A SIMPLE METHOD FOR MEASURING POWER, FORCE AND VELOCITY PROPERTIES OF SPRINT RUNNING

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SUMMARY
The aim of this study was to propose and validate a simple field method to determine individual force, velocity and power output properties of sprint running. On the basis of 5 split times, this method models the horizontal force an athlete develops over sprint acceleration using a macroscopic inverse dynamic approach. Low differences in comparison to force plate data support the validity of this simple method to determine force-velocity relationship and maximal power output, which constitutes interesting tools for sprint training and performance optimization.

INTRODUCTION
Sprint running is a key factor of performance in many sport activities, such as track and field events or team sports. This ability implies large forward acceleration, which has been related to the capacity to develop high amounts of horizontal power output onto the ground, i.e. high amounts of horizontal external force at various speeds over sprint acceleration [2, 4]. The overall mechanical capability to produce horizontal external force during sprint running is well described by the linear force-velocity (F-v) relationship [2, 5]. This relationship characterizes the mechanical limits of the entire neuromuscular system during sprint propulsion and is well summarized through the maximal force ($F_m$) and velocity ($v_0$) this system can develop [5] and the associated maximal power output ($P_{max}$). Moreover, the slope of the F-v relationship determines the individual F-v mechanical profile, i.e. the ratio between force and velocity qualities, which has recently been shown to determine explosive performances, independently from the influence of $P_{max}$ [6]. These parameters are a complex integration of numerous individual muscle mechanical properties, morphological and neural factors affecting the total external force developed by lower limbs, but also of the technical ability to apply the external force effectively onto the ground. Recently, Morin and colleagues showed that sprint performances (6x-sprints, 100m-events or repeated sprints) are as much (or even more) related to the technical ability to applied force onto the ground as to the total force developed by lower limbs [3, 4]. Consequently, we think that determining individual F-v relationship and $P_{max}$ values during sprint propulsion is of great interest for coaches and sport practitioners. Such evaluations hitherto required to test athletes on instrumented specific treadmills measuring force, velocity and power output very accurately [5]. However, such devices are very rare, and using them forces athlete to report to a laboratory and can be challenged due to the non-ecological testing conditions. A simple method for determining F-v relationships during sprint running in field conditions could therefore be very interesting to generalize such evaluations for training or scientific purposes. The aim of this study was (i) to propose a simple field method for measuring horizontal force using an inverse dynamics approach applied to the body center of mass during sprint running acceleration, and (ii) to validate it by comparison to reference force plate measurements.

METHODS
Nine elite or sub-elite sprinters (23.9 ± 3.4 years, 76.4 ± 7.1 kg, 1.82 ± 6.90 m, 100-m records: ranging from 9.99 to 10.49 s) performed 7 maximal sprints (2 x10 m, 2 x15 m, 20 m, 30 m and 40 m) from which individual F-v relationships, $F_0$ and $v_0$ values (force and velocity-axis intercepts of F-v regression curves, respectively), and $P_{max}$ values ($P_{max} = F_0 \cdot v_0 / 4$, [6]) were determined from horizontal external force obtained by two methods.

Reference method
During each sprint, the horizontal ground reaction force was measured by a 6.60 m long force plate system. The position of the starting block was set differently for each sprint in order to virtually reconstruct the ground reaction force signal of an entire single 40-m for each athlete. The instantaneous running velocity was obtained from force plate data and velocity at the entrance of the force plate area measured by high speed video (300 Hz). Force and velocity were averaged for each step (contact + aerial phases).

Simple method proposed
During a running acceleration, velocity ($v$)-time curve has been shown to follow a mono-exponential function:
During running \[4\]. Since the proposed method models these over each lower limb extension, i.e. each contact phase computed from values of force, velocity and power averaged in Table 1. The absence of significant difference and the mechanical entities from the body center of mass very low bias (< 5 %) between the two methods for horizontal external force \((F_0)\) was modeled over time as:

\[ F_0(t) = m \cdot a(t) + F_{air} \]  \hspace{1cm} (4)

with \(F_{air}\) the aerodynamic friction force to overcome during sprint running computed from running velocity and an estimation of runner’s frontal area and drag coefficient [1].

**RESULTS AND DISCUSSION**

F-v relationships and power output capabilities obtained with the two methods were compared using paired t-tests, systematic bias and absolute bias (in percentage of the reference method values) computations between the proposed and reference methods on \(F_0, v_0\) and \(P_{max}\) values.

**CONCLUSIONS**

This study proposed a simple method to determine F-v and maximal power output values for sprint running using only 5 split times from 10 to 40-m acceleration phases, which is easy to set in field conditions. Comparisons to force plate measurements supported its validity and accuracy to determine force, velocity and power output capabilities during sprint running. This method allows sport practitioners and coaches to evaluate force, velocity and power output capabilities of athletes during sprint running in field conditions, which can be very interesting to orient and individualize exercises and training loads according to strengths and weaknesses of each athlete.

**REFERENCES**


\[ v(t) = v_{max}(1-e^{-a \cdot t}) \]  \hspace{1cm} (1)

\[ x(t) = v_{max}(t + \tau e^{-a \cdot t}) \cdot v_{max} \tau \]  \hspace{1cm} (2)

\[ a(t) = (v_{max}/\tau) e^{-a \cdot t} \]  \hspace{1cm} (3)

For each athlete, the best sprint times at 10, 15, 20, 30 and 40 m were measured from a pair of photocells located at the finish line of the 7 sprints, and used to determine \(v_{max}\) and \(\tau\) using equation 2 and least square regression. From these two parameters, instantaneous velocity and acceleration were computed using equations 1 and 3, respectively. The net horizontal external force \((F_0)\) was modeled over time as:

**TABLE 1:** Mean ± SD of \(F_0, v_0\) and \(P_{max}\) obtained with the two methods, and bias between the two methods.

<table>
<thead>
<tr>
<th></th>
<th>Reference Method</th>
<th>Simple Method</th>
<th>Bias</th>
<th>Absolute Bias (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(F_0) (N)</td>
<td>654 ± 80</td>
<td>636 ± 89</td>
<td>-17.0 ± 37.9</td>
<td>5.18 ± 3.83</td>
</tr>
<tr>
<td>(v_0) (m.s(^{-1}))</td>
<td>10.20 ± 0.36</td>
<td>10.52 ± 0.72</td>
<td>0.34 ± 0.52</td>
<td>4.75 ± 3.39</td>
</tr>
<tr>
<td>(P_{max}) (W)</td>
<td>1669 ± 253</td>
<td>1679 ± 289</td>
<td>9.57 ± 62.78</td>
<td>2.81 ± 2.68</td>
</tr>
</tbody>
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**Figure 1:** Typical F-v relationships obtained with the reference method (dashed regression line determined from black points) and modeled by the simple method (black line).