A SIMULATION OF STROKE EFFICIENCY DURING FRONT CRAWL BY USING THE SWIMMING HUMAN SIMULATION MODEL

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KEY WORDS: Human swimming, Computer simulation, Unsteady fluid force, Stroke efficiency.

INTRODUCTION: Nakashima *et al.* (2005) have developed a swimming human simulation model (SWUM) considering rigid body dynamics and unsteady fluid for the whole body. By using this model, it comes to be able to estimate the mechanical efficiency during human swimming which has been difficult to obtain its actual measurement value. The purpose of this study was to estimate the mechanical efficiency during front crawl in varied swimming velocity. If this estimation is considered reasonable and proper, the SWUM may become a useful tool to create a new efficient stroke movement in the water.

METHOD: In the SWUM software, a swimmer's body is modelled as a series of rigid segments which consists of 21 truncated elliptic cones (Fig.1). The relative motion between the segments is given as a joint motion and the absolute motions in six degrees-of-freedom of the whole swimmer's body are solved by six equations of motion for each segment. To identify the coefficient of drag force tangential to a longitudinal axis of the cone, $\mathbf{C_t}$; the coefficient of drag force normal to the axis, $\mathbf{C_n}$; and the coefficient of inertial force due to the added mass, $\mathbf{C_a}$; an exploratory experiment has been conducted. By entering the coefficients, in addition the actual data of geometry, density and relative joint motion of all body segments into the SWUM, the fluid force acting on each part of the body, joint torque and a total power output are calculated. The mechanical efficiency is obtained by dividing the power output (swimming velocity x active drag of a swimmer) by the total power input.

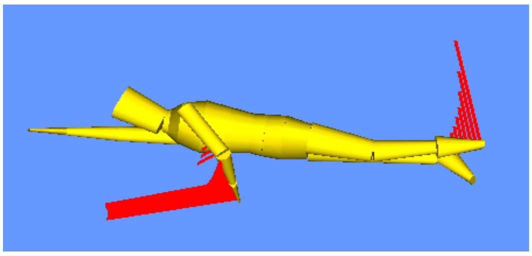

Figure1 Modeling of a swimmer's body

Table 1 Change of mechanical efficiency due to an increase of swimming velocity

Velocity (m/s)	Stroke length (m/stroke)	Power output (W)	Power input (W)	Mechanical Efficiency (%)
0.73	2.20	9.58	61.95	15.50
0.91	2.26	18.36	100.50	18.30
1.15	2.31	37.83	189.78	19.90
1.33	2.33	57.13	280.38	20.30
1.57	2.35	91.60	440.61	20.78
1.90	2.38	159.60	750.34	21.20

RESULTS & DISCUSSION: Changes of stroke length, power output, power input and mechanical efficiency due to an increase of swimming velocity are shown in Table 1. Although the mechanical efficiency rose with an increase in the velocity, it reached steady-state value, which was around twenty percent, at the velocity over 1.15 m/s. As these results were different from the absolute value in previous studies, it seems to be necessary to discuss the phenomenon hydrodynamically in order to assess the validity of the data.

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A KINEMATIC ANALYSIS OF FREESTYLE FLIP TURN PUSH-OFF

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During freestyle flip turn, selected kinematic variables of the push-off following a flip turn were recorded. The horizontal and vertical displacements of different parts of swimmer's body such as shoulder, centre of gravity, hip, knee, and ankle were calculated from underwater videography. The horizontal and vertical velocities of these points were then calculated and traced by TC Win Programming. Four experienced swimmers (three males and one female) performed three complete turns with kinetic variables recorded for each turn. The kinematic analysis was performed through the use of APAS Analysis System, which involved under water video analysis of the push-off and glide phases of the flip turn. It was demonstrated that the collection of kinematic variables used in this study allowed a more comprehensive analysis of the freestyle flip turn.

Keywords: kinematic variables, flip turn, push-off, freestyle swimming

INTRODUCTION:

In order to improve turn performance, a swimmer must optimize all aspects of the event they are contesting. An optimal outbound turning technique requires maximising the distance achieved from the wall push-off by minimising the deceleration caused by drag force (Lyttle et al., 1999). Selection of the appropriate time spent gliding, kicking, and when to resume stroking (Sanders&Byatt-Smith, 2003, Blanksby, et al., 1996) appears critical to reducing total turn time.

To increase turn efficiency, a swimmer must use the increased velocity gained from the push-off to their advantage. Inappropriate selection of and inefficiencies in underwater movement style, technique and kick resumption time can all contribute to less than optimal turn exit performance due to energy losses caused by increased drag. Appropriate definition and measurement is necessary to accurately quantify swim turn performance.

Improvements in turn times can lead to substantially improved events times. Despite the obvious importance, there has been a paucity of quantitative research conducted on this respect of competitive swimming. Differences in the distances between the commencement and completion of turns have made direct comparisons between studies difficult. Of the few researchers investigating aspects of the kinematic profiles of turn, Takahashi et al., (1982), examined the range of the knee flexion that occurred during push-off in a flip turn and Shahbazi et al. (2006, 2005) examined the relation between turn speed and swimmers' body shape and uper and lower limbs.

The lack of any comprehensive kinematic swimming turn analysis is largely due to problems in designing accurate and reliable equipment for aquatic environment. The kinematic analysis is also hindered by the lack of a consistent definition of the total turn time, while in kinetic analysis, the exact time of hand/foot contact is difficult to ascertain due to the presence of a bow wave. The aim of this study was to provide a more comprehensive analysis of kinematic parameters that affect the turning performance of experienced swimmers performing a freestyle flip turn.

METHODS:

This study required push-off distance, glide time, and glide distance records of several segments. These records were obtained from digitized video of the swimmer from an under water view, Shahbazi and Sanders (2004). Three top university swimmers participated to this study. Markers representing fixed points on the ankle, knee, hip, and centre of gravity were used to represent the motion of these segments. Video data of swimmers may be collected in various ways provided that the camera is viewing from below the water surface. All data for our kinematic study were collected using fixed camera. A JVC handicam sampling at 50Hz was at 3m from the plane of motion of swimmers. A scale line has been used which compromised black markers positioned at 1m intervals on a taut cable directly under the midline of the swimmer and aligned in the direction of travel of the swimmer. The subjects wore a white body suit to maximize contrast of a black marker fixed in the line with the points on ankle, knee, hip, and centre of gravity. These points were then digitized by APAS Analysis System. Analyses of the raw data were digital filtering at 4 Hz. In order to get better results, the time-displacements obtained by APAS were then transferred to TCwin programme for tracing and calculating the velocity and acceleration profiles for better interpreting push-off kinematics.

RESULTS AND DISCUSSION:

The importance of streamlining in underwater gliding distance to account for 95% of the variance in the push-off time to minimize the resistance forces during the glide was crucial in our study. Clarys et al. (1979) supported this finding with evidence that merely raising the head above the fully extended arms would increase considerably the drag encountered by the body, Following a tumble turn, Blanksby et al. (1996) found faster round trip times when swimmers were streamlined following the push-off. The exploratory analysis showed how the various kinematic variables of different body parts during the wall push-off part of wall release were affecting the wall exit velocity.

In their primary modelling, Shahbazi et al. (2005) showed how a swimmer might be considered as a bent prism and in order to acomplish the turn as fast as possible the swimmer should bend the body as much as it is possible to gain higher angular velocity to touch the wall. In their second study Shahbazi et al. (2006) they modelled the swimmwe as two equal prisms hinged together. In this model they found out that the angle between uper and lower prisms played an important role in swimmer turn speed.

The kinematic characteristics were primarily a consideration only during the push-off phase, and push-off time represented the period from the first forward displacement of shoulders, hips, CG, knees, and ankkles after wall contact until the feet left the wall. Figure 1 outlines profiles of horizontal and vertical displacements of different body segments during the data analysis of the push-off. As can be seen on Figure 1, shoulders have the most and the ankles the least horizontal displacements and hip and CG have exactly the same displacement variations. The vertical profiles show that sole the knees variation is noticeable, while other parts have about the same smooth variations. On Figure 2, the Ankles showed noticeable variation and the CG had the maximum horizontal velocity at release (2m/s) from the wall, while other parts had smooth increasing variations. On the contrary, the vertical profiles show that Knees and Ankles had the maximum maximum, while the other parts having the constant speed. On Figure 3, the CG and Ankles show a maximum horizontal acceleration at release supporting well the horizontal velocity variations, while Hips, CG, and Shoulders show constant accelerations. The vertical acceleration profiles indicate noticeable Ankles, Knees, and Hips variations, while Shoulders and CG having constant acceleration.

Final horizontal velocities recorded in this study were about the peak outgoing velocities reported by Blanksby et al. (1996) and lower than those reported by Takahashi et al. (1982). As can be seen on Figure 2, analysis of the velocity profiles during push-off showed that subjects actually reached their peak push-off velocity prior to leaving the wall. This is possibly due to the drag reaching higher values than the propulsive force generated in the final portion of feet plantar flexion.

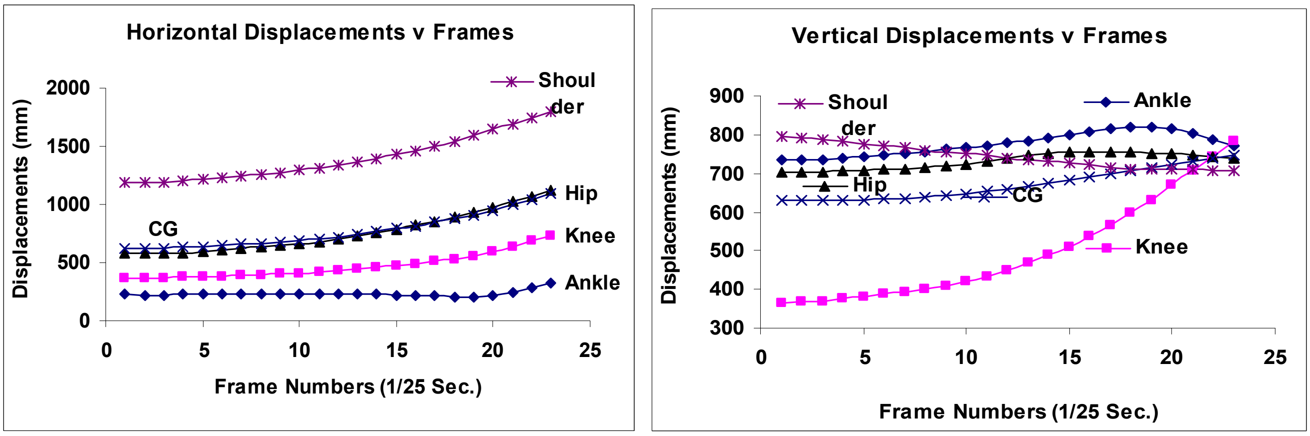

Figure 1 The horizontal and vertical displacements of Ankle, Knee, Hip, CG, and Shoulder are presented. The horizontal displacements have about the same behavior but knee vertical displcement has remarkable variation.

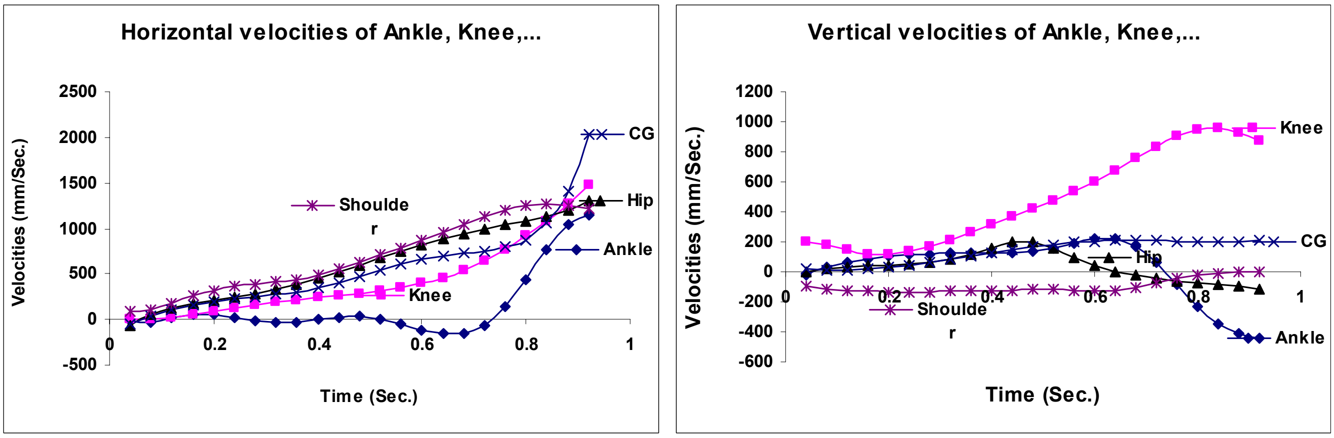

Figure 2 The horizontal and vertical variation of velocities of Ankle, Knee, Hip, CG, and Shoulder are presented. The movements of Ankle and CG are remarkable in horizontal direction, while Ankle, Knee, and Hip movements are remarkable in vertical direction.

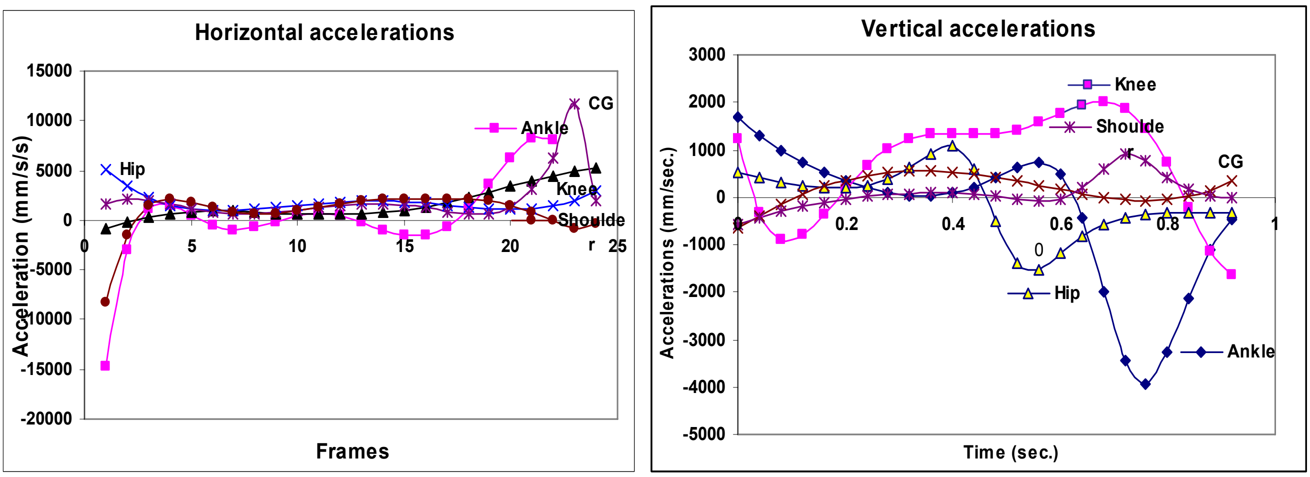

Figure 3 The horizontal and vertical accelerations of Ankle, Knee, Hip, CG, and Shoulder are representad. Horizontal CG and Ankle accelerations are noticeable, while Knee, Ankle, and Hip variations are more important than the others.

CONCLUSION:

This study claryfied the different parts of body kinematics in details and showed the horizontal and the vertical velocities and accelerations. The kinematic variables were studied to see their role in producing a greater wall velocity and providing a better understanding of push-off phase of freestyle flip turn. The results of this study can be used in conjuction with the results from analyses of other literature on the freestyle turn to optimize total turn performance.

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