

The effect of springboard fulcrum position on the kinematics of junior divers

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INTRODUCTION

During a springboard dive take-off, divers depress the board, storing elastic energy in the board that is subsequently returned to the diver, propelling them into the air [2]. The springboard that is currently used in all international competition is the Maxiflex 'B' (Duraflex International, Sparks, NV). This board is constructed from a single piece of aluminium alloy, fixed to a base via a hinge and supported by an adjustable fulcrum located 1.88m from the fixed end [3]. The springboard has a scale of 1 – 9 on the fulcrum from which the diver can choose a setting; with 1 being the stiffest setting and 9 the loosest [3]. Each setting changes the fulcrum position by approximately 0.075 m [3] and the stiffness by about 300 N.m [5].

Elite springboard divers push fulcrum back to increase energy storage during depression of the board ($E = k \cdot x^2$). A looser fulcrum setting has been shown to increase dive height in elite springboard divers [2], which is beneficial for diving performance [4]. Younger and less experienced divers, however, move the fulcrum forward to create a stiffer, more controllable springboard. The aim of this investigation was to investigate the effect of moving the fulcrum position on the diving performance of high level junior divers.

METHODS

Eight divers (13.25 ± 1.04 years old) who had competed at national age-group diving championships were recruited from the NSW Institute of Sport. Five forward somersault dives were performed off a 1 m Maxiflex B springboard at three different fulcrum settings. The fulcrum settings were their preferred position (6.25 ± 0.65), minus one (tight) and plus one (loose) position from the preferred.

Each dive was filmed using a Casio Exilim EX-FH20 camera and the three best trials from each setting digitised at 70 frames per second using SkillSpector software (Video4Coach, Denmark, 2009). Data were filtered using a zero lag 4th order Butterworth filter at 4 Hz. Ninety five anthropometric measures were recorded to calculate segment inertial characteristics according to Yeadon [6]. Two dimensional video analysis, together with the inertial measures, was used to calculate the lower limb joint angles, work done during take-off, dive height and angular momentum of each dive.

The work performed by the diver during take-off was defined as the sum of the change in kinetic energy and potential energy, with mass removed from the equations to normalize results between divers [4]. Dive height was defined as the

difference between the height of the centre of gravity at take-off and at peak dive height. Angular momentum was calculated using the method of Hamill et al. [1] and was averaged throughout the flight phase.

Statistical analyses were conducted on the following variables: hip, knee and ankle angles at touch-down, maximum depression and take-off landing; angle of lean; maximum board depression; dive height; work during take-off and angular momentum. Repeated measures analysis of variance was used to determine changes in performance with fulcrum position, using $P \leq 0.05$ as the requirement for statistical significance (PASW Statistics, Version 18).

RESULTS AND DISCUSSION

Moving the fulcrum from one setting tighter than preferred to one setting looser than preferred resulted in greater depression of springboard (0.03 m, $p=0.035$), increased the knee flexion at touch-down (2.1°, $p=0.037$) and increased the knee and ankle extension at maximum board depression (6.5°, $p=0.000$; 5.9°, $p=0.004$, Table 1). There was no change, however, in maximum height achieved during the dive ($p=0.191$) or average angular momentum during the dive ($p=0.237$) with fulcrum movement. Similarly, there was no change in energy given to the diver during take-off ($p=0.22$), indicating that the additional energy stored in the board during depression was not returned to the diver. For reasons of brevity, kinematic variables showing no change with fulcrum position have been eliminated from Table 1.

The looser fulcrum setting resulted in a greater knee flexion angle at touchdown. As divers land on the springboard they experience a flexion torque caused by the springboard reaction forces [4]. When a diver uses a looser fulcrum setting the greater knee flexion would increase this torque about the knee. The divers flex their knees immediately after contact as an impact absorption mechanism; however they must limit the amount of flexion to prevent excessive eccentric absorption of potential energy by providing a greater extension torque. If a diver is unable to overcome the flexion torque then no additional energy will be placed into the spring system.

A large variation in individual results for dive height and work provide an understanding as to why there were no measurable benefits from the increase in springboard depression. Some subjects were unable to maintain the same amount of work performed on the springboard at the looser fulcrum setting, and subsequently there was no increase in their dive height. As springboard depression is increased the energy storage and

return should also be increased, however some divers performed less work at the looser fulcrum setting. A possible explanation for this could be that they may not have been able to apply a sufficient extension torque to overcome an increase in flexion torque. An alternate hypothesis could be an increased difficulty in controlling the more horizontally oriented take-off forces that would result from a more obliquely oriented diving board under a looser fulcrum setting.

Table 1: Kinematic and kinetic changes between the three fulcrum settings. * Indicates a significant difference between fulcrum settings ($P \leq 0.05$).

	Loose	Preferred	Tight
*Knee Angle at Touch-down (degrees)	55.8 ± 4.7	53.5 ± 7.5	53.7 ± 6.3
*Knee Angle at Max Depression (degrees)	40.3 ± 8.5	43.4 ± 6.6	46.8 ± 7.1
*Ankle Angle at Max Depression (degrees)	72.4 ± 7.5	75.7 ± 7.0	78.3 ± 6.0
*Spring Board Max Depression (m)	0.49 ± 0.08	0.48 ± 0.07	0.46 ± 0.07
Dive Height (m)	0.95 ± 0.27	1.02 ± 0.19	0.91 ± 0.25
Work / mass (N.m.kg ⁻¹)	3.3 ± 1.0	3.4 ± 1.0	3.5 ± 1.3
Angular Momentum (kg.m.s ⁻¹)	27.6 ± 7.4	26.6 ± 6.1	27.4 ± 7.3

Future work would benefit from investigating the within-trial variance at different fulcrum settings. Such work would require a more automated digitizing system to generate kinematic results from a larger number of trials for each subject.

CONCLUSIONS

Previous research has shown that senior elite divers were able to increase the maximum height during a dive by using a looser fulcrum setting [2]. The present cohort of junior divers, however, was unable to use the increased knee extension range of motion and downward deflection of the springboard successfully to apply additional energy into the system. These findings suggest that junior national divers are unable to control the springboard as the stiffness is reduced. It is therefore recommended that coaching decisions to move the fulcrum back be made cautiously, giving consideration to the individual divers' ability to control a looser setting.

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