SUPPORT SCULL KINEMATICS IN ELITE SYNCHRONIZED SWIMMERS

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INTRODUCTION

Elite synchronized swimmers must be able to perform routines requiring extraordinary anaerobic capacity while appearing to move smoothly and "effortlessly" both above and below the water. In world competitions, the winners must not only excel technically, but artistically, as well. To date there has been no systematic scientific investigation of kinematic differences in skill execution that may translate to differences in either technique effectiveness or economy among elite synchronized swimmers. This study represents an initial exploratory investigation of this general topic. Specifically, the purpose of this pilot study was to analyze kinematic similarities and differences among performances of the support scull in crane and double-leg support positions by three elite synchronized swimmers.

METHODS AND PROCEDURES

Subjects were three members of the 1994 World Champion United States Synchronized Swimming Team, including Jill Savery, Nathalie Schneyder, and Becky Dyroen-Lancer, the current World Champion in all synchronized swimming categories. The subjects were selected by the National Coaches from among team members as representing high (Dyroen-Lancer), medium (Savery), and low (Schneyder) body buoyancies. Recently assessed % body fat calculations for these subjects were 18.1%, 18.9%, and 15.5%, respectively, after correction for bone mineral content.

The skill chosen for analysis was the support scull, an important basic skill that is commonly used to support the performer in an inverted position with one or both legs projecting above the water. This skill has also been associated with overuse injuries of the shoulder among synchronized swimmers (Weinberg, 1986). Two underwater cameras were operated at 60 Hz to record the subjects performing the support scull in crane (one leg vertical and one leg horizontal) and double-leg (both legs vertical) positions.

Three sequential stroke cycles chosen at random were digitized for each subject in both positions. The raw data were smoothed with a cubic spline function and combined into three-dimensional position coordinates using the Direct Linear Transformation algorithm. Kinematic variables of potential interest were quantified and graphed for both sides of the body over the three sequential stroke cycles. These included stroke cycle time; motion of the head in X (frontal plane), Y (vertical), Z (sagittal plane), and resultant directions; range of motion of the upper arm with respect to vertical; range of motion of the forearm with respect to horizontal; projections of forearm motion on XZ, XY, and YZ planes; horizontal and vertical ranges of motion of the wrist; range of motion of the hand with respect to horizontal; and linear velocity of the wrist in X, Y, Z, and resultant directions.

RESULTS AND DISCUSSION

One performance variable assessed by judges in synchronized swimming competitions is the stability of the body positions maintained when compulsory skills are executed. In this study a point on the top of the head was used as an index of total body motion. Resultant head displacement ranged from **2.6 cm** to **5.9** cm across subjects, with approximately equal contributions in the X, Y, and Z directions. The National Team Coach observing the data collection indicated at the time that improvement was needed in the degree of stability visually observable in trials in which subsequent analysis showed more than 4 cm of head displacement. It may be the case that displacements of a synchronized swimmer's body smaller than approximately 4 cm over a period of several seconds are not visually discernable, even to the experienced eye.

Kinematic differences were observed for all subjects across the two positions studied. Dyroen-Lancer, Savery, and Schneyder exhibited greater mean vertical motion of the wrist by **2.9** cm, **5.3** cm, and **5.9** cm, respectively, in the double leg as compared to the crane position. There appeared to be a general pattern of slightly greater wrist range of motion across subjects in X and Z directions, as well, in the double leg position as opposed to the crane position, although this observation was less consistent across stroke cycles. Velocity curves also showed greater amplitudes for the double leg position as compared to the crane position. These findings are logical since in the double-leg support position as compared to the crane position the sculling motion must generate force to support approximately twice as much weight unassisted by the force of buoyancy above the surface of the water.

Shorter stroke cycle times were also displayed by all three subjects in the double-leg support position than in the crane position, reflecting the increased stroke velocity needed in the double-leg support position. This variable also revealed a pattern of differences across subjects, with mean stroke cycle times of 0.81 s and 0.72 s for Dyroen-Lancer, 0.70 s and 0.64 s for Savery, and 0.66 s and 0.61 s for Schneyder in the crane and double-leg support positions, respectively. These values correspond to the National Coaches' subjective assessments of subject "floatability," with greater perceived body density associated with faster stroke cycles.

Although Schneyder's assessed per cent body fat (15.5%) was lower than those of the other two subjects, it is notable that Dyroen-Lancer's percent body fat (18.1%) is actually slightly less than Savery's (18.9%). Another factor that appears to play a contributing role in a synchronized swimmer's "floatability," however, is body anthropometry . The lighter the segments of the lower extremity, the less force that is needed to support the legs above the water. Although no objective assessment of the volumes or weights of the leg segments of these swimmers has been conducted, Dyroen-Lancer's relatively thin legs may provide her with a substantial advantage over some other synchronized swimmers in terms of the lower force required for her to maintain inverted sculling positions with one or both legs above the water.

One particularly interesting difference that emerged among the subjects was that Dyroen-Lancer maintained the orientation of her forearms substantially closer to the horizontal throughout the stroke cycles in both positions than did the other two subjects. Forearm orientation ranged from 0-23 and 0-26 degrees for Dyroen-Lancer, from 0-47 and 0-40 degrees for Savery, and 0-44 and 0-43 degrees for Schneyder in the crane and double-leg support positions, respectively. It is possible that this difference enables Dyroen-Lancer, who is noted for appearing to perform "effortlessly," to generate more vertically directed lift force as compared to the other subjects.

CONCLUSIONS

The results of this preliminary investigation indicate that there may be substantial kinematic differences across athletes in basic skills performed by elite synchronized swimmers. The results also support the need for further investigation of synchronized swimming skill biomechanics. Topics that appear to be deserving of attention include: 1) the relationship between kinematics and skill effectiveness,

2) any relationship between athlete body density and preferred technique,
3) the relationship between kinematics and overuse injury incidence, and
4) identification of "model" kinematics for young synchronized swimmers who aspire to reach the elite level.

REFERENCES

Weinberg, S.K. (1986). Medical aspects of synchronized swimming. Clinical Sports Medicine, 5(1):159-167.