THE EFFECT OF RESISTED AND ASSISTED FREESTYLE SWIMMING ON STROKE MECHANICS

Benjamin K. **Williams**[1], Peter Sinclair', and Margy **Galloway**
[1]**Sydney** University, Sydney, NSW, Australia
New South Wales Institute of Sport, Sydney, NSW, Australia

A three-dimensional analysis was conducted on the stroke mechanics of four female junior elite swimmers. They swam one 50 m freestyle trial for each of three conditions: resisted, assisted, and free swimming. Stroke length (SL), stroke rate (SR), maximum hand depth (rnax hand depth), body roll, and average forward velocity (avg fwd v) were evaluated. There was a significant difference ($p < 0.05$) found between conditions among SL. SR, rnax hand depth, and avg fwd v. During the resist trial, SL, SR, max hand depth, and avg fwd v all decreased. During the assist trial, SL, SR, avg fwd v increased, and rnax hand depth decreased. The changes due to resisted swimming suggest an undesirable affect on stroke mechanics. While some changes seen in assisted swimming may appear beneficial, both methods of tethered training remain questionable.

KEY **WORDS:** swimming, resisted, assisted, stroke mechanics, 3-dimensional analysis

INTRODUCTION: With swimming races being decided by only fractions of a second, many different training methods have been devised to improve performance. Two such methods commonly used by coaches and swimmers today are sprint-assisted and sprint-resisted training. Sprint-resisted training aims at improving the strength of a swimmer by increasing the resistance a swimmer works against. While sprint-assisted training aims at increasing stroke rate without decreasing stroke length, or improving the swimmers ability to apply a force over a greater distance without decreasing stroke rate (Maglischo et al.,1985).

There is however, only a limited amount of research that has looked specifically at the effects of these tethered training methods on freestyle stroke mechanics. One of the few (Takahashi 8 Wilson, 1997) found that resisted swimming significantly decreased stroke length (SL), stroke rate (SR), and velocity (V), while not changing stroke hand depth or stroke width. However, Takahashi and Wilson did not draw any conclusions as to whether resisted swimming would be beneficial or detrimental to training. Swimming paddles, a form of resisted training, were found to produce movement patterns and movement speeds unlike those of natural freestyle swimming (Payton 8 Lauder, 1995). They concluded that these changes might therefore compromise the efficacy of this form of training.

Maglischo et al. (1984) demonstrated that freestyle stroke mechanics changed when partially tethered, resulting in a shorter, slower underwater arm stroke. They then questioned the impact of these adjustments and their possible negative effect on performance. In a further study Maglischo et al. (1985) cast doubt on the efficacy of both assisted and resisted training on butterfly stroke mechanics, as the swimmers tended to change their stroke patterns and appear less efficient. However, they stated that resisted swimming may not have long term consequences on stroke mechanics during free swimming if it was used only as a small part of the training session.

Even less research has been published on the effect of assisted swimming training and its effect on swimming performance. A training program consisting of swimming with swim fins, showed a greater improvement in mean time than that of a control group (Rowe, et al., 1977). However, there was no analysis done on the stroke mechanics, and the authors warned about the possibility of the loss of stroke efficiency from the continued use of swim fins.

It is clear that there are mixed conclusions from these studies, and there is a need for further research in this area. It is the aim of this paper to further the understanding of the effects that both assisted and resisted swimming have on freestyle stroke mechanics. This was achieved by conducting a three-dimensional analysis on the stroking techniques of swimmers under those various conditions.

METHODS: Stroking characteristics of four swimmers were analysed and compared while varying the mode of swimming from normal, resisted, and assisted swimming.
Subjects. The subjects were four female junior elite swimmers from the New South Wales Institute of Sport 'Beyond 2000 squad'. The subjects were aged 17.0 ± 2.3 years with heights and weights of 1.67 ± 0.06 m and 57.5 ± 4.2 kg. Their personal best times for 50 m freestyle averaged 27.6 ± 1.2 s. The testing took place at a training camp in the middle of the season.
Testing Equipment. Two underwater video cameras filmed the swimmers simultaneously at 50 Hz. A calibration frame was floated out into the testing space (25 m from the end of a 50 m pool) via polystyrene floats on each of the 6 verticals. The effective calibration space was 4 m in the swimming direction, 1 m deep, and 1.65 m wide. Each camera saw 19 markers that were digitized separately.
The first underwater camera was placed on the pool floor 1.5 m below the surface, 2.6 m from the cube and angled upwards at 30". The second underwater camera was attached to one of the pool ladders 1.1m below the surface such that both cameras formed an angle of 60" between optical axes (positioned 30" either side of the direction of motion).
A Power Reel (Total Performance Inc.) was used for both the resisted and assisted trials. It was a motorised reel with a cable running out that attached to the swimmer via a velcro belt around the waist. The belt was worn so that the cable ran from the swimmers stomach out in the swimming direction (but ran low enough as to not effect the stroke) during the assisted trial, while being worn so the cable ran from the swimmers back behind them during the resisted trial. In assisted mode, the Power Reel pulled all swimmers at a velocity equivalent to a 27.5 s (± 0.4 s) lap time. The device controlled the cable force in order to achieve this velocity. In resisted mode, the Power Reel applied a constant force of 17.5 N to retard the swimmer. For this condition, therefore, velocities differed between subjects.
Procedure. The subjects were filmed swimming three 50 m sprints randomized by condition: resisted, assisted, and normal freestyle. Subjects had a familiarization session where they swam a number of resisted and assisted trials the day before testing. All subjects were instructed to swim with a normal stroke pattern for each condition and give maximal effort for each trial. A lap time and stroke count were recorded at the end of each trial.
Data Analysis. Using 14 body landmarks, one complete stroke cycle, from right hand entry to right hand entry, was digitized via video analysis software (Ariel Performance Analysis Software). The two camera views were combined to give a three-dimensional model of the underwater part of the arm stroke.
The following variables were used for the purpose of analysis:

- stroke length (SL) – difference in horizontal displacement (of the hip) during one stroke,
- stroke rate (SR) – number of strokes per minute,
- maximum hand depth (max hand depth) – maximum vertical displacement of the hand during the stroke,
- maximum hand velocity (max hand v) – relative to a fixed point in the pool,
- body roll of shoulder and hip angles relative to the horizontal (max hip angle, rnin hip angle, max shoulder angle, min shoulder angle),
- average forward velocity throughout the stroke (avg fwd v) – relative to a fixed point in the pool,
- average lap times.

Statistical Procedures. One way analysis of variance with repeated measures was used with three levels corresponding to free swimming, resisted and assisted tethered swimming. All the variables were tested for sphericity before analysis and the 0.05 alpha level adopted to test significance.

RESULTS: Mean, standard deviation, and significance are given for all the variables under the different conditions in Table 1. Significance is given at $p < 0.05$. Avg fwd v has been reported during the single stroke analysed for each trial. For the free, resisted and assisted conditions, these velocities resulted in respective mean lap times of 30.8 ± 1.0 s, 38.0 ± 1.0 s, and 27.5 ± 0.4 s.

Table **1** Mean, Standard Deviation, and Significance Values for Variables with Respect to the Different Trials

Variable	Free mean (± SD)	Resisted mean (± SD)	Assisted mean (± SD)	significance' (p value)
***SL** (m)	1.94 (± 0.06)	[illegible]	2.00 (± 0.06)	0.001
***SR** (strokeslrnin)	47.6 (± 3.4)	44.7 (± 1.8)	51.1 (± 0.8)	0.016
*Max hand depth (m)	0.44 (± 0.03)	0.41 (i 0.05)	0.37 (± 0.06)	0.016
Max hand v **(m/s)**	3.92 (± 0.72)	3.38 (f 0.77)	3.13 (± 0.47)	0.350
Max shoulder angle (deg)	22.0 (± 3.5)	22.4 (± 5.1)	23.9 (± 4.0)	0.767
Min shoulder angle (deg)	-28.1 (± [illegible]1.2)	-29.3 (± 9.9)	-30.0 (f 1.82)	0.962
Max hip angle (deg)	34.2 (± 3.5)	37.2 (± 11.4)	30.3 (± 3.4)	0.366
Min hip angle (deg)	-29.2 (f12.0)	-32.6 (i 18.1)	-20.7 (± 3.8)	0.328
***Avg** fwd v (mls)	1.55 (± 0.10)	1.24 (± 0.06)	1.73 (± 0.09)	0.001

* $p < 0.05$.

There was a significant difference among SL, SR, max hand depth, and avg fwd v between the trials. No significant differences were found between the trials for max hand v, max or min shoulder angle, and max or min hip angle. The difference in SL and SR can be seen more clearly in Figure 1.

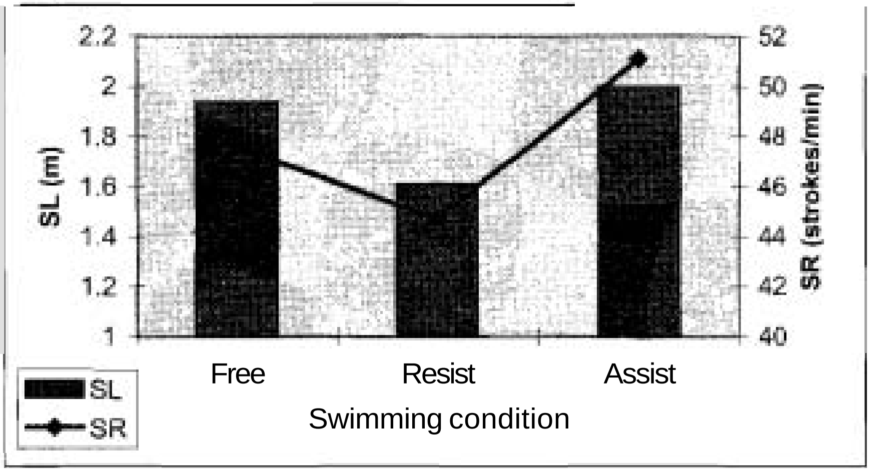

Figure **1** -The Difference in **SL** and SR for Each Condition.

DISCUSSION: The purpose of this paper was to add to the current knowledge of the effects of resisted and assisted swimming on freestyle stroke mechanics. The results indicate that there are a number of significant changes in the mechanics of the freestyle stroke during resisted and assisted swimming.

The resisted swimming caused a significant decrease in stroke length, stroke rate, and maximum hand depth. This suggests a negative effect on stroke mechanics, as optimally, swimmers are encouraged to increase stroke length while maintaining stroke rate (Maglischo et al., 1985). The present results are consistent with the findings of Takahashi & Wilson (1997) in that resisted swimming produced a decrease in both stroke rate and stroke length with no significant change in stroke depth when compared to free swimming. For the assisted condition however, stroke depth was significantly lesser than for free swimming.

While an increase in stroke rate, as seen in the assisted trial, may be a desirable effect, the modified stroke pattern (decrease in maximum hand depth), and increase in stroke rate still makes this form of training questionable. It is possible that these swimmers, although stroking at a higher rate, did not maintain their effective propulsion. As hand depth has been directly correlated with hydrostatic lift (Chatard et al., 1990), the decrease seen in maximum hand depth during assisted swimming, therefore, could be construed as being detrimental to performance. It might appear that the swimmers had let themselves be pulled along by the tether rather than trying to maintain their normal stroke patterns.

There were no significant changes found in the maximum hand velocity for either the resisted or assisted trials. This suggests that, during the assisted swimming, the subjects may have let the tether pull them along while their underwater hand speed relative to the body in fact slowed from that seen in the free trial. Analyse of the resisted trial suggests that the hand has had to increase its velocity relative to the body in maintaining the velocity relative to the water, thereby altering the speed of movement, decreasing the stroke rate and the stroke length (Table 1).

There was no significant change in body roll between the different trials, in either shoulder or hip angles. Since some studies have shown that body roll and upper limb motion is equal to the medial-lateral motions shown in the hand paths of the stroke (Liu, Hay, & Andrews, 1991), it would appear that resisted or assisted swimming has no effect on this motion of the stroke.

CONCLUSION: There appears to be a large number of undesirable changes made to the stroke mechanics during resisted swimming, which makes this form of training questionable. Assisted swimming does appear to have a beneficial effect on stroke rate, but comes with other adjustments to the stroke that may be detrimental. Perhaps, with proper instruction (by a coach) on how to stroke under this condition, this form of training may be seen as beneficial.

Further analysis with an increased number of subjects is progressing to investigate the hydrodynamic forces produced while swimming with a resisted or assisted tether. It is anticipated that this analysis will provide greater insight into how the kinematic changes affect swimming propulsion. To more thoroughly investigate these training techniques, it is recommended that longitudinal studies be performed to determine whether assisted or resisted training can improve performance to a greater extent than by free swimming.

REFERENCES:

Chatard, J.C., Collomp, C., Maglischo, E., & Maglischo, C. (1990). Swimming skill and stroking characteristics of front crawl swimmers. International *Journal* of Sports Medicine, **11** (2), 156-161.

Liu, Q., Hay, J.G., & Andrews, J.G. (1991). Interactions between body roll, hand relative motion, and handpath during the pull phase in freestyle swimming. In American Society of Biomechanics: Proceedings for the 15th Annual Meeting (pp. 120-121). Tempe, Arizona: University of Arizona.

Maglischo, C.W., Maglischo, E.W., Sharp, R.L., Zier, D.J., & Katz, A. (1984). Tethered and nontethered crawl swimming. In J. Terauds (Ed.), Sports Biomechanics (pp. 163-176). Del Mar, California: Research Center for Sports.

Maglischo, E.W., Maglischo, C.W., Zier, D.J., & Santos, T.R. (1985). The effect of sprint-assisted and sprint-resisted swimming on stroke mechanics. Journal of Swimming Research, **1** (2), 27-33.

Payton, C.J., & Lauder, M.A. (1995). The influence of hand paddles on the kinematics of front crawl swimming. *Journal* of Human Movement Studies, **28,** 175-192.

Rowe, E.L., Maglischo, E.W., & Lytle, D.E. (1977). The use of swim fins for development of sprint swimming speed. Swimming Technique, **14,** 73-76.

Takahashi, T., & Wilson, B.D. (1997, August 25-29). The effects of tethered swimming on freestyle stroke techniques. Paper presented at the XVIth International Society of Biomechanics, University of Tokyo.