Palestrica of the third millennium – Civilization and Sport
Vol. 13, no. 4, October-December 2012, 348–353

CASE STUDIES
STUDII DE CAZ

Application of mechatronics systems to 110 meters hurdles training – a case report

Modalităţi de aplicare a sistemelor mecatronice în antrenamentul probei de 110 metri garduri – studiu de caz

Florentina Nechita
Faculty of Physical Education and Mountain Sport, "Transylvania" University, Braşov

Abstract

Background. The idea behind the study is that the structure of the 110 meters hurdles tryout includes a relatively large range of technical elements, which, by their assembly, involves drivelines in motion and offers the chance to study different kinematics parameters. This tryout reveals a high degree of technical complexity, involving ample resources in training techniques in order to improve the training methods.

Aims. This research concerns the analysis of the hurdles runner's step technique at the case study level. Reporting experimental research on this case contributes to a very positive effect in improving technique based on extrinsic feedback.

Methods. In this research, the kinematics parameters of the hurdles runner's pace obtained by comparing data are dependent on the investigation conducted by the video analysis method.

By using the video analysis method, record processing methods were highlighted, methods based on a video analysis software which emphasised the possibilities of capturing and observing the technical execution of hurdles runner's stride by changing each sequence in time and by transferring the sequences in descriptive points per millimetre sheet. This allows the specialized information to be operated upon and organised, thus obtaining precise qualitative and quantitative evaluation.

Results. The progress of the values to kinematics parameters F2 and F3 shows that the work focused specifically on existing faults, positive values of 8° upturn being registered at the moment of the hurdle attack and 12° in the downward phase when landing after the hurdle.

Conclusions. Based on the performance achieved by the athlete (junior national champion, I, 60 mg - 8.16 sec., 2011) the kinematics parameters values obtained are important factors in the efficiency of the hurdles runner's stride.

Keywords: sports training, kinematics, technique, 110 meters hurdles race.

Rezumat

Premize. Ideea care stă la baza studiului este că structura probei de 110 metri garduri cuprinde o gamă relativ mare de elemente tehnice, care prin asamblarea lor implică în mişcare lanţuri cinematice sau oferă studierea diferiţilor parametri cinematici. Această probă scoate în evidenţă o tehnică cu un grad mare de complexitate, fapt care implică o amplă organizare în pregătirea sportivă, vizând ameliorarea tehnicii acestei probe.

Obiective. Cercetarea se referă la analiza tehnicii pasului alergător de garduri la nivelului studiului de caz CA. Raportarea cercetării experimentale asupra acestui caz contribuie la obţinerea unor efecte pozitive în perfecţionarea tehnicii pe baza unui feedback extrinsec.

Metode. În cadrul cercetării, valorile parametrilor cinematici ai pasului alergător de garduri obţinute prin compararea datelor devin dependente de investigarea realizată prin metoda analizei video.

Prin utilizarea metodei analizei video s-au evidenţiat modalităţile de prelucrare a înregistrărilor pe baza unor software de analiză video, subliniindu-se posibilităţile de captare şi de constatare a execuţiei tehnice a pasului alergător de garduri, prin modificarea fiecărei frecvenţe în timp şi transpunerea secvenţelor în puncte descriptive pe foaia milimetrică. Acest lucru permite o exploatare şi o închegare a tuturor informaţiilor de specialitate, obţinându-se astfel o evaluare calitativă şi cantitativă precisă.

Rezultate. Progresul valorilor la parametrii cinematici F2 şi F3 denotă faptul că s-a lucrat concret pe greşelile existente determinate, înregistrându-se valori favorabile de 8° în faza ascendentă în momentul atacului gardului, iar la faza descendentă în momentul aterizării după gard de 12°.

Concluzii. Pe baza performanţelor sportive obţinute de către atletul CA (campion naţional de juniori I, 60 mg – 8,16 sec., 2011) valorile obţinute la parametrii cinematici devin factori importanţi în eficienţa pasului alergător de garduri.

Cuvinte cheie: antrenament, cinematică, tehnică, proba de 110 m garduri.

Received: 2012, October 28; *Accepted for publication:* 2012, November 16
Address for correspondence: Faculty of Physical Education and Mountain Sport, Transylvania University, Braşov, Colina Universităţii str. no.1, code 500068
E-mail: florenechita1977@yahoo.co.uk

Introduction

Starting from the idea that sports training is a complex process, we must consider the fact that there is a time when the adaptation stimuli acting on the athlete are determined by a dynamic integration of different factors, such as: management of the subject and of the specialists, financial conditions etc. The various specialized studies have developed principles, rules and norms of particular value in practice.

The concept of sports training is the main element linking specialists in the field literature as it is an important factor in action sports (Allen, 1976; Ballesteros, 1993; Demeilles, 1985; Bompa, 2000; Homenkov, 1963; Wazny, 2000).

Kirsch (1969) presents the basic sports training, which prepares the basis of performance. The author refers to the planned development of physical qualities and specific learning of the basic motor skills in the sports industry. From this point of view, the author mentions that the purpose of sports training is to direct the athlete towards "maximum personal performance".

Sports training can be understood as a "group of actions performed in a lesson or in a series of lessons for the precise effects resulting in expression embodied in the sports results or performance or it may be understood as an assembly of theoretical and practical actions taken to produce sports performance. The sports training is based on a workout plan that includes goals (final, intermediate and initial), contents, methods, operating systems (means/ exercise) and control samples" (Raţă, 2005).

We have to also take into account the great enthusiasm of the studies oriented towards the analysis of genetic factors, hereditary skills of athletes, thereby selecting athletes and even shaping the future after proper preparation.

Skinner (2010) argues that the influence of genetic factors is modelled by practicing exercise. The author presents genetic background as being the crucial condition of the human body in terms of physical activity and health. He defines training as follows: "training status is an art and a science," believing that if you try some form of exercise and it pays off, you can start another form in order to obtain optimum efficiency.

Significant factors in achieving peak performance are those developing and improving sports personality. Training as a lengthy process influences the sportsman's personality, thus being very important to focus on the knowledge and to careful monitor the conduct of the athletes and to develop the necessary qualities for adaptation at all levels. The stage nature of the training particularly influences the personality through the content and nature of socio-cultural influences.

Monea & Monea (2008) pointed out that "upgrading the training process involves finding the most efficient ways, means and methods to achieve high performance".

Due to the technical development and training methodology, a significant increase in performance in various sports has been noted. Modern methods of training increasingly focus on the maximum development of motor actions, together with the process of acquiring the corresponding technique.

It is recommended, in the training of athletes, to use a type of training based on a number of tools and procedures in order to induce improved results, including mental training.

Grosz (2009) and Vealey (1991) present mental training as a display of operational movements:

- The items of the sports technique are structured by the coach together with the athlete.
- The objectives of this mental exercise will be "drawn from video observations, verbal information and information on the movements of the athletes".
- The great importance of the essence of the professor - athlete pair regarding a complex of movements, the steps that will be recorded, coded and internalised, especially by young juniors.

The most important steps with a high degree of practicality are targeted, such as: "setting the ideal technique based on viewing the records depicting the evolution of an experienced sports model, viewing and analysing an athlete's training errors and raising awareness regarding the elements that were performed correctly."

The learning of any motor act is based on the existing models in the literature obtained from numerous and extensive biomechanical studies (1), (2), (3). This refers specifically to the basic mechanism of driving ability and the details of its implementation (Dragnea quoted by Potop et al., 2010).

Outlining the basic elements of human movement is based on a continuous improvement of tools and methods used for the monitoring of its technical aspects. This shows the effectiveness of the means used in the sports training process (Mihai, 2010).

Bidiugan (2009) states that sports training methodology requires adaptation to the influence of technology, thereby achieving an objective type of control of the development of athletes during training and competition.

Hypothesis

The quantification of individual independent variables of the hurdles runner's stride techniques provides objective monitoring of the tryout tested and promotes the optimisation of the quality level of technical training.

Material and methods

a) *Research Protocol*

The period of research experiments was October 2009 - August 2010 and actions taken included three tests: initial testing - T1 (October 2009), intermediate testing - T2 (April 2010) and final testing - T3 (August 2010).

Video recordings took place in two different locations, namely The Olympic Stadium of Poiana Braşov and "Dumbrava Minunată" Braşov.

In terms of the sequence of covering the research, the process steps and activities were:

Stage I - T1 included initial activities in the context of setting the kinematics parameters:

- Recording the hurdles runner's stride under standard conditions for the case study;
- Processing video analysis and quantitative determination of kinematics parameters;
- Detecting technical errors in video analysis;

- Designing the technical training purposes for improving the correction of errors that were objectively detected for the kinematics parameters.

Stage II - T2

- Comparative analysis between T1 and T2 values;

- Developing an individualized training program for optimizing kinematics parameter values, including the hurdles runner's stride technique.

Stage III - T3

- Comparative analysis of kinematics parameter values at T2 - T3.

b) *Subjects*

The research subject is a junior category I athlete, ranked top 10 at the Junior National Championship in the 110 meters hurdles tryout. Being in a state of early education and intervention, at this level, training can bring real benefits in terms of strengthening and improving sporting technique based on extrinsic feedback.

c) *Materials*

In this research, regarding the step of the hurdles runner, the optical image system (sheet millimetre) was used, by developing mathematical coordinates for each phase investigated. This system revealed something that is very important, namely transforming images into numerical data. Thus, the images of the hurdles runner's pace recorded by the camera indicate duration of movement, movement speed, horizontal distance and angles in attacking the hurdles and landing phases.

Imaging refers to a specific subject performing motor action as figurative reproduction. Thus, the athlete's action is obtained in the phase of crossing the hurdles, with the possibility of observing the athlete's technique through the use of the AVI playback in the frame, scoring the decisive moment of technical execution, which is important for the subject and the researcher.

d) *Methods*

For this study, the most important method was the video analysis, which enabled us to process video images based on video analysis software (Nechita & Mihailescu, 2010), and scientifically outlined millimetre based methods of calculation.

This method is applied and used for athletic training as a means of correcting technical errors in the 110 meters hurdles tryout in order to achieve sports performance. This method indicates a way to improve running technique in hurdling.

Way of illustration of measuring kinematics parameters

The indicators of kinematics parameters used for the monitoring of the technical preparation of the 110 meters hurdles tryout are:

Vx – The speed of horizontal separation when attacking the hurdle;

Vy – The speed of horizontal landing;

Hs – **The hip point height above ground;**

Hsg – **The maximum distance of the point of the hip** over the hurdle;

F2 – The angle of the scapular-humeral joint with the ankle joint on attacking the hurdle;

F3 – The angle of the scapular-humeral joint with leg (attacking leg), when landing on the ankle joint;

Vtg – **Phase of flight time over the hurdle;**

Dx – The horizontal distance to the hurdle plane;

Dy – The horizontal distance of the landing after the hurdle.

The working procedure used is based on advanced technological tools: computer software and video analysing it. After designing of these compositions, digitalisation is used to mark each parameter separately depending on each of the motor cinematic action phases. These specific motor phases of the hurdles runner's step will be found under the following names:

F1 - pulse phase before hurdle;

F2 - attacking ascending phase;

F3 - shift of the hurdle phase;

F4 - landing descending phase;

F5 - touching the ground phase.

Each phase has a coefficient called the "frame" and shared playing time. Processing AVI focuses on the following possibilities:

- Making compositions using the software;

- Transporting the images through each phase (F1, F2, F3, F4 and F5) using spread sheets and their translation into descriptive points;

- Turning the descriptive figurative points into representations on the millimetre sheet;

- Signalling the origin of the system on the image (sheet millimetre) by developing mathematical coordinates for each stage investigated (Fig. 1).

e) *Statistical methods*

The comparative analysis of the case study is based on descriptive research instruments (imaging mathematical coordinates) (Fig. 1), applying the techniques of observation and data collection from all three assessments: initial, intermediate and final. This analysis is a qualitative method because it emphasizes the individualization of the athlete. Following the minute character of this analysis it can be said that the research conducted the comparative analysis of the determined kinematics parameter values.

The research approach is reflected in defining and describing the current situation as a comparative analysis between T1 and T3 (Table III). From a statistical point of view, the comparison of kinematics parameters of the hurdles runner's pace gives a descriptive study that highlights the relationship between Ox and Oy variables (mathematical coordinates).

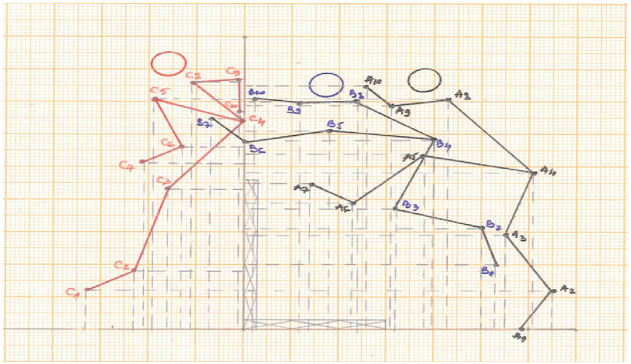

Fig. 1 – Figurative system, descriptions points A, B and C for phases F1, F2 and F3, CA.

This document provides a record for an individual athlete by developing a system of origins of each parameter using pairs of mathematical points (sets of numbers), which records and monitors at the same time kinematics parameter values for each step over the hurdle.

The descriptive representation for the hurdles runner's pace phases consists in the setting of moments of data observation using a system determined by pairs of points, which are then converted into mathematical coordinates (Ox, Oy). The exemplifying of the descriptive imaging transferred into figurative presentation for the "*horizontal separation speed when attacking the hurdle, in the case study*, CA" indicator is:

Vx consists of the following coordinates:

• F1, point A – frame 72, 2.38 sec. playback time;

• F2, point B - frame 99, 3.27 sec. playback time;

• F3, point C – frame 147, 4.85 sec. playback time;

Frame 72 = {A1, A2,....A10};

Frame 72 {A1 (5.9; 0); A2 (6.5; 1.2); A3 (5.5; 2.9); A4 (6.1; 4.8) A5 (3.8; 5.9); A6 (2.3;3.9); A7 (1.4; 4.5); A8 (4.3; 7.1); A9 (3.1; 6.9); A10 (2.6; 7.5)};

Frame 99 = {B1, B2,....B10};

Frame 99 {B1 (5.3; 2); B2 (5; 3.1); B3 (3.2; 3.7); B4 (4; 5.8) B5 (1.8; 6.1); B6 (0; 5.7); B7 (-0.7; 6.5); B8 (2.4; 7); B9 (1.2; 6.9); B10 (0.2; 7.1)};

Frame 147 = {C1, C2,....C10};

Frame 147 {C1 (-3.3; 1.2); C2 (-2.3; 1.8); C3 (-1.7; 4.3); C4 (0; 6.4) C5 (-1.9; 7.1); C6 (-1.3; 5.6); C7 (-2.1; 5.1); C8 (-1.1; 7.6); C9 (-0.1; 7.7); C10 (-0.1; 6.7)};

t = changes Frame 72, Frame 99, Frame 147/time unit;

t = (2.38+3.27+4.85)/25 frames/sec.;

t = 0.42 sec. real time;

Vx = d/t;

Vx = 1.3685 m/0.42 sec.;

Vx = 3.25 m/sec.

The kinematics parameter values were recorded on individual data sheets at the moments when they were determined. Their record allows for the observation of positive or negative time and the correction of objectively detected technical individual errors.

Results

Methodological recommendations on optimizing technical training workout

After the determination of kinematics parameters values, the following technical faults of the subject (CA) were found:

Table I

Technical errors detected by video analysis CA, T1.

Kinematics parameters	Technical errors CA/T1
Vx	Work movements involved in F1-F3 phases are slow.
Vy	The moment of "floating" from the hurdle plane to the ground.
Hs – Hsg	Too high hurdle crossing.
F2	Inadequate trunk working when crossing the hurdle.
F3	The descent stage of the attacking leg with the trunk slightly bent backward.
Vtg	The work of the segments involved in the crossing of the hurdle is too slow.
Dx	The placement of the trailing leg before the hurdle is inadequate.
Dy	Improper movements of the foot descent on attacking the hurdle

The identified faults are due to the following aspects (Table II):

Table II

Causes of errors determined from video analysis in CA T1.

Case study	Technical errors	Causes of errors
CA	The activity of the movement involving F1-F3 phases is slow.	Lack of coordination of movements involved in the attack of the hurdle and poor development of motor qualities involved in the movement.
CA	The moment of "floating" from the hurdle to the ground.	The mass centre of the body is located too high above the hurdle.
CA	Too high hurdle crossing compared to both models.	The distance from which the hurdle is attacked is too small.
CA	Inappropriate working of the trunk when crossing the hurdle.	Insufficient bending of the trunk when crossing the hurdle.
CA	Improper movements of the attacking leg after descending.	Lack of forward trunk bending during landing after the hurdle.

Correcting the determined technical errors after the initial assessment can be made easier using video analysis, which has the role to show the mistakes in the hurdle crossing phase sequence. The correction of mistakes should start with the errors in the crossing of the hurdle and only subsequently will the other technical mistakes of secondary importance be eliminated. However, in many cases the correction of the main errors entails the correction of secondary ones.

After finding these technical mistakes with the help of this software and identifying the causes of the errors, there is a shift in sports practice towards the correct methodology, using specific individual work, with a variety of specific exercises, aimed at effectively correcting technical errors.

Thus, the study of video analysis objectively determines the necessary methods for correcting the technique, based on the kinematics modelling parameters that play an important role in analysing the athlete's own movements when crossing the hurdle. It provides athletes with the opportunity to compare model results to their own representations.

After an appropriate routing of the specific preparation indicators, the negative effects of technology improved towards the end of the annual cycle, which is demonstrated by the comparative dynamics of the formulated value of T1 and T3 - case study (CA). We should mention that the test subject was recovering from an injury at T2, but this obstacle was overcome, the subject having positive values, thus confirming the effectiveness of the individualized amendatory training program applied.

Table III

Comparative dynamics of the formulated value of T1 and T3, CA.

Kinematics parameters	CA		Differences CA/T1-T3
	T1	T3	
Vx	3.25 m/sec	2.49 m/sec	0.76 m/sec
Vy	1.04 m/sec	1.02 m/sec	0.02 m/sec
Hs	1.4845 m	1.4613 m	0.0232 m
Hsg	0.4175 m	0.3943 m	0.0232 m
<F2	40°	32°	8°
<F3	110º	98º	12°
Vtg	0.510 sec	0.707 sec	0.197 sec
Dx	1.3685 m	1.5541 m	0.1856 m
Dy	0.6494 m	0.8350 m	0.1856 m

Toma (2002) states that sciences (mathematics, informatics and cybernetics) are becoming increasingly retrievable in the field of sports, becoming the essence of sports training. The author says that, at a global level, they are "basic components in training not only for great performers, but also in the preparation of future performers". If we relate our findings to the essence of the article, we can conclude from what the aforementioned author states that research is based on the opportunity to experience "effects, limitations and advantages of new technologies" and the use of the camera and image processing in the case of athletes is part of this (Toma, 2002).

Discussion

The technical correction of the determined errors can be done easily using video analysis, which shows the mistakes in the hurdle crossing phase sequence.

Table III presents the kinematics parameters determined from tests T1 and T3 and the differences between these tests.

- CA has a difference in horizontal velocity to the hurdle plane of 0.76 m/sec. This difference is favourable because the subject improved the Dx parameter value. The subject experienced an increase of 0.18 m in the Dx parameter.

- The parameter Vy: CA has a difference of 0.02 m/sec. This difference expresses an improvement in the Dy technical parameters. The subject showed an improvement of 0.18 m.

- The comparative analysis of the Vtg parameter shows a value of 0.19 sec. This reflects an individual technical improvement in this parameter.

- Values of parameters Hs and Htg: positive differences were found. The reported differences were 0.02 m. This shows the improved technique in crossing the hurdle, which confirms that work was efficiently done based on the training program.

- Individual progress is favourable for F2 and F3, from 40° to 32° in F2 and 110° to 98° in F3. This results in a favourable difference of 8° and 12° in F2 and F3.

- In terms of the kinematics parameters Dx and Dy, CA has a difference of 0.18 m for Dx and Dy. We can say that these are the most important parameters because their values depend on other kinematics parameters involved in the act of crossing the hurdle.

These comparative increases from a test to another over a relatively short time period suggest the performance of efficient work aimed at improving the runner's stride technique and thus achieving athletic hurdles performance.

Conclusions

1. Using the "Adobe after effects" and "Quick AVI Splitter" software, an example of good practice in the use of advanced technology, for measuring and analysing kinematics parameters of hurdles runner's pace for the purpose of monitoring the various stages of preparation proved to be an adequate technical training objective for the 110 meters hurdles tryout.

2. The video analysis revealed a series of technical mistakes in the execution of the hurdles runner's steps, deficiencies in technical training. After detecting the technical errors with this software and identifying the causes of errors in the kinematics parameters, we could move towards individualized correction methodology, using a variety of specific exercises for the effective correction of technical errors. Thus, the video analysis study objectively determined the methodical steps necessary for the rationalization of the technique, based on kinematics modelling parameters, with an important role in analysing the athlete's own movements when crossing the hurdle.

3. For the correct application of this interdisciplinary research we recommend the effective use of this sports training model, taking into account the methodological aspects of the tryout.

Conflicts of interests

Identifying the equipment and instruments within Department D04 "Advanced Mechatronic Systems", Faculty of Mechanical Engineering, Transylvania University Braşov.

Acknowledgement

The article is based on the results of the author's doctoral thesis.

References

Allen D. Antrenamentul ciclic-o metodă cu o largă adaptabilitate. În Sportul de performanţă 133. Ed. CCEFS, Bucureşti, 1976, 49-53.

Ballesteros JM. Manualul antrenamentului de bază. Ed. CCPS, Bucureşti, 1993; 5-64.

Bidiugan R. Analiza bibliografiei privitoare la utilizarea informaţiei de cinematică în sportul de performanţă. Raport de cercetare, nr.1, IOSUD Universitatea din Piteşti, FEFS, 2009.

Bompa T. Teoria şi metodologia antrenamentului - periodizarea. Ed. Ex Ponto, Bucureşti, 2002; 5-13.

Demeilles L. Antrenamentul atletic. Ed. CCEDT, Bucureşti, 1972; 141.

Grosz WR. Antrenamentul mental în schiul alpin. Internaţional Scientific Conference, New educational evolutions for sports, management, health therapy and free time in european context. Transilvania University of Braşov Publishing House, Braşov, 2009; 201-203.

Homenkov L.S. Bazele ştiinţifice ale sistemului contemporan de antrenament utilizat în atletism. Autoreferat al tezei de doctorat, Moscova, 1963; 23.

Kirsch A. Cu ce să începem sportul la copii şi juniori. Ed. SDIS, Vol III, Bucureşti, 1969; 38-39.

Mihai I. Researches concerning the utilization of the kinematicanalysis movement software in 2d system - Dartfish in the male triple jump event technique monitoring. Ovidius University Annals-Series Physical Education and Sport, Supp, 2010; 10(2):517-520.

Monea G, Monea D. Măsurări şi evaluări în sportul de performanţă, Ed. GMI. Cluj-Napoca, 2008; 122.

Nechita F, Mihăilescu L. Optimizarea pregătirii tehnice prin monitorizarea elementelor cinematice în proba de 110 metri garduri. Palestrica Mileniului III, 2010; 11(4):357-361.

Potop V, Câmpeanu M, Toma-Uricheanu S. Influenţa mijloacelor specifice de pregătire şi dinamica parametrilor efortului în învăţarea elementelor tehnice din gimnastica artistică feminină. Palestrica Mileniului III. 2010; 11(4):332-339.

Raţă G. Psihopedagogia sportului de performanţă. Note de curs, Ed. Univ. Bacău, 2005; 7-12.

Skinner JS. The influence of genetic factors on the response to exercise and training general principles of exercise prescription. Conf. Fitness and Physical Activity, Braşov, 2010, mai 27.

Toma Ş. Utilizarea simulatorului de condiţii ca mijloc de corectare a tehnicii la copii înotători (10-12 ani) (note preliminare). Preocupări actuale de optimizare a activităţii de educaţie fizică şi sportive de performanţă. Conferinţă Internaţională de Comunicări Ştiinţifice, Galaţi, 31 mai-1 iunie 2002; 195-199.

Vealey RS. Antrenamentul intern prin reprezentare mentală. Sportul de performanţă 315. Ed. CCPS Bucureşti, 1991; 31-42.

Wazny Z. Dezvoltarea sistemului de antrenament sportiv. Metodologia antrenamentului. Ed. CCPS, Bucureşti, 2000; 51-75.

Visited Websites

(1) Milan Č. Colin Jackson's Hurdle Clearance Technique. Biomechanical Laboratory, Faculty of Sport, University of Ljubljana, Slovenia - http://www.coachr.org/hurdles.htm visited 2010

(2) McDonald C. Indiana University The Angular Momentum Of Hurdle Clearance. http://www.coachr.org/hurdles.htm visited 2010

(3) Kruger A, Edelmann-Nusser J. Biomechanical analysis in freestyle snowboarding: application of a full-body inertial measurement system and a bilateral insole measurement system. Sports Technology. 2009; 2(1–2):17-23 http://onlinelibrary.wiley.com/doi/10.1002/jst.89/pdf visited 2010.