TETHERED AND NONTETHERED CRAWL SWIMMING

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Tethered Swimming has been used to train competitive swimmers in completely and partially tethered forms. Tethered swimming has also been used for research purposes because it is easier to monitor physiological and biomechanical responses when subjects are not moving (4)(6)(8)(9). When completely tethered, swimmers remain in one spot while they stroke against the water resistance while being held back by a rope or cable. On the other hand partially tethered swimmers move ahead while being restricted by some device like surgical tubing, mini-gyms, exer-genies, and rope and pulley devices with weights attached at one end. The concern has been that tethered swimming might have a detrimental effect on stroke mechanics. If this is true, then tethered swimming might produce negative training effects and produce questionable validity as a testing and research procedure.

PURPOSE OF THE STUDY

The purpose of this study was to compare the stroke mechanics of crawl swimmers while swimming normally (nontethered) and partially tethered.

METHODS AND PROCEDURES

All of the subjects for this study were participants in the distance freestyle events at the 1983 U.S.S. Indoor Senior National Swimming Championships (Table 1.). At the time of testing they were in the midst of intensive training for the 1983 U.S.S. Outdoor Senior National Swimming Championships. They were in the second week of attendance at a Senior Development Camp at the United States Olympic Training Center in Colorado Springs, Colorado.

The subjects were filmed with two Canon Scopic 16 mm movie cameras in plastic underwater housings. Each subject was filmed from the side and front simultaneously at 63 pictures per second. An orthogonal reference measure consisting of two 3.0 foot poles was placed in the feild of veiw. A large black "clapper" device was operated by an assistant who closed the jaws of the device when the swimmers' right hand entered the water in the feild of veiw, to synchronize frames from the two cameras.

Table 1
SUBJECT PROFILES

Name	Sex	Age	Height	Weight	500 yd. Freestyle Time
C.H.	Male	17	6′2"	175	4:30.19
C.G.	Female	17	5′5"	118	4:54.00
K.N.	Female	18	5′7"	125	4:57.00
J.K.	Female	17	5′9"	140	4:56.30
L.S.	Female	16	5′7"	124	4:59.00
K.n.	Female	17	5′9"	137	5:00.20
J.E.	Male	19	6′2"	164	4:28.00
S.B.	Male	17	6′1"	150	4:32.50
D.F.	Male	18	6′0"	169	4:31.00

FIGURE 1

SWIMMING STROKE PATTERN SIDE VIEW

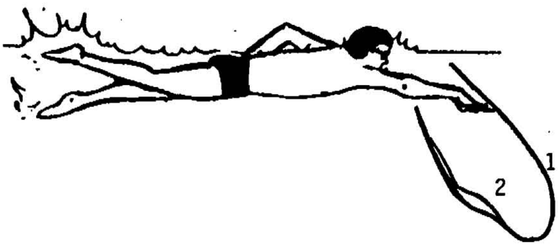


FIGURE 2

STROKE PATTERN FRONT VIEW

The control mechanism from a Biokinetic Swim Apparatus was adapted to partially tether the swimmer. The free end of the 1/8 inch nylon rope from the resistance device was attached to a belt around the swimmers' waist.

Each subject was filmed while swimming four 30.0 foot freestyle sprints. The subjects swam the first sprint nontethered. They were then given one or two practice trials while partially tethered. Following the practice trials and a short rest they swam one partially tethered sprint with the speed selector set at 0, for the greatest possible tethereing effect. The third trial was free while the fourth was tethered.

FIGURE 3

J.E. SWIMMING STROKE PATTERN SIDE VIEW

UNCORRECTED

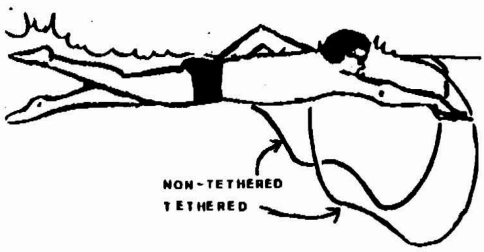


FIGURE 4

J.E. SWIMMING STROKE PATTERN SIDE VIEW

CORRECTED

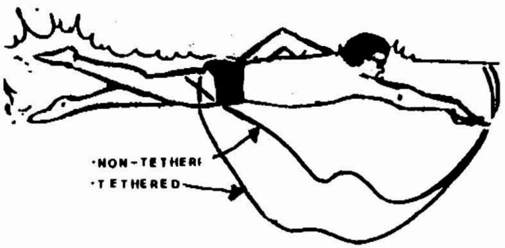
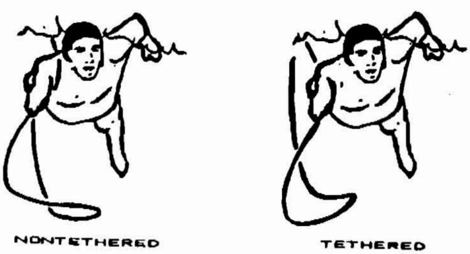


FIGURE 5

S.B. SWIMMING STROKE PATTERN FRONT VIEW



The films were analyzed with an Eiki Motion Analyzer and a Numonics Digitizer, Model 1224. For each subject, one complete underwater stroke of the right arm was digitized during the nontethered and tethered trials. The positions of six segmental endpoints and a reference measure were determined in each frame. The endpoints were:

1. tip of the middle finger
2. base of the first finger
3. base of the little finger
4. center of the wrist
5. center of the elbow
6. acromion process of the shoulder

DATA ANALYSES

Each swimmer's nontethered and tethered trials were compared by using one underwater stroke of the right arm for the following:

1. Stroke patterns and arm angles.
2. Total time for one underwater stroke.
3. Angular displacement and angular velocity of the hand.
4. Time spent in each phase of the arm stroke.
5. Backward velocity and displacement of the hand relative to the shoulder.
6. Downward velocity and displacement of the hand.
7. Upward velocity of the hand.
8. Inward and outward displacements and velocities of the hand.
9. Elbow and wrist flexion during each phase of the armstroke.
10. Body inclination.

A chi-square test, two-way classification with Yates' correction for continuity, was used to compare differences for significance at the .05 level. The right armstroke was partitioned into the following segments for purposes of analysis:

1. The Entry (E).
2. The Downsweep (D). It begins with the catch and continues until the hand begins moving inward.
3. The Insweep (I). Begins with the fist inward motion of the ahnd and ends when the hand begins to sweep outward.
4. The Upsweep (U). Begins when the hand starts to move outward from underneath the body and ends when the other hand releases pressure on the water near the swimmer's thigh.
5. The Release (R).

RESULTS AND DISCUSSOIN

The results of an earlier, unpublished, study indicated that the stroke patterns of competitive swimmers were remarkably similar during repeated armstrokes (1). This is illustrated by the stroke patterns in Figures 1 and 2. These stroke patterns and the patterns in Figures 3,4, and 5 were drawn from computer tracings of the coordinates for the swimmers' right middle finger. These stroke patterns illustrate some of the differences identified between the subjects in the present study. The stroke patterns in figure 3 were drawn from a side veiw. They depict the movements of the hand relative to the reference measure that was used. The corrected side veiw stroke patterns are shown in Figure 4. They are typical of the differences that were observed between subjects' nontethered and tethered trials.

The stroke patterns in Figure 5, from the front veiws illustrate another important change that occured for most of the subjects during the tethered trials. There also was a tendency to move the hand out and in, less during the entry, downsweep, and insweep portions of the underwater armstroke. All of the subjects exhibited differences from their usual stroke patterns during their tethered trials.

When tethered, the subjects:

1. took longer to complete the armstroke.
2. did not spend the same amounts of time in each phase of the armstroke.
3. tended to move their hands through a smaller arc.
4. had resultant hand velocities markedly different from their nontethered swimming trials.
5. had greater downward inclinations from head to feet and more lateram movements of their hips and legs.

The times listed in Table 2 confirm that every swimmer studied in this portion of the analysis required a longer time to complete one underwater stroke of the right arm when tethered . The average time was .95 seconds when swimming nontethered and 1.04 seconds tethered,- significant at the .01 level. The subjects tended to move their right hand through a smaller arc at a significantly (.05) slower average speed, when tethered. Table 3 shows that 4 of 5 subjects had lesser angular displacements when swimming tethered and that all five had lower average angular velocities. The group's mean difference in angular velocity was 20 d/sec. Figure 6 shows time spent in each phase of the stroke. On the average, the tethered subjects spent .09 seconds less in the downsweep and .07 seconds longer in the upsweep. Subject J.E.'s resultant hand velocities during his nontethered and tethered swimming trials were compared in Figure 7. This comparison was representative for all swimmers.

Subjects kicked considerably deeper during the tethered trials and the sideward movement of the hips was more noticeable. They drove their hands downward more rapidly with their wrists flexed to a greater extent. They also made their catch at a deeper point before the left arm had reached the usual release point at the thigh.

Tethered swimmers seemed to be applying force with the arm in front before releasing pressure with the arm behind. This overlap of propulsive

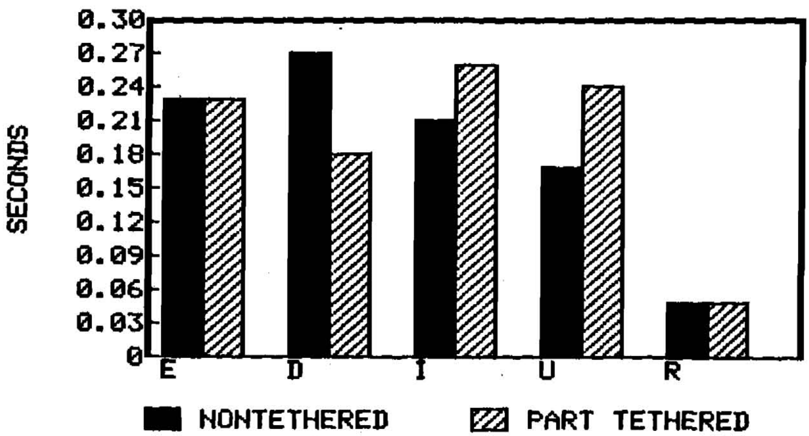
Table 2
TIME FOR ONE UNDERWATER STROKE OF THE RIGHT ARM WHEN SWIMMING

Subject	Nontethered	Tethered
C.H.	1.06 secs	1.18 secs.
C.G.	.88 secs	.94 secs.
K.N.	.88 secs.	1.00 secs.
J.K.	.94 secs.	1.00 secs.
L.S.	1.06 secs.	1.12 secs.
k.n.	1.04 secs.	1.12 secs.
J.E.	.82 secs.	1.02 secs.
S.B.	.88 secs.	.94 secs.
Mean =	.95 secs.	1.04 secs.
S.D. =	.10 secs.	.09 secs.

Chi-Square = 12.25
df = 2 P < .01

FIGURE 6

AVERAGE TIME IN STROKE PHASES



NON SIG. $\chi^2 = 4.79$ NON SIG. $\chi^2 = 12.30$ NON SIG.

DF=2 DF=2

P<.10 P<.01

NON SIG.

Table 4
AVERAGE DOWNWARD HAND VELOCITIES FROM ENTRY TO CATCH WHEN SWIMMING

	Average Velocities	
Subject	Nontethered	Tethered
C.H.	3.79 fps	4.27 fps
C.G.	5.67 fps	9.92 fps
K.N.	4.50 fps	5.65 fps
J.K.	4.20 fps	7.40 fps
L.S.	5.24 fps	5.69 fps
K.n.	7.67 fps	7.67 fps
J.E.	4.37 fps	3.39 fps
S.B.	4.32 fps	9.52 fps
Mean =	5.06 fps	6.28 fps
s.d. =	1.31 fps	2.22 fps

Chi-Square = 5.27
df = 2 P < .10 Non significant

FIGURE 7

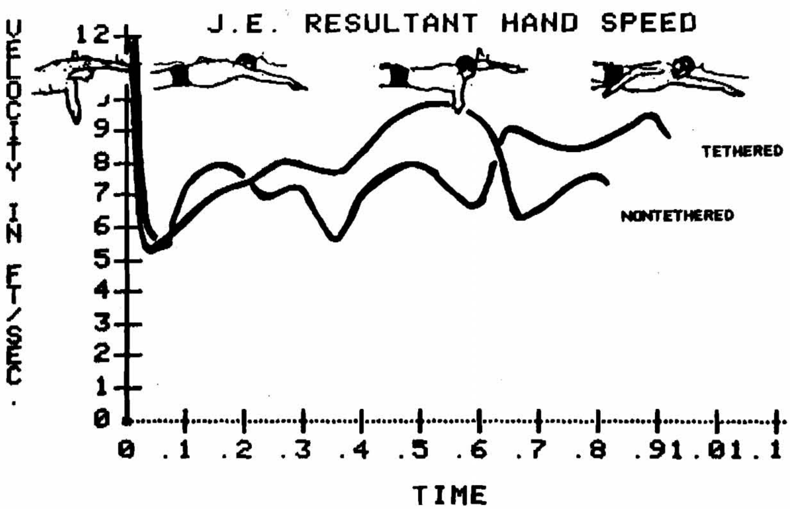
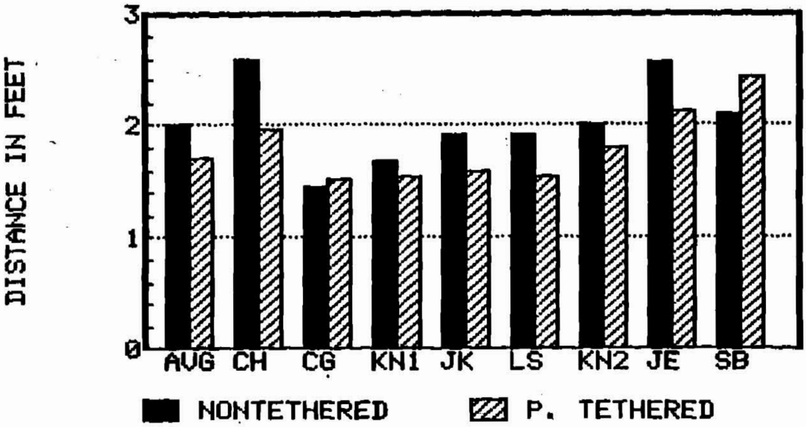


FIGURE 8

DOWNWARD HAND DISP. WHEN SWIMMING



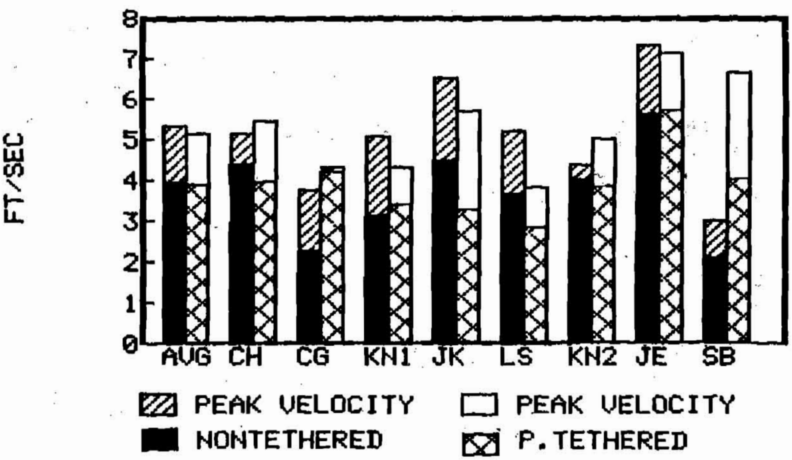
X^2 =5.84

DF=2 P<.10 NON SIGNIFICANT

FIGURE 9

AVERAGE AND PEAK VALUES FOR DOWNWARD

HAND VELOCITY WHEN SWIMMING



AVG. VEL.

X^2 =.80

DF=2

NON SIG.

PEAK VEL.

X^2 =2.27

DF=2

NON SIG.

FIGURE 10

J.E. SWIMMING

UP-DOWN HAND VELOCITY

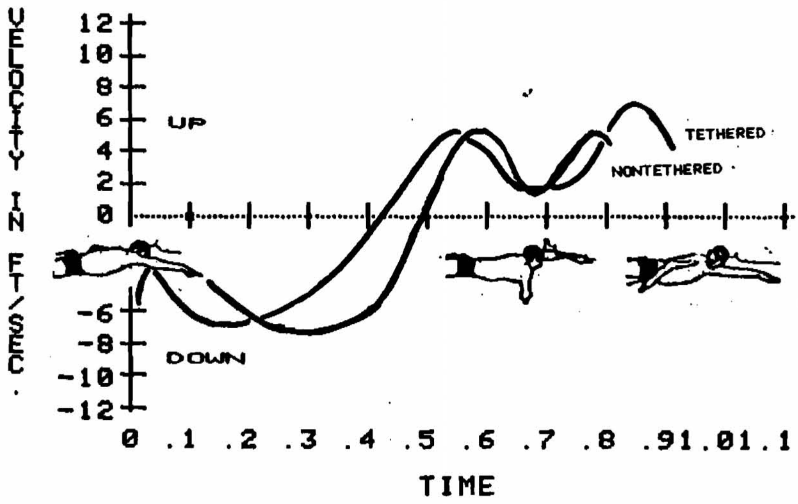
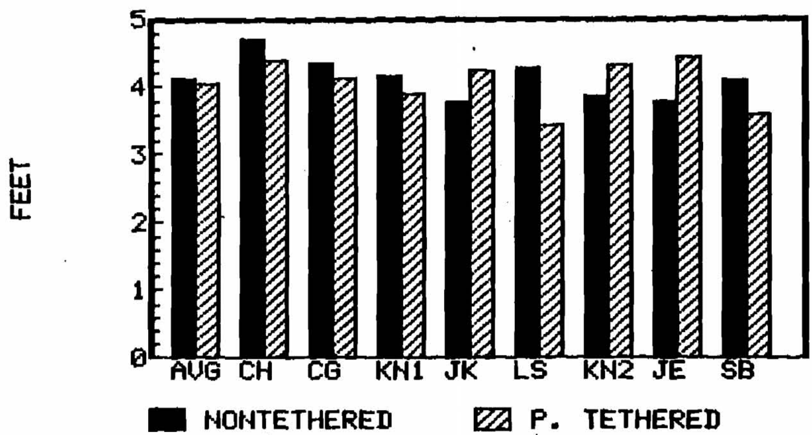


FIGURE 11

BACKWARD DISPLACEMENT OF THE RIGHT HAND

WHEN SWIMMING CORRECTED



$X'^2 = 3.02$

DF=2

NON SIGNIFICANT

FIGURE 12

AVERAGE AND PEAK VALUES FOR BACKWARD HAND VELOCITY WHEN SWIMMING

CORRECTED

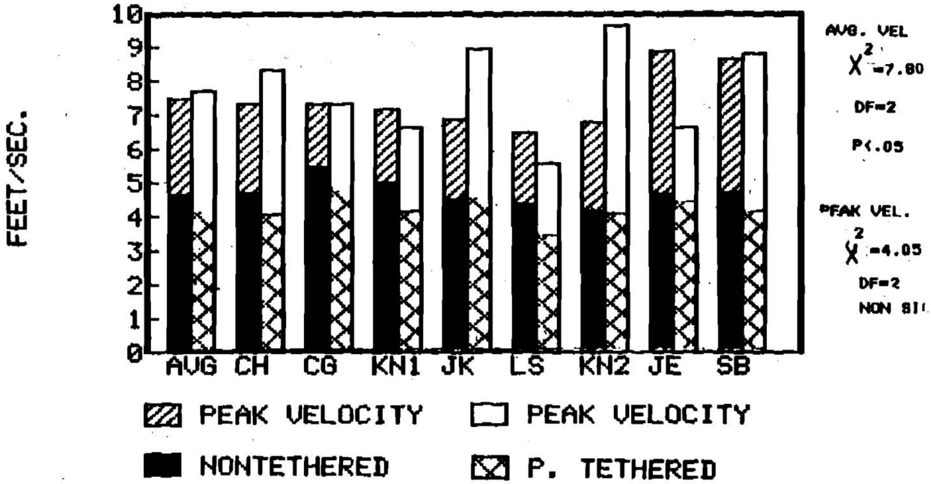


FIGURE 13

K.N.SWIMMING

FORWARD-BACKWARD HAND VELOCITY

CORRECTED

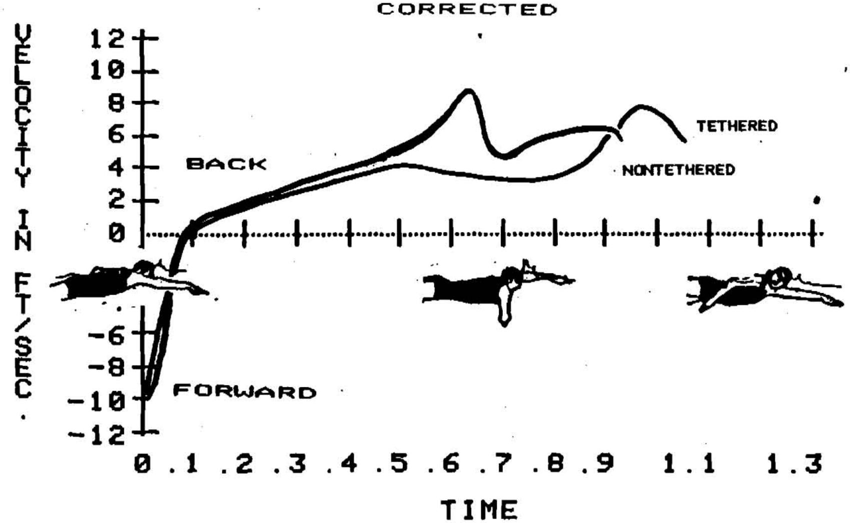


FIGURE 14

K.N SWIMMING
IN-OUT HAND VELOCITY

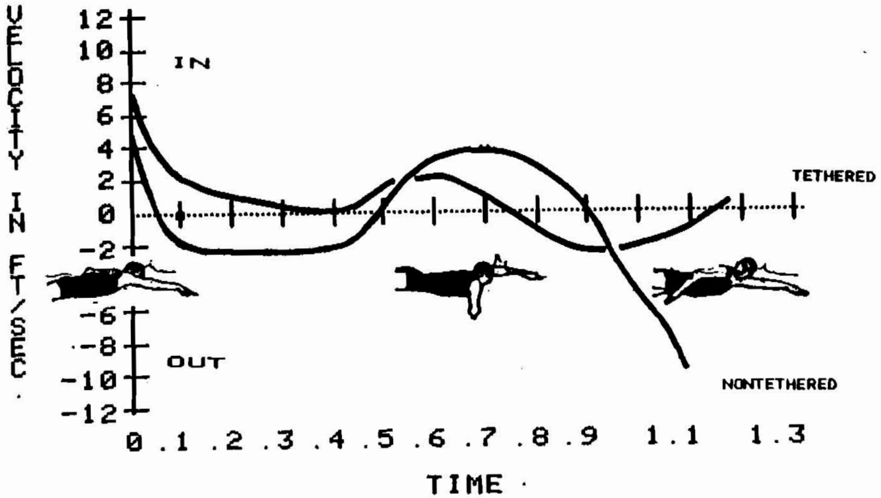
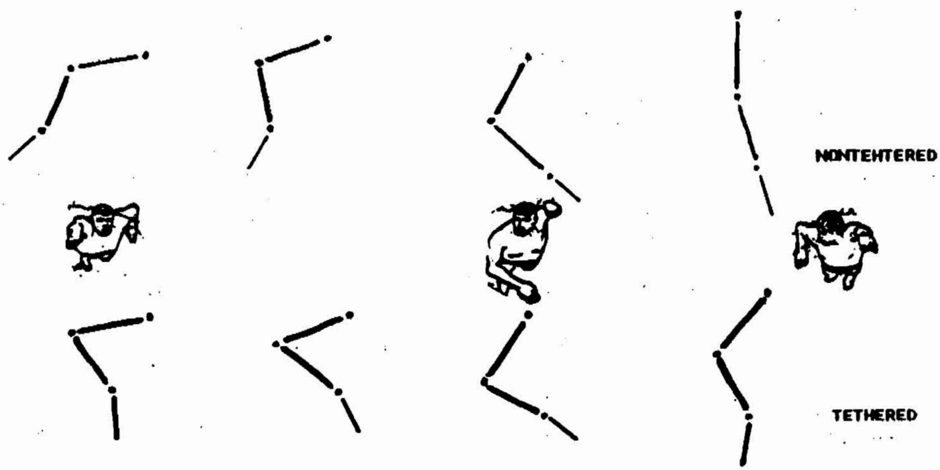


FIGURE 15

K.N. JOINT ANGLES – SWIMMING



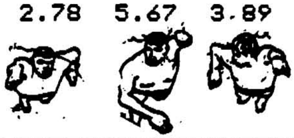
force may have been an attempt to overcome the additional resistance.

All tethered subjects exhibited less outward hand displacement during the downsweep. The figures for both average and peak lateral hand velocities are listed in Table 9. The peak velocities for tethered swimmers showed slower maximum outward hand speeds during the outsweep, and slower maximum inward hand speeds during the insweep.

TABLE 9

AVERAGE AND PEAK VALUES FOR IN AND OUT HAND VELOCITIES DURING THE PROPULSIVE PHASE OF THE RIGHT ARMSTROKE

Subject	Trial	Swimming: Average Vel. Out	In	Out	Peak Vel. Out	In	Out
C.H.	NT	1.85	3.38	4.08	3.50	5.17	5.33
	PT	2.20	2.14	2.50	2.95	2.60	2.60
K.N.	NT	2.31	2.70	3.10	2.50	3.95	4.55
	PT	.03	1.82	2.09	.05	2.35	2.71
J.E.	NT	2.55	5.16	4.67	4.00	8.17	5.67
	PT	2.42	5.16	3.83	3.67	7.17	7.33
S.B.	NT	2.57	6.46	6.92	5.33	10.77	7.17
	PT	2.78	5.67	3.89	5.17	7.33	6.00



Subject	Trial	Average Vel. Out	In	Out	Peak Vel. Out	In	Out
Mean =	NT	2.32	4.43	4.69	3.83	7.02	5.60
	PT	1.86	3.37	3.04	2.96	4.86	4.66
Pulling							
C.H.	NT	2.47	2.80	3.00	4.17	4.50	3.50
	PT	2.17	3.12	2.73	3.03	3.87	4.65
K.n.	NT	-.94	2.14	2.92	-1.13	3.19	3.12
	PT	-.72	2.35	2.26	-.92	3.25	2.70
J.E.	NT	4.25	3.90	2.02	4.33	7.00	3.16
	PT	2.03	4.32	4.33	2.83	6.00	4.33
S.B.	NT	2.83	3.70	1.61	4.67	5.83	2.67
	PT	2.04	3.24	3.33	2.67	6.00	3.33
D.F.	NT	2.63	3.44	2.72	3.50	4.33	4.50
	PT	1.67	1.62	2.94	2.83	2.17	3.83
Mean =	NT	2.25	3.19	2.45	3.10	4.97	3.39
	PT	1.43	2.93	3.12	2.08	4.25	3.76

Values are expressed in ft/sec.

CONCLUSION

Following are the ways in which the subjects in this study appeared to change their stroke mechanics when tethered:

1. They required a significantly longer time to complete one underwater armstroke. The average difference in time was .09 seconds.
2. There was a tendency for the subjects to move the right hand through a shorter arc.
3. The average angular velocities of the subjects' hands were slower.
4. Less time was spent in the downsweep phase of the armstroke.
5. The subjects required a longer time to complete the upsweep phase of the armstroke.
6. The subjects appeared to kick deeper.
7. There was a tendency for the subjects to stab their hands downward into the water with greater speed.
8. The subjects made their catch at a deeper point.
9. The subjects flexed their wrists to a greater extent from the entry and through the propulsive phases.
10. There was a tendency for the subjects to sweep their hands downward less.
11. The subjects swept their hands upward slower. The difference was .86 ft./sec.
12. The average backward velocities of the subjects' hands were slower. The difference was .47 ft/sec.
13. The subjects used less lateral motion during the down and in portions of their armstrokes
14. There was greater elbow flexion.

The potentially detrimental adjustments when tethered makes this method questionable where training and testing of swimmers is concerned. Through repeated tethered training, swimmers performances would probably deteriorate. Also, biomechanical research could be misleading if tethered procedures were used to gather data on swimmers.

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