DEVELOPMENT OF A COMPLEX MEASURING UNIT FOR SPRINGBOARD DIVING

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Based on a springboard with a force platform a complex measuring unit was developed to be used in springboard diving. The platform is composed of three plates, and based on the principle of strain measurement for vertical and horizontal forces. Using a computer based video system as a new component the board's angle of inclination can be measured automatically. After locating two markers of the springboard in the first picture, the video system tracks the markers during the board movement itself. Feedback pictures for the diver will be selected for defined events because of the synchronized data from force measuring and the board inclination. With this image of the diver and an added reference picture (model stick-figure) the difference between the model and the actual performance were shown to the athletes.

KEY WORDS: springboard diving, measuring unit, board reaction force, feedback training.

INTRODUCTION: Approach and take-off in springboard diving is one important part of the diving performance and there are modifications of the techniques until today. Since the 70s of the last century elastic springboards in diving were in focus of scientific investigations. Bergmaier (1970) in Switzerland and Stein (1970) in Germany measured forces during the take-off. Bergmaier placed a Kistler force platform (mass = 18.3 kg) at the end of a springboard to measure the forces directly. Stein applied strain gauges under the springboard and measured the bending of the board. With a predetermined fulcrum position forces were calculated. The advantage of the measurement system of Stein was the unaffected mechanical properties of the board. Stein used the system also at international competitions and as a feedback system during diving training.

Later research groups used an accelerometer on the board tip. Miller and colleagues (Jones & Miller, 1996; Miller, Osborne & Jones, 1998) used an accelerometer and video to describe the movement of the board and the interaction between diver and board. The German group Fricke, Koethe and Wagner (1991) applied also an accelerometer, but in addition they used the results of the measuring system and synchronized video to inform the divers about their performance (training with measurement systems). One problem of the measurement of acceleration was the rotation of the board. The board tip not only moves up and down, but also backwards and forwards. Because of the board tip rotation the vertical and horizontal acceleration patterns could not be easily interpreted. Jones and Miller (1996) compared the vertical acceleration patterns with double differentiation of vertical board tip coordinates taken from the video digitizing. The two patterns "showed unmistakable similarity" (p. 399), but they were "unsuccessful in attempts to derive consistent vertical board tip position information by integrating the accelerometer output" (p. 400).

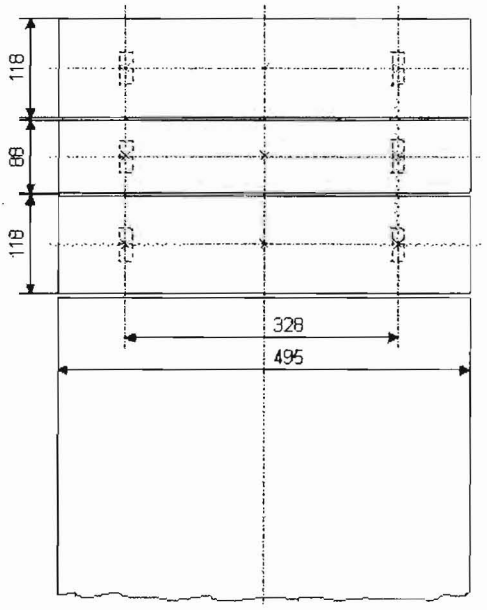


Figure 1: Measuring board with three force plates (units in millimeter).

Huo, Nitsche and Nicol (2000) developed a new measuring springboard with the possibility to measure horizontal and vertical forces. The platform on the board (see Figure 1) is composed of three plates, each with four strain gauges for the measurement of vertical and horizontal forces. In contrast to the accelerometer systems the measuring board from Huo, Nitsche and Nicol was 1.5 kg heavier. Huo, Nitsche and Nicol (2000) report that athletes would tolerate the slight changes of the board properties.
In 2002 this measuring board was transferred to our research group. The aim of our work is to further develop a complex measurement system for feedback training with athletes in springboard diving.

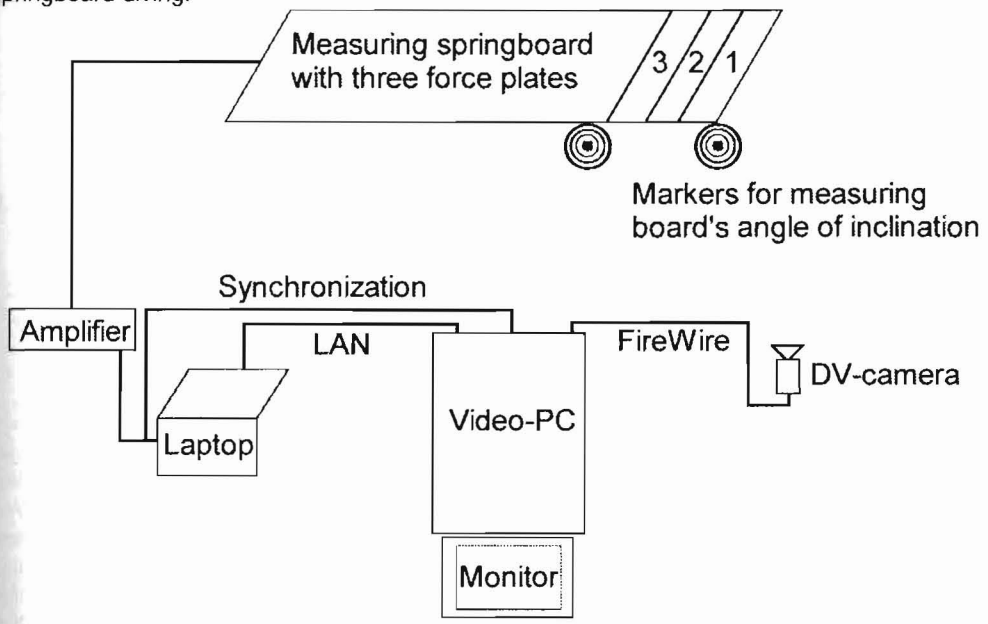


Figure 2: Measuring unit for springboard diving.

METHODS: Because of incomplete data about the calibration of the existing system and some necessary changes at the amplifier a recalibration of the measuring board was realized. Thereafter new components were added to built the new complex measurement system (see figure 2 for an overview of the components).
To use the data from the measuring board for vertical and horizontal forces it is important to know the angle of the measuring plane. Because of the above-mentioned problems with accelerometers we used video to measure the angle of inclination of the board. Using a computer based video system (50 frames per second) as a new component, the board's angle of inclination could be measured automatically within seconds. After locating two markers of the springboard in the first picture (see figure 3), the video system tracks the markers during the board movement itself. This was a requirement for a feedback system, to inform the athletes after a short interval about their performance. One advantage of the makers and the video systems is the possibility to use it on every board in the diving halls, not only on the measuring board. The digital video system with the auto tracking software was first used in weight lifting, to track the movements of the weight discs (Institute for Applied Training Science, 2003).

Figure 3: Board with markers.

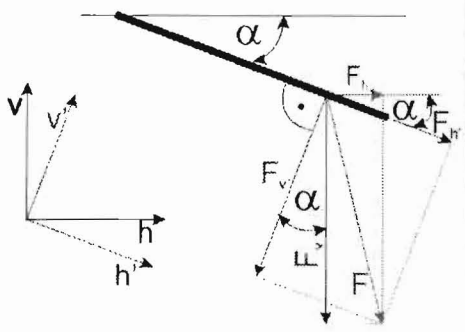
The data from the measuring board and the video system are savedon different computers but it is synchronized by a signal from the motherboard of the video computer. This signal will be recorded simultaneously with the force data. Results from the auto tracking of the board depression were stored and the file could be used over a local area network (LAN) for further analysis.

To record the data from the measuring board and its further analysis a new computer program had to be developed. After recording and calibration of the force data a transformation of this data to the horizontal plane (h, v) by using the synchronized data from the board's angle of inclination is necessary (see Figure 4). The following equations have been applied to calculate the transformed data:

$$F_v = F_{v'} \cos\alpha + F_{h'} \sin\alpha \qquad (1)$$

$$F_h = F_{h'} \cos\alpha - F_{v'} \sin\alpha \qquad (2)$$

where: α – angle of inclination
F_v – vertical force
F_h – horizontal force
$F_{v'}$ – measured vertical force
$F_{h'}$ – measured horizontal force



By using the data from board depression and the transformed force data, previously defined events were identified. These events depended on the dive (running dives - forward and reverse, and dives standing on the board tip - backward and inward) and will be in agreement with the divers coaches. Such events are for instance maximum angle of inclination and take-off (last contact of the diver with the board). For every event the numbers of the event pictures were transferred to the feedback software. This software adds a special stick figure showing the optimal performance for the event to the picture of the event. After their performance the athletes could have a look at these pictures (see Figure 5) and get the differences between the model and the actual performance.

RESULTS AND DISCUSSION: As a result we can show an example for a backward dive. After the performance of the diver force data were used to prove if the diver lift their feet off the board (sometimes called "crow hop"). The FINA Diving Rules and Regulations D 8.2.4.5 define: "When executing a standing dive, the diver shall not lift the feet of the board or platform during the arm swing or prior to the take-off. If the feet leave the board or platform each judge shall deduct ½ to 2 points from his award according to his opinion" (Federation Internationale de Natation, 2002, p. 159). If the diver lifts the feet we are able to show him/her the picture of the mistake.

Then the three calculated pictures (see Figure 5) were shown. Pictures are (1) angle of inclination with diver's weight (last time before maximum angle of inclination), (2) maximum angle of inclination of the board and (3) athletes' take-off. In picture 1 the diver should have the minimal angle of the knee joint.

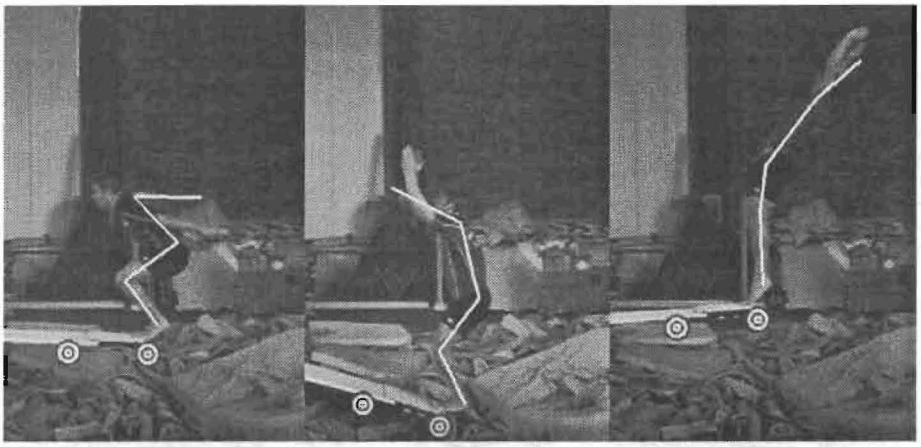


Figure 5: Feedback pictures for the diver left: board's angle of inclination with diver's weight, middle: maximum angle of inclination and right: take-off.

CONCLUSION: Altogether we can report, there is a new feedback system for springboard divers. Further investigations will focus the attention on effects of training with this feedback system. This year athletes will train regularly with this system. First we place emphasis on dives standing on the board tip, especially backward dives. In addition to the feedback training with the pictures, we want to check the possibility to give the athletes information about parameters, like dive height, calculated from the force data.
The system will not only be used for dry land training but also in the diving hall with dives into the water which is possible due to the measuring board being waterproof.

REFERENCES:

Bergmaier, G. (1970). Biomechanik des Wasserspringens. Zürich: Diplomarbeit an der Eidgenoessischen Technischen Hochschule.
Federation Internationale de Natation. (2002). FINA Handbook 2002-2005. Lausanne.
Fricke, B., Koethe, T., & Wagner, R. (1991). Training mit Unterstuetzung durch das Mess- und Informationssystem (MIS) Absprung Kunstspringen. In Institut fuer Angewandte Trainingswissenschaft (Ed.), Messplaetze fuer moderne Trainingskonzeptionen des Spitzensports (S. 31-36). Leipzig: Bundesausschuss fuer Leistungssport.
Huo, M., Nitsche, S., & Nicol, K. (2000). Messung der dynamischen Interaktion auf dem Sprungbrett. In K. Nicol & K. Peikenkamp (Hrsg.), Apparative Biomechanik - Methodik und Anwendungen (S. 95-101). Hamburg: Czwalina Verlag.
Institute for Applied Training Science (2003). Wettkampfanalyse. Retrieved 01.12.2003, from http://www.iat.uni-leipzig.de/iat/fg5/gewichtheben/wettkampf.htm.
Jones, I.C., & Miller, D.I. (1996). Influence of Fulcrum Position on Springboard Response and Takeoff Performance in the Running Approach. Journal of Applied Biomechanics, 12, 383-408.
Miller, D.I., Osborne, M.J., & Jones, I.C. (1998). Springboard oscillation during hurdle flight. Journal of Sports Sciences, 16(6), 571-583.
Stein, G. (1970). Biomechanische Untersuchungen des Absprungs im Kunstspringen. Unpublished Dissertation, Deutsche Hochschule fuer Koerperkultur (DHfK), Leipzig.

Acknowledgement
The investigation was supported by the Federal Institute for Sport Science (BISp), Bonn Germany (VF 0408/05/06/2002-2004).