 s of the v curves of each swimmer were removed. This allowed us to minimize the effect of the initial impulse resulting from the start, when the participant pushed off from the wall, and to primarily concentrate the analysis on the leg kicking actions with fins and barefoot. The mean velocities were calculated over 2-s periods (Figure 6) on three phases of the total v curve: mean v corresponding to the initial 2–4 s of the total effort time, mean v corresponding to the half of total effort time, and mean v corresponding to the last 2 s of total effort time. Total effort time was defined as the time duration

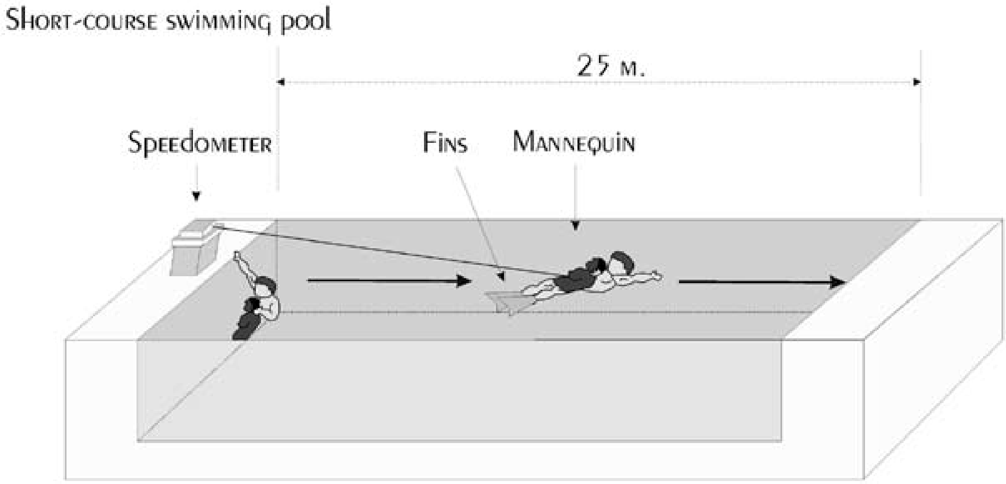


Figure 4 — Illustration of the 25-m event, including the materials used.

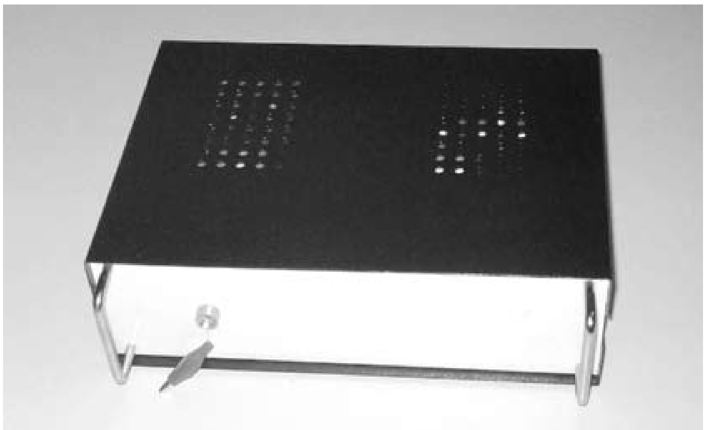


Figure 5 — Speedometer.

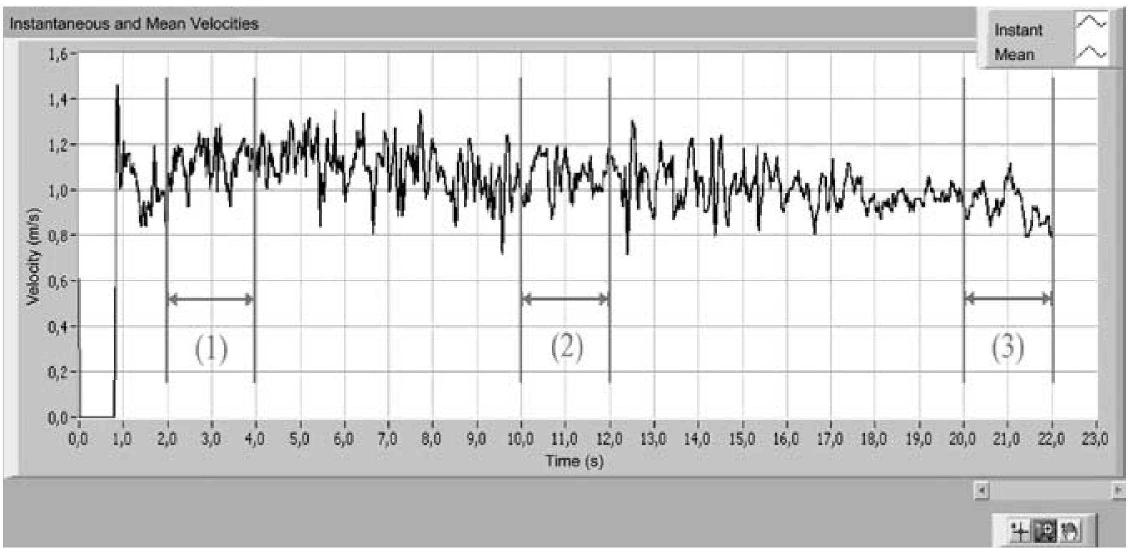


Figure 6 — Instantaneous velocity curve, $v(t)$, obtained using the velocimetric system and time intervals used to calculate mean initial (1), half (2), and final (3) velocities.

between the first and the last v peaks of the $v(t)$ curve, after the initial impulse had been removed.

The mean slopes corresponding to the individual regression lines plotted between initial and half mean velocities, between half and final mean velocities, and between initial and final mean velocities were calculated. The mean fatigue indices (FI) for the first and second half and the total effort time were calculated according to the following formula:

$$FI = (\bar{X}iv - \bar{X}fv).\bar{X}iv^{-1} \quad (1)$$

where $\bar{X}iv$ is the mean v computed during 2 s in the beginning of each part of the test in analysis (the total test distance and each half were considered) and $\bar{X}fv$ is the mean v computed during 2 s at the end of the respective distance.

Mean v, slope of the $v(t)$ decline (v decay), and FI in the first and second halves of each 25 m, and in the total test, were used as fatigue criteria to study the fatigue induced during the total effort time, and during each half part, by the three conditions (i.e., barefoot or with one of the two types of fin).

Statistical treatment included comparison of mean values using factorial repeated-measures ANOVAs. The normality (Shapiro–Wilk test), sphericity (Mauchly test), and homoscedasticity (verified in accordance with sphericity result) of all distributions were verified before means were compared. A t test for repeated measures was used to compare v_{mean}, slopes, and FIs corresponding with the first and second halves of the total effort time. Statistical significance was established at 95%.

Results

In Table 1, the mean v values measured during 2 s in the beginning, half, and end of the 25-m test for the three test conditions are presented. It can be observed that in mannequin-carry efforts performed with barefoot kicking, the mean v values were always lower than with fins, irrespective of the fin type ($p \leq .05$). These results coincide with those of Paredes et al. (1996) and the first author (Abraldes, 2004, 2005, 2006, 2007) in very similar studies. Similar results also were found by

Table 1 Mean Velocity (m/s) for Initial, Half, and Final 2-s Phases of the Total Carry Effort While Barefoot and With Flexible and Fiber Fins, *M* ± *SD*

Period	Barefoot	Flexible fins	Fiber fins
Initial	0.67 ± 0.06†	1.03 ± 0.10†*	1.09 ± 0.12*
Half	0.66 ± 0.07†	0.98 ± 0.20*	1.07 ± 0.19*
Final	0.57 ± 0.10	0.93 ± 0.12*	1.01 ± 0.12*

Note. Observed power: .087.

†Significant difference ($p \leq .05$) from final velocity. *Significant difference ($p \leq .05$) from barefoot.

Zamparo et al. (2006), who studied economy and efficiency of swimming performed with and without different fin types.

Significant differences in mean *v* were not found between carries performed with the two different fin types, showing that, apparently, for our lifeguard participants, fiber fins did not provide a more significant swimming aid than flexible fins, as expected from the results of the first author (Abraldes, 2005) related with chronometric performances.

Also in Table 1, the reader can observe the comparison between the three test conditions for the change of the mean *v* results during the 25-m test (with the first 2 s of test removed). The mean *v* slowed from the start of the carry effort until the end, when the swimming was performed with barefoot kicking ($p \leq .05$). The use of flexible fins helped the lifeguards maintain *v* between the middle and the end of the effort, despite the fact that the value was lower than the one with fiber fins. The *v* of the total 25-m carrying effort seemed to be easily maintained when fiber fins were used, because any differences between the mean *v* correspond to the initial, middle, and final stages. According to these findings, fiber fins seem to be better suited for lifeguards than flexible fins or swimming barefoot.

Table 2 presents the results obtained for swimming while barefoot kicking and contrasted with the two trials swimming while using the two fin types. Readers should note that the measures are of the total time duration for the 25-m carry effort, as well as the corresponding mean velocities, the mean velocities of each half, and the *v*-decline mean slopes corresponding to the first and second halves of the trial (Figure 7[a]) and to the total test (Figure 7[b]), as well as the respective FIs. Please note that the *v*s were calculated minus the first 2 s of the test, as explained earlier.

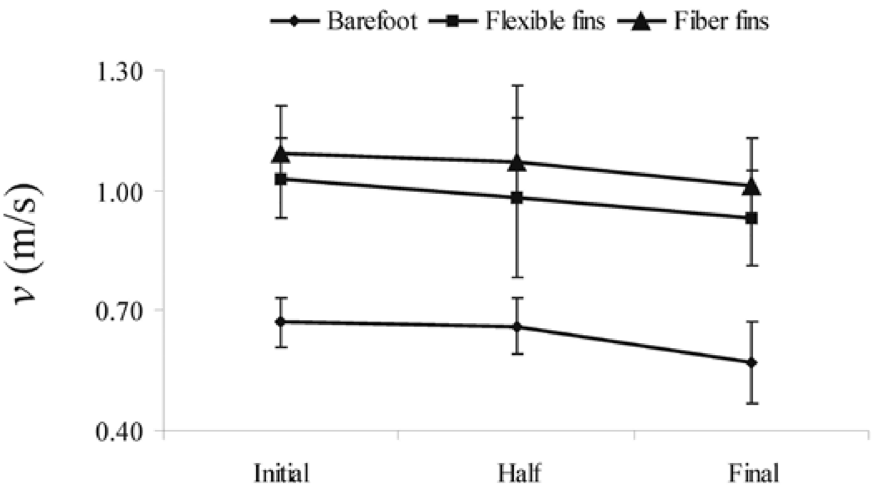
Table 2 Mean Duration of the Mannequin-Carry Effort (*t*); Mean Velocities (v_{mean}, m/s) per Half Part (1, 2) and for the Total (T) Test, Slopes of *v*(*t*) Decline (m/s²), and Fatigue Indexes (FI, %), *M* ± *SD*

	Barefoot	Flexible fins	Fiber fins
t	34.85 ± 4.94	22.68 ± 2.54*	21.51 ± 2.41*
v_{mean} 1	0.67 ± 0.07†	1.04 ± 0.12†*	1.10 ± 0.14*
v_{mean} 2	0.63 ± 0.09	0.98 ± 0.12*	1.06 ± 0.15*
v_{mean} T	0.65 ± 0.08	1.01 ± 0.12*	1.08 ± 0.14*
Slope 1	–0.02 ± 0.07†	–0.05 ± 0.14	–0.02 ± 0.13
Slope 2	–0.09 ± 0.04	–0.05 ± 0.15	–0.07 ± 0.14
Slope T	–0.11 ± 0.10	–0.09 ± 0.08	–0.09 ± 0.13
FI 1	2.62 ± 11.09†	5.03 ± 14.14	1.97 ± 12.02
FI 2	14.05 ± 7.11	2.12 ± 18.34	4.75 ± 12.67
FI T	15.90 ± 14.61	9.06 ± 7.72	7.39 ± 11.17

Note. Observed power: .293 (v_{mean} × Fin Type); .087 (Slope × Fin Type); .34 (FI × Fin Type).

*Significantly different ($p \leq .05$) from barefoot. †Significantly different ($p \leq .05$) between the first and second measures per test condition.

(a)



(b)

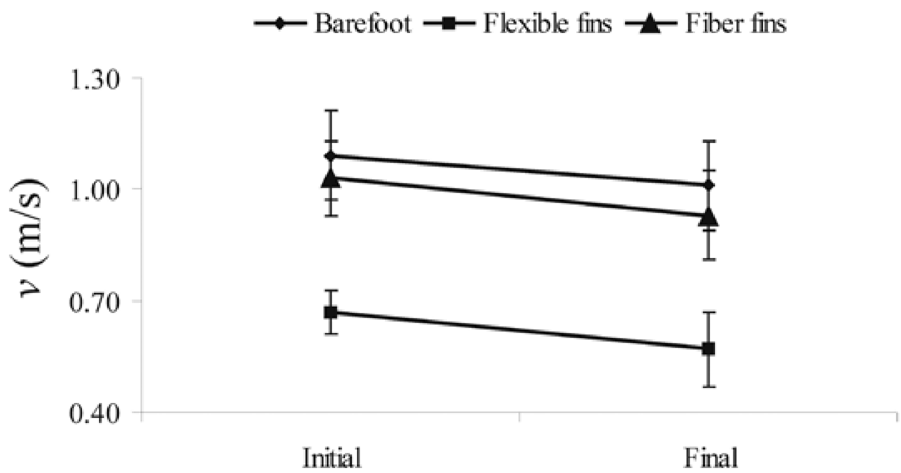


Figure 7 — Mean slopes of velocity, v (m/s), drop observed for the (a) first and second half and for the (b) total carry effort performed by lifeguards while barefoot and with flexible and fiber fins.

Discussion

It was noticeable, but not at all surprising, that swimming while kicking with fins was significantly faster than swimming while barefoot kicking. There was no difference in v between swimming trials using the two fin types. The results obtained for carrying mean velocities (v_{mean}/T) conformed to the previous findings obtained with overall time taken, despite the exclusion of the data of the first 2 s of the 25-m test. This means that using fins is preferable to kicking barefoot, but doubts persist on the best fin *type*.

Differences between the partial *v* values also were significant. Apparently, mean *v* drops from the first to the second phase of the carry effort for each of the three conditions. For fiber fins the differences found between mean *v*s of the first and second halves of the effort were not significant. These matched the results already observed for the comparison of the v_{mean} of each of the three 2-s phases studied during the total carry effort and reinforced the idea that fiber fins allow better maintenance of *v* during the entire carry effort. In this sense, it seems that the size of the fins is more important than their rigidity for short carrying sprints in lifesaving rescues. Lifeguards should possibly choose a bigger rather than a flexible fin.

Analyses of the slopes and FI in each test condition showed significant differences just between the first and second halves of the event for the barefoot kicking condition. No differences between the first and second parts of the event were observed between the two fin types. This suggests that using fins helps lifeguards delay the fatigue effects observed for barefoot kicking.

No significant differences in slope, or in FI, were found between the three studied conditions (kicking barefoot vs. fins); these results seem to be contradictory to those previously presented. What is really essential, however, is not a better slope or FI but the higher carrying *v* allowed by a specific fin type. Complementarily, the lack of significant differences might be explained by the small number and high intervariability of the participants tested, suggesting the need for further research based on more homogeneous samples.

According to the results, we can state that using fins, irrespective of their type, seems to be advantageous for lifeguards because they produce higher swim *v* than barefoot swimming and they allow a steadier *v* during a short sprint bout, with less pronounced absolute *v* decays between the first and second halves of a 25-m distance. This better maintenance of *v* decay was the only variable that allowed us to suggest that fiber fins might be more suitable for use by lifeguards.

The results obtained for slopes and FI as mechanical fatigue indicators did not allow us to discriminate between the two fin types studied. Authors such as Zamparo et al. (2006) have used other parameters including economy and efficiency to characterize barefoot swimming and swimming using different types of fins. They could not conclude anything about a possibly better fin type. Previous results by the first author (Abraldes, 2004, 2005) also pointed in the same direction, although others have concluded otherwise. Apparently, differences often depend on sample characteristics (e.g., skill level, number of participants) and fin types.

Conclusions

Higher and significant mean *v*s were observed during mannequin carry when fins were used, but no effect was associated with fin type. The absolute *v* drop during the carry effort was higher when fins were not used, which suggests a higher rate of fatigue, despite the fact that the relative decays in *v* were not different across conditions. Therefore, the results pointed toward the convenience and advantage of lifeguards' using fins in rescue situations. From the results of this study, the only advantage in favor of one of the fin types studied suggested that the fiber-type fins can provide a steadier *v* during a short sprint. This outcome was shown by the difference noted between the test initial and final *v* values obtained for the flexible fins.

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