STANDING JUMP LOFT TIME MEASUREMENT:

an acceleration based method

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Abstract: This paper describes two methods for the measurement of loft time in vertical jumps using signals from an acceleration sensor. The vertical jump accelerometer characteristic curve is presented and notable regions corresponding to key stages of the kinetic activity are identified. Using the accelerometer signals along three dimensions two different algorithms were devised to compute the loft time. These algorithms are based on the morphology of the signal. The first uses the the maximum value of the curve during the landing stage; the second uses the time interval between minimum and maximum values of the acceleration during the flight and landing stages, respectively. To validate these algorithms, a standard algorithm to compute the loft time from force platform signals was employed and these values taken as ground truth. Performance assessment was performed by computing the relative errors between the loft time determined from the force signal and the values obtained with each of the proposed approaches. Preliminary results for a set of 60 jumps let to relative errors of 7.0% for the first method and 2.9% for the second method.

1 INTRODUCTION

Vertical jumps are part of a variety of sports. In athletic field vertical jump measurements are used both to optimize and measure the performance of various types of movements.

Performance of standing vertical jumps can be accessed by measuring the time the athlete is in the air – jump loft or flight time (Linthorne N. P., 2001). The typical approach for measuring the loft time uses force platform signals. With this approach the jump must be performed while standing on the force platform, that collects vertical force data. Force-time curves contain kinetic and temporal information that can be used to determine parameters that objectively measure the performance of athletic movements (Dowling, 1993). These platforms are rectangular metal plates provided with force sensors and connected by cabling to a data acquisition system and computer. Due to their weight (ranging from about 11 kg to 57 kg) and dimensions (usually between 0.4 m × 0.6 m and 1.2 m × 1.2 m) (amtiweb) the platforms are usually used only in laboratory work, restrained the outside work by the portability issues.

Acceleration data can be used to study the characteristics of human movement (Hassan, M. R., 2006) and assess parameters that identify one's state of physical activity. In jumping studies, acceleration signals are also an important source of information.

In this paper we present two different algorithms for determining vertical jumps loft times using a three axial accelerometer. In this case, the portability issues are lessened because the accelerometer and the acquisition system employed are light-weighted wireless devices.

The two algorithms were applied to a set of 60 vertical jumps and validated with a standard algorithm for computation of loft time from force platform signals.

Like on the vertical force curve, six interest regions can be identified on the acceleration-time curve: rest, preparation, take-off, flight, landing. and recovery. Following the last stage a rest period can also be present. Figure 1 shows the vertical force and acceleration signals acquired during a vertical squat jump.

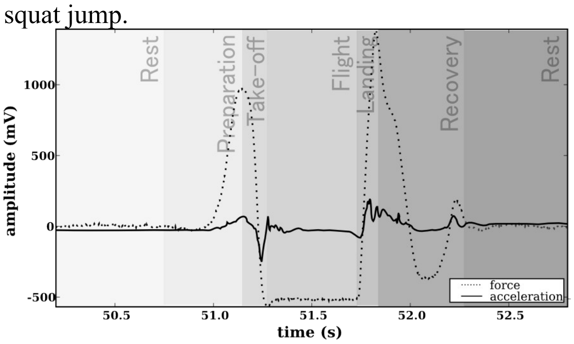

Figure 1. Stages of a vertical squat jump.

Some key points can be identified on the acceleration signal that are characteristic of the different stages of the jump and that are repeated as a pattern when a series of jumps is acquired. The biggest oscillations of the signal are noticed at the beginning of the flight stage and the landing stage - when the jumper leaves the ground and when his feet first contact the ground after the flight, respectively. A recovery phase follows the landing. During this period of time the acceleration oscillates and converges to its rest value which is reached when the jumper finishes the jump. The fact that the flight stage is clearly demarcated on the force curve is usually used to compute the duration of the flight – loft time. As we can see in Figure 1, the acceleration curve has also characteristic features that can be related with the loft time. Two of these features were used in this work to estimate the duration of the flight stage.

2 MATERIALS

The experimental set-up consisted of a bioPlux8 wireless electrophysiological data acquisition system (Silva, H., 2005, plux.info) to which we connected a xyzPlux triaxial accelerometer and a force platform (AMTI- LG 6-4-2000). With this apparatus force and acceleration (along three dimensions) were synchronously recorded during the vertical standing jumps.

The accelerometer was placed at the jumper's low back on the skin surface (Figure 2). The force platform signal was used for result comparison.

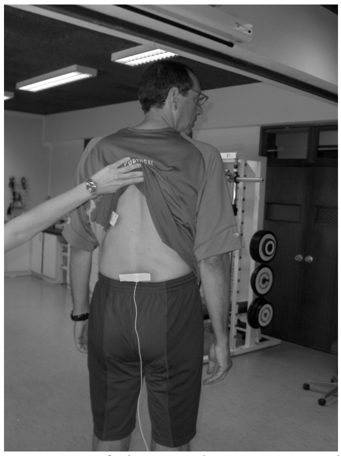
Figure 2. Placement of the accelerometer at the jumper's low back skin.

3 METHODS

The methodology for determining the flight time was based on the morphological analysis of the acceleration curves of a set of 60 jumps.

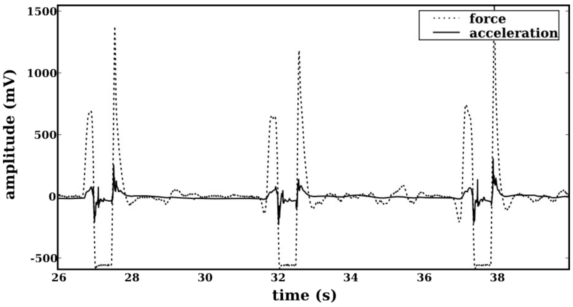

Figure 3. Acceleration and force curves of a series of 3 vertical jumps.

By comparing the acceleration curve of a set of jumps with the respective vertical force curve (Figure 3) we observe that some of the acceleration curve characteristic features seem to be related with the duration of the flight stage, namely at the flight and landing stages. Using notable points of these stages we devised two different algorithms to compute the loft time. The average acceleration curve was determined from the acceleration signals of the three dimensions and low passed using a moving average filter using a window of 250 points (Proakis J. G.,1995). Each of the algorithms uses different measurements of time and amplitude taken from this signal.

The first algorithm uses the landing stage curve amplitude (Figure 4). This stage is characterized by sharp variations of the acceleration signal due to the vibration of the accelerometer when the feet first contact the force platform on the landing. The low-passed signal obtained from the smoothing still preserves this impact peak whose amplitude (v_{a1}) was measured and used as a predictor variable for the loft time.

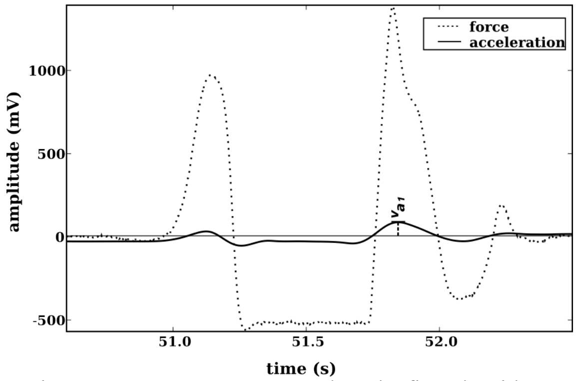

Figure 4 – Jump parameter used on the first algorithm.

The second algorithm determines the time interval between the minimum of the smoothed signal on the flight stage and the impact peak. With this algorithm, a direct measure of the loft time is obtained (Figure 5).

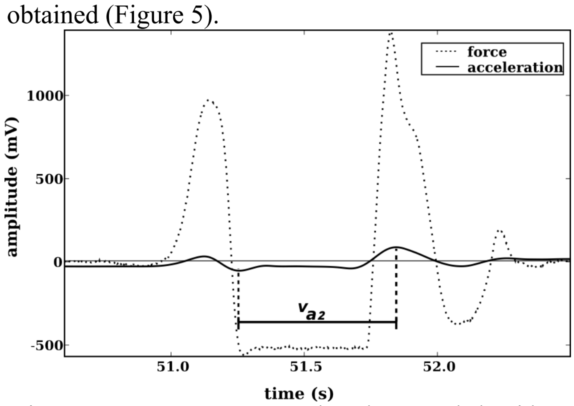

Figure 5 – Jump parameter used on the second algorithm.

For result comparison purposes, we determined the jump loft time of the 60 jumps from the force platform signal and took these values as ground truth. A standard algorithm was employed that computes the time during which the jumper is not touching the force platform - the time interval between the take-off and landing instants - where the force signal has a negative plateau (Figure 6).

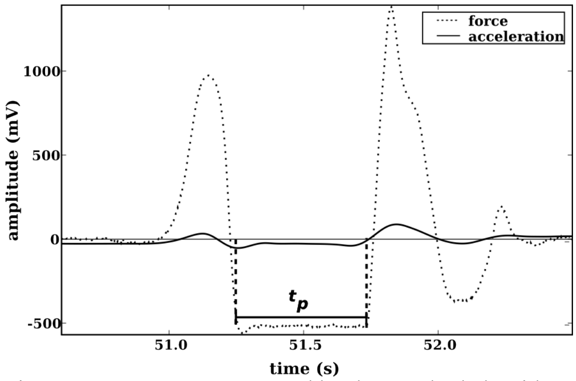

Figure 6 – Jump parameter used by the standard algorithm.

4 RESULTS

The two independent variables measured on the acceleration signal (v_{ai}) were plotted against the loft time determined from the force platform signal (t_p). The scattergrams of these two variables are shown in Figure 7.

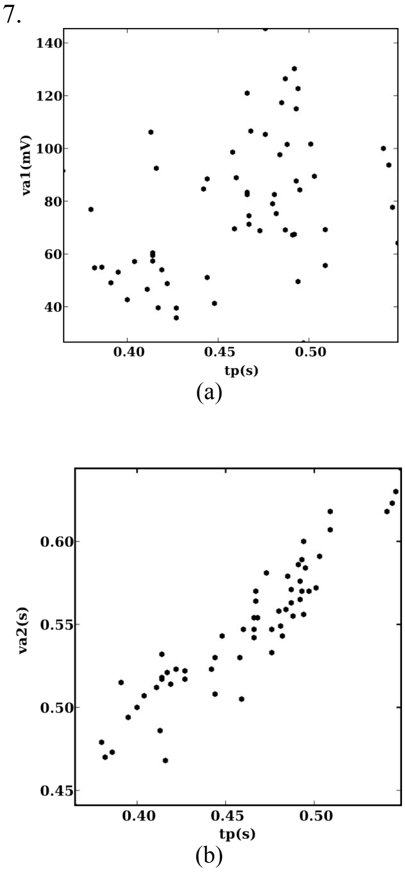

Figure 7. Scattergrams of the loft time measured with the standard algorithm versus (a) the variable measured with

algorithm 1 and (b) the variable measured with algorithm 2.

A high correlation between the loft time measured from the force platform signal and the time interval measured from the acceleration curve (v_{a2}) can be seen is Figure 7b. This is a much better predictor of the flight time than the amplitude of the landing stage impact peak (r=0.382 and r=0.933 respectively). The regression equations for both variables are given by (1) and (2):

$$t_{p1} = 6{,}406 \times 10^{-4} v_{a1} + 4{,}102 \times 10^{-1} \text{ (s)} \quad (1)$$

$$t_{p2} = 0{,}967\, v_{a2} - 0{,}068 \text{ (s)} \quad (2)$$

Using these equations we can obtain estimates of the loft time (t_{pi}) from the variables measured from the accelerometer signal (v_{ai}).

The loft time relative error associated with each of the algorithms *i* was determined for each jump *j* ($\delta_{\varepsilon ij}$), taking as "real" loft times the values measured from the force platform signal(t_{pj}).

$$\delta_{\varepsilon_{ij}} = \frac{\left(t_{p_j} - t_{p_{ij}}\right)}{t_{p_j}}, i=1,2\,; j=1,\ldots,60 \quad (3)$$

The accuracy of the algorithms was assessed by determining the corresponding average loft time relative errors:

$$\overline{\delta_{\varepsilon i}} = \frac{\sum \delta_{\varepsilon ij}}{n}, i=1,2\; j=1,\ldots,60 \quad (4)$$

The results led to relative errors of 7,0% for the first algorithm and 2,9% for the second algorithm Taking as reference the mean loft time determined for the set of 60 jumps with the regression equations (1) and (2) these relative errors correspond to 32 ms and 13 ms, respectively.

Both algorithms are also affected by a common base error of 0.1% which is characteristic of the acquisition unit and inversely proportional to its sampling rate.

Usually, when the force platform is used to determine the loft time an associated error of 0,5% is introduced because the algorithm is susceptible of the parameters chosen by the user as the initial and final points of the flight stage. In contrast, the algorithms we propose are automatic.

4 CONCLUSIONS

The time interval between the minimum acceleration value of the flying stage and the maximum acceleration value of the landing stage is the best of the two devised measures, showing a good correlation with the real loft times (r=0.933 and δ_{ε}.=2,9%).

Although associated with errors, these preliminary results indicate that these algorithms are good alternative methods for the computation of loft time, taking advantage of the use of an accelerometer instead of a force platform, which is more expensive and less portable.

In addition to the flight time other parameters used to assess the performance of the jump can be found on the acceleration signal, such as the height of the jump. Furthermore, information on the dynamic behaviour of the jumper, namely during the flight stage can also be obtained from the acceleration signal, which is impossible to study with only the vertical force signal.

In the future, we plan to study the load distribution between inferior members during the take-off and landing stages by combining acceleration and force analysis and study the on-flight behaviour of the jumper.

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