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The ability of isoinertial assessment to monitor specific training effects

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Aim. **The aim of this study was to investigate the ability of isoinertial assessment to monitor training effects. Both parametric and curve analysis of the results were used to underline the specificity of maximal strength and maximal velocity resistance training methods.**
Methods. **Twenty-four untrained subjects were randomly assigned into three groups: a maximal strength-training group (heavy loads: 80% to 98% of the one repetition maximum [1-RM]), a maximal velocity-training group (light loads: 25% to 50% of 1-RM) and a control group. All the subjects were tested in bench press exercises before and after the 6-week training period. An isoinertial dynamometer was used to assess velocity and power at four increasing loads: 35%, 50%, 70% and 95% of the 1-RM load. Post-test protocol also included a trial at 105% of the 1-RM load.**
Results. **Isoinertial assessment demonstrated for both training groups significant gains at each load. Some specific adaptations appeared: strength training presented a greater increase for average power (+49%, P<0.001) and average velocity (+48%, P<0.001) at 95% of 1-RM, while velocity training emerged as a more effective way to improve performance at 35% and 50% of 1-RM (+11 to 22%) in comparison with strength training (+7 to 12%). The analysis of power and velocity curves specified that strength training enhanced performance earlier in the movement, while velocity training extended the propulsive action at the end of movement.**
Conclusion. **The original combination of parametric and curve isoinertial assessment appears to be a relevant method for monitoring specific training effects. The complementarity of both strength and velocity training programmes underlined in this study could lead to practical applications in profiling training programmes.**

KEY WORDS: Muscle, skeletal - Muscle strength - Exercise - Physical fitness.

Resistance training has been highly recommended in order to maximize the standard of performance in many sports. Therefore, the assessment of muscular function appears particularly important to understand how various acute programme variables and their interactions affect force, power and velocity.[1]

One interesting way to investigate the influence of specific resistance training on the neuromuscular system involves monitoring training-induced changes in performance under various loading conditions, exploring either force-velocity or force-power relationships. Surprisingly, most studies have involved the isokinetic method in order to verify whether resistance training at a specific velocity would affect performance only

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at that velocity or at a broader range of velocities.[2-5] Most commonly, sport-specific training, and particularly resistance training, aims to increase velocity in movements involving constant load exercise, and not to increase load during constant velocity exercise. Consequently, isokinetic assessment does not appear to be the most specific tool for reflecting training-induced changes in performance. Moreover, most exercises during sport resistance training involve acceleration and deceleration of a constant mass about the associated joints, entailing the development of isoinertial force.[6] Therefore, the conditioning tenet of specificity strongly suggests the promotion of the isoinertial concept of strength assessment with the aim of detecting specific training effects.

Isoinertial assessment consists of monitoring muscle performance during usual constant load weightlifting tasks. The most popular methods consist of the one repetition maximum procedure (1-RM), often used as a measure of strength for athletic profiling,[1, 7, 8] and of vertical jumps, representative of leg power.[1] These methods, though presenting great external validity and dynamic specificity,[1] do not enable coaches to monitor training effects through a complete force-velocity relationship. Over the last few years, newly designed isoinertial dynamometers, using a cable-extension position transducer, rotary encoder, infrared sensor or accelerometer, have been developed to measure the velocity and power exerted at different loads through common weightlifting exercises.[6, 9-14] Such an approach allows the description of force-velocity and force-power relationships. The fact that isoinertial testing movements closely mimic training movements strongly suggests that the assessment involves a high level of specificity and sensitivity. However, only limited research has used this form of dynamometry to quantify the influence of a specific resistance training method on muscular performance. The study by Wilson *et al.*[15] combined a force platform and rotary encoder (the Plyometric Power System) in order to investigate the adaptation evoked by plyometric and weight training on dynamic performance. Force and rate of force development data during squat and bench press exercises were collected with the force platform. The rotary encoder was only used to measure the bar displacement and no information was provided regarding gains in velocity or power after training. Kraemer *et al.*[16] used the same dynamometer in order to compare the effect of different resistance training methods on strength/power performance in women. In that case, the rotary encoder was used to evaluate power output. Upper and lower body were tested using a ballistic shoulder press with 30% of the 1-RM and squat jumps with both 30% and 60% of the 1-RM. Nevertheless, the authors did not report velocity measurements during the exercises. The work by Almasbakk and Hoff [17] is one of the rare studies to have used isoinertial tests in order to investigate the influence of strength training on the force-velocity relationship. Unfortunately, the paper did not describe how the velocity was measured, nor did it presented power data. Hence, all theses studies failed to clarify load-power and load-velocity relationships, and gave incomplete information on specific training effects.

The aim of the present study was to evaluate the ability of an isoinertial assessment to monitor specific forms of resistance training. The relevance of the method was tested through a parametric approach allowing the description of load-power and load-velocity relationships as well as through the analysis of curve representing velocity and power development during movement. The survey also aimed specifically to describe the influence of strength and velocity resistance training programmes on neuromuscular performance.

Materials and methods

Subjects

Twenty-four healthy male subjects without a history of previous injury participated voluntarily in the study. Their amount of recreational sport activity did not exceed two hours per week. None of them had undertaken a previous strength-training programme. Subjects were randomly assigned into three equal- sized groups, which consisted of 1) maximal strength-training group (strength); 2) maximal velocity-training group (velocity); and 3) control group (control) (Table I). Before starting the training programme, no difference had been observed between the three groups with regard to maximal bench press performance (BP 1-RM). All subjects were informed of the risks associated with this study before giving their written consent to participate.

Testing procedures

The subjects were carefully familiarized with BP exercises and testing procedures one week before the

TABELLA I.—*Number of subjects, mean (standard deviation) age, height, body mass and BP 1-RM in each group.*

Groups	Number	Age (years)	Height (cm)	Body mass (kg)	BP 1-RM (kg)
Strength	8	24 (1.4)	178.4 (2.8)	73.7 (7.2)	59.3 (14.1)
Velocity	8	23.7 (2.2)	182.9 (5.7)	76.4 (7.6)	61.3 (8.6)
Control	8	23.2 (1.5)	179.3 (3.3)	77.9 (10.7)	61.2 (10.7)

TABLE II.—*Summary of study design.*

Familiarization	Isoinertial pretest			6-week period	Isoinertial post-test		
	Load	Trials	Rest		Load	Trials	Rest
Familiarization	35%	3	1 min	Strength training	35%	3	1 min
with BP	70%	2	3 min	or	70%	2	3 min
+	50%	3	1 min	velocity training	50%	3	1 min
1-RM	95%	2	3 min	or	95%	2	3 min
				control	105%	1	3 min

measurements. The familiarization included: 1) several sets of BP exercises; 2) technical corrections (total elbow extension, breathing, maximal velocity intention); and 3) standardized advice throughout each set. During this session, the one repetition maximum determination (1-RM) was performed according to the standard methods established by Kraemer and Fry.[8] (Table II) Prior to starting exercise, the BP position was individually determined: the barbell in the starting position rested three centimetres above the subject's nipple line; hand positions on the bar were defined as to the distance measured between elbows when arm abduction corresponded to 90°. BP performance was assessed only during the concentric phase. During the whole movement, subjects had to keep their back on the bench and their hips flexed at 90°. The recording of initial barbell height, distance between the hands, and chest position allowed for the perfect reproduction of the starting position through successive sessions.

All subjects were tested in BP following standardized modalities [12] and at the same time of day, before and after a six week (6 W) training period. They were instructed to abstain from doing strenuous physical activity for 48 h before each testing day. The resistive charges to be used during the isoinertial assessment were based on the initial 1-RM BP performance. In the pretest, these charges were, respectively, 35%, 50%, 70% and 95% of the 1-RM load. Three trials were performed at 35% and 50% of 1-RM (1 min of rest between each trial) and two trials at 70% and 95% of 1-RM (3 min of rest). Subjects were instructed to perform each movement as quickly as possible and to focus their concentration particularly at the end of the movement, in order to reach the highest velocity. Only the best trial, selected according to the peak velocity, was selected for each load testing. Test conditions were identical in the post-training test, which also included one trial at 105% of the initial 1-RM load.

Isoinertial dynamometer

The dynamometer used in the present study has been recently described [12] and was used to monitor velocity and power during isoinertial vertical BP exercises performed on a Smith machine (Multipower M433, Salter SA, Barcelona). Equipment used to yield isoinertial parameter measurements included an accelerometer (ICS Sensors, model 3140, USA) and a cable-extension position transducer (Celesco Transducer Products, Inc., model PT5DC, USA), both positioned at the same extremity of the bar. The uniaxial piezoresistive accelerometer consists of a semiconductor strain gauge, which is bonded to a cantilever beam, end-loaded with a mass. When motion occurs, the beam bends, which creates a strain proportional to acceleration, and a corresponding change in voltage can be measured. This device was horizontally fixed onto a block used to guide the bar. A cable-extension position transducer is positioned on the ground in such a way that the cable can be attached at the extremity of the bar with a strict vertical movement. A potentiometer gave an electric output signal proportional to the stroke

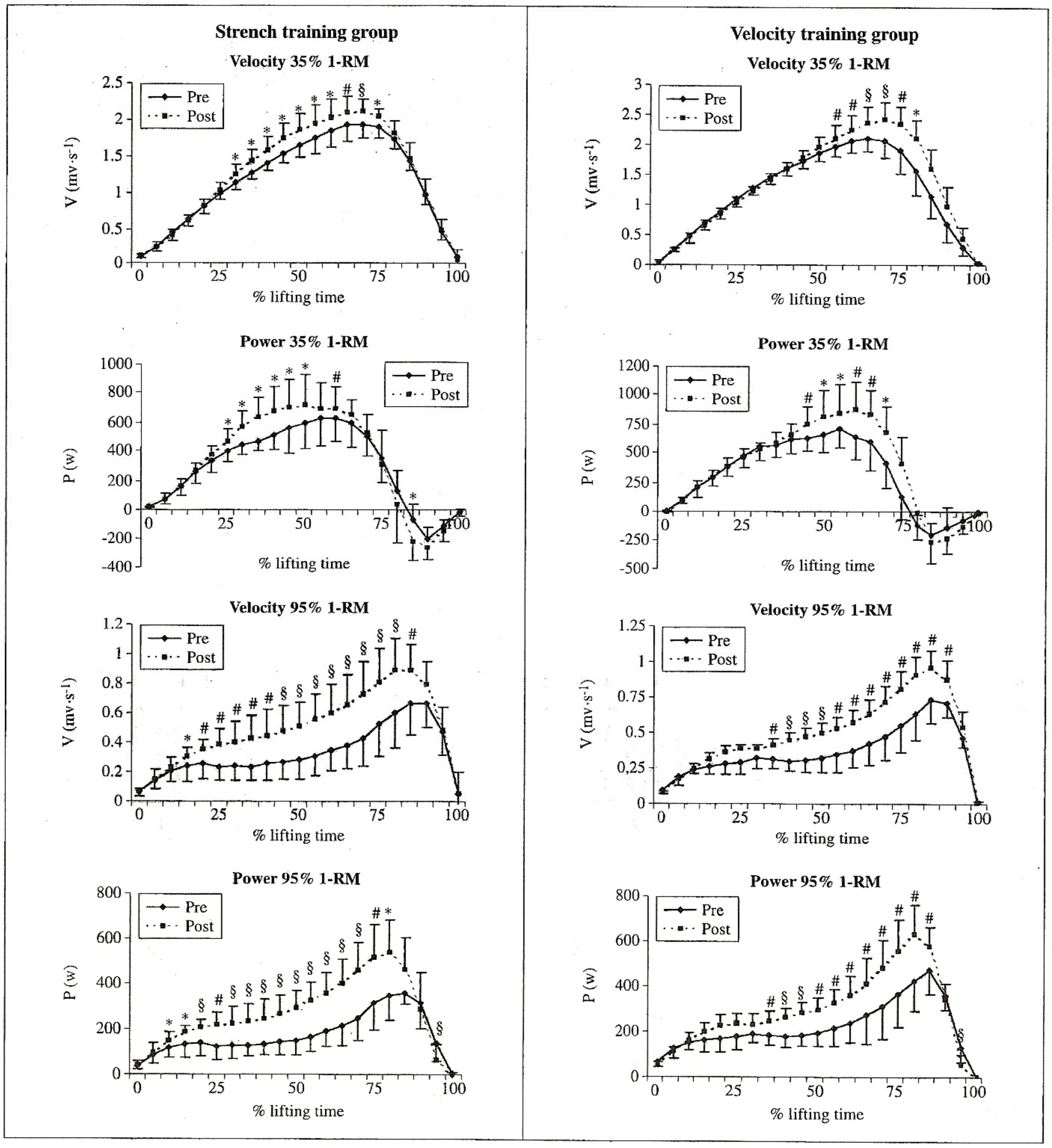

Figure 1.—Graphical representation of velocity and power at the two relative charges (35% an 95% of the 1 RM) for both training groups before and after the training programme (*P<0.05; #P<0.01; §P<0.001).

range. An analogue-to-digital interface (PCMCIA Dakcard, 6024E, National Instrument, USA) transferred both accelerometer and position transducer signals to a notebook computer. Labview software (National Instrument, USA) enabled measurement coordination, data analysis, storage of information and instantaneous presentation of results. Distance and acceleration parameters were directly measured by the devices with a sampling rate of 1 000 Hz. Velocity was derived from displacement (v=dx/dt), whereas power resulted from the product of the lifted mass, acceleration and velocity (P=m.a.v). A lowpass filter was used to smooth velocity and acceleration data with the low cut of a 17Hz frequency.

Data processing

The analysis of parameters was demonstrated to be reproducible and consisted of measuring peak velocity (PV, $m.s^{-1}$), average velocity (AV, $m.s^{-1}$), peak power (PP, W), and average power (AP, W) for each load during concentric movements.[12]

The analysis of curve represented the instantaneous evolution of velocity and power during each lifting. The curve was reconstituted by connecting to each other the values recorded every 5% of the total lifting time (Figure 1).

Training programme

Subjects in both experimental groups trained for 6 weeks (6 W) following specific and standardized programmes as presented in Table III. The group performed workouts designed hypothetically to obtain maximum strength gains by using nearly maximal loads (80-98% of 1-RM).[7] The velocity group undertook workouts designed to favour maximal-power and velocity gains by using weights of 25% to 50% of 1-RM.[7] A period of relative recovery was introduced after 3 weeks of training and this allowed a new 1-RM determination. The training loads used on weeks 5 and 6 were adjusted accordingly. The workload, corresponding to the total percentage of 1-RM lifted during the training period, was identical in both groups. Each training session was supervised by the same experimenter. Subjects were instructed to finish each movement with the highest velocity, whatever the load to be lifted. During the 6W training period, control subjects were instructed to continue only their usual daily activities.

TABLE III.—*Resistance training programme for strength and velocity groups.*

Strength	Velocity
Week 1 (2x/week)	
1×10×60%	2×10×25%
2×6×80%	3×8×30%
1×3×90%	2×8×40%
Week 2 (2x/week)	
1×10×60%	2×10×25%
1×6×80%	2×8×30%
2×3×90%	2×8×40%
Week 3 (3x/week)	
1×10×60%	2×10×25%
1×6×80%	1×6×50%
2×3×90%	2×6×40%
1×2×95%	2×8×30%
Week 4 (1x/week) + 1-RM evaluation	
1×10×60%	2×10×25%
1×6×80%	3×8×30%
2×3×95%	2×8×40%
1×2×98%	
Week 5 (3x/week)	
1×10×60%	2×10×25%
1×6×80%	2×8×30%
1×4×90%	2×8×40%
1×3×95%	2×6×30%
1×2×98%	
Week 6 (3x/week)	
1x10x60%	2×10×25%
1×6×80%	1×6×50%
2×3×90%	3×6×40%
2×2×98%	3×6×30%
Total workload (% 1-RM)	
27 385 % 1-RM	27 660 % 1-RM

Statistical analysis

All measured values were reported as mean ± standard deviation (SD). A multivariate analysis of variance (MANOVA) was used in order to determine whether the groups differed before the specific training period. Changes in performance within individual subjects were assessed after the training period with a paired t-test. Statistica 6.1 (Statsoft Inc., France) software was used for statistical analysis.

Results

Parametric analysis

In the pretest, no significant differences appeared between the groups with regard to isoinertial perfor-

TABLE IV.—*Evolution of quantitative performances between pre- and post-tests in control, strength and velocity groups.*

Load %	Control			Strength			Velocity		
	Pretest	Post-test	Diff (%)	Pretest	Post-test	Diff (%)	Pretest	Post-test	Diff (%)
PP (W)									
35	726±178	742±156	(+2.2)	693±145	776±150	(+12.0)*	734±142	866±162	(+18.0)**
50	698±109	740±153	(+6.1)	666±118	726±133	(+9.0)	710±158	821±180	(+15.6)**
70	623±109	628±150	(+0.8)	605±77	687±102	(+13.6)*	687±192	751±180	(+9.3)
95	470±158	473±147	(+0.5)	461±60	586±94	(+27.1)*	501±136	635±148	(+26.7)***
PV (m.s-1)									
35	2.04±0.20	2.04±0.21	(+0.1)	1.98±0.16	2.12±0.15	(+7.4)**	2.06±0.23	2.34±0.21	(+13.6)***
50	1.67±0.08	1.71±0.12	(+2.6)	1.63±0.15	1.79±0.10	(+9.5)**	1.66±0.22	1.91±0.22	(+14.9)***
70	1.23±0.12	1.23±0.13	(+0.3)	1.22±0.18	1.38±0.16	(+13.2)**	1.25±0.16	1.41±0.16	(+13.2)*
95	0.77±0.20	0.77±0.16	(-0.5)	0.76±0.16	0.96±0.16	(+25.7)**	0.76±0.14	0.96±0.15	(+25.8)***
AP (W)									
35	308±66	305±59	(-0.8)	303±62	337±55	(+11.2)***	307±62	374±70	(+21.7)**
50	313±49	332±53	(+6.1)	321±65	345±63	(+7.6)**	328±63	382±55	(+16.7)***
70	295±39	308±61	(+4.5)	299±50	345±51	(+15.2)**	325±69	374±67	(+15.2)**
95	196±65	207±72	(+5.8)	185±42	276±47	(+48.8)***	217±57	280±70	(+28.9)**
AV (m.s-1)									
35	1.17±0.12	1.16±0.11	(-0.4)	1.16±0.07	1.25±0.06	(+7.1)***	1.21±0.13	1.35±0.10	(+11.4)**
50	0.98±0.03	1.00±0.04	(+2.0)	0.98±0.06	1.07±0.06	(+9.4)***	0.99±0.10	1.12±0.10	(+12.8)***
70	0.70±0.04	0.71±0.06	(+1.9)	0.71±0.08	0.82±0.09	(+15.2)***	0.73±0.09	0.84±0.07	(+16.1)**
95	0.35±0.10	0.36±0.10	(+2.8)	0.35±0.11	0.51±0.12	(+47.7)***	0.37±0.08	0.49±0.10	(+32.0)**

Significant differences between pre- and post-tests are represented as: *P<0.05);**(P<0.01);***(P<0.001).

mance. The performance of those in the control group did not change significantly between the pre- and post-tests, while both strength and velocity training groups presented significant improvements for each load tested. The strength training improved most notably average performance at 95% of 1-RM (+48.8% for AP and +47.7% for AV; P<0.001). All subjects of the strength group succeeded in lifting the 105% charge, while only 6 out of 8 subjects reached this level in the velocity group. In the control group, only 1 subject managed to lift this charge. In the velocity group, the best relative increase was also observed at 95% of 1-RM (+25.8% to +32%). However, the greatest absolute changes in velocity were observed at 35% (+0.28m.s-1 for PV) and 50% (+0.25m.s-1 for PV) of 1-RM (P<0.001). Moreover, at these two charges, improvements in power and velocity were greater in the velocity group (+11.4% to +21.7%) compared with the strength group (+7.1% to +12%) (Table IV).

Curve analysis

Figure 1 displays for both trained groups the velocity and power measurements, at every 5% of total lifting time before and after the training period, for the lowest and highest relative loads (respectively, 35% and 95% of 1-RM). The improved part of lifting systematically occurred earlier in the strength group in comparison with the velocity group. In contrast, velocity and power values showed greater improvement in the velocity group during the last part of the movement.

Velocity and power curves are both characterized by two separate phases. The accelerating and decelerating phases correspond, respectively, to the increase and decrease in velocity, while the propulsive and braking phases correspond, respectively, to positive and negative power. The proportion of acceleration and propulsive phases systematically increases with load (P<0.001). Specific training modified the proportions of these phases. Responses recorded at 35% of 1-RM were as follows: strength training did not change accelerating phases but did increase the braking phase (P=0.052), while, interestingly, velocity training improved acceleration and shortened the braking phase (P<0.05). At 95% of 1-RM, the accelerating phase was reduced in both groups, but more significantly in the strength population (p<0.01). The relative time at which PP values arise indicates the moment that should correspond to the most explosive part of the lifting. After the training period, PP recorded for 35%

of 1-RM occurred at 50% of the total lifting time in the strength group and at 60% in the velocity group.

Discussion

In various sporting pursuits, it is important to determine how a resistance programme affects both force and velocity performance. Isoinertial dynamometers seem particularly appropriate in this context of evaluation and have been reported to be more effective than isometric or isokinetic dynamometers in accurately detecting temporal changes in strength as a result of training.[18] Surprisingly, most isoinertial studies have used the 1-RM determination in order to assess change in maximal strength exclusively.[1, 18] A few studies have used a dynamometer to evaluate gains in force and power after a training period.[15-16, 19, 20] However, in many sports the main objective of resistance training is not to enhance the 1-RM but rather to increase velocity and power during sub-maximal and specific constant load exercise. Surprisingly, to our knowledge, isoinertial dynamometers have rarely been used to detect change on the velocity parameter.

In the present study, an isoinertial protocol was designed in order to describe extensively load-power and load-velocity relationships and to highlight possible effects of training. The results of the control group suggested that no familiarization effect occurred between the pre- and post-test. An acquaintance with the evaluation procedure and tested exercise can result in an increase in performance between the first and second testing sessions when using isoinertial evaluation.[21] The special care that was given to the familiarization session and the strict standardization of the protocol probably explains why no significant learning effect occurred in the control group.

The present study demonstrated that isoinertial assessment was able to monitor specific training effects. The analysis of parameters revealed that six weeks of strength and velocity training induced significant improvements, not only at the specific training loads, but also at other relative loads. These findings suggest both specific and non-specific performance enhancement. In the two training groups, non-specific adaptations were favoured by repeated practice of loaded BP during training despite the variance in the load to be lifted. This general improvement has been shown to entail the development of more efficient coordination and activation patterns within the nervous system.[2, 22-24] Such neural adaptations have been previously described in untrained subjects and could play a key role in the initial strength gains induced by a resistance training programme.[17, 23, 25]

Some controversy exists as to the adaptations in the force-velocity relationship following specific resistance training. Several isokinetic studies have shown significant gains only around the training velocity, without changing performance at distant velocities.[2, 3] Other studies have revealed that resistance training may significantly increase peak torque at a specific, as well as other, angular velocities.[4, 18, 26] The instruction given to the subjects may partly explain these divergent findings. According to Behm and Sale,[26] the intended rather than the actual movement speed creates a high velocity adaptation. According to this theory, heavy resistance exercises, performed slowly, should improve the speed of movement when they are carried out with high velocity intention. In a study by Almasbakk and Hoff,[17] two groups benefited from six weeks of BP training using either light or heavy weights and received the same instructions to maximize the high speed of contraction. Interestingly, both training programmes showed equal effectiveness in improving the maximal velocity contraction for a given absolute resistance.[17] In the present study, the intention to perform heavy BP exercises with the highest velocity during training could explain why velocity was so significantly enhanced at non-specific light loads.

However, even where a significant increase has been shown to occur at each load, most studies support the velocity-specificity concept: the greatest improvements concern training velocities.[5] In the present study, results were in agreement with that theory: even though changes were significant in the whole force-velocity relationship for both training populations, the most significant improvements corresponded to the loads used through specific training exercises.

Isoinertial assessment revealed that the strength training group presented the greatest changes at the heaviest loads, especially for average measurements. Previous studies have confirmed that, in short term training, the use of heavy loads represents the most efficient method in order to improve maximal strength.[7, 9, 17] Wilson *et al.*[9] compared three training groups (weight, maximal power and plyometric) and showed that only the weight training programme significantly increased maximal isometric strength after 5 weeks. Almasbakk and Hoff[17] investigated different

BP training methods and confirmed a significant improvement of 1-RM, present only in the heavy load training group. In line with the results of the present study, this research also demonstrated the effectiveness of strength training in increasing performance at the lightest loads. Such significant gains observed in the strength group could result, as discussed above, from the intention to lift the barbell at high velocity during training. The fact that after a training period, the assessed charges corresponded to a lower percentage of the final maximal strength, could also explain why light load barbells were lifted with an increased velocity.

The velocity group presented significant gains at each load, but at the same time, revealed a more pronounced improvement than the strength group at the lowest relative charges used in the tests (*i.e.* 35% and 50% of 1-RM), suggesting a specific training response. These adaptations remained less impressive than those observed at 95% of 1-RM, but it is well known that velocity trainability is more uncertain than strength trainability.[27, 28] These results highlight the ability of our velocity training programme to develop high levels of velocity in BP exercises.

When the analysis of training effects is based on peak measurements (PP and PV), the regime for the velocity training group clearly represents the best method for improving performance at the lightest loads. In addition, this method appears to be as effective as strength training at the highest loads. When isoinertial results are based on averaged measurements (AP and AV), the superiority of velocity training at the lightest loads is less evident and strength training clearly demonstrates its superior effectiveness at the highest loads. In the present study, the comparison of both approaches (peak *vs.* average) highlights results that could be considered as contradictory. Therefore, the choice of the parameter (average *vs.* peak value) may influence the conclusion of a study, especially when it concerns the influence of training on F-V relationships. The parametric analysis seemed insufficient to understand completely the influence of the two specific training programmes on BP performance.

A curve analysis of velocity and power would provide additional information about how training affects BP performance. Such a curve analysis exists but remains unusual in the context of muscular function assessment. Torque curves allow the detection of muscle abnormalities that are not highlighted by quantitative measurements during isokinetic exercises.[29] Biomechanical research has exploited isoinertial curve analysis in order to compare variations in exercise performance, such as the influence of countermovement or projection during BP or squat exercises.[11, 30] However, no research to date has used isoinertial curve analysis in order to study training effects.

As demonstrated by isometric studies, curve analysis can reveal specific training effects that cannot be highlighted by standard measurements. For instance, Hakkinen [24] reported that plyometric training does not significantly change maximal isometric strength. However, curve analysis has demonstrated that this training method greatly increases the rate of force development. Conversely, Hakkinen showed that maximal strength training induces great change in maximal isometric force without modifying the rate of force development.[24]

With the aim of performing an accurate analysis of training effects, the authors explored the shape of isoinertial curves. This approach (Figure 1) reveals that, depending on the training programme, adaptation occurred in distinct phases of the movement. In comparison with velocity training, strength training maximized velocity and power production earlier in the movement. This phenomenon, which could be observed at each load, was particularly marked at 95% of 1-RM, and accounted for the very high levels of improvement observed for AP and AV. One might have expected the initial phase of concentric movement to be preferentially enhanced in the strength group, because the strength training load stresses this early phase of movement to a greater extent.[15] Such a force production, probably resulting from an increase in the number of actomyosin cross-bridges in parallel and from structural changes, remains essential for moving supra-maximal loads. This strength enhancement may explain the success of all subjects in this group in lifting up the 105% load.

Conversely velocity training did not change the early phase of movement, but improved performance most notably in the second half of the movement. At the 35% load level, subjects significantly increased and delayed their maximal velocity by extending the acceleration phase and minimizing the braking phase. The intention to finish the movement as fast as possible might have increased the agonist activity for a longer period, while the antagonist activity was decreased. Such a phenomenon could result from spinal and/or supra spinal adaptations. At the end of BP movement, the fast stretch of antagonist muscles (biceps brachii, coracobrachialis, brachialis) may release a protective reflex contraction. When it occurs early, this response reduces the development of maximal velocity. The repetitive practice of fast BP exercises during the training period may have delayed the stretch reflex, allowing the production of a greater velocity in the second half of the movement. A change in muscle synergy and/or an agonist-antagonist activation pattern might also be evoked.[23] These hypotheses are supported in the case of the lightest loads by evidence of a shortened braking phase (Figure 1), signifying a later antagonist response.

However, these factors cannot explain the gains observed in the case of heavy loads, and other adaptations are likely to have been responsible for the increase in power and velocity. Changes in muscle activation (change in motor unit recruitment and/or firing patterns), in myosin heavy chain isoform, in ATPase and consequently in maximal fibre velocity, have already been described with short term high velocity training [3, 24, 31, 32] and may have induced significant velocity improvement in the present study. Such adaptations could also explain the fact that velocity was improved not at the outset but in the fastest part of the movement, when fibre II recruitment is at its maximum. Obviously these hypothetical adaptations have not been verified in our study and we must remain critical in our interpretation. The mechanisms related to the observed adaptations deserve further investigation.

With regard to isoinertial parameter and curve analysis, it appears that both training methods induced specific adaptation. The evidence of this study shows that performing resistance training with short (5 to 8 reps) maximal light load (20% to 50% of 1-RM) series is an efficient way to improve maximal movement velocity and power, as would be expected in throwing, jumping or smashing sports actions. Using heavy loads (80% to 100% of 1-RM) appears to be the best way to increase maximal strength. The intention to perform an exercise as quickly as possible, especially at the end of the movement, should be counselled in order to obtain additionally high power and velocity improvements. Nevertheless, it has been demonstrated that the use of only one training method leads quickly to a plateau phase in strength development.[24] The combination of various training methods has been shown to favour the greatest increase in performance.[32-34] The present isoinertial analysis underlines the complementarity of the two studied training methods. Further research needs to explore how far the combination of these training methods over a longer period could improve performance and how performance enhancement is related to functional performance.

Conclusions

In conclusion, the present study demonstrated the ability of isoinertial dynamometric assessment to monitor specific training effects. The use of such a measurement tool demonstrates how a resistance programme may increase exercise velocity and power at different load levels. The findings indicate that the parametric analysis of results should consider both average and peak measurements in order to cover different specific aspects of training. Even though changes were significant at each load for both training groups, the most significant improvements were specific to training modalities: strength training improved in particular AP and velocity at the highest loads, while velocity training induced superior absolute gains in PV at the lightest loads. The curve analysis deserved particular attention in the training follow-up as it served to highlight that strength training improved power and velocity, particularly in the first part of the movement, while velocity training improved peak performance and delayed its occurrence. Further research should involve the use of isoinertial dynamometers when endeavouring accurately to plot change in neuromuscular performance, occurring as a consequence of free weight training.

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