Validity of a new contact mat system for evaluating vertical jump

Article *in* Motriz. Revista de Educação Física · March 2011

DOI: 10.5016/1980-6574.2011v17n1p26

Motriz, Rio Claro, v.17 n.1, p.26-32, jan./mar. 2011 doi: http://dx.doi.org/10.5016/1980-6574.2011v17n1p26

Artigo Original

Validity of a new contact mat system for evaluating vertical jump

Noé Gomes Borges Júnior [1]
Lucas Borges [2]
Jonathan Ache Dias [3]
Marcelo Diederichs Wentz [4]
Daniela Junckes da Silva Mattos [4]
Raquel Petry [3]
Susana Cristina Domenech [1]

[1] Departamento de Ciências da Saúde da Universidade do Estado de Santa Catarina, Florianópolis, SC, Brasil
[2] Engenharia Elétrica da Universidade Federal de Santa Catarina, Florianópolis, SC, Brasil
[3] Mestre em Ciências do Movimento Humano pela Universidade do Estado de Santa Catarina, Florianópolis, SC, Brasil
[4] Mestrando em Ciências do Movimento Humano pela Universidade do Estado de Santa Catarina, Florianópolis, SC, Brasil

Abstract: The purpose of this study was to verify the validity of the flight and ground contact time measurement of a contact mat, SaltoBras (SB), comparing it to an oscilloscope (OS) and to a force plate (FP). For that, the SB was placed upon a FP. At first, four male and two female performed 15 jumps on the SB and the flight times were obtained. After, they performed six consecutive jumps and the ground contact times were obtained. SB software was valid in comparison with the OS, but underestimated the flight (~0.30 %) and ground contact (~1.01 %) time measurements when comparing it to the FP. Despite the differences, the error found between SB and FP was systematic, and two prediction equations were defined and added to the software for correction. The results suggest that SB is a valid instrument for the evaluation of vertical jump.

Keywords: Instrumentation. Validity of tests. Biomechanics.

Validade de um novo tapete de contato para avaliação do salto vertical

Resumo: Este estudo teve como objetivo verificar a validade da medida de tempo de vôo e de contato de um tapete de contato, SaltoBras (SB), comparando-o com um osciloscópio (OS) e uma plataforma de forças (PF). Para isso o SB foi colocado sobre uma plataforma de forças. Primeiramente, quatro homens e duas mulheres realizaram quinze saltos sobre o SB e o tempo de vôo foi obtido. Depois, os mesmos realizaram seis saltos consecutivos e os tempos de contato foram obtidos. O SB apresentou-se valido em relação ao OS, mas subestimou o tempo de vôo (~0.30 %) e de contato (~1.01 %) quando comparado a PF. Apesar das diferenças, o erro encontrado entre SB e PF apresentou-se sistemático e duas equações de predição foram definidas e inseridas no software para a correção dos erros. Os resultados sugerem que SB é um instrumento válido para a avaliação do salto vertical.

Palavras-chave: Instrumentação. Validade de testes. Biomecânica.

Introduction

The vertical jump is a fundamental skill extensively studied in the literature (DAVIS *et al*. 2003; HASSON *et al*., 2004). Its performance appears to provide a useful mean of estimating lower extremity functional strength and is a well-documented measure of human power (BOSCO *et al*., 1983; NEWTON; KRAEMER, 1994; CORDOVA; AMSTRONG, 1996).

The most utilized parameter for the evaluation of the vertical jump is the jump height which is considered as the displacement of the center of mass (CM) of the body from the standing position to the highest vertical position and several protocols and systems are currently employed to measure it (GARCÍA-LOPEZ *et al*., 2005; JAGGER *et al*., 2008; MUSAYEV, 2003). According to Baca (1998), the three methods used in scientific studies to evaluate the jump height are: the video-based method (VID), the method based in the vertical ground reaction force (VRF) and the flight time method (FT). The VID is considered as the reference criterion, or gold standard method, for vertical jump measurement (ARAGON-VARGAS, 2000; LEARD *et al*., 2007) and utilizes as parameters reflective markers placed on the body of the evaluated subject.

Force plates (FP) have been used and allow the vertical jump height to be estimated integrating the kinetic and temporal variables produced by the force-time curves, by analyzing the VRF which allow the jump impulse to be calculated as well as the take-off velocity and power (CORDOVA; AMSTRONG, 1996; JAGGER, 2004; LARKINS; SNABB, 1999; SACCO *et al*., 2004; LINTHORNE, 2001).

Vertical jump height has been estimated also by the flight time from a FP or by a contact mat (CMT) connected to a modified timer, utilizing computer technology for being a simple and reliable method (GARCÍA-LOPEZ, *et al*., 2005; HOPKINS *et al*., 2001; ARAGON-VARGAS, 2000), besides being portable and less expensive than VID or a FP. Based on similar principles, different commercial CMT have been utilized in the literature including the Ergo Jump® (BOSCO *et al*., 2003), the Just Jump or Run® (LEARD *et al*., 2007), SportJump® (GARCIA-LOPEZ *et al*., 2005) and Newtest Powertimer 300-series® (ENOKSEN *et al*., 2009) . In a similar way, the flight time has been measured with photosensitive cells (MUSAYEV, 2003) and also with photogrammetric systems connected to a timer (BACA, 1999; KIBELE, 1998). Besides the use of the flight time to estimate the jump height, the ground contact time is also used to estimate the muscle power of the lower limbs, as proposed by Bosco (1983).

The vertical jump height estimation based in the flight time is calculated by the formula below as shown by Kibele (1998):

$$h = \frac{1}{2} \cdot g \cdot \left(\frac{1}{2} \cdot t\right)^2 \quad (m) \qquad [1]$$

where h is the jump height (m), t is the flight time of the jump (s) and g is the acceleration of gravity (9.81 m/s^2).

However, the validity of this equation is argued by some studies (KIBELE, 1998; ARAGON-VARGAS, 2000; MOIR, 2008). According to Aragon-Vargas (2000), the FT underestimates the jump height in approximately 10 cm in relation to the VID, being necessary to use an equation suggested by the author to correct the values obtained by the FT.

Due to the necessity of our research group to have a low cost equipment to evaluate vertical jump, a new CMT system called SaltoBras (SB) was developed (hardware and software) utilizing the equation proposed by Aragon-Vargas (2000) to ensure the validity of the jump height measurement. As the method is valid, it was therefore necessary to verify the validity of the time measurement of the developed equipment, as performed by Garcia-Lopez *et al*., 2005.

Finally, the purposes of this study were: 1) to verify the time measurement validity of SB software by comparison with an oscilloscope and 2) to verify the time measurement validity of the entire system (hardware and software) by comparison of the flight and ground contact time measurements with a FP.

Methods

Participants

Four male and two female healthy volunteers (age 25.5 ± 2 years; height 1.75 ± 0.06 m; body mass 67.5 ± 5.6 kg) participated of the study. The purposes and procedures of this research were explained to each participant, who read and signed an informed consent form prior to participation. All the procedures were approved by the local Human Subjects Ethics Committee (protocol number: 14/08).

SaltoBras System

The SaltoBras system (LABIN, Santa Catarina State University, Brazil) weights 2.56 kg, with dimensions of 0.60 x 0.45 x 0.03 m (long x wide x thick) and force threshold of 5.6 N. The whole structure of the SB is covered by two anti-slip rubber films with isolated corners (figure 1a). Inside the main structure there are two flexible metallic plates (figure 1b) isolated from each other by a rubber film (figure 1c) which was hollowed into squares with 2.5 cm sides. A distance of 0.2 cm was preserved between the squares in order to ensure the electric isolation between the metallic plates, when nothing is placed on the system. The system was connected to the computer parallel port by an electronic system (hardware). The principle is based on the change in logic level (TTL - High, Low) in the error pin of the parallel port. The system acts as a conventional electric switch. When a force is applied to the system the metallic plates touch each other closing the electric circuit and changing the logic level on the parallel pin from one (High) to zero (Low). When the force is removed the circuit opens once again and the logic level changes from zero (Low) to one (High). The flight time and ground contact time is measured by the duration of each logic level.

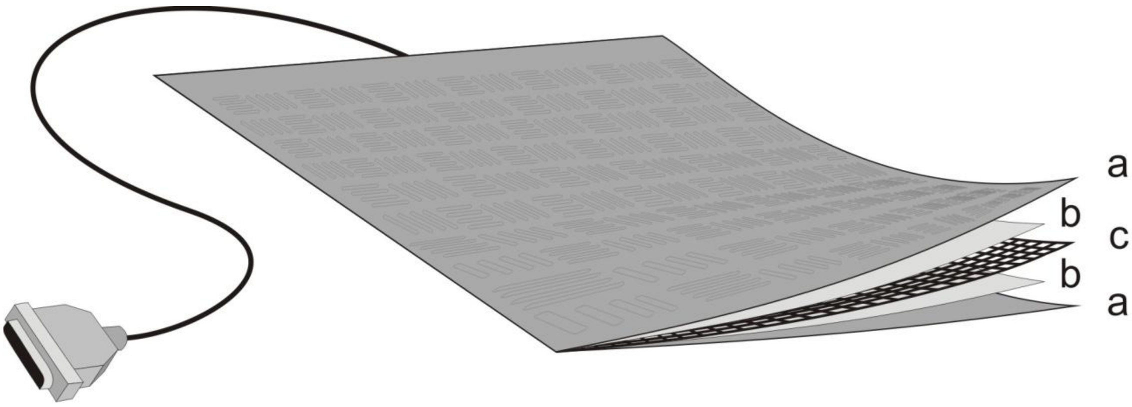

Figure 1. The structure of SaltoBras: 1a) anti-slip rubber film; 1b) flexible metallic plates and 1c) hollowed rubber film.

The software of the SB system was developed using C++ language and can be used to control and follow the test in real time and record the information in a data file. Different protocol parameters can be selected in the software. It is possible to determine the number of performed jumps, the acquisition time and whether the subject will begin the test standing on the SB or off the system before jumping on it. It is also possible to follow the height obtained in each jump in real time, as well as the flight time and the ground contact time. At the end of the test, a graph representing these values is generated, so that the evaluator can obtain immediate feedback. The time resolution of the SB was set at 0.02 s (500 Hz) which was verified with a signal generator (Yokogawa, FG 300, Tokyo, Japan) and the Oscilloscope (Tektronix®, TDS1002, Beaverton, USA) with a sample rate of 2 GHz. The system measures flight time (ms), ground contact time (ms) and allows vertical jump height to be estimated with the use of the equation proposed by Aragon-Vargas (2000):

$$h\,(m) = 0.117 + 1.002 \cdot t \qquad [2]$$

where h is the jump height (m) and t is the flight time of the jump (s).

Procedures

To verify the time measurement validity of SB software in comparison with an Oscilloscope and the flight and ground contact time measurements in comparison with a FP, the SB was placed upon a Kistler® force plate (Quattro Jump, 9290AD, New York, USA) and the Oscilloscope was connected to the SB hardware. The FP was set to zero considering the weight of SB. The FP consists of a piezoelectric portable system on which different jump types can be performed. The force threshold of the FP is < 0.2 N and the acquisition frequency was set at 500 Hz.

First, to verify the flight time measurement, each participant was positioned on the SB and performed 15 jumps with a 30-second interval between the trials. The protocol was controlled by the FP software and during the interval the participants waited out of the SB to avoid the possible drift effect of the piezoelectric platform.

After that, to verify the ground contact time measurement, each participant performed six consecutive jumps and the five ground contact times between the jumps were analyzed. Two separated protocols were utilized, because the FP software during the protocol of continuous jumps does not provide the flight time of the jumps, preventing the joint analysis of flight and ground contact time. The number of jumps performed in both steps was established to ensure representative data to compare both equipments, allowing the elaboration of prediction equations and avoiding the fatigue of the evaluated subjects.

The jumps were performed according to the Bosco Protocol (BOSCO *et al*., 1983) of the 'vertical countermovement' jumping method (rapid flexion of the hip, knee, and ankle joints). This protocol recommends that the single jump begins with straight legs and with a 90° of flexion before take-off. Participants were instructed to keep their hands placed on their hips during all jump assessments and to assume a self-selected foot position.

Statistical Analysis

The data normality was verified by Shapiro-Wilk and Kolmogorov-Smirnov tests. Wilcoxon and Paired t-test were used to determine if the flight and ground contact times values obtained from SB and FP were significantly different, respectively. In addition, linear regressions were used to predict the flight and ground contact time of the FP by the SB time measurement. The statistical analysis was performed using SPSS for Windows (v.14; SPSS Inc., Chicago, USA) and significance was set at $p \leq 0.05$.

Results

It can be observed in table 1 and 2 the measure of central tendency and variability, as well as the absolute differences of flight and ground contact times obtained in the sequence of jumps of all the participants, by SB and FP. In both tables it can be seen that the time value measured by the SB software in all of the tests was exactly the same as the one measured by the OS. This fact demonstrates that the software is valid for the measurement of time.

Table 1. Comparison of flight time measurement by the SaltoBras and Force Plate (n=90).

Median ± IIQ (ms)			Δ (ms)
SB	OS	FP	
487.5 ± 152.7	487.5 ± 152.7	489.0 ± 152.5	1.5*

Abbreviations:SB, SaltoBras; FP, Force Plate; OS, Osciloscope; IIQ, Interquartile range; Δ, difference between SB and FP.
*p<0.01

Table 2. Comparison of ground contact time measurement by the SaltoBras and Force Plate (n=30).

Mean ± SD (ms)			Δ (ms)
SB	OS	FP	
645.4 ± 68.1	645.4 ± 68.1	652.0 ± 67.6	6.6 ± 4.7*

Abbreviations: SB, SaltoBras; FP, Force Plate; OS, Osciloscope; SD, Standard Deviation; Δ, difference between SB and FP.
*p < 0.001

The results demonstrated that there is an underestimation tendency of the SB in relation to the FP. Regarding the flight time the underestimation was of approximately 0.30% and the ground contact time of approximately 1.01%. However, these errors were systematic, as the linear regression (Figure 2) between the SB and FP showed that the majority of the data points lie close to the line of best fit. Two prediction equations were defined and explained ~99% of the variation of the flight and ground contact times of the FP.

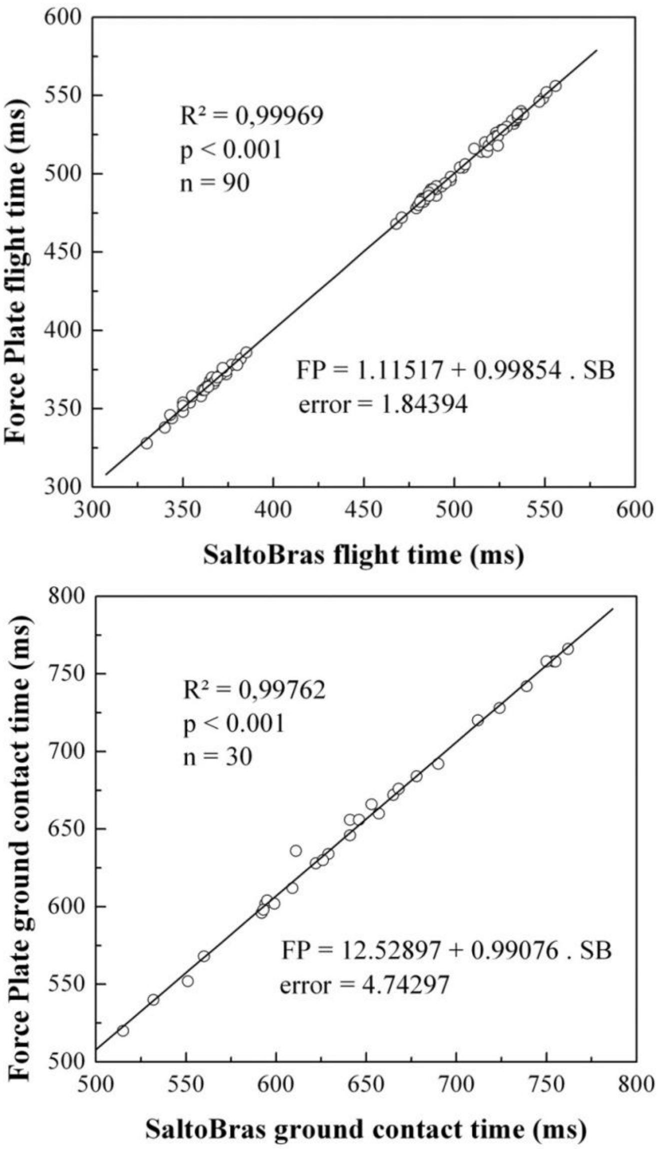

Figure 2. Linear regression of the flight time and ground contact time recorded with the force plate (FP) and the SaltoBras (SB).

Discussion

The first purpose of this study was to verify the validity of SB software regarding the time measurement. Utilizing an Oscilloscope and considering its accuracy, it was possible to verify that the SB software measures time with extreme accuracy.

The second purpose of this study was to verify the validity of the entire system by comparing the measurements of flight and ground contact time of SB with the measurements of a FP. The results showed, despite the differences encountered between the two equipments, with a tendency of underestimation of the time values by SB when compared to the FP, the errors were systematic, making it possible to elaborate prediction equations (figure 2) to correct these errors, which were added in the SB software.

A previous study (GARCÍA-LOPEZ *et al*., 2005), that performed the time measurement validity verification of SportJump (SJ) CMT, evaluated the same parameters as the present study (flight and ground contact time). These parameters were compared with a Dinascan 600 M force plate (considered by the author as the reference system), a Psion Organizer II system, a high-speed camera (Kodak Motion SR-500-C) and a LED filmed by the camera. Unlike the present study the authors found significant differences of 9.2 ± 1.3 ms between the flight times measured by the SJ and the FP, with an overestimation of the SJ. In the present study, significant differences were also found between the FP and the SB, however, different than the study by Garcia-Lopez *et al*. (2005), there was an underestimation of the time measurement by the SB (table 1).

Regarding the ground contact time, the present study found similar differences (table 2) to the ones found by Garcia-Lopez *et al*. (2005) (6.9 ± 3.7 ms), where an underestimation of the ground contact times measured by the SJ when compared to the ones measured by the FP was also encountered. Despite the limitations of the present study in relation to the number of comparisons with other equipments with similar principles, some comments may be made in order to clarify the possible reasons for the underestimation tendency for the ground contact time measured by SB in relation to the FP. This tendency may be caused by the difference in the sensitivity between the SB and the FP. Because the FP is a piezoelectric system, it is extremely sensitive to load, presenting a force threshold of < 0.2 N. The SB, on the other hand, due to its mechanical characteristic, presents a higher force threshold, around 5.6 N. Considering that the ground contact time is defined as the time in which the subject is in contact to the ground between two consecutive jumps, the SB probably underestimates this value because during the landing, at the instant when the foot touches the surface of the SB, the FP already detects the event by the alteration of the vertical reaction force and only on the following instants the SB detects the touch of the foot closing the circuit of the system. During takeoff, on the other hand, when the foot is about to leave the surface of the system, the SB no longer detects the contact of the foot due to the fact that the circuit is open, but the FP still measures minimal values of vertical ground reaction force, therefore making the ground contact time longer when measured on the FP.

According to Enoksen *et al.* (2009) there is very few information in the literature regarding the validity of CMTs. With the exception of Garcia-Lopez *et al.* (2005) no work presented the flight time and ground contact time measurement errors in CMT. However, the verification of the validity of CMTs using the comparison of the jump height directly with other methods is performed in some studies, but not mentioning the flight time values. Leard *et al.* (2007) performed a concurrent validation of the Just Jump® (JJ) CMT in comparison with a 3-camera motion analysis system. For the author, when the vertical jump height is estimated based on FT, the JJ has a high validity with the VID. However, the author did not present the flight time values in his study or the equation utilized to estimate the jump height based on FT, making it difficult to compare the results to the ones found in the present study. Enoksen *et al*. (2009) also use an approach where they do not present which equation is utilized to estimate jump height. The authors conclude that in their study, the instrument is reliable, but not valid, because it overestimates the height values in comparison to the values estimated from the double integration of the ground reaction force measured by a FP.

It can be observed that despite some recent works, as the ones by Leard *et al.* (2007) and Enoksen *et al*. (2009), attempting to evaluate the validity or reliability of CMT, Aragon-Vargas (2000) already confirmed the reliability of the method to estimate the jump height based on the flight time, regardless weather it was measured by a FP or a CMT, and proposed an equation to adjust the values of jump height according to the gold standard method (VID). For this reason, in the present study we opted to add in the SB software the equations encountered to correct the values of time measured by SB, and the equation proposed by Aragon-Vargas (2000) to estimate the vertical jump height based on the corrected flight time.

Finally, the results presented here and the adjustments made in the software suggest that the SB is a valid instrument for flight and ground contact time measurement during vertical jump and for the estimation of the vertical jump height.

Referências

ARAGON-VARGAS, L. F. Evaluation of four vertical jump tests: Methodology, reliability, validity, and accuracy. **Measurement in Physical Education and Exercise Science**, Philadelphia, v. 4, n. 4, p. 215-228, 2000. Available in: <http://dx.doi.org/10.1207/S15327841MPEE0404_2>. Access in: Oct. 20 2009.

BACA, A. A. Comparison of methods for analyzing drop jump performance. **Medicine and Science in Sports and Exercise**, Philadelphia, v. 31, n. 3, p. 437-442, 1999.

BOSCO, C. et al. A simple method for measurement of mechanical power in jumping. **European Journal of Applied Physiology and Occupational Physiology**, Berlin, v. 50, n. 2, p. 273-282, 1983. Available in: <http://dx.doi.org/10.1007/BF00422166>. Access in: Oct. 20 2009.

CORDOVA, M. L.; AMSTRONG, C. W. Reliability of ground reaction forces during a vertical jump: implications for functional strength assessment. **Journal of Athletic Training**, Dallas, v. 31, n. 4, p. 342-345, 1996. Available in: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1318919/ . Access in: Mar. 10 2006.

DAVIS, D. S. et al. Physical characteristics that predict vertical jump performance in recreational male athletes. **Physical Therapy in Sport**, Kidlington, v. 4, n. 4, p. 167-174, 2003. Available in: <http://dx.doi.org/10.1016/S1466-853X(03)00037-3>. Access in: Oct. 20 2009.

ENOKSEN, E.; TONNESSEN, E.; SHALFAWI, S. Validity and reliability of the Newtest Powertimer 300-series testing system. **Journal of Sports Sciences**, London, v. 27, n. 1, p. 77-84, 2009.

GARCÍA-LOPEZ, J. et al. Validation of a new method that measures contact and flight times during vertical jump. **International Journal of Sports Medicine**, Stuttgart, v. 26, n. 4, p. 294-302, 2005.

HASSON, C. J. et al. Neuromechanical strategies employed to increase jump height during the initiation of the squat jump. **Journal of Electromyography and Kinesiology**, Kidlington, v. 14, n. 4, p. 515-521, 2004. Available in: <http://dx.doi.org/10.1016/j.jelekin.2003.12.004>. Access in: Oct. 20 2009.

HOPKINS, W. G.; SCHABORT, E. J.; HAWLEY, J. A. Reliability of power in physical performance tests. **Sports Medicine**, Auckland, v. 31, n. 3, p. 211-34, 2001.

JAGGER, J. R. et al. The acute effects of dynamics and ballistic stretching on vertical jump height, force and power. **Journal of Strength and Conditioning Research**, Philadelphia, v. 22, n. 6, p. 1844-1849, 2008. Available in: <http://dx.doi.org/10.1519/JSC.0b013e3181854a3d>. Access in: Oct. 20 2009.

KIBELE, A. Possibilities and limitations in the biomechanical analysis of countermovement jumps: a methodological study. **Journal of Applied Biomechanics**, Champaign, v. 14, n. 1, p. 105-117, 1998.

LARKINS, C.; SNABB, T. E. Positive versus negative foot inclination for maximum height two-leg vertical jump. **Clinical Biomechanics**, Kidlington, v. 14, n. 5, p. 321-328, 1999. Available in: <http://dx.doi.org/10.1016/S0268-0033(98)90089-4>. Access in: Oct. 20 2009.

LEARD, J. S. et al. Validity of Two Alternative Systems for Measuring Vertical Jump Height. **Journal of Strength and Conditioning Research**, Philadelphia, v. 21, n. 4, p. 1296-1299, 2007. Available in: <http://journals.lww.com/nsca-jscr/Abstract/2007/11000/Validity_of_Two_Alternative_Systems_for_Measuring.55.aspx>. Access in: Mar. 10 2009.

LINTHORNE, N. P. Analysis of standing vertical jumps using a force platform. **American Journal of Physics**, College Park, v. 69, n. 11, p. 1198–1204, 2001.

MOIR, G. L. Three different methods of calculating vertical jump height from force platform data in man and women. **Measurement in Physical**

Education and Exercise Science, Philadelphia, v. 12, n.4, p. 207-218, 2008.

MUSAYEV, E. Optoelectronic vertical jump height measuring method and device. **Measurement: Journal of the International Measurement Confederation**, Amsterdam, v. 39, n. 4, p. 312-319, 2003. Available in: <http://people.brunel.ac.uk/~spstnpl/Publications/VerticalJump(Linthorne).pdf>. Access in: Mar. 10 2009.

NEWTON, R. U.; KRAEMER, W. J. Developing explosive muscular power: implications for a mixed methods training strategy. **Journal of Strength and Conditioning Research**, Philadelphia, v. 16, n. 5, p. 20-31, 1994.

SACCO, I. C. N. et al. Influence of ankle devices in the jump and landing biomechanical responses in basketball. **Revista Brasileira de Medicina do Esporte**, São Paulo, v. 10, n. 6, p. 453-458, 2004. Available in: <http://www.scielo.br/scielo.php?pid=S1517-86922004000600001&script=sci_arttext&tlng=en>. Access in: Mar. 10 2009.

Endereço:
Noé Gomes Borges Júnior
LABIN/CEFID – UDESC
Rua Pascoal Simone, 358 Coqueiros
Florianópolis SC Brasil
88080-350 Telefone: (48) 3249.6258
e-mail: nborgesjr@gmail.com

Recebido em: 6 de outubro de 2009.
Aceito em: 9 de setembro de 2010.