Force-Velocity Relationship on a Cycle Ergometer and Knee-Extensor Strength Indices

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Catalog Data

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Mots clés: force, pente de montée de force, exercice isométrique, mouvement isocinétique, puissance maximale anaérobie

Abstract/Résumé

Maximal anaerobic power (P_{max}) is often measured on a friction loaded cycle ergometer by means of an all-out exercise against a single braking force or from the force-velocity relationship. The relationship between braking force (F) and peak velocity (V) in cycling is linear: \( V = V_0 (1-F/F_0) \) where \( V_0 \) and \( F_0 \) correspond to the intercepts with the velocity axis and force axis, respectively. The aim of the present paper was to test the hypothesis that parameter \( F_0 \) expresses strength ability. The first study (12 male volleyball players) showed significant correlations between \( F_0 \) and maximal isometric voluntary force (MVF) or maximal isometric rate of force development (MRFD) during isometric knee extension with data expressed either in absolute units (0.66 < r < 0.81, P < 0.01) or related to quadriceps muscle mass kgQ or kgQ^{0.9} (0.58 < r < 0.82, 0.05 < P < 0.001). In the second study (24 male athletes), \( F_0 \) was significantly correlated with the peak torques in isokinetic Biodex knee extension at four angular velocities (0, 1.57, 3.14 and 4.19 rad · s⁻¹) with the values ex-

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pressed in absolute units (0.49 < r < 0.83, 0.05 < P < 0.001). When the results were related to kgQ or kgQ², the correlation coefficients increased with velocity (0.22 < r < 0.69) and were significant (0.05 < P < 0.001) except at 0 rad · s⁻¹. Nevertheless, the interest of the determination of F₀ in addition to Pₘₐₓ is questionable because similar coefficients of correlation were obtained between Pₘₐₓ and strength performances.

La puissance maximale anaérobie (Pₘₐₓ) est souvent mesurée sur ergomètre mécanique à frottement au moyen de sprints maximaux contre une seule force de freinage ou à partir de la relation charge-vitesse. La relation entre la force de freinage (F) et le pic de vitesse (V) sur bicyclette est linéaire: V = V₀(1-F/F₀) où V₀ et F₀ correspondent respectivement aux intersections avec les axes des vitesses et des forces. L'objectif de la présente étude était de tester l'hypothèse que le paramètre F₀ est une expression des qualités de force. Dans une première étude (12 volleyeurs) F₀ était significativement corrélé avec la force maximale isométrique (MVF) et la montée maximale de force isométrique (MRFD) pendant une contraction isométrique des extenseurs du genou que les valeurs soient exprimées en valeurs absolues (0.66 < r < 0.81, P < 0.01) ou rapportées à la masse du muscle quadriceps kgQ ou kgQ² (0.58 < r < 0.82, 0.05 < P < 0.001). Dans une deuxième étude (24 athlètes masculins), F₀ était significativement corrélé avec les pics des moments produits lors d'extensions du genou sur ergomètre isocinétique Biodex à quatre vitesses angulaires (0, 1.57, 3.14 et 4.19 rad · s⁻¹) avec les grandeurs exprimées en valeurs absolues (0.49 < r < 0.83, 0.05 < P < 0.001). Lorsque les données étaient rapportées à kgQ ou kgQ², les coefficients de corrélation augmentaient avec la vitesse (0.22 < r < 0.69) et étaient significatifs (0.05 < P < 0.001) excepté à 0 rad · s⁻¹. Cependant, l'intérêt de déterminer F₀ en plus de Pₘₐₓ est discutable car des coefficients de corrélation similaires étaient obtenus entre Pₘₐₓ et les différents indices de force.

**Introduction**

Maximal anaerobic power (Pₘₐₓ) is often measured on a cycle ergometer by means of an all-out exercise test against a single braking force related to body mass (e.g., the Wingate test) or from the force-velocity relationships on an isokinetic (Sargeant et al., 1981) or friction loaded ergometer for peak velocity (Nakamura et al., 1985; Vandewalle et al., 1985a, 1987a, 1987b) and S-s averaged-velocity (Nadeau et al., 1983). In contrast with the hyperbolic force-velocity relationship of an isolated muscle (Hill, 1938) or a monoarticular exercise (see a review in Gölch, 1994), the relationships between braking force and peak velocity are linear for arm (Vandewalle et al., 1983) as well as for leg (Vandewalle et al., 1985a, 1987a, 1987b) exercise. The same linear relationship has been described between torque and velocity for maximal exercises on an isokinetic cycle ergometer (Sargeant et al., 1981) or an electronic cycle ergometer with strain gauges bonded on the cranks (Capmal and Vandewalle, 1997). These linear relationships have been observed for pedal rates between 50 and 200 rpm (Capmal and Vandewalle, 1997; Sargeant et al., 1981; Seck et al., 1995). The discrepancy between isolated muscle contraction and cycling has not been explained yet (Capmal and Vandewalle, 1997). The relationship between braking force (F) and peak velocity (V) can be written as proposed by Vandewalle et al. (1985a, 1987a, 1987b; Equation 1):

\[
V = V₀(1-F/F₀) \quad \text{and} \quad F = F₀(1-V/V₀)
\]
where parameters $V_0$ and $F_0$ correspond to the intercepts with the velocity axis and force axis, respectively (Figure 1). The values of $V_0$ and $F_0$ have the dimensions of maximal velocity at zero braking force axis and the braking force corresponding to zero velocity, respectively.

Given the linear relationship between $F$ and $V$, it can be demonstrated that $P_{\text{max}}$ corresponds to an optimal velocity and an optimal braking force equal to $0.5V_0$ and $0.5F_0$, respectively (Vandewalle et al., 1985a).

When compared to other tests measuring anaerobic power (Ayalon et al., 1974; Pirtney and Crielard, 1979), the force-velocity test on a cycle ergometer enables the investigator to determine parameters $V_0$ and $F_0$ in addition to $P_{\text{max}}$. It has been demonstrated that optimal velocity for $P_{\text{max}}$ was significantly correlated with the proportion of fast twitch muscle fibers in the vastus lateralis (Hautier et al., 1996; Sargeant et al., 1994). Consequently, $V_0$ should also depend on the percentage of fast fibers as optimal velocity for $P_{\text{max}}$ is equal to $0.5V_0$. As a consequence, the highest values of $V_0$ are observed in subjects practicing sprint and power events (Vandewalle et al., 1987a; i.e., in subjects with a high percentage of fast muscle fibers; Mero et al. 1981; Sleivert et al. 1995). However, the value of $V_0$ also depends on body height (Vandewalle et al., 1989) when crank length is not adjusted to leg or arm length (Vandewalle et al., 1985b).

The significance of $F_0$ has not been studied, yet. $F_0$ has the dimension of a maximal force at zero velocity (i.e., the dimension of a maximal isometric force, and, in theory, should be correlated with muscle strength). Therefore, it could be interesting to determine the parameter $F_0$ to estimate strength ability in addition to $P_{\text{max}}$. In the male adult, $F_0$ is generally calculated by a large extrapolation from velocity data higher than 100 rpm, only. Indeed, it is difficult to cycle against a
high braking force (more than 80 N) with the usual friction loaded cycle ergometers because of an insufficient moment of inertia of their flywheel. Moreover, curvilinear force-velocity relationships have also been proposed for isokinetic cycling exercises (McCartney et al., 1985). Consequently, the validity and the accuracy of $F_0$ as a strength index is debatable and it is not obvious that the determination of this parameter in addition to $P_{\text{max}}$ is interesting in athlete testing.

In the present study, we compare the results of a force-velocity test on a Monark cycle ergometer with different strength indices. As $F_0$ has the dimension of a maximal force at zero velocity, in a first investigation (isometric study), we correlated $F_0$ with the maximal rate of force development and the peak force during maximal isometric contraction of the quadriceps extensors. A second investigation (isokinetic study) has been designed to correlate $F_0$ with peak torques measured on an isokinetic ergometer during maximal knee extension at different angular velocities (from 0 to 4.19 rad · s$^{-1}$) because previous studies have found that isometric tests are sometimes poorly correlated with dynamic performances (Baker et al., 1994; Mero et al., 1981). In addition, the results of the isometric and isokinetic knee extension tests were also correlated with $P_{\text{max}}$ to verify whether the determination of $F_0$ gives additional or the same information as $P_{\text{max}}$.

**Materials and Methods**

**ISOMETRIC STUDY**

Twelve male, right-handed volleyball players of a national league (19.6 ± 0.8 years, 186.2 ± 4.8 cm, 78.3 ± 8.3 kg) volunteered as subjects in the first study comparing $F_0$ and isometric strength. These subjects were chosen because the force-velocity test was proposed as a component of a test battery for volleyball players (Driss et al., 1998).

The subjects performed a force-velocity test and the isometric test on separated days. Three isometric knee extensions were performed with the right and left legs in a random order with a 5-min recovery between trials and a 10-min recovery between legs. Anthropometric data were collected in the first session.

**ISOKINETIC STUDY**

Twenty four male right-handed athletes [8 gymnasts (26.5 ± 3.96 years, 170.6 ± 4.03 cm, 68.1 ± 4.73 kg), 7 weight-lifters (20.7 ± 3.73 years, 165.4 ± 10.28 cm, 71.57 ± 14.17 kg) and 9 endurance subjects (32.78 ± 10.53 years, 173.1 ± 5.49 cm, 70.44 ± 5.59 kg)] participated in the second experiment comparing $F_0$ and isokinetic strength.

The force-velocity test and the isokinetic test were performed on separated days. Anthropometric data were collected in the first session.

**FORCE VELOCITY RELATIONSHIP**

In both studies, the force-velocity relationship in cycling was determined on a Monark 864 cycle ergometer according to the protocol proposed by Vandewalle et al. (1985a, 1987a, 1987b). Toe clips and well-fastened straps avoided losing the pedals when cycling.
The force-velocity test was performed in both studies but the device measuring pedal rate was different. In the isometric study, pedal velocity was measured by means of a magnetic transducer linked to a PC computer, which displayed 1-s averaged velocity. In the isokinetic study, the flywheel velocity of the cycle ergometer was measured by means of an optoelectronic transducer and a digital tachymeter, which displayed 1-s averaged pedal velocity.

The force-velocity test consisted of measuring peak velocity (V) during short maximal sprints (about 6 s) on a cycle ergometer against different braking forces, which were set before the beginning of each sprint. The subjects were vigorously encouraged to reach maximal pedaling rate as soon as possible. The tests began with a braking force equal to 19.6 N. After 5 min of recovery, the braking force was increased by either 14.7 N or 19.6 N, and the same exercise was performed again until the subjects were unable to reach a peak velocity higher than 100 rpm. The highest braking forces ranged from 78.5 N to 127.5 N. The value of V was measured during each sprint for each braking force (F) and were used to calculate the force-velocity relationship according to the least square method. The sprints with the first and second braking forces were performed again at the end of the test and were taken into account in the computation of the force-velocity relationship. Consequently, the subjects generally performed 6 to 8 short all-out sprints.

First a linear relationship between velocity (V) and braking force (F) was computed according to the least square method:

\[ V = a - bF \]

Thereafter, this relationship was transformed according to Vandewalle et al. (1985a):

\[ V = V_0 \left(1-F/F_0\right) \text{ and } F = F_0 \left(1-V/V_0\right) \]

with \( V_0 \) and \( F_0 \) equal to the intercepts with the velocity axis and force axis, respectively (\( V_0 = a \) and \( F_0 = a/b \)). In this model, the value \( F_0 \) had the dimension of the braking force corresponding to zero velocity.

Since a linear relationship between F and V is assumed (Figure 1), \( P_{\text{max}} \) corresponds to an optimal velocity and an optimal braking force equal to 0.5 \( V_0 \) and 0.5 \( F_0 \), respectively (1985a). Consequently, \( P_{\text{max}} \) was calculated as equal to 0.25 \( V_0 \) * \( F_0 \) (Equation 2):

\[ P_{\text{max}} = 0.5 V_0 * 0.5 F_0 = 0.25 V_0 * F_0 \]

**ISOMETRIC FORCE-TIME CURVE**

The isometric force-time curve (Figure 2) during 5 s was determined during unilateral maximal isometric knee extensions against a stiff strap blocking the insteps of the subjects. The subjects sat with the hip and knee angles at 90°. They were restrained around the pelvis and the thigh with straps to ensure isolation of the muscle group of interest (knee extensors).

The strap was linked to a 2000 N strain gauge transducer connected to the data acquisition card of a PC computer which stored the data at a 1000 Hz sampling rate. Then torques were calculated by multiplying force data and arm lever, i.e. the distance between knee rotation center and the middle of the leg strap (0.34 to 0.45 m).
The subjects were instructed to perform the most explosive isometric strength exercise without focusing on maximal isometric strength. Thereafter, they were encouraged to produce their maximal isometric strength before they relaxed. The subjects were instructed to exert a small force on the strap just before the beginning (Viitasalo 1982). After data collection, the computer calculated Maximal Voluntary isometric Force (MVF) corresponding to the highest force averaged over 20 ms. Thereafter the computer calculated the maximal slope of the force-time curve as equal to the highest difference in force between two points of the force-time curve separated by a 20 ms interval. This 20 ms interval was chosen as a digital filtering to eliminate the effect of a very small 50 Hz voltage superimposed to the output of the force transducer. This slope was considered as the Maximal Rate of Force Development (MRFD). Knee extension performances were recorded for the right (MVF_R and MRFD_R) and left (MVF_L and MRFD_L) legs. The values of MVF and MRFD, which corresponded to the best results of three trials were correlated with F_0 for each leg. MVF_R+L and MRFD_R+L corresponded to the sum of the best unilateral performances of the right and left limbs for MVF and MRFD, respectively.

**ISOKINETIC MEASUREMENTS**

Peak isokinetic knee extension torques were measured on a Biodex dynamometer (Brut Controller model). The subjects were harnessed to the testing apparatus with straps around the chest, pelvis, thigh, and above the malleoli. The time-torque
curve computed by the Biodex system took into account gravitational torques. Indeed, as the knee extension was performed in the vertical plane, net torque was calculated by the dynamometer as equal to the algebraic sum of the exerted torque and the torque corresponding to the action of gravity on the lever arm and the moving limb. Gravitational torques exerted on the moving limb and the lever arm were estimated by measuring torque during passive knee flexion before the test. The angle between the thigh and the trunk was approximately 95°.

The subjects were instructed to perform knee extension from 90° to 180° at three angular velocities (1.57, 3.14, 4.19 rad.s⁻¹) in a random order. At each velocity, three trials were performed in a row. In addition, peak isometric torque was measured during a 5-s isometric extension with the knee angle at 120°. Two-minute recovery intervals were allowed between the exercises at the different velocities. The best torques at each velocity (T0, T1.57, T3.14 and T4.19) were correlated with F0.

THIGH VOLUME AND QUADRICEPS FEMORIS MASS

Surface measurements of the subject’s thigh lengths (L) and circumferences (O1, O2, and O3) were measured together with skinfold (Sk) measurements of the thigh according to Jones and Pearson (1969). Thigh volume (Vol) was then calculated from the formula proposed by Andersen and Saltin (1985)[1]:

\[
\text{Vol} = L \left(12\pi\right)^{-1} \left(O_1^2 + O_2^2 + O_3^2\right) - \left(Sk - 0.4\right) 2^{-1} \left(O_1 + O_2 + O_3\right) 3^{-1}
\]

The quadriceps femoris muscle mass (kgQ) was then calculated:

\[
\text{kgQ} = 0.307 \times \text{Vol} + 0.353
\]

The values of F0, MVF, MRFD and peak torques were related to quadriceps femoris muscle mass (kgQ). As strength is proportional to the physiological muscle cross sectional area, strength data should be related to muscle volume with an exponent equal to 0.67. Consequently, F0, MVF, MRFD and peak torques were also related to quadriceps muscle mass\(\times 3\) (kgQ\(\times 3\)).

**Statistical Analysis**

Pearson product moment correlation (r) and statistical differences between correlation coefficients were computed with Statistica software. Statistical significance was accepted at \(P < 0.05\).

**Results**

**ISOMETRIC STUDY**

The mean values of MVF\(_r\) and MVF\(_l\) were 319.93 ± 79.1 Nm and 326.8 ± 65.8 Nm, respectively. The mean values of MRFD\(_r\) and MRFD\(_l\) were 2790.9 ± 753.9 N \cdot m \cdot s\(^{-1}\) and 2825.3 ± 607.3 N \cdot m \cdot s\(^{-1}\), respectively. The differences in MVF and MRFD between the left and right legs were not significant (\(P > 0.05\)).

When the data were expressed in absolute units (N, N \cdot m, N \cdot m \cdot s\(^{-1}\)), all the correlations between F0 and the strength indices were significant. F0 was significantly correlated with MVF and MRFD for the right leg or the left leg as well as
MVF^{R+L} and MRFD^{R+L} (Table 1). When the data were related to kgQ or to kgQ^{2/3}, \( F_0 \) was significantly correlated with isometric strength indices. Similar results were obtained for the correlations between \( P_{\text{max}} \) and the different strength indices.

\( F_0 \) and \( P_{\text{max}} \) were highly correlated when data were expressed in absolute units (\( r = 0.97 \)), or related to kgQ (\( r = 0.98 \)) and kgQ^{2/3} (\( r = 0.97, P < 0.001 \)). On the other hand, \( P_{\text{max}} \) and \( V_0 \) were not significantly correlated.

**ISOKINETIC STUDY**

The value of \( F_0 \) was significantly correlated with the absolute values of peak torques at all the angular velocities (T0, T1.57, T3.14 and T4.19; Table 2). The correlation coefficients between \( F_0 \) and peak torques increased with angular velocity (Figure 3).

When the data were related to kgQ or to kgQ^{2/3}, \( F_0 \) was significantly correlated with peak torques (Table 2 and Figure 4) except for T0. Similar results were observed for the correlation between \( P_{\text{max}} \) and peak torques when the data were expressed either in absolute values or related to kgQ and to kgQ^{2/3}.

As in the isometric study, \( F_0 \) and \( P_{\text{max}} \) were highly correlated when data were expressed in absolute units (\( r = 0.97 \)), or related to kgQ (\( r = 0.82, P < 0.001 \)) and to kgQ^{2/3} (\( r = 0.94 \)). Furthermore, \( P_{\text{max}} \) and \( V_0 \) were not significantly correlated.

**Discussion**

The results of the present paper confirmed the hypothesis that the parameter \( F_0 \) of the force-velocity relationship on a cycle ergometer is an index of maximal strength. In contrast with the previous studies, which found that isometric tests were poorly correlated with dynamic performances (Baker et al., 1994; Murphy and Wilson,

| Table 1 Correlation Coefficients Between the Strength Indices (MVF and MRFD) of the Left (L), Right (R), Left + Right (L + R) Legs and \( F_0 \) or \( P_{\text{max}} \) in the Isometric Study |
|-----------------|----------|----------|----------|----------|----------|----------|
|                 | \( F_0 \) |          | \( P_{\text{max}} \) |
|                 | L        | R        | L+R      | L        | R        | L+R      |
| MVF             |          |          |          |          |          |          |
| Nm              | 0.69     | 0.68     | 0.73     | 0.66     | 0.74     | 0.75     |
| Nm.kgQ^{-1}     | 0.63     | 0.67     | 0.70     | 0.62     | 0.73     | 0.73     |
| Nm.kgQ^{2/3}    | 0.59     | 0.64     | 0.66     | 0.58     | 0.71     | 0.69     |
| MRFD            |          |          |          |          |          |          |
| Nm.s^{-1}       | 0.81     | 0.72     | 0.79     | 0.76     | 0.79     | 0.81     |
| Nm.kgQ^{-1}     | 0.80     | 0.71     | 0.80     | 0.82     | 0.78     | 0.82     |
| Nm.kgQ^{2/3}    | 0.82     | 0.70     | 0.78     | 0.79     | 0.78     | 0.81     |

*Note:* Data were expressed in absolute units and related to quadriceps muscle mass (kgQ^{-1}) or quadriceps muscle mass^{2/3} (kgQ^{2/3}). \( P < 0.05 \) for \( r > 0.55 \).
**Figure 3.** Relationship between $F_0$ and peak torques (T) at different velocities (0, 1.57, 3.14 and 4.19 rad.s$^{-1}$) in the isokinetic study. The data were expressed in absolute units.

**Table 2 Correlation Coefficients Between Peak Torques at 0 (T0), 1.57 (T1.57), 3.14 (T3.14), 4.19 (T4.19) rad.s$^{-1}$ and $F_0$ or $P_{max}$ in the Isokinetic Study**

<table>
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<tr>
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<tr>
<td><strong>T0</strong></td>
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<td><strong>T3.14</strong></td>
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<td>Nm</td>
<td>0.49</td>
<td>0.54</td>
<td>Nm</td>
<td>0.82</td>
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<td>Nm.kgQ$^{-1}$</td>
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<td>Nm.kgQ$^{-1}$</td>
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<td>Nm.kgQ$^{2/3}$</td>
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<td>Nm.kgQ$^{2/3}$</td>
<td>0.66</td>
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<td><strong>T1.57</strong></td>
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<td><strong>T4.19</strong></td>
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<td>Nm</td>
<td>0.76</td>
<td>0.77</td>
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<td>Nm.kgQ$^{-1}$</td>
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<td>Nm.kgQ$^{-1}$</td>
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<td>Nm.kgQ$^{2/3}$</td>
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*Note:* Data were expressed in absolute units and related to quadriceps muscle mass (kgQ$^{-1}$) or quadriceps muscle mass$^{2/3}$ (kgQ$^{2/3}$). $P < 0.05$ for $r > 0.39$. 
1996), MVF and MRFD of the knee extensors in the isometric study were significantly correlated with F₀. Similarly, the results of the isokinetic study showed high correlations between F₀ and peak torques measured in dynamic conditions.

It should be mentioned that significant correlations were still observed when these parameters were related to kgQ or kgQ^2/3 and even in a homogenous sample such as the volleyball group. In contrast with MVF in the isometric study, the relationship between T₀ and F₀ in the isokinetic study was not statistically significant when data were related to quadriceps muscle mass. This difference could be partly explained by the fact that T₀ was measured at 120° of knee extension and that the torque exerted on the pedals is maximal for a knee angle around 90° (Capmal and Vandewalle, 1997; Gregor, 1985; Patterson and Moreno, 1990), the angle corresponding to the measurement of MVF in the isometric study. Indeed, several studies (Murphy and Wilson, 1996; Murphy et al, 1995) have demonstrated that
significant correlations between isometric and dynamic strength performances are mainly observed when force is measured at similar angles during isometric and dynamic exercises.

It is possible that $F_0$ is an index of explosive and dynamic strength rather than maximal isometric strength. The results of the isokinetic study showed that the correlation coefficients between $F_0$ and peak torques measured in the dynamic conditions increased with velocity: the correlation coefficient between $F_0$ and isokinetic torque at 3.14 or 4.19 rad $\cdot$ s$^{-1}$ were significantly higher ($p < 0.05$) than the same coefficient at 0 rad $\cdot$ s$^{-1}$. In the isometric study, the correlation coefficients between $F_0$ and MVF (expressed in Nm, Nm $\cdot$ kgQ$^{-1}$ or Nm $\cdot$ kgQ$^{-2/3}$) were lower than the correlation coefficients between $F_0$ and MRFD (Table 1) but these differences were not significant.

It must be noted that the correlation coefficients between $F_0$ and the different indices of strength in the isometric and isokinetic conditions were similar to the correlation coefficients between the same strength indices and $P_{\text{max}}$ (Table 1 and Table 2). Consequently, the interest of the determination of $F_0$ in addition to $P_{\text{max}}$ is questionable. This result was probably the consequence of the homogeneity of the experimental groups with regard to $V_0$. Indeed, the value of $P_{\text{max}}$ depends on $F_0$ and $V_0$ (Equation 2). The coefficient of variation of $F_0$ was equal to 13.4 and 19.1% in the isometric and isokinetic study, respectively. But, the coefficients of variation of $V_0$ were low and equal to 3.3 and 4.8% for the isometric and isokinetic studies, respectively. No subjects in both studies presented very low values of $V_0$ (e.g., 180 rpm as in some marathon runners). The lowest values were 224 and 204 rpm in the isometric and the isokinetic study, respectively. Similarly, no subjects presented very high values of $V_0$ (for example 280 rpm as in olympic sprint cyclists). The highest values of $V_0$ were 247 and 257 in the isometric and isokinetic studies, respectively. Given the low variance of $V_0$, most of the variance of $P_{\text{max}}$ was explained by the variance of $F_0$ and, consequently, $P_{\text{max}}$ was highly correlated with $F_0$ but not with $V_0$. The most powerful subjects in the present study were the strongest ones, also. It is likely that the correlation coefficients between strength indices and $P_{\text{max}}$ would have been lower in less homogenous samples with regard to $V_0$.

The correlation coefficient between $F_0$ or $P_{\text{max}}$ and the isometric and isokinetic strength indices were significant but not very high. For the highest correlation coefficient in the present study (0.82 for the correlation between MRFD and $F_0$ or $P_{\text{max}}$), the variance of the independent variable (MRFD) only explained 67% of the variance of $F_0$ or $P_{\text{max}}$. Several explanations can be proposed. First, the variance of $F_0$ was not very large. Secondly, the low correlation coefficients could be the result of errors ($F_0$ was calculated by extrapolation) or day-to-day variations in $F_0$ and the strength measurements. The error due to extrapolation should be lower when the velocity range is larger and includes low pedal frequencies as in the studies with an isokinetic cycle ergometer (Sargeant et al., 1981) or a lode cycle ergometer with torque measurement (Capmal and Vandewalle, 1997). For example, the value of $F_0$ is overestimated when the value of $V_0$ is underestimated because of a submaximal effort at the lowest braking force (e.g., 19.6 N). In this case, the error in $P_0$ is small because $P_{\text{max}}$ is equal to $0.25 V_0^2 F_0$ and the error in $F_0$ is offset by the error in $V_0$. Thirdly, $F_0$ should express the strength of the different muscle groups active during cycling, not only the quadriceps (as in the knee extension tests used in the present study) but also other muscle groups such as the gluteus maximus,
hamstring muscles and ankle flexors.

In conclusion, the parameter $F_0$ of the force-velocity relationship on a cycle ergometer is significantly correlated with different strength indices measured during knee extension in isometric and isokinetic conditions. $F_0$ is better correlated with the isometric rate of force development and peak knee extension torques at high velocities than with maximal isometric force. However, it should be mentioned that similar coefficients of correlation were obtained between maximal anaerobic power ($P_{\text{max}}$) and strength performances in the present investigation, so the usefulness of calculating $F_0$ in addition to $P_{\text{max}}$ in this type of athletes is questionable.

References


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