NEW WAY OF DETERMINING HORIZONTAL DISPLACEMENT IN COMPETITIVE TRAMPOLINING

Katja Ferger, Michel Hackbarth

Institute of Sport Science, University Gießen, Germany

Original article

Abstract

The assessment criteria for competitive trampolining, which is primarily both a technical and a compositional form of sport, have been extended by the addition of some objectively measurable parameters in recent years. In addition to the degree of difficulty and the movement execution score, which is often perceived as subjective, the actual "time of flight" for the athlete was introduced as an objective (performance) criterion. Beyond this, it is proposed that, in the future, the athlete's position should be recorded during the routines in the form of a series of positional profiles and that this information should be introduced as a further scoring criterion for "horizontal displacement" in the next Olympic cycle. Using a self-developed measuring system for determining both parameters (time of flight and positioning), the resulting possibilities for controlling training and performance, as well as the options for further development of the competition system or the sport of trampolining itself are described here.

Keywords*: trampolining, position determination, force sensors, measurement system.*

INTRODUCTION

International Gymnastics Federation (FIG) develop judging within Code of Points within each Olympic Cycle. Changes in judging are prepared by Technical Committies of each sport discipline with aim to make judging more precise and fair. New technologies, which can upgrade judging, should have high degree of reliability and validity. In trampoling judges evaluate difficulty, performance and time of flight (ToF). Following the introduction of Tof as a new scoring criterion during the last Olympic cycle, various studies have demonstrated the problems inherent in obtaining accurate time measurements using the Time Measurement Device system (TMD; Acrosport Co. Ltd., 2010). A comparison of the performance of the TMD with that of a laser-based light curtain to measure the heights of jumps and ToF conducted by Eisele and colleagues (Eisele, et al., 2015) confirmed the results in terms of lack of accuracy of the measuring system used previously for determining the ToF (Ferger, et al., 2013). The alternative measuring device used by Eisele and colleagues, manufactured by Sick AG, to determine ToF is indeed both reactionless and contactless, and broaches the possibilities for position determination on the trampoline bed. This measuring device cannot, however, provide important and immediate feedback for training and competitive situations, because of its time-consuming calibration and evaluation procedures.

There are a few key requirements for a measurement and information system, which should be able to operate in competition and training. In view of the new regulations for points scoring assessments (Code of Points/COP) for the next Olympic cycle (2017 – 2020), position determination is increasingly gaining in importance (FIG, 2016). This results in various requirements of a measuring and information system for determining ToF and positioning for both individual and synchronized trampolining competitions.

In order to be able to focus on other sports- and scientific-related questions beyond ToF and position determination, a measurement and information system for competitive trampolining was developed in a joint co-operative project between Eurotramp Trampoline Kurt Hack GmbH and Wassing Messtechnik GmbH. As a first step, a list of requirements for the measurement and information system planned was drawn up, taking into account the areas of training data documentation, safety, incentive function, equipment documentation and the further development of the competition system:

• precise and accurate location determination on the equipment;

• precise and accurate ToF determination;

• simplicity of the system and software;

• uninterrupted, reactionless and contactless measurements;

• high temporal resolution;

• availability of the results in real time and for training data documentation purposes;

• sport-specific interpretation and/or visualisation of the measurements; and

• integration into the Fédération internationale de Gymnastique's (FIG) completion and scoring system

The deduction for horizontal displacement (HD) in individual and synchronized trampolining is calculated from the landing positions on the bed. The subdivision of the bed into different zones, which are each associated with corresponding deductions, is the foundation for the scoring of horizontal displacement (Figure 1).

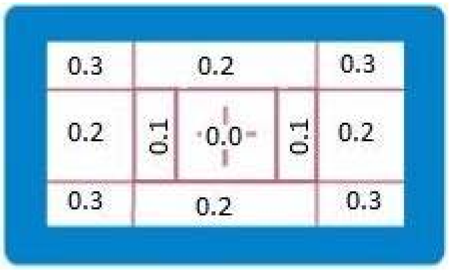

Figure 1. Deductions based on zones .

Judges need to determine the HD score visually in FIG competitions when there is no measurement system (FIG, 2016). Whether there is a difference in the deduction between a judge and the HD measurement system and whether the real landing position on the bed and, therefore, the right deduction is displayed with the HD measurement system need to be verified. A high-speed camera filming the trampoline at a vertical angle from the ceiling is a simple yet effective tool for determining the real zone in which the athlete lands. A recording with a high temporal resolution provides the ability to evaluate the deductions calculated by the HD measurement system. The aim of this study is to examine a possible application of the measurement system mentioned for horizontal displacement in competitive trampolining.

METHODS

The development of the measurement and information system, with technical details and system functionalities, is described in the following. The force sensors (Figure 2) (developed and constructed by Wassing Messtechnik GmbH) represent the technical core of the entire system. They use optoelectronic sensors and measure normal forces in a one-dimensional plane. The loads on the force platforms, which are positioned under the feet of the trampoline, produce a deformation of the metal plate or of the sensor and, thus, also a change in light intensity. Consequently, two voltages are measured, which are looped through the force plates via 8P8C modular connectors. The signal, containing 8 voltages, is broadcasted again through an 8P8C cable to the analogue to digital converter. After conversion, the digitalized signal is fed with a micro USB-to-USB cable into a windows-based laptop or computer (Figure 2). The overall cable length from force plate to laptop and, therefore, the distance between the trampoline and the judges, is tested up to 40 m. After taring the force plates under the feet of the trampoline, a custom C++ -based software visualises the single vertical forces applied on each force plate and the force summarized. The scanning is carried out effectively at 2 kHz (internally 50 kHz, mean average formation over 25 values). This means that current measurement values are available every 0.5 ms. The size of each of the force plates means that a resolution of better than 0.5 N is achieved at an accuracy of 1 %.

The basic principle is to measure the reaction forces on the trampoline at the set-up points (action = reaction), obtain the information desired by means of an appropriate evaluation and display this information. In addition to the development of a suitable sensor system for recording the static and dynamic forces occurring, the development of an evaluation device was promoted based on a systems theory analysis. The challenge was to analyse the raw data measured by the force sensors and to be able to separate the internal dynamics of the measuring apparatus from those of the athletes themselves. The resulting times of flight and positional data calculated can be simultaneously displayed in real time on the computer (Figure 3).

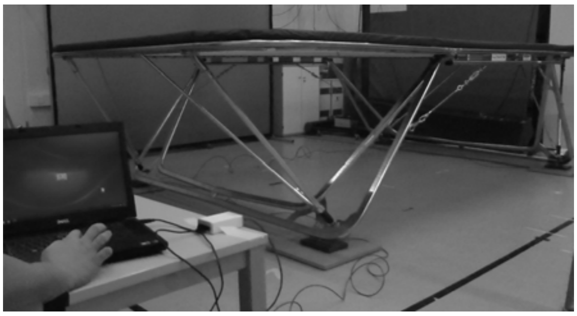

Figure 2. Force platforms under the trampoline connected to processing and output hardware.

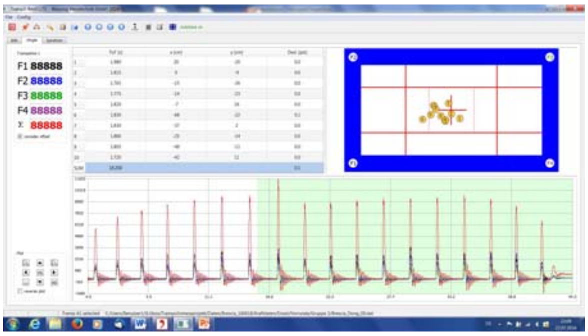

Figure 3. Screenshot – Sample display of results (Time of flights: ToF[s], positional profile based on the x and y co-ordinates measured; x/y [cm] with the corresponding deductions: Ded. [pts] and force curves).

It is both possible and essential to have a multiplicity of ways of displaying the results because of the many requirements of the system formulated in advance in both training and competition settings, and because of the differentiated reporting of the data to the various users (athletes, referees, competition judges, trainers and spectators). The measured values (ToF, position and force path profiles) are currently displayed in a tabular format, as force path curves and positional profiles. At the same time, these data are also recorded on a storage device (USB stick or SD card). The relevant data on jumps are animated in real time and the athlete can also be superimposed on this data stream by using an optional camera.

The first AERE World Cup in Brescia, Italy, (June17 – 19, 2016) was used as a test event for the system. The AERE World Cup was an official FIG competition and the measurement system was cleared for testing by the FIG Technical Committee. An international competition judge determined the deduction for horizontal displacement visually according to the landing of the athletes to evaluate the location determination. The competition judge was located in the upper area of the stands while the data were being obtained. From there, the cloth of both trampolines, including the zones, were completely visible. The deductions from 441 jumps from 25 male athletes were documented for a comparison between the judge and the system. All subjects were over 18 years of age. The jumps are, in both systems, divided into four categories: neutral zone, 0.1, 0.2 and 0.3 points deduction. If the deduction from the force plates and the visual deduction determined by the judge were the same, the jump was marked as a "match". In case of a different deduction between the system and the judge, the jump was marked as a "no match". With an expected error in the deduction due to the division of the cloth into zones, we set the maximal tolerable difference at 5 %.

Even though the competition judge is experienced and highly trained, a more precise and reliable measurement is necessary for a scientific view. Consequently, a comparison between the force plate system and a camera system took place in a Deutsche Olympische Sportbund training centre. A Basler acA1600-100 high-speed camera (Basler AG, Ahrensburg, Germany) with 100 Hz temporal resolution and 1600 x 1200 pixel video resolution was placed on the ceiling over a trampoline to record the exact landing position of the athlete. The camera was positioned at a ceiling height of 7.5 m aligned at a 90 ° angle to the bed, with the focus over the cross in the middle of the bed (Figure 1). Two male (17 and 20 years old) and two junior female athletes (10 years old each) performed ten routines each with a total number of 384 jumps. In addition to the permission of their coach and parents, all four participants were previously informed and gave their consent. The sample displays both ends of the weight range of usual participants in trampolining competitions: 32 kg for the female junior competitors and 67 and 68 kg for the male competitors. Using the position of the feet at the first contact with the bed in relation to the zones from high-speed video and the centre of pressure from the force plate system in relation to the zones, a comparison between the methods was made. The jumps are, in both systems, divided into four categories: neutral zone, 0.1, 0.2 and 0.3 points deduction. The results from both systems were compared for each jump and divided into the two groups ("match" and "no match"). Taking studies on artistic gymnastics into account (Čuk , 2015; Leskošek, et al., 2012; Pajek, et al., 2013) and with an expected error in the deduction due to the division of the cloth into zones, we set the maximal tolerable difference at 5 %. Chi-square provides a testing of proportion between expected and practical frequencies.

RESULTS

The 25 male athletes each performed two routines in the qualifying round at the AERE World Cup in Brescia. One routine consisted of 10 Jumps. Out of 500 possible Jumps, the athletes were able to perform 441. The missing jumps were due to forced stops, ranging from dangerous deductions to entirely missing the bed and injuries. The deduction estimated between the judge and the HD measurement system matched are represented in Table 1.

Table 1
Proportion of agreement between judges and force plate system.

	Technology yes	% from Total
Judges yes	425	96.4
Judges no	16	3.6
Total	441	100

The deduction in points of the two methods for the comparison with a high-speed camera was the same in 368 out of 384 jumps (95.83 %), and did not match in 16 jumps (4.17 %).

Table 2
Proportion of the comparison results over the sample. (S1 and S2 male, S3 and S4 female juniors).

Subject	Match	No Match	Sum
S1	93	3	96
S2	92	3	95
S3	95	2	97
S4	88	8	96
Sum	368	16	384

Table 2 shows the proportion of the comparison between the participants. The proportion of jumps in the categories "match" and "no match" do not differ significantly within the sample (χ^2 (3) = 5.75, $p < 0.05$). The proportions of the deduction categories were nearly the same (χ^2 (3) = 0.84, $p < 0.05$) for camera and the force plate system.

DISCUSSION

The benefits and possibilities for competitive trampolining with this system on hand are tremendous. Using the positions measured by the device together with the athletes' times of flight, it is possible, among other things and depending on the actual jump sequences, to create positional profiles and statements about spatial and temporal synchronicity.

Time of flight and position determination allow a systematic surveillance of individual jumps, jump sequences, and compulsory and voluntary routines during the training process. The recording and control of the interactions between the performance-related factors (ToF, bed contact time, distance travelled on the bed during the routine and/or during the individual jump sequences, force applied and the height of the jumps) additionally provide an opportunity to identify the athletes' deficiencies and reserve assets, and give valuable indications for (athletics) training which are appropriate for this specific type of sport (Lenk, et al., 2016; Lenk, et al., 2017). With an increased focus on position determination, together with the time recording for the ToF and/or bed contact times, it is possible to provide stimuli for jumping which are oriented around the body's centre of gravity and, thus, also improve the athletes' safety. In addition, the graphic representation of the data in real time offers the option of providing an "exciting" representation of the competition for the spectators.

These data can also be used retrospectively to obtain additional pointers for making improvements in equipment. The determination, for instance, of the state of the equipment (e.g. loss of elasticity) and the setting up of the equipment can be optimised on different types of surfaces (concrete, wooden and point elastic floors, competition stages and many more).

The observed percentage of disagreement between judge and system are neither an error of technology nor an error of judges. It is rather a problem of the different translation of the Code of Points. The judges are instructed to look for the athletes' feet during the bed contact. In the case if one foot is out of the neutral zone the judge indicate a deduction. In the same case the system detect the centre of mass inside the neutral zone and no deduction. These are the cases in which no agreement could be reached.

Obviously, further development of the competition system can be carried out. Only the ToF measurement of the TMD is currently used in both individual and synchronized competitions for determining measurements for the performance criterion ToF and for making the various deductions in the synchronized acrobatic moves. Different options are available for use in either the individual or the synchronized competitions.

For individual competitions, in addition to the determination of a movement profile over the distance covered, the subdivision of the bed into different zones, each associated with corresponding deductions (Figure 3), together with the total number of deviations from the midpoint, (Figure 4) represent other options for establishing a positional or an accuracy criterion. There is an issue in determining jumps on the lines which separate the different zones, especially considering the results of the comparison between the judge and the system. As a further development, the landing positions of the system should be evaluated with a more valid method, for example, using a kinematic camera system with markers on the athlete's feet.

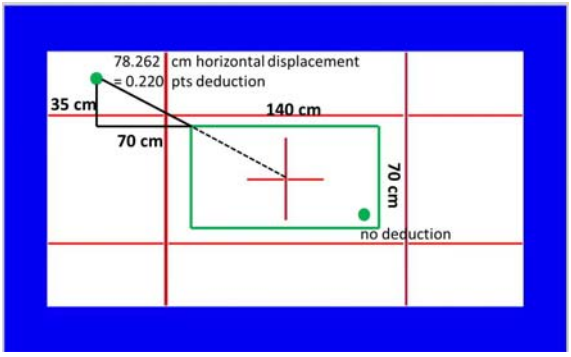

Figure 4. Deviations from the midpoint.

The determination of position in synchronized routines appears even more complex. Up to now, it has been possible to integrate an assessment of synchronicity into the score based solely on the time differences in landing. The new system broaches the possibility of being able to actually see and evaluate the synchronicity in a new way. The following aspects of synchronicity can now be observed in a more differentiated way: The synchronicity of the execution, which is reflected in the E-score, the time synchronicity in relation to the athletes landing on the equipment at the same time (ToF) and spatial synchronicity based on the athletes assuming the same landing positions.

In summary, performance-relevant factors which can be displayed in real time, such as ToF, contact with the bed, position on the bed, synchronicity and the forces and progressions which are produced, offer the possibility of providing competition judges with objective criteria for evaluating athletes' performances, and the athletes and their trainers with information for a more targeted management of their training and performance control, as well as making the competition more transparent and easier to follow for spectators and, thus, more enjoyable. In addition in the future, the setting up of the equipment can be optimised on different types of surfaces (concrete, wooden and point elastic floors, competition stages and many more), as can the determination of the state of the equipment (e.g. loss of elasticity).

There is also a great potential for the system in the field of training data documentation: individual positional profiles, flight times and time spent on the bed, as well as force progressions. It also offers the possibility of becoming the basis of a scientifically based and systematic method of controlling training and performance times. Furthermore, the subdivision of the definition of synchronicity into time, spatial and execution synchronicity shows that synchronicity cannot merely be assessed with reference to time differences in landing and, therefore, by the ToF. The solution currently being considered of making deductions in the various zones to form an HD score within the overall score, both in individual as well as in synchronized competitions, must certainly be discussed critically. This is because the problem in potentially uncertain cases where the line in a landing is clearly visible between the feet and the measuring system detects the body's centre of gravity on the line could be solved by the possibility described in terms of the deviation from the midpoint (c.f. Figure 4). In the end, the implementation of this system into the official competition system in a way which is acceptable to all parties remains a challenge.

CONCLUSION

New force plate system to measure gymnast's horizontal plane displacement in competitive trampolining showed high agreement with judges and with camera system. All evaluations were in agreement within error of less than 5 %. We could define new force plate system as valid and reliably.

New force plate system can be at this stage used at competitions to evaluate not only ToF, but also gymnast's horizontal plane displacement. When trampoline is fixed in gym hall it can be used also in training process. With whole data (ToF, HD), time of landing, time of take off, with added information about kind of jump, it can, therefore, be viewed as the first step in a long-term project of in-process training and competition research into competitive trampolining.

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Corresponding author:

Dr. Katja Ferger
Institute of Sport Science
University Gießen
Germany
Tel.: +49 (0)641 9925232
Fax: +49 (0)641 9925239
E-mail: katja.ferger@sport.uni-giessen.de