©Journal of Sports Science and Medicine (2011) **10**, 472-477
http://www.jssm.org

Research article

A low-cost contact system to assess load displacement velocity in a resistance training machine

Bernat Buscà ✉ and Anna Font
Faculty of Psychology, Education Sciences and Sport Blanquerna – Ramon Llull University, Barcelona, Spain

Abstract
This study sought to determine the validity of a new system for assessing the displacement and average velocity within machine-based resistance training exercise using the Chronojump System. The new design is based on a contact bar and a simple, low-cost mechanism that detects the conductivity of electrical potentials with a precision chronograph. This system allows coaches to assess velocity to control the strength training process. A validation study was performed by assessing the concentric phase parameters of a leg press exercise. Output time data from the Chronojump System in combination with the pre-established range of movement was compared with data from a position sensor connected to a Biopac System. A subset of 87 actions from 11 professional tennis players was recorded and, using the two methods, average velocity and displacement variables in the same action were compared. A t-test for dependent samples and a correlation analysis were undertaken. The *r* value derived from the correlation between the Biopac System and the contact Chronojump System was >0.94 for all measures of displacement and velocity on all loads ($p < 0.01$). The Effect Size (*ES)* was 0.18 in displacement and 0.14 in velocity and ranged from 0.09 to 0.31 and from 0.07 to 0.34, respectively. The magnitude of the difference between the two methods in all parameters and the correlation values provided certain evidence of validity of the Chronojump System to assess the average displacement velocity of loads in a resistance training machine.

Key words: Velocity, testing, strength training, speed events.

Introduction

Training techniques that simulate the velocity profiles associated with the functional performance of each discipline, such as throw or jump training, may optimize functional adaptation (De Villarreal et al., 2009). The time to move the different resistance training loads, the range of movement completed in each repetition, the velocity produced in such movements and the power exerted in each load are especially useful to control the training process. Coaches are able to readjust training programs in real time while taking into account the kinematic parameter data obtained for several important exercises in resistance training including bench press, leg press, half squat and leg extensions. In this respect, resistance training is relevant in modern sport and has generated several research efforts on assessment methods and instruments in recent years. Working together with physicians, biomechanists and physiologists, sport coaches have contributed to the development of more accurate, valid and reliable systems to assess kinematic variables in resistance exercises. Thus, optical encoders, cinematographic video analysis and accelerometry have been used to measure output velocity in resistance training exercises (Bosco, 1995; Cormie et al., 2007; Drinkwater et al., 2007).

Several validity studies related to this technology have reported their utility for assessment of the kinematic parameters for muscular work. For example, Drinkwater et al. (2007) compared the power output of an optical encoder controlled by newly designed software with 50-Hz video recording and reported variation coefficients ranging from 1.08% to 3.06% in squat, throw and bench press exercises respectively. Jandačka and Vaverka (2009) proposed a new system to measure mechanical power output during a bench press exercise; their Qualysis system combines dynamic and kinematic measurements. To obtain the exact position in time and space, eight high speed video cameras captured motion of certain points in space at a frequency of 240 Hz. When validating the system against a force platform output, they did not find significant differences in motion velocity. However, a significant difference in average force exerted was found. Leard et al. (2007) performed a validation study of vertical jump simultaneously assessed by a jump mat, a Vertec® tool, with a 3-camera motion analysis system as a criterion reference. In this study, highly significant Pearson correlations were found between the three methods, but an analysis of variance showed significant differences between the Vertec® jump apparatus and video system outcomes (p=0.97). Hutchinson and Stone (2009) estimated the concurrent validity between a new vertical jump height measurement system (the Vertical Jump Mat) and the Vertec® system. The authors reported a significant relationship ($R^2 = 0.83$; $p < 0.001$) between both devices. While this type of technology is particularly useful for coaches, accessibility may be limited due to high-cost, exercise movement limitations or a complex output data analysis. A low-cost technology that uses the same systems to assess jump, free barbell exercises and resistance training machines may present a better solution for coaches and sportsmen.

The jump mats with a chronograph system are a contact system that provides reliable and precise data about speed events in sport. Taking into account the basis of this assessment methodology, another kind of contact system permits control of other speed events apart from jumps. In this respect, Chronojump is a useful system created for the assessment and data management of speed actions in sport based on a precise chronograph (chronopic) that detects electric potential changes. The system consists of free software that uses the open hardware Chronopic (De Blas and González-Gómez, 2005). The

Received: 02 March 2011 / Accepted: 05 June 2011 / Published (online): 01 September 2011

signal of Chronopic V.3 was tested for its reliability and validity through a comparison between an oscilloscope and the Chronopic output data of square waves from 9 to 1.5 Hz at intervals of 0.5 Hz (De Blas et al., 2009). The average error at high and low signal was 0.04% and 0.13%, respectively. The open character of this technology consists of a complete guide available for download, the software installation and an application to buy or build the hardware and sensors. Thus, the accessibility of the system and the low cost of materials and components constitute a valuable tool for sports coaches and, at the same time, a precise instrument for research in speed event measurements.

Using the Chronojump system, contact sensors to control the output velocity in a bench press exercise were proposed (Buscà and De Blas, 2008). In this study, the authors compared the new contact system against an optical linear encoder connected to the Musclelab® acquisition data system. A mean relative error of 2.26% (± 1.04%) was found, but observing the correlation values for each load, an assessment problem was detected on the lowest loads (20 kg). Upon attending to this circumstance, a new relative error was calculated excluding the 20-kg actions with a significant diminution of mean relative error (1.85% ± 0.98%). The authors detected some problems with the stiffness of the contact system, which were provoked by fluctuations in the range of movement in resistance training exercises executed at high velocities. They concluded that a more compliant contact system could better detect these fluctuations and improve the validity of measurements, and suggested that the system could be adapted to any resistance training machine.

Hence, the aim of the present study was to examine the validity of a new system to assess the displacement velocity of a resistance training machine. For this purpose, functional resistance exercise data were analyzed. It was hypothesized that the range of movement and mean velocity outcome of a leg press exercise assessed by the Chronojump System was not significantly different from the outcome obtained by a position sensor connected to the Biopac System.

Methods

Description of the system

The system consists of a double conductive contact bar connected to a skypic (Chronopic) that records time at 1000 Hz. The skypic is also connected to a personal computer (PC) with Chronojump 0.9 software for data evaluation. The newly developed Chronopic v.3 system (Figure 1) only contains the components needed for sports time assessment (e.g., Bosco tests). It is licensed as open hardware to be accessible, allow derivative development and to be fully peer-reviewable.

The contact bars consist of 20-cm long iron sticks (4 mm in diameter) subjected to a suction pad on one of the edges. The suction pad has dual properties. First, they facilitate the ability to fix the bars at any position on the plastic panels that cover the load system in resistance training machines. Second, they possess the necessary compliance properties to adapt to minimal variations at the upper limit of the range of movement (ROM). Through a conductive cable, this part of the circuit is connected to a positive pole of skypic. The other part of the circuit is an iron stick that fixes the load and is connected through another cable that goes to the negative pole of the skypic (Figure 2). At the upper limit of the ROM, the iron bar is moved up because of the pre-measured ROM is not the real ROM completed in each repetition. The compliance and elasticity of the suction pad permit a contact time that will be used to calculate the real ROM. Afterwards, the skypic (0.05 kg in mass, 0.07 m x 0.05 m x 0.01 m (W x L x H) in dimension) sends the signal using the USB port on a PC correctly configured using the Chronojump Software utilities (see Figure 1).

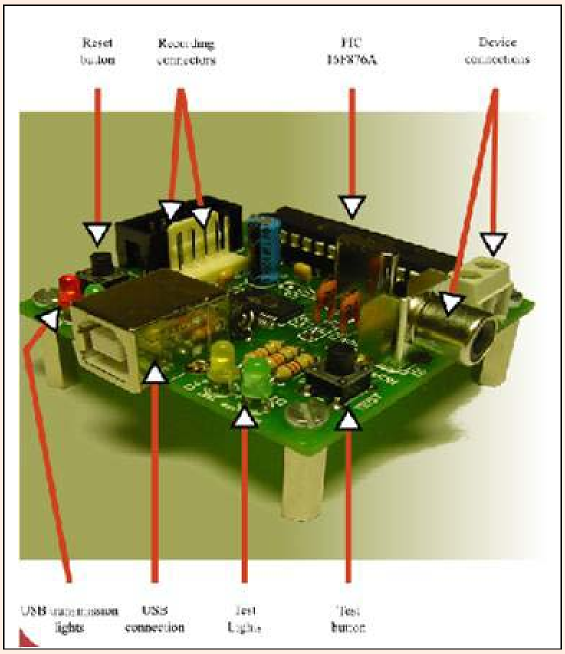

Figure 1. View of Chronopic v.3

Subjects

A group of 10 healthy professional tennis players (7 female and 3 male, age = 20.2 ± 3.2, height: 1.74 ± 0.04, weight: 60.4 ± 5.2, national ranking: 10.2 ± 3.3), members of a training group based at the International Training Tennis Center of Barcelona, were voluntarily recruited for this study. The study and its protocol was reviewed and approved by the Research Ethic Committee of Ramon Llull University of Barcelona (Spain) and conducted in accordance with recognized ethical standards.

Experimental design and data collection

Measurements were performed simultaneously using two methods. The contact system connected to a Chronopic recorded the time for each phase of movement (concentric and eccentric) using the contact sensors and the data were sent to the Chronojump 0.9 software. Concurrently, a position sensor WSB 16k-200 (ASM, Inc., Moosinning, Germany) connected to a Biopac MP100 through the transducer amplifier DA100C (Biopac Systems, Inc., CA, United States) recorded variations in position during the exercise, and the software Acqnowledge 3.0.9. (Biopac Systems, Inc., CA, United States) plotted and recorded the position and velocity on a time scale. In addition, the contact iron sticks were also connected to the Biopac System to analyze the contact time through a digital channel of the HLT100C transducer and plotted together with the other signals in the Biopac System. Hence, pre-measured displacement, non-contact time and contact time were recorded by Chronojump System. In the same action, time, variations of position and velocity were recorded by Biopac System. The Biopac System, transducer and the position sensor used for the experiment provided the possibility to adjust the sampling rate parameters and to manipulate the gain and filter options to obtain the input signal from the contact system in the same action. Through the sensitivity of the system and the functions of the software, calculated data and plots were available in a real-time scale. This system was used in different muscle physiology studies (Adams et al, 2004; Wang et al., 2005).

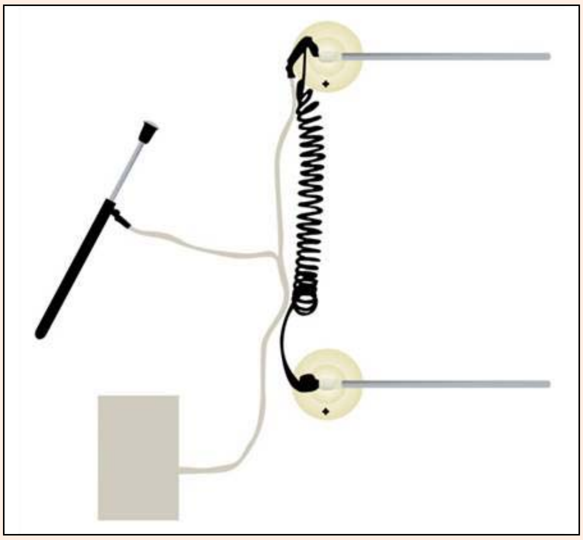

Figure 2. **A schema of the contact system.**

Prior to exercise data collection, anthropometric measurements (weight and height) were obtained. First, a static measurement of range of movement in a leg press machine (Technogym, SpA Inc., Gambettola, Italy) was established and iron stick sensors were placed at the lower and upper limits using the suction pads (see Figure 3). The technique for the leg press exercise, as described by Zatziorsky and Kraemer (2006), was explained to the subjects and corrected. The motion range was individually adjusted and controlled by means of a light controlled signal (Chronopic) in the highest and lowest peak of the motion trajectory. After a simple warm-up including dynamic global movements and a specific leg press machine familiarization with a 20-kg load, subjects were asked to complete 3 sets of 10 repetitions using a leg press machine using 40, 50 and 60 kg loads respectively as fast as possible. The use of these specific loads permits the development of maximum power of the subjects in the leg press machine. Data to support this was provided by the coach and previously measured by a linear encoder with Smartcoach® device. The small hook of the position sensor was placed on the iron stick that fixes the load in the resistance training machine and the optical sensor was placed on the floor vertically below the iron stick. Rest time was 3 minutes between sets, on average, while the experimenters adjusted the load and reset the data measurement systems to a ready state. Each set was assessed by both systems, and the output data of contact and non-contact time from the Chronojump System was immediately recorded into a Microsoft Excel® spreadsheet. The experiment lasted 15 minutes, on average, per subject. After the experiment, data from the concentric phase of each repetition from the Biopac System signal was calculated using Acqnowledge 3.0.9. software.

Figure 3. **The system adapted to a leg press training machine.**

Data analysis

Only the validity of the concentric phase was analyzed in this functional study because a controlled velocity in an eccentric phase is a safety technique to avoid injuries working with this type of machines. Consequently, the subjects were only required to press as powerful as possible during the concentric phase. Firstly, the Biopac System output data consisted of change in position in a vertical plane (Displ_BS) in m, peak velocity (PV_BS) in m·sec^{-1}, mean velocity (MV_BS) in m.sec^{-1} and duration (Time_BS) in sec. The mean of the average velocity of the duration from the contact with the upper limit of the time-point corresponding to the greatest value of the position peak, was also calculated. This permits establishment of the coefficient associated with the mean velocity for the noncontact time and the pre-measured distance. This coefficient was established by dividing the pre-measured distance by time, as assessed by the Chronojump System. Afterwards, the mean velocity and the first half of the contact time were used to extrapolate the additional distance covered by the iron sticks at the end of the concentric phase. The Chronojump System (CS) output data consisted of: the distance of range of the pre-measured movement ($preDispl_{CS}$) in m, concentric non-contact time ($NCTime_{CS}$) in sec and contact time in the upper limit ($CTime_{CS}$) in sec.

To calculate the time for the entire concentric phase ($Time_{CS}$) the following equation was used:

$Time_{CS}=[(NCTime_{CS} + CTime_{CS})]*2^{-1}$

The estimated range of movement ($Displ_{CS}$) using the Chronojump System was calculated using the following equation:

$Displ_{CS} = preDispl_{CS} + [(preDispl_{CS}*(NCTime_{CS})^{-1})*(CTimeCS*2^{-1})]$

The estimated mean velocity (MV_{CS}) using the Chronojump System was calculated using the following equation:

$MV_{CS} = Displ_{CS}*(Time_{CS})^{-1}$

Statistical analysis

Standard statistical analysis methods were used to calculate means and standard deviations. A student's t-test for dependent samples was used to test the null hypothesis that the Chronojump range of movement measurement and the mean velocity was not different from the Biopac System's position sensor measurements. The magnitude of the difference was determined by the Effect Size (Cohen, 1988). The Effect Size was considered either small ($0.2 < ES \leq 0.5$), moderate ($0.5 < ES \leq 0.8$) or large ($ES > 0.8$) (Nakagawa and Cuthill, 2007). A correlation analysis was performed to evaluate the relationship between the two measures by calculating the Pearson product moment correlation. Following the method of Hopkins (2010), we considered a correlation over 0.90 as nearly perfect, between 0.70 and 0.89 as very large, and between 0.50 and 0.69 as large. In addition, linear regression was calculated for the displacement data when comparing the systems. Statistical analysis was performed using a statistical software package SPSS (Version 18.0 for Windows, SPSS, Inc., Chicago, IL). Significance was accepted at $p < 0.05$ for all tests.

Results

The mean of the non contact time for all lifts was 0.59 ± 0.06 sec (range, 0.47 to 0.78) and was the same for both measurement systems because the duration of each concentric phase with the Biopac System was checked with a contact system and plotted for the time-scale. The mean distance obtained by the Biopac System was 0.36 ± 0.05 m (range, 0.25 to 0.47), and the mean distance obtained by the Chronojump System was 0.35 ± 0.04 m (range, 0.24 to 0.43). Mean velocity obtained by the Biopac System was 0.61 ± 0.07 $m \cdot s^{-1}$ (range, 0.43 to 0.85), and the mean velocity obtained by the Chronojump System was 0.59 ± 0.06 $m \cdot s^{-1}$ (range, 0.43 to 0.76). The Standard Error of Measure (*SEM*) ranged from 0.001 to 0.002 for all loads. The validity of the distance and velocity measurements using the Biopac System with position sensors and the Chronojump system are expressed with 95% confidence limits. The *ES* was 0.18 in global distance (displacement?) and 0.14 in velocity and ranged from 0.09 to 0.31 and from 0.07 to 0.34, respectively (Table 1). The *r* value derived from the correlation analysis between the Biopac System and the contact Chronojump System was >0.94 for all measures of distance and velocity on all loads ($p < 0.01$). The linear regression equation of the relationship between displacements assessed by both methods (Figure 4) was:

$y = 0.916x + 0.020$

Discussion

The main finding was the high validity of displacement and velocity estimation by the Chronojump System and valuable data for accuracy in comparison with the criterion data from the Biopac System with the position sensor. The non-contact time value of both devices was the same because the contact system was also connected to Biopac System through a digital channel. This connection permits the determination of the exact contact point together with position and velocity parameters in the Biopac System. Average velocity and distance estimation from the Chronojump System did not significantly differ with respect to the selected criteria for all loads once we established the paired differences. Furthermore, when we considered the effect size correlation, a small magnitude in the difference (Cohen, 1988) was found for both parameters for all loads (Table 1). According to these data, Jandacka and Vaverka (2009) found similar values of the effect size when they compared velocity data from the Qualysis photogrammetric system and the dynamometric system in a bench press exercise. Concretely, they reported an ES of 0.35 for the lightest load tested (18 kg) and an ES of 0.05 for the heaviest load tested (47.7 kg). In this respect, the correlation data reported in this study

Table 1. The validity of the Chronojump System, compared with the Biopac System, and the linear encoder (criterion measure) distance and velocity calculations (n=10).

Parameter	Paired Differences			95% confidence interval of mean differences				
	M	*SD*	*SEM*	Lower	Upper	t value	df	Significance
Distance 40kg	-.007	.014	.001	-.010	-.004	-4.83	86	.000
Distance 50kg	.015	.011	.001	.012	.017	11.30	77	.000
Distance 60kg	.031	.013	.001	.028	.035	21.00	75	.000
Velocity 40kg	-.012	.024	.002	-.017	-.007	-4.76	86	.000
Velocity 50kg	.027	.020	.002	.022	.031	11.81	77	.000
Velocity 60kg	.056	.019	.002	.051	.060	24.81	75	.000
Global Distance	.012	.020	.001	.009	.014	9.19	242	.000
Global Velocity	.022	.035	.002	.017	.026	9.66	242	.000

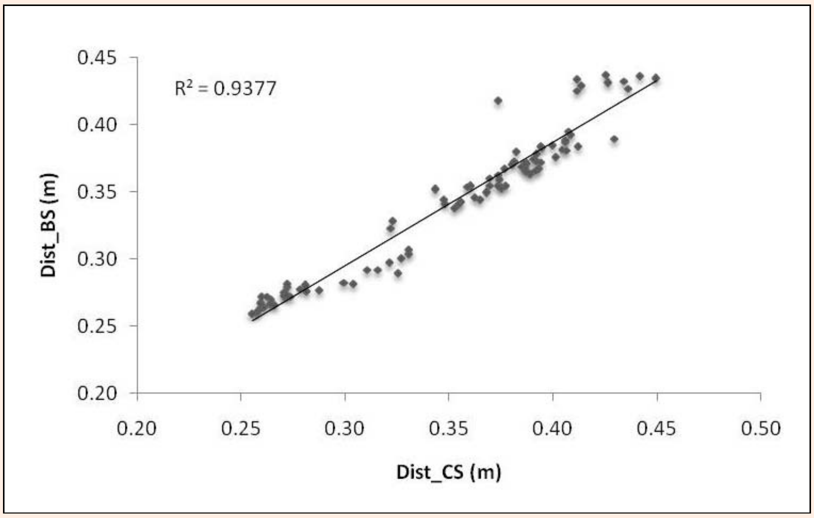

Figure 4. The association between the distances measured by both methods.

confirm the validity of the Chronojump system, because all the correlations were ≥0.94. We could consider these values as a reflection of the similarity of both the systems. Drinkwater et al. (2007) obtained Pearson product moment correlations greater than 0.97 in a bench press power output validity study. They also reported coefficients of variations ≤3% for power output in all movements. Moreover, Buscà and De Blas (2008) reported correlation values ≥0.96 for average velocity between the Musclelab System and another Chronojump contact system. They also reported similar values for other kinematic parameters including time, displacement and power output.

The major problem detected by Buscà and De Blas (2008) in the contact system was the stiffness of the sensors. This stiffness resulted in worse displacement estimation and, consequently, lower correlation values compared to the criterion system. The authors concluded that the inclusion of a more compliant sensor would improve displacement estimation and thereby justify validating the new contact system to assess the velocity of displacement in a resistance training machine or in a free weight barbell. In this respect, the increased compliance offered by the suction pads improved the sensitivity of the system, because the contact time to the upper limit iron sticks was taken into account for the displacement estimation. Thus, the linear regression value is better (R^2= 0.93 reported in the present study) with respect to the less compliant system (R^2 = 0.85 in the cited study). The increased compliance is a valuable characteristic of other systems based on optical encoders including Gymaware (Kinetic Performance Technology, Mitchell ACT, Australia) and Musclelab (Ergotest Technology A. S., Langensund, Norway). However the high cost of these technologies prevents frequent access by coaches for both training and testing.

With respect to the increased inter-system differences in displacement and velocity with higher loads, this may be caused by the static pre-measured ROM protocol. The subjects were asked to remain static for about 3 seconds to help establish the exact position of the iron stick in its upper limit. With heavier loads, the subjects may be less precise in maintaining the static position for the necessary time to determine the upper limit by the experimenter. Nevertheless, despite the fact that the magnitude of the inter-system differences was already small, this factor should be taken into careful consideration during the testing protocol.

The practicality of the new system appears to represent a useful choice for coaches and athletes. The low cost of the sensors together with the availability of the system permits the use of Chronojump during resistance training sessions for every sport. Using the system, coaches and athletes are able to assess these primary factors to control velocity, work and power of each repetition and by acquiring real-time feedback for these parameters. For power estimation, the dynamics and the kinematics of limb motion for a given exercise should be taken into account as suggested by Jandačka and Vaverka (2009). For this reason, the Chronojump software (version 0.9) only provides time and average velocity for the pre-established distance but no power values. In addition, velocity feedback is provided by the Chronojump software through pre-established resistance training intervals of velocity in moving the loads, as is characteristic of the mentioned systems in some of their validity studies: Ergopower (Bosco, 1995), Musclelab (Amonette et al., 2003) and Gymaware (Cronin et al., 2004). This feedback consists of an acoustic signal that provides information about the athlete's adjustment at a certain speed range programmed by the coach and based on testing data of peak velocity for each exercise in resistance training.

Conclusion

In conclusion, the Chronojump contact system is a valid tool for assessing displacement velocity in a resistance training machine. The compliance of the system and its versatility facilitate ease of use in any resistance training machine. The hardware and software conform to open license standards and could represent a no-cost solution for strength and conditioning coaches, physical education teachers and athletes. Nevertheless, to become a useful device for resistance training sessions further research is needed. The system with the compliance of the suction pads could be tested in a free weight barbell bench press or any vertical displacement exercise. For this purpose, it is necessary to design a panel to correctly fix the suction pads. Moreover, the testing protocol could be replicated with other resistance training machines to determine the validity of the device in other types of movements. Besides, the data obtained by Chronojump System could be confronted against a photogrammetric analysis using high-speed video cameras and other encoder-based devices available in the market.

Acknowledgements
No funds from any organizations were received for this work and the authors have no conflicts of interest directly relevant to the content of this paper. We would like to recognize the Chronojump contributors' efforts, especially the work of Xavier De Blas.

References

Adams, G.R., Cheng D.C., Haddad, F. and Baldwin, K.M. (2004) Skeletal muscle hypertrophy in response to isometric, lengthening, and shortening training bouts of equivalent duration. *Journal of Applied Physiology* **96**, 1613-1618.
Amonette, W.E., Casperson, S., Bentley, J., DeWitt, J.K., Garcia, Y. and Guilliams, M.A. (2003) Evaluation of the MuscleLab Power Testing System using bench press and leg press exercise (ROI_MusLab). *Nasa Report* **12**.
Bosco, C. (1995) Evaluation and control of basic and specific muscle behavior. *Exercise & Society Journal of Sport Science* **10**, 10-29.
Buscà, B. and De Blas, X. (2008) A new low-cost gadget design to measure weight bar velocity in a bench press using Chronojump. In: *Book of abstracts 13th Annual Congress of ECSS, Estoril, Portugal 9-12 July*. 443.
Cohen, J. (1988) *Statistical power analysis for the behavioral sciences* Hillsdale, N.J.: L. Erlbaum Associates.
Cormie, P., McBride, J.M. and McCaulley, G.O. (2007) Validation of power measurement techniques in dynamic lower body resistance exercises. *Journal of Applied Biomechanics* **2**, 103-118.
Cronin, J.B., McNair, P.J. and Marshall, R.N. (2002) Is velocity-specific strength training important in improving functional performance? *The Journal of Sports Medicine and Physical Fitness* **42**, 267-273.
Cronin, J.B., Hing, R.D. and McNair P.J. (2004) Reliability and validity of a linear position transducer for measuring jump performance. *Journal of Strength and Conditioning Research* **18**, 590-593.
De Blas, X. and González-Gómez, J. (2005) *Proyecto Chronojump: Sistema de Medida de la Capacidad de Salto usando Software y Hardware Libres.* Actas I Congreso de Tecnologías del Software Libre. 223. (In Spanish)
De Blas, X. and González-Gómez, J. and Gómez, R. (2009) Validity of new chronopic V.3 open hardware to measure time on jump related tests. *Medicine and Science in Sport and Exercise* **41** (Suppl. 1), 61.
De Villarreal, E.S., Kellis, E., Kraemer, W.J. and Izquierdo, M. (2009) Determining variables of plyometric training for improving vertical jump height performance: A meta-analysis. *Journal of Strength and Conditioning Research* **23**, 495-506.
Drinkwater, E.J., Galna, B., McKenna, M.J., Hunt, P.H. and Pyne, D.B. (2007a) Validation of an optical encoder during free weight resistance movements and analysis of bench press sticking point power during fatigue. *Journal of Strength and Conditioning Research* **21**, 510-517.
Hopkins, W.G. (2010) A scale of magnitudes for effect statistics. *Sportscience*. Available from URL: http://www.sportsci.org/resource/stats/effectmag.html. Accessed 12/9/2010.
Hutchison, A.T. and Stone, A.L. (2009) Validity of alternative field system for measuring vertical jump height. *Journal of Exercise Physiology Online* **12**, 6-11.
Izquierdo M., Häkkinen K., Gonzalez-Badillo J., Ibáñez J. and Gorostiaga E.M. (2002) Effects of long-term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports. *European Journal of Applied Physiology* **87**, 264-271.
Jandaĉka, D. and Vaverka, F. (2009) Validity of mechanical power output measurement at bench press exercise. *Journal of Human Kinetics* **21**, 33-43.
Leard, J.S., Cirillo, M.A., Katsnelson, E., Kimiatek, D.A., Miller, T.W. and Trebincevic, K. (2007) Validity of two alternative systems for measuring vertical jump height. *Journal of Strength and Conditioning Research* **21,** 1296-1299.
Nakagawa, S. and Cuthill, I.C. (2007) Effect size, confidence interval and statistical significance: a practical guide for biologists. *Biological Reviews Cambridge Philosophical Society* **82**, 591-605.
Wang, Y.T., Cheng, S., Limroongreungat, W. and Change, L.S. (2005) Contributions of selected fundamental factors to wheelchair basketball performance. *Medicine and Science in Sport and Exercise* **37**, 130-137.
Wernbom, M., Augustsson, J. and Thomeé, R. (2007) The Influence of frequency, intensity, volume and mode of strength training on whole muscle cross-sectional area in humans. *Sports Medicine* **37**, 225-264.
Zatsiorsky, V.M. and Kraemer, W.J. (2006) *Science and practice of strength training*. Champaign, Ill.: Human Kinetics.

Key points

- The assessment of speed in resistance machines is a valuable source of information for strength training.
- Many commercial systems used to assess velocity, power and force are expensive thereby preventing widespread use by coaches and athletes.
- The system is intended to be a low-cost device for assessing and controlling the velocity exerted on each repetition in any resistance training machine.
- The system could be easily adapted in any vertical displacement barbell exercise.

AUTHORS BIOGRAPHY

Bernat BUSCÀ
Employment
Prof. of Faculty of Psychology, Education Sciences and Sport Blanquerna, Ramon Llull University, Barcelona, Spain.
Degree
PhD
Research interests
Game analysis, tactical assessment, training and testing.
E- mail: bernatbusca@gmail.com

Anna FONT
Employment
PhD Student of Faculty of Psychology, Education Sciences and Sport Blanquerna, Ramon Llull University, Barcelona.
Degree
PhD candidate
Research interests
Tennis techinques, game analysis, training and testing.
E-mail: AnnaFE@blanquerna.url.edu

✉ **Dr. Bernat Buscà**
FPCEE Blanquerna. c/ Císter, 34, 08022 Barcelona, Spain