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A new contact mat wireless system for estimating vertical jump height

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ABSTRACT

Among the different devices available for the assessment of the vertical jump height based on the flight time measurement, the contact mats are surely one of the simplest and portable systems and, for this reason, they are more widely used. This paper deals with the comparative evaluation of the performances of a new contact mat system with respect to a force platform. Some tests have been performed and the relative comparative results will be presented. The study shows a significant concurrent validity of Wi-JumpLe system for the flight and ground contact time measurements. In conclusion, the new contact mat structure together with the electronic measurement system is legitimate to assess vertical jump height and leg extensors muscle power.

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Keywords: biomechanics, jump analysis, measurement, contact mat, force platform

1. Introduction

The vertical jump test is one of the most prevalent method of assessment on sport performance. In fact, the jump height is highly correlated with leg extensor muscles power. Several systems are commercially available for such a measurement [2]: some of them make use of mechanical wheel meter (e.g. with a measuring tap connected to a waist belt and to the ground), while other are based on the flight time measurement. The contact mats are based on this last method as well as the photoelectric cells systems (e.g. in [3-4]) and the force platforms [5] that are considered the reference standard method for this kind of measurement. In this field, since at least 40 years, the contact mats have been widely used to evaluate the jump height ensuring an effective scientific validity. Furthermore, until by its invention (Bosco C., 1978), the structure of the contact mat, consisting of metal bars equally arranged over its entire surface, has been remained almost unchanged until now.

The aim of this study consists of the evaluation of the performances of a new contact mat (Wi-JumpLe System, Wess srl – Rome, Italy), built by replacing, over the whole surface, the metal bars with conductive fabric. Therefore, this new contact mat presents a significant weight reduction together with a good handling and, consequently, a good improvement of its portability.

In particular, it has been evaluated the concurrent validity of this new mat with force plate measurements for estimating vertical jump height. Five subjects performed (three times for each of the tests) the following tests: maximal squat jumps test (SJ), countermovement jumps test (CMJ) and continuous jumps test (CJ) for a time of five seconds. The flight time and the ground contact time of vertical jumps performed on a force platform have been respectively acquired and they have been correlated with those provided by the Wi-JumpLe System in order to examine their concurrent (criterion-related) validity.

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2. System description

The system evaluated in this study ("Wi-JumpLe" System) is a wireless system for flight and ground contact time measurements that makes use of a new kind of contact mat where the metal bars system has been replaced by a conductive fabric structure and a proper insulating material. The scheme of the system is shown in Fig. 1; it consists of three main elements:

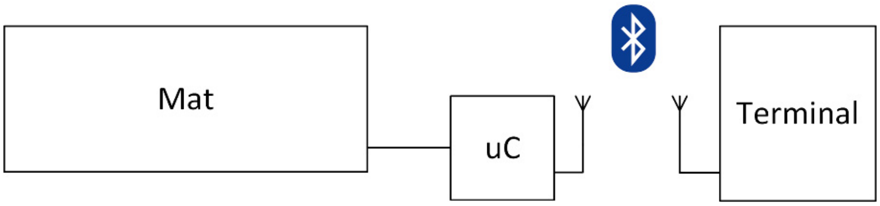
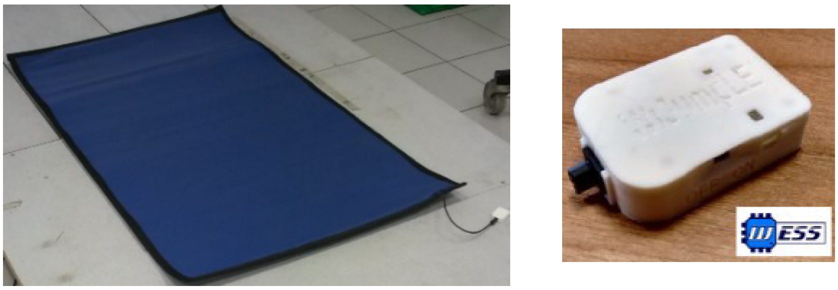


Fig. 1. Wi-Jump System block scheme.

1. The mat (shown in Fig.2a): it is made of two sheets of conductive fabric and a layer of special insulating material is placed between them. Such a structure is fastened on two rubber sheets for anti-slip purpose. Therefore, this mat results quite lighter and easier to carry with respect to most of the other contact mats commercially available.
2. The electronic circuit (shown in Fig.2b) is represented by a microcontroller system devoted to the measurement of the flight and ground contact time of the vertical jumps performed on the mat. These measurements are carried out at a sampling rate of 2 kHz and a resolution of 10 bits. Moreover, the microcontroller is able to transmit, via a Bluetooth 4.0 low energy radio link, the acquired data to a proper terminal unit for the data processing and visualization. The electronic system is powered by a LiPo high capacity battery.
3. The terminal unit (an Android v.5.2 based system) is able to handle the received data by processing them to evaluate the specific performance indexes and parameters (e.g. coordination index, stiffness, etc.). Moreover, it is able to manage the database of the athletes and properly store the test results.

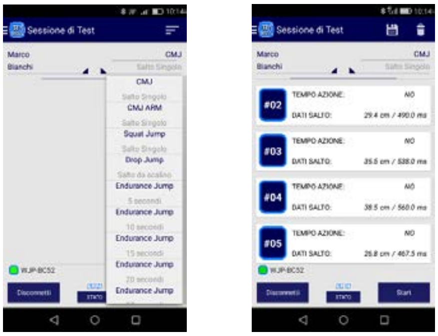
When the subject performs a jump on the mat, the special insulating material placed between the two conductive fabric sheets modifies its own impedance value allowing the electronic system to recognize a pressure on the mat's surface. In this way, the microcontroller is able to evaluate the time range when a low impedance value is measured (ground contact time – the subject is on the mat) and the time intervals when it is measured a high impedance value (flight time – the subject has performed the jump and he is, in such a time range, in phase of flight).



a) b)

Fig. 2. (a) Contact mat; (b) Electronic circuit for measure and wireless transmission.

Figure 3 shows two different screenshot of the software program on the Android terminal unit. In particular, in fig. 3a) the user is able to select the specific test which will be measured and in fig. 3b) some results measured for a countermovement jumps test (CMJ) are reported.



a) b)

Fig. 3. Screenshots of the software program on the terminal unit

3. Procedures

The technical validation of this new contact mat wireless system (Wi-JumpLe) was performed at the "Laboratorio di Fisiologia, Ergonomia, Postura e Movimento" of the INAIL research Centre at Monte Porzio Catone (Rome Italy). In particular, the mat system has been evaluated in comparison with a force platform system (BTS P-6000 Force Plates – BTS Spa – Italy) which presents a resolution of 16 bits over the selected range and an acquisition frequency set to the value of 680 Hz. The offset of the force platform has been compensated by using a proper calibration procedure before each jump.

3.1 Participants

The testing procedure has been planned involving five subjects. They were healthy college-age men, physically active (they are all physical education students) and had significant experience in explosive activities as jumping and, in particular, with the class of jumps employed in this study. In particular, their mean age, height and weight were 22,3 +/- 2.3 years, 178.3 +/- 4.2 cm and 73 +/- 4.1 kg respectively. A written informed consent was obtained from all the participants after familiarization and explanation of the benefit and risks involved in the procedures adopted. The study was approved by the Ethical Committee of the School of Sports and Exercise Science – University of Rome "Tor Vergata" – Faculty of Medicine and Surgery. Moreover, all the tests were carried out in accordance with the Declaration of Helsinki.

3.2 Testing Procedure

These subjects performed maximal squat jumps test (SJ), countermovement jumps test (CMJ) and continuous jumps test (CJ) for five seconds. Moreover, each of the test has been repeated three times each.

It is worth noting that these classes of tests are the most commonly used for the evaluation of the athletes' performances according with the well-known Bosco protocol [1]. It is worth to note that the flight time values have been acquired by using both the systems for all the tests, while the ground contact time values has been acquired for the CJ test only.

An athlete can perform different types of vertical jumps according with various factors, including: initial position (static or after a run-up), land (with just a foot or both), movement of the arms (with or without arm movement) and legs (counter-movement or squats). In particular, when it is performed the SJ test (fig.4a), the subject starts from the half-squat position (legs flexed to about 90°), with the trunk as vertical as possible and the hands on the hips, then extend the lower limbs without performing any countermovement (without any additional bending of the legs) as faster as possible just to take-off. The height of the jump, the difference between the maximum vertical position reached by the center of gravity and its initial height, gives indications on the ability of the subject to express explosive power [5-7].

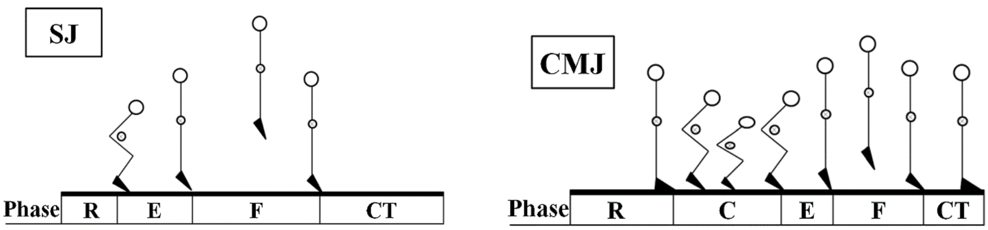


Fig. 4. (a) SJ test; (b) CMJ test

Furthermore, in the CMJ test (fig.4b) the subject starts from an upright position with the hands on the hips and executes a vertical jump after a downward counter movement with bend legs at about 90°. The CMJ is a test in which, during the eccentric phase, the subject increases his downward acceleration by stretching the active (cross-bridges) and passive (tendons) elastic elements. In this way, the subject can reuse, in the following concentric phase, the elastic energy he has stored [10 – 11]. In addition, during the eccentric phase, the activated muscle spindles generate a stretch reflex that increases the firing rate of α-motoneuron of the extensors muscles. Therefore, the performance increment of CMJ in comparison to the SJ is probably due to the reuse of elastic energy and to the stretch reflex.

Moreover, the Continuous Jump (CJ) is a test that, in addition to providing information about the visco-elastic properties of the extensor muscles of the legs, is widely used to evaluate the characteristics of the metabolic processes that support the muscle work for a period. This test can usually range from five to sixty seconds depending on the required evaluation and on the kind of the subjects involved. The execution method of the jumps is essentially the same as the CMJ, with the only difference that in this case the jump performance is reiterated during all the test. In particular, in this study, all the CJ tests have been performed for a time length of five seconds.

In all the performed tests, all the athletes have been notified to keep their hands placed on their hips during all jump assessments and to assume a proper position and a correct body balance during the whole session.

Fig. 5 Wi-JumpLe system placed on the BTS P-6000 Force Plates

In order to perform the comparative tests, the contact mat has been placed over the force platform (as depicted in figure 5) and, for each test, the values of the flight time have been simultaneously acquired by both the systems. In this way, we were able to examine its concurrent validity in a real-time environment. Moreover, the values of flight and ground contact time have been respectively measured with a millisecond accuracy according to the Bosco criteria. As reported above, while the values of flight time have been acquired for all the kind of the tests, the values of ground contact time have been acquired for the CJ test only. The value of the height of the jump is obtained by using kinematic equations that allow calculating it thru only the flight time value:

$$h_{jump} = 1.226 \cdot (T_{\text{Flight}})^2 \quad (1)$$

3.3 Statistical Analysis

The data obtained by these measurements have been verified by standard statistical methods. In particular, the normal distribution of the data has been verified by the Shapiro-Wilk and Kolmogorov-Smirnov tests. Moreover, the homogeneity of variance was verified by the Levenne's test and the paired t-test has been used to compare the measures respectively obtained by of both the devices in order to verify if they were significantly different. In addition, linear regression was used to predict the flight and ground contact time of the FP by the Wi-JumpLe time measurements.

4. Results

The results obtained by this comparative measurements are summarized in the following Table 1 and 2. Moreover, they are depicted in figures 6a and 6b.

In particular, both the tables show the measure of the central tendency and the respective variability, as well as the absolute differences of flight and ground contact times obtained in the sequence of jumps of all the subjects, by the Wi-JumpLe system and the force platform respectively.

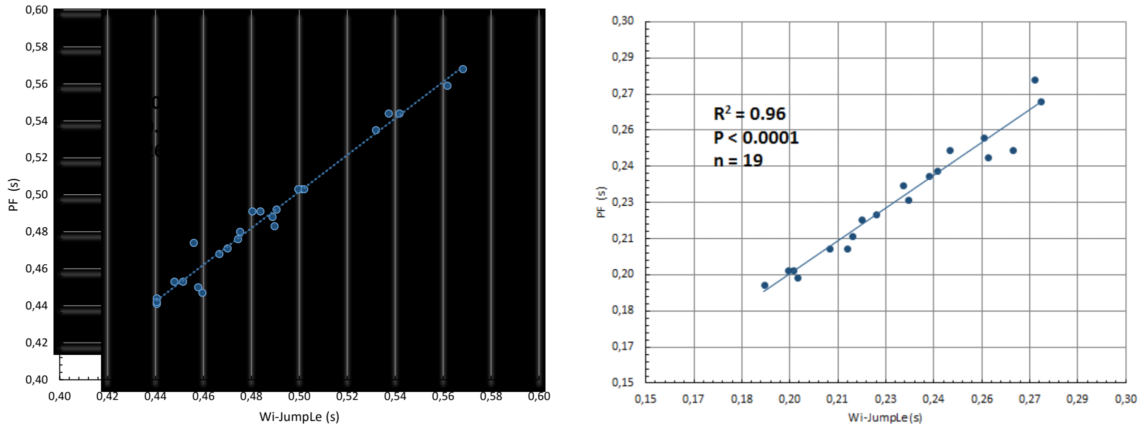
	Wi-JumpLe (ms)	FP (ms)	Error (ms)
Mean Value	485	487	2
Median + IQR* Value	505 ± 64	505 ± 63	2.5 ± 15.5
* IQR = Inter Quartile Range			

Table 1. Comparison of flight time measurement by the Wi-Jump and Force Platform (n=26).

	Wi-JumpLe (ms)	FP (ms)	Error (ms)
Mean Value	229	227	2
Median + IQR* Value	231 ± 44	234 ± 43	- 6 ± 11
* IQR = Inter Quartile Range			

Table 2. Comparison of ground contact time measurement by the Wi-Jump and Force Platform (n=20).

The results show that the measurements of the flight time values present an overall underestimation tendency by the Wi-JumpLe systems to compute with respect to the FP of about 2ms (approximately 0.41%). It is worth to note that the error presented a maximum value of 18ms (3,70%). Moreover, there is an overall overestimation tendency of the Wi-JumpLe system of about 2ms (approximately 0.87%) with a maximum error value of 17ms (7,42%) also in the measurements of the ground contact time values. Anyway, it is worth to note that these maximum values of the errors have been measured during the same jump session and could be correlated to a random event in the measure or the particular execution of the jump. In fact, you can note that the linear regression between Wi-JumpLe and FP shows most of the data points that are lying close to the line of best fit.



a) b)

Fig. 6. (a) Flight Time; (b) Ground Contact Time

The computed Intraclass Correlation Coefficient (ICC) for both the sets of measurements shows very high values. In particular, the ICC relative to the flight time values is equal to 0.9867, while the same coefficient is 0.9727 for the ground contact time values.

5. Discussion

A concurrent validity study has been performed on measurements of flight time of a new contact mat system with the respect to the reference standard represented by a force platform. The results obtained from this study show a very high value for the intraclass correlation coefficient (ICCs) for validity. A systematic negligible difference was observed between the force plate and the Wi-JumpLe System in the measured flight time values as well as ground contact time values.

Therefore, there is an evidence that a significant concurrent validity of the Wi-JumpLe System for both the flight and ground contact time measurement exists. In this study, it was not verified the validity and the repeatability of the measurements along the time that could be affected by any alteration in the property of the polymeric materials that compose the mat.

6. Conclusions

In conclusion, the new conductance device is legitimate to assess vertical jump height and leg extensors muscle power. In fact, the latter can be estimate by using both flight and ground contact time values. Further investigations will be required to verify the performances of the contact mat due to the possible variation in the behavior over time of the polymeric microstructure that compose it.

Acknowledgements

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