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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_0) 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 (6s-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.

<u>Reference method</u>

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).

<u>Simple method proposed</u>

During a running acceleration, velocity (v)-time curve has been shown to follow a mono-exponential function:

$v(t) = v_{max}.(1-e^{(-t/\tau)})$ (1)

with v_{max} the maximal velocity reached and τ the acceleration time constant. The horizontal position (x) and acceleration (a) of the body center of mass as a function of time during the acceleration phase can be expressed after integration and derivation of v(t) over time as follows:

$x(t) = v_{max}.(t + \tau.e^{(-t/\tau)}) - v_{max}.\tau$ (2)

$a(t) = (v_{max}/\tau).e^{(-t/\tau)}$ (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 τ 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_h) was modeled over time as:

$F_h(t) = m.a(t) + F_{air}$ (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].

Statistical analyses

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.

RESULTS AND DISCUSSION

F-v relationships obtained by the two methods were well fitted by linear regressions (r^2 from 0.92 to 0.99, P < 0.001). Figure 1 presents typical F-v obtained from the two methods. Mean ± SD of F_0, v_0 and P_{max} values are presented in Table 1. The absence of significant difference and the very low bias (< 5 %) between the two methods for F_0, v_0 and P_{max} values support the validity and accuracy of the simple method to determine F-v relationships and maximal power output values. The differences observed here between methods could be due to model approximations (inverse dynamic approach applied to the body center of mass, aerodynamic friction force estimation, velocity-time curve exponential model), to inaccuracy in body center of mass split time measurements by photocell timers, and also to the inter-step variability in force plate measurements. Moreover, due to methodological concerns associated with force plates, F-v relationships had to be determined from several sprints, which added intra-subject variability in mechanical measurements, and in turn variability in parameter computations.

Usually, F-v relationships and P_{max} values have been computed from values of force, velocity and power averaged over each lower limb extension, i.e. each contact phase during running [4]. Since the proposed method models these mechanical entities from the body center of mass displacement-time curve over sprint acceleration, the resulting parameters correspond to the whole running propulsion, and encompass both contact and aerial phases. Thus, these relationships that consider neuromuscular capabilities, technical abilities and step kinematics pattern, are more representative of the individual mechanical properties of the sprint propulsion than the lower limbs mechanical capabilities. Finally, the proposed method is very simple to set in field conditions since it only requires time-distance data during a sprint acceleration, which can be obtained from photocell timer or from radar measurements.

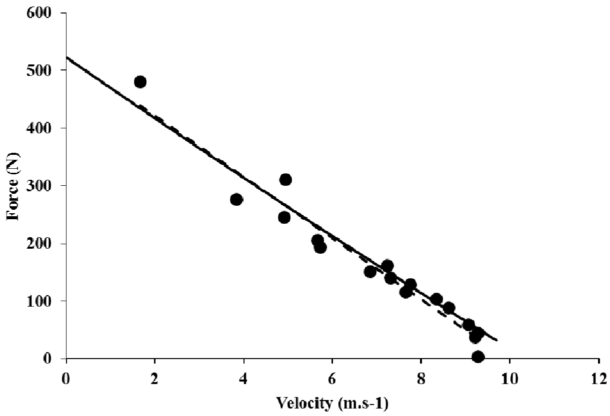

Figure 1: Typical F-v relationships obtained with the reference method (dashed regression line determined from black points) and modeled by the simple method (black line).

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.

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TABLE 1: Mean ± SD of F_0, V_0 and P_{max} obtained with the two methods, and bias between the two methods.

	Reference Method	Simple Method	Bias	Absolute Bias (%)
F_0 (N)	654 ± 80	636 ± 89	-17.0 ± 37.9	5.18 ± 3.83
v_0 (m.s^{-1})	10.20 ± 0.36	10.52 ± 0.72	0.34 ± 0.52	4.75 ± 3.39
P_{max} (W)	1669 ± 253	1679 ± 289	9.57 ± 62.78	2.81 ± 2.68