FACTORS INFLUENCING VARIATION IN DIVE HEIGHT IN 1M SPRINGBOARD DIVING

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The aim of this study was to determine the factors contributing to variation in dive height in performing a 1m springboard dive. 15 performances of a forward dive pike by an international diver were recorded using high speed video (250 Hz) and were digitised manually. The relationships between variables at hurdle landing, during board contact and dive height were determined. Hip extension during board contact accounted for 77% of the variance in dive height.

KEY WORDS: variability, touchdown, hip extension, board contact, foot placement

INTRODUCTION: In springboard diving, divers start the hurdle from approach steps and then project themselves upwards by jumping from an active leg toward the end of the diving board to achieve a hurdle flight. At the end of the hurdle flight, the diver contacts the board using both feet to begin the contact phase and depress the board. Most of the stored energy during depression will be converted to kinetic energy during the recoil phase and diver would be projected into the air (Figure 1). Several studies have identified the factors associated with achieving dive height during flight (Harper, 1966; Sanders & Wilson, 1988). However, little is known about the movement variability in different stages of dives, specifically the relationship between touchdown variables and dive height has not been developed.

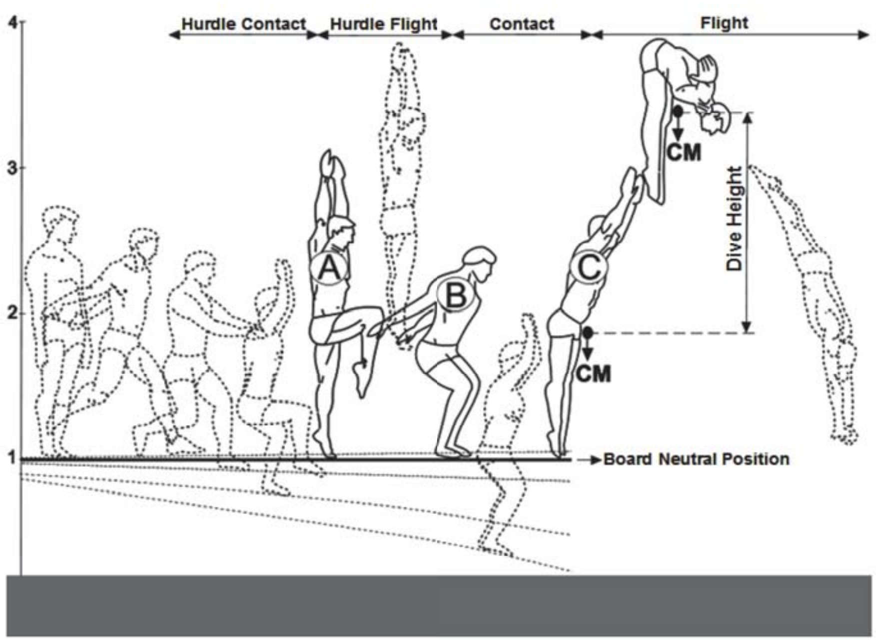

Figure 1: 1M springboard forward pike dive. Positions: A= hurdle takeoff, B= touchdown, C= takeoff.

It is agreed that the diver should aim for maximum dive height while generating sufficient angular momentum for rotation and keeping a safe distance away from the springboard. It is expected that vertical touchdown velocity and body configuration might make a major contribution to the dive height. The inter-relationship between dive height, foot distance from the end of the board, body configuration at touchdown and changes in configuration during the contact phase may determine the most significant factors responsible for variation in dive height.

As landing near the end of the board decreases the board stiffness, foot placement has a key role in changing the board stiffness. The diver starts the hurdle by jumping from an active leg toward the end of the diving board and there is inevitably an amount of variability in foot placement from trial to trial. It might be expected that there could be an adjustment for the variability of foot placement in the hurdle and that such variability might contribute to the variability in dive height. The aim of this paper was to investigate which factors are responsible for dive height and to what extent the change in touchdown variables can explain the variance in dive height. In order to understand the effect of a diver's kinematic variables at touchdown and during contact on dive height, a biomechanical analysis of a diver on 1m springboard was carried out.

METHOD: 15 trials of a forward pike dive performed by a male international springboard diver (mass = 69.7 kg, height = 1.79 m) were recorded using a high speed video camera (frame rate 250 Hz, exposure time 4 ms, resolution 1280 x 1024 pixels). Before data collection, the purpose and details of the study were explained to the diver and all procedures were approved by the Loughborough University ethics committee.

Each dive was split into 4 phases (Figure 1) and the video manually digitised. In the hurdle contact and hurdle flight 20 points on the body were digitised, in the board contact phase 11 points were digitised and in the dive flight phases 14 points on the body were digitised. For each digitised image the mass centre location was calculated using a segmental inertia method (Yeadon, 1990) along with the whole body orientation and the joint configuration angles (ball, ankle, knee, hip, shoulder, and elbow). In addition the board displacement was calculated during the board contact phase along with foot placement position throughout the dive. All phases were expressed with respect to the board neutral position and all touchdown variables were measured at board neutral position.

In order to investigate the contribution of variables to dive height (vertical distance travelled by the mass centre from takeoff to peak of flight), stepwise multiple regression analysis was performed using SPSS. The touchdown variables from the hurdle landing and body configuration variables during the board contact phase were chosen as the independent variables and dive height as the dependent variable. Three regression models were determined to explain the contributions to dive height. In the 1st regression model the touchdown variables were chosen against dive height with an entry significance level of 5%, in the 2nd regression model the same conditions as model 1 were used with an entry significance level of 10%. In the 3rd regression model all variables were included and entry significance levels of both 5% and 10% were investigated.

RESULTS: The diver was highly consistent in performing forward pike dives (Table 1). In terms of body configuration, there was a relatively large standard deviation in hip angle at touchdown (SD = 5.0°; Table 1) and less variability in knee angle (SD = 2.7°; Table 1). The hip extension during board contact from maximum hip flexion to maximum hip extension was the variable most correlated with dive height ($R^2 = 0.765$, $p < 0.01$). The coefficient of determination from Pearson correlations of the vertical mass centre touchdown velocity against dive height was 0.511 ($p < 0.05$).

Although it was expected that there might be adjustment for the variability of the foot placement in the hurdle, the standard deviation of the toe distance from the end of the board at board contact (0.060 m) was larger than in the hurdle (0.025 m). In the 1st regression model only vertical touchdown velocity was significant and this accounted for 51% of the variation in dive height (Table 2). When the entry significance level was changed to 10%, hip angle at touchdown was also included with 63% of the variance in dive height explained (Table 2). It can be hypothesised that the remaining variation comes from body configuration changes during board contact.

The 3rd regression model could use any of the variables calculated (Table 1), but choose only to include hip extension with 77% of the variation in dive height explained (Table 2). Although the amount of hip extension explains 77% of the variance in dive height, this factor is highly dependent on the touchdown variables. Since it explains more of the variance in dive height than the touchdown variables, hip extension during contact is the most important variable for explaining dive height variability.

Table 1: The mean and standard deviation of all variables and their R^2 against dive height

	(mean ± SD)	R^2 against dive height
dive height relative to board neutral [m]	1.74 ± 0.05	1
hip extension (max flex to max extension) [°]	66.0 ± 4.7	0.765
CM vertical velocity at touchdown [m/s]	4.77 ± 0.07	0.511
hip angle at hurdle touchdown [°]	98.9 ± 5.0	0.445
toe distance from board tip at takeoff [m]	0.115 ± 0.060	0.424
knee angle at hurdle touchdown [°]	102.3 ± 2.7	0.0002
knee extension (max flex to board neutral) [°]	74.9 ± 2.83	0.0007

Table 2: Stepwise regressions for estimating dive height from touchdown and contact variables

model	number of parameters	parameters	P	standardised coefficient	constant coefficient	R^2	adjusted R^2
1	1	vertical velocity	.003	.715	-.877	.511**	.474
2	2	vertical velocity	.038	.488	.374	.632*	.570
		initial hip angle	.071	-.415			
3	1	hip extension	.000	.875	1.11	.765**	.747

note: model 1 and 2 only included touchdown variables, *significant at p<0.1 **significant at p<0.05

DISCUSSION: The knee angle at touchdown and knee extension during board contact are not significantly correlated with dive height. This may be a consequence of the small variation in these knee angle parameters. However vertical touchdown velocity and hip angle at hurdle landing together explain 63% of the variance in dive height. Much of the remaining variation may be accounted for by hip extension during board contact as it explains 77% of the variance in dive height on its own.

Despite the fact that larger hip extension during board contact increases the dive height, execution of the hip flexion towards the end of the board contact in order to generate angular momentum degrades the dive height. This decrease in dive height in forward pike dives relative to more complicated dives is lower because lower somersault angular momentum is required. This suggests that lower dive height is to be expected in more complicated dives such as 1½, 2½ or 3½ somersault dives due to the requirement for more angular momentum. The dive height for a number of different dives was optimised by Kong (2005) using a simulation model. Kong's (2005) optimal solutions were only able to increase the dive height by an average of 0.16 m above that of the recorded performances. However, no increase in dive height was found for forward pike dives. Although Kong (2005) reported that the reason for the lack of increase in dive height may have been associated with a limitation of the simulation, the diver might have already been using close to optimum technique in forward pike dives. This may be related to the fact that this dive is relatively simple and not so technically challenging as multiple somersault dives. More variability might be expected in more complex dives. Traditionally the mechanical work done on the springboard is defined as the amount of board depression. The amount of energy that the diver has put into the diving board depends on both vertical touchdown velocity and body extension performed during the contact phase. The amount of hip extension from maximum hip flexion to the maximum hip extension during board contact determines the amount of additional energy that the diver put into the board. Greater hip extension increases the dive height. Variation in hip extension primarily accounts for the variation in dive height which is small (< 3%) indicating the consistency of performance of this diver.

CONCLUSION: This elite diver exhibited low variability in all measures of technique and performance (joint angles, foot placement, dive height) with no outliers in the 15 performances of the forward dive pike. The variation in dive height can be largely accounted for by the vertical touchdown velocity from the hurdle and the hip extension during the contact phase.

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