THE EFFECT OF *POLO* DRILL SWIMMING ON FREESTYLE KINEMATICS: A PILOT STUDY

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The purpose of this pilot study was to compare temporal performance variables and kinematic parameters during the entry and catch phase of freestyle and *Polo* drill swimming. Five well-trained freestyle swimmers performed 400 m of *Polo* drill and freestyle through a 8.91 m^3 calibrated space recorded by eight synchronised cameras. Differences were assessed by a paired t-test and effect size (d) calculations for each variable. Significant differences occurred with respect to stroke length, stroke rate, stroke duration, entry and catch duration, hip velocity and vertical displacement and trunk inclination. The finger displacement and velocity, elbow angle and shoulder displacement were not significantly different through the entry and catch phase of the stroke. This work identified that while notable differences exist between freestyle and Polo drill swimming, there is an indication that some key parameters may be similar.

KEYWORDS: front crawl, technique, 3-Dimensional video analysis

INTRODUCTION: Training observations and coach interviews have illustrated that swimming coaches typically “break the stroke down” or decompose the stroke in order to simplify and facilitate skill learning (Junggren, Elbæk, & Stambulova, 2018). Such practice tasks are typically referred to as drills and prescribed within part-whole training approaches (Whelan, Kenny, & Harrison, 2016). However, empirical evidence suggests that drills may inadvertently compromise the movement behaviour they were designed to promote (Reid, Whiteside, & Elliott, 2010). Given that task decomposition is a common training approach observed in Australian swimming, the investigation of the ‘head-up freestyle’ drill provides an excellent vehicle in which to explore this issue further. ‘Head-up freestyle’, also termed *Polo* drill, resembles a water polo swimmer and is prescribed with one intent to promote the entry and catch phase of the stroke (Lucero, 2015). The entry and catch phase is understood to be an important phase of the stroke as it establishes the foundation for efficient and fast freestyle (Seifert, Chollet, & Bardy, 2004). The aim of this study was to compare the *Polo* drill with freestyle swimming to determine how temporal performance variables and kinematic parameters might compare in the entry and catch phase of the stroke.

METHODS: ***Participants:*** Five well-trained freestyle swimmers (3 male, 2 female, age 20.20 ± 2.71 years) volunteered to participate in this study. Nineteen black skin markers (36 mm in diameter) were affixed to each participant to enable the identification of anatomical landmarks during digitisation. Marker locations included the vertex of head; shoulder, elbow, wrist, hip, knee, ankle and metaphalangeal joints; and the end of the middle fingers and big toes.
Experimental Setup: The experimental protocol took place in a four-lane 25 m level deck, indoor pool. An 8.91 m^3 calibration frame, containing seventy black circular markers (36 mm in diameter), was used to calibrate the swimming volume and was positioned in the water 0.5 m (*z*-axis) above water and 1.0 m (*z*-axis) underwater creating an above and below water calibration area (Figure 2). The frame was videoed simultaneously by eight stationary SwimPro® cameras (four above and four under the water surface) recording at 30 Hz. Overall

RMS reconstruction and maximal errors were 7.8 mm and 14.5 mm (above water), respectively; and 8.6 mm and 16.4 mm (below water), respectively.

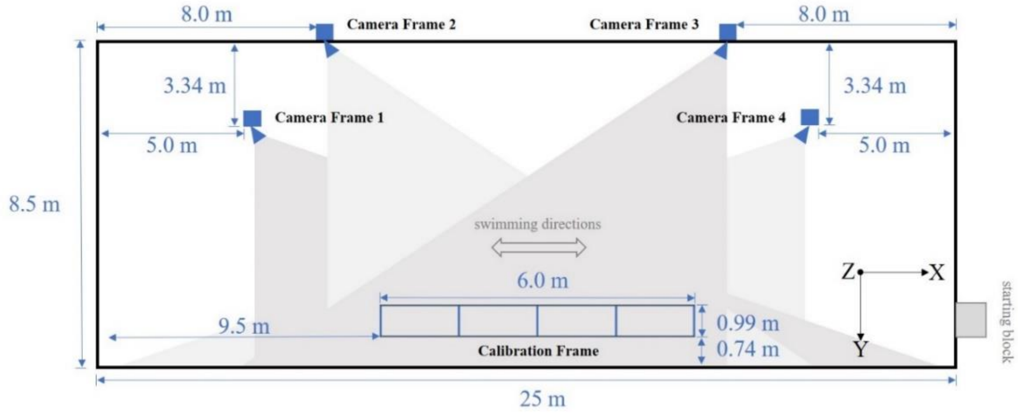

Figure 2: Experimental setup, calibration frame position and SwimPro® cameras' field of view

Experimental Procedures: Following the warm-up, participants performed 400 m of both freestyle and the *Polo* drill. Specifically, participants alternated between swimming 2 x 25 m of *Polo* drill before moving onto 2 x 25 m of freestyle.
Data Analysis: One stroke cycle, on both the left and right side of the participant performing the *Polo* drill and freestyle, was selected for analysis and the body landmarks were digitised using the custom-built MATLAB toolbox, Cinalysis. The DLT method was used to perform the 3D reconstruction and smoothed using a second-order Butterworth filter. Cut-off frequencies where chosen based on residual analysis and ranged between 3 and 8 Hz.
The performance variables calculated included the following: stroke length (SL), stroke rate (SR), swimming velocity (SV) and total stroke duration (SC). Further, the stroke was divided into the entry and catch, pull, push and recovery phases. The finger velocity, elbow angle, mean trunk inclination, shoulder vertical displacement and hip vertical displacement during the entry and catch phase of the stroke were calculated as detailed by Gourgoulis et al. (2014) and McCabe, Psycharakis, and Sanders (2011).
Statistical Analysis: To compare differences between freestyle and *Polo* drill swimming, a paired t-test was used. Due to the small sample size, the Shapiro-Wilk test was used to verify that the data was normally distributed and the level of significance was set as $p < 0.05$. The effect size was calculated using Cohen's d to describe the magnitude of difference.

RESULTS: Significant differences in SL, SR, SC and percentage of time spent within the entry and catch phase were observed between freestyle and *Polo* drill swimming (Table 1). Polo drill swimming displayed a higher SR and shorter SL and SC. Further, the entry and catch phase showed a decreased relative stroke duration.
Hip vertical displacement and horizontal velocity and trunk inclination differed significantly between freestyle and *Polo* drill swimming (Table 2). Hip vertical displacement and trunk inclination increased during *Polo* drill swimming where hip horizontal velocity decreased.

Table 1: Temporal performance variables and relative duration of stroke phases

	Freestyle	Polo Drill	Difference	t-Value	P	d
Stroke length (m)	2.75 ± 0.43	2.20 ± 0.29	0.55 ± 0.34	5.14*	<0.001	0.78
Stroke rate (Hz)	0.46 ± 0.04	0.56 ± 0.06	-0.1 ± 0.07	-4.79*	<0.001	2.17
Swimming velocity (m/s)	1.24 ± 0.15	1.21 ±0.11	0.03 ± 0.16	0.66	0.53	0.19
Stroke duration (s)	2.21 ± 0.16	1.82 ± 0.19	0.39 ± 0.24	5.16*	<0.001	2.38
Entry and catch (% of SC)	46.82 ± 4.71	34.97 ± 8.74	11.85 ± 6.91	5.42*	<0.001	1.87
Pull (% of SC)	12.64 ± 4.22	16.04 ± 3.86	-3.4 ± 5.74	-1.88	0.09	0.79
Push (% of SC)	17.52 ± 3.56	19.16 ± 3.59	-1.63 ± 6.39	-0.81	0.44	0.49
Recovery (% of SC)	23.02 ± 4.91	29.84 ± 6.74	-6.81 ± 6.15	-3.50*	0.01	1.22

Note: *Significant difference

Table 2: Kinematic parameters in the entry and catch phase of the stroke

	Freestyle	Polo Drill	Difference	t-Value	P	d
Elbow angle (°)	129 ± 42	143 ± 39	-14 ± 50	-0.86	0.41	0.31
Finger vertical displacement (m)	-0.12 ± 0.07	-0.14 ± 0.04	0.03 ± 0.07	1.14	0.28	0.37
Finger horizontal velocity (m/s)	1.47 ± 0.43	1.29 ± 0.51	0.18 ±0.32	1.77	0.11	0.17
Shoulder vertical displacement (m)	-0.04 ± 0.03	-0.02 ± 0.04	-0.02 ± 0.04	-1.13	0.29	0.41
Hip vertical displacement (m)	-0.28 ± 0.04	-0.33 ± 0.05	0.05 ± 0.03	4.86*	<0.001	0.41
Hip horizontal velocity (m/s)	1.26 ± 0.12	1.22 ± 0.12	0.04 ± 0.06	2.30*	0.05	0.12
Trunk inclination (°)	19.43 ± 3.97	23.25 ± 5.56	-3.82 ± 4.42	-2.73*	0.02	0.43

Note: *Significant difference

DISCUSSION: This study aimed to identify differences between freestyle and *Polo* drill swimming by investigating temporal performance variables and kinematic parameters in the entry and catch phase of the stroke. The main findings revealed that SL decreased significantly during *Polo* drill swimming. This decrease coincides with previous reports suggesting that swimming freestyle with the head above water decreases swimming velocity and subsequently decreases SL and increases SR (Zamparo & Falco, 2010). Further, *Polo* drill swimming caused a significant increase in the trunk inclination. Previous studies have suggested that an increased trunk inclination increases the frontal surface area of the swimmer and subsequently disrupts the streamline body position (Naemi, Easson, & Sanders, 2010).

Polo drill swimming did not significantly alter SV despite the decrease in SL and increase in SR. The lack of significance in this study might be attributed to the small size of samples (d < 0.2) and maximal error represented in the derived velocities. Nevertheless, the significant decrease in SC and SL could suggest that SV might have a tendency to decreases during *Polo* drill swimming.

The relative duration of the entry and catch phases decreased signification during *Polo* drill swimming but with no significant difference to the other stroke phases. Interestingly, given that the *Polo* drill can be prescribed to promote the entry and catch phase of the stroke, it was hypothesised that this phase would either increase or not alter significantly. This suggests that it is possible that the *Polo* drill may benefit skill learning in other stroke phases.

The elbow flexion angle presented no significant differences between freestyle and *Polo* drill swimming. However, looking at the elbow angle on an individual basis showed that three of the participants displayed a greater elbow flexion during *Polo* swimming. Studies have shown that a greater elbow flexion helps promote a greater propulsive surface on the upper-limbs and helps better position the hand to avoid slippage through the water during the entry and catch and pull phase of the stroke (Seifert, Toussaint, Alberty, Schnitzler, & Chollet, 2010). Polo drill swimming may promote this greater elbow flexion through the entry and catch phase.

The finger vertical displacement and horizontal velocity showed no significant differences between freestyle and *Polo* drill swimming. Several investigators believe that a deeper pull pattern could be beneficial to the generation of propulsion through the water and hand velocity is an important determinant of propulsion (McCabe et al., 2011). Therefore, the findings from this pilot investigation suggest that *Polo* drill swimming does not significantly influence the effectiveness of the arm action.

The shoulder vertical displacement showed no significant difference between freestyle and *Polo* drill swimming despite the increased trunk inclination. Sanders and Psycharakis (2009) reported that while hip roll is influenced by the kicking action and swimming speed, the shoulder roll is not greatly influenced. Although shoulder roll was not assessed in the current study, the similar shoulder vertical displacement between freestyle and Polo drill swimming might be at odds with previous findings.

The hip vertical displacement and the trunk inclination increased significantly between freestyle and the *Polo* drill. These findings might be considered a consequence of the *Polo* drill; however coaches may want to consider the increased hydrodynamic resistance and greater mechanical power required in this position compared to freestyle (de Jesus et al., 2012). The leg kick is believed to help maintain a low-resistant horizontal alignment (Gourgoulis et al., 2014).

Therefore, a strong kick action might avoid excessive inclined positions during *Polo* drill swimming.
Significant differences were observed in the horizontal hip velocity. The decrease during Polo drill swimming may be attributed to a decreased leg kick or SV (Gourgoulis et al., 2014). However, as the leg kick was not assessed in the current study, this parameter should be assessed in a future study in order to draw accurate conclusions about the effect of leg kick on *Polo* drill swimming. Further, future research directions are to investigate the entire underwater stroke phases using a larger same size before more general conclusions can be drawn.

CONCLUSION: This study has provided a comparison of freestyle and *Polo* drill swimming. Despite the obvious differences, the aim of this study was to investigate the specific stroke phase and kinematic variables the *Polo* drill aims to improve in the freestyle stroke. Temporal differences were observed in SL, SR, SC and the relative duration of the entry and catch phase. The elbow angle, finger vertical displacement and velocity and shoulder vertical displacement were not altered significantly when *Polo* drill swimming despite the increase in trunk inclination and hip vertical displacement. The results indicate that *Polo* drill swimming does affect particular aspects of the entry and catch phase of the freestyle stroke. Future work should investigate the transfer of skills from *Polo* drill swimming to freestyle. If negative transfer effects arise or no improvement is visible in the skill itself coaches should be cautious with the prescription of that particular drill.

REFERENCES
de Jesus, K., Figueiredo, P., de Jesus, K., Pereira, F., Vilas-Boas, J. P., Machado, L., & Fernandes, R. J. (2012). Kinematic analysis of three water polo front crawl styles. *Journal of Sports Sciences, 30*(7), 715-723.
Gourgoulis, V., Boli, A., Aggeloussis, N., Toubekis, A., Antoniou, P., Kasimatis, P., . . . Mavromatis, G. (2014). The effect of leg kick on sprint front crawl swimming. *Journal of Sports Sciences, 32*(3), 278-289.
Junggren, S. E., Elbæk, L., & Stambulova, N. B. (2018). Examining coaching practices and philosophy through the lens of organizational culture in a Danish high-performance swimming environment. *International Journal of Sports Science & Coaching, 13*(6), 1108-1119.
Lucero, B. (2015). *The 100 Best Swimming Drills*: Aachen : Meyer & Meyer Sport, 2015.
3rd ed.
McCabe, C. B., Psycharakis, S., & Sanders, R. (2011). Kinematic differences between front crawl sprint and distance swimmers at sprint pace. *Journal of Sports Sciences, 29*(2), 115-123.
Naemi, R., Easson, W. J., & Sanders, R. H. (2010). Hydrodynamic glide efficiency in swimming. *Journal of Science and Medicine in Sport, 13*(4), 444-451.
Reid, M., Whiteside, D., & Elliott, B. (2010). Effect of skill decomposition on racket and ball kinematics of the elite junior tennis serve. *Sports biomechanics, 9*(4), 296-303.
Sanders, R., & Psycharakis, S. (2009). Rolling rhythms in front crawl swimming with six-beat kick. *Journal of Biomechanics, 42*(3), 273-279.
Seifert, L., Chollet, D., & Bardy, B. (2004). Effect of swimming velocity on arm coordination in the front crawl: a dynamic analysis. *Journal of Sports Sciences, 22*(7), 651-660.
Seifert, L., Toussaint, H. M., Alberty, M., Schnitzler, C., & Chollet, D. (2010). Arm Coordination, Power, and Swim Efficiency in National and Regional Front Crawl Swimmers. *Human Movement Science, 29*, 426-439. doi:10.1016/j.humov.2009.11.003
Whelan, N., Kenny, I. C., & Harrison, A. J. (2016). An insight into track and field coaches' knowledge and use of sprinting drills to improve performance. *International Journal of Sports Science & Coaching, 11*(2), 182-190.
Zamparo, P., & Falco, S. (2010). *Head out swimming in water polo: A comparison with front crawl in young female players.* Paper presented at the Proceedings of the XI Int. Symposium for Biomechanics and Medicine in Swimming.

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