3D KINEMATIC AND KINETIC ANALYSES OF TWO METHODS FOR GRAB START TECHNIQUE

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This study compared two swimming start techniques of GI (hands between the feet grab start technique) and GO (hands outside the feet) utilizing 3D simultaneous and synchronized kinematic and kinetic analysis. Eight experienced university swimmers were subjects of a series of specified trials. The comparison has consequently been made through evaluation of 46 variables obtained from force plate and motion analyzer. The results indicate that greater reaction force, resultant force in CM. and resultant moment about CM were produced in the GO than in GI. However, significantly higher values in reaction moment about horizontal axis and CM vertical coordinates were associated with GI. It has been shown that although GO will result in lower performance.

KEY **WORDS:** biomechanics, swimming, grab start, kinematic, kinetic

INTRODUCTION: Start times account for approximately 25 percent of time spent swimming 25 m races; 10 percent, swimming 50 m races; and 5 percent swimming 100 m races. Data gathered over several years indicate that, on the average, improving the start can reduce times by at least 0.10 s per pool length (Costill & Richardson, 1996)
The significance of these improvements is evident by the fact that only 0.45 s separated the first and third place finishers in the 100 m freestyle Short Course Swimming World Championship (Berlin2001).
Following the introduction of Grab Start techniques by Hanauer in 1967, several authors have compared conventional and grab start (Bowers & Cavanagh, 1974). The concept of using a track start was further introduced by Fitzgerald in 1973. This led to a series of studies aimed at comparing the grab and track start techniques (Jurgens, 1999). Here the kinematic analyses were common mode of comparisons (Miller et al., 1984), although force analysis had also been utilized (Shierman, 1979). Studies of grab start techniques presented so far (Counsilman et.al., 1988), do not seem to have included the 3D kinematic and kinetic analyses of two grab start techniques of GI (the performer grabs the front edge of the platform by placing the hands next to each other, between the feet) and GO (the feet are close to one another and the hands are placed just outside the feet, grabbing the platform's edge). The emphasis of this paper is on the block phase in conjunction with reaction and center of mass kinetic and kinematic parameters.

METHODS: For the purpose of this study eight experienced male members of the university swimming team had undergone a three month, three sessions per week, training program supervised by an experienced coach. The objective was to bring the entire group to an approximately equal level in adoption of the two methods of grab start. The average individual characteristics are as follows: age, 21.75 years (SD=2.71); height: 179 cm (SD=9) and weight: 744 N (SD=93.93). The times for covering the eight meters from the platform were recorded. Reaction parameter evaluation was performed by a Kistler 9281 forceplate with the sampling rate of 200 Hz. The start performances were recorded through adoption of two Kodak high-speed cameras recording at 250 Hz with 120-degree angle utilizing the DLT method. The emphasis has been placed upon the block time for motion analysis, although the timing data were used for the entire activity inclusive of block, flight and glide times. For 3D calibration, a special grid with 12 markers was used. The anthropometric biomechanical model of Hanavan-Dempsters (1964) 15-body segment was adopted. The starting procedure was under FINA swimming rules. The starting signal was synchronized with the trigger of forceplate and cameras. Winana software was used to analyze the motion followed by processing the reaction data through Bioware software. Here, 28 (13-main) biomechanical variables including 9 (3-main) reaction variables obtained from the force plate, 5(3-main) kinematic variables, 6 (3-main) kinetic variables from the motion analyzer and 8 (4-main) variables obtained from the timing devices. There were three axes in the 3D grid. X-axis is perpendicular to the sagittal plane (named lateral axis), y-axis is parallel to the sagittal plane and in upward direction (named vertical axis) and z-axis is parallel to the sagittal plane and in forward direction (named horizontal axis). For all variables the "x, y and z" demonstrate lateral, vertical & horizontal (in the direction of swimming) directions correspondingly.

Reaction Parameters: Fx, Fy, Fz and F reaction forces (Nor) %bodyweight; Mx, My and Mz: reaction moments (Nm); COPx and COPz: center of pressure coordinates (m); center of mass kinematic variables: Xcm, Ycm and Zcm: center of mass coordinates (m); Vcm: center of mass velocity (m/s); Acm: center of mass accelerations (m/s^2); center of mass kinetic variables: Fcm: forces in center of mass (N); Mxcm, Mycm, Mzcm and Mcm: moments about center of mass (N.m); MoMcm: moment of momentum about center of mass (N.m.s); Time Variables (s): R-T: (reaction time) time interval between starting signal and first sensible movement; H-T: (hand time) time interval between first sensible movement and hands separation from platform; F-T: (foot time) time interval between hand separation and feet separation from platform; I-T: (impulse time) time interval between first sensible movement and feet separation from platform (s); B-T: (block time) time interval between starting signal and feet separation from platform; Fl-T: (flight time) time interval between feet separation from platform and first water touch; G-T: (glide time) time interval between first water touch and first hand touch with the assumed plane in eight meters; T-T: (total time) time interval between starting signal and first hand touch with the plane in eight meters; Data analyzed with common descriptive statistics methods and ANOVA single factor ($p=0.05$).

RESULTS **AND** DISCUSSION: The main results of this study are presented in Tablel. Table 1 indicates that GO has significantly ($p<0.05$) higher values for the following variables: reaction forces in all directions, CM vertical coordinate, resultant force and moment about CM. It can also be noticed that in GI, reaction moment about vertical axis is significantly higher. Values obtained in this research agree with the previous studies. The flight times found to be 0.365 s and 0.350 s for GI and GO respectively. Miller et al. has found them to be: 0.38 and 0.40 s, for 100 m and 200 m breaststroke events respectively, 0.33 and 0.31 s, for 100 m and 200 m butterfly events respectively, 0.38 and 0.30 s, for 100 m and 200 m freestyle events respectively and 0.33 and 0.334 s, for 100 m and 200 m individual medley events respectively. All for male swimmers (same as current study gender). The mean block time were 1.04 and 1.13 s for GI and GO respectively, which are slightly greater than that of Miller et al. which was found to be 0.78 s, for 100 m breaststroke events, 0.82 s for 200-m butterfly events, 0.82 and 0.83 for 100 and 200 m individual medley events respectively.

These differences may be explained by the proficiency level of studying groups (university swimmers vs national champion swimmers) and the difference between racing and non-racing conditions.

The significant comparison criteria for the two methods were: reaction forces, reaction moment about vertical axis, CM vertical coordinate, CM resultant force and resultant moment about CM.

F. As far as the reaction parameters was concerned GO exhibits significantly higher reaction forces in all directions and consequently a higher resultant reaction force. That could be due to hands creating more forces in GO. The hands position in GO leads to a more effective grip and acts in a more efficient manner in producing both vertical and horizontal reaction forces.

My. GI has significantly higher reaction moment about vertical axis. It seems that swimmer's position in GI creates a greater twisting effect on the platform. This may be explained by the existence of nonsymmetrical forces that cause moments about vertical axis. Furthermore, GI is less symmetric with reference to the sagittal plane. It seems that performers in GO act much more stable in preventing platform twist.

Ycm. Analyzed data indicate that in GO, the performer has higher CM average height along the block phase. This could have been caused by higher upward hands movement in GO. In GI hands movements are further forward, due to limitations imposed by the posture.

Fcm and Mcm. The CM resultant force and moment in GO is higher than GI. It is useful to notice that the CM force and moments for individual body segments are higher in GO, which results in a total higher CM resultant force in GO.

Table1 Reaction, Kinematic, Kinetic and Time Results Including Mean and SD for GI and **GO,** F and P Values.

Variables	GI		GO		**ANOVA**	
Reaction Parameters	Mean	SD	Mean	**SD**	F	P
Fx(N)	-0.01	0.032	-0.005	0.028	16.57	0
Fy(N)	1.25	0.403	1.37	0.479	42.78	0
Fz(N)	0.236	0.248	0.29	0.254	25.5	0
F(N)	1.29	0.421	1.42	0.473	43.5	0
Mz(Nm)	-2.42	15.18	-3.27	13.0	1.97	0.16
Mx(Nm)	-94.3	80.4	-99.2	86.7	1.96	0.16
My(Nm)	0.737	6.45	0.196	4.38	5.1	0.024
COPz(m)	0.092	0.059	0.091	0.065	0.096	0.76
COPx(m)	-0.002	0.019	-0.002	0.015	0.166	0.68
CM Kinematic Parameters						
Xcm(m)	0.8	0.043	0.788	0.038	0.024	0.88
Ycm(m)	0.588	0.082	0.596	0.077	29.4	0
Zcm(m)	0.594	0.275	0.583	0.253	0.055	0.81
Vcm(m/s)	0.792	1.136	0.801	1.19	0.30	0.59
Acm(m/s2)	3.558	54.7	4.37	80.1	0.13	0.72
CM Kinetic Parameters						
Fcm(N)	2642	2695	3057	4085	14.36	0
Mxcm(Nm)	89.2	1712	85.9	2644	0.001	0.98
Mycm(Nm)	-144	2660	-123.4	2805	0.037	0.85
Mzcm(Nm)	38.9	2258	25.16	2676	0.022	0.88
Mcm(Nm)	2524	2965	2831	3745	8.70	0.003
MoMcm(Nms)	46.7	48.171	47.7	46.6	1.08	0.30
Time Parameters						
R-T(s)	0.4	0.102	0.49	0.311	0.60	0.45
H-T(s)	0.285	0.087	0.305	0.085	0.22	0.65
F-T(s)	0.355	0.04	0.335	0.042	0.95	0.35
I-T(s)	0.64	0.111	0.64	0.083	0	1
B-T(s)	1.04	0.16	1.13	0.322	0.50	0.49
FI-T(s)	0.365	0.054	0.35	0.041	0.39	0.54
G-T(s)	0.904	0.269	0.842	0.272	0.20	0.66
T-T(s)	2.309	0.205	2.32	0.207	0.03	0.86

Time Variables Relations.
(I-T)= (H-T)+ (F-T)
(B-T)=(R-T)+(H-T)+(F-T)
(B-T)= (I-T)+(R-T)
(T-T) =(B-T)+(FI-T)+ (G-T).

GI has lower reaction moments about lateral and horizontal axes, and it is more capable of stabilizing platform's tilt and somersault motions. Average center of pressure horizontal coordinate in GI is closer to the front edge of platform (1 mm), but the two methods have equal average center of pressure lateral coordinate. Analyzed data indicate that in GO, the performer has lower average CM horizontal coordinate.

The average velocity for GO is higher along the block phase. CM acceleration in GO is greater. Moment about all axes in GI is higher. It may therefore be concluded that in GI the performers body is capable of producing more twist, summersault and tilt motions. Moment of momentum about CM is also higher for GO.

The time data indicates that, GI has less block time, but GO is faster in Flight and Glide phases. There is a 0.09 s difference between the block times in two methods, due to GI's lower reaction time by -0.09 s, shorter hands time by -0.02 s, and higher feet time by +0.02 s, although the impulse time for both methods are equal (0.64 s). In the flight phase, GO is faster than GI by +0.015 s. Glide time in GO is 0.062 s less than GI's. Finally GI with the total time of 2.309 s is faster than GO with the total time of 2.322 s.

CONCLUSION: The conclusion of this study is that GI and GO are very similar, but GI seems to be faster than GO. The two techniques are different for the positions of hands, and consequently different biomechanical variables. Aithough GO is capable of producing higher values in most of the considered kinematic and kinetic variables (which may cause faster flight and glide time), it is slower at block phase than GI. Furthermore, GI's faster block phase overcomes the deficiency of its flight and glide times, and is therefore more effective than GO.

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