RFD

Research report

Rate of force development (RFD)

Balshaw 2022 | Oranchuk 2019 | Blazevich 2020 | James 2025 | + Vanderka 2016

01	**Strength training doesn't make you faster** Balshaw et al. (2022): greater maximal strength and greater absolute explosive output did not mean a faster response after normalization.
02	**It's not about the speed of movement - it's about intention** Oranchuk et al. (2019) and Blazevich et al. (2020): fast-force intent can improve RFD even when actual movement velocity is zero or low.
03	**Be specific** James et al. (2025): transfer between rapid force production in isometric and dynamic actions is variable.

Data, author quotations, and training protocols.

1. Strength training doesn't make you faster

Balshaw et al. (2022) - greater absolute strength did not mean faster use of the available maximum capacity.

What kind of study was this?

This was a cross-sectional study, not a multi-year training intervention. The authors compared 49 men without systematic lower-body resistance training with 14 men who had trained heavily and regularly for at least 3 years, primarily to increase maximal knee-extensor strength. In the trained group, the mean duration of this type of training was 4 +/- 1 years.

The study measured maximal voluntary torque, torque produced during the first 25-150 ms of contraction, rate of torque development, muscle activation, and contractile properties evoked by electrical stimulation of the femoral nerve.

> **Limitation noted by the authors**
>
> Because the study was cross-sectional, the entire difference between groups cannot be attributed to training alone. The authors explicitly note that this design provides weaker evidence than a longitudinal study.

Data supporting the point

Parameter	Difference between groups	Comment
Maximum voluntary torque	407 +/- 63 Nm in trained participants vs 245 +/- 45 Nm in untrained participants: +66%; $p < 0.001$.	The trained participants were substantially stronger at maximum.
Maximum quadriceps anatomical cross-sectional area	138 +/- 14 cm2 vs 90 +/- 12 cm2: +54%; $p < 0.001$.	The trained group had substantially greater muscle size in the measured region.
Absolute explosive torque at 25-150 ms	Trained participants: +41% to +64%; all comparisons $p <= 0.001$.	In absolute terms, the stronger group produced more torque even very early in the contraction.
Absolute rate of torque development	Trained participants: +31% to +64%; all comparisons $p <= 0.001$.	Absolute RFD was higher, but the group also had 66% higher maximal torque.
Torque at 75 ms relative to the participant own maximum	Trained participants: -13%; $p = 0.056$.	A tendency toward a lower relative value; the result did not cross the conventional $p < 0.05$ threshold.

Parameter	Difference between groups	Comment
Torque at 100 ms relative to the participant own maximum	Trained participants: -16%; $p = 0.002$.	After normalization, the stronger group expressed a smaller proportion of its own maximum by 100 ms.
Torque at 150 ms relative to the participant own maximum	Trained participants: -11%; $p = 0.001$.	The same pattern was still present at 150 ms.
RFD in the 50-100 ms window relative to the participant own maximum	Trained participants: -21%; $p < 0.001$; standardized difference $d = 1.44$.	This is the clearest result showing that, after normalization, the trained group was slower during the fastest-rising portion of the curve.
Quadriceps activation during explosive contraction	No significant differences between groups in the 0-50, 50-100, or 100-150 ms windows.	The greater absolute output was not explained by greater agonist activation during the explosive phase.
Electrically evoked torque at 50 ms relative to its peak	Trained participants: -10%; $p < 0.001$.	This result indicated slower intrinsic muscle contractile properties, independent of voluntary neural drive.
Time to peak torque in electrically evoked contractions	Eight-pulse train: +8% longer, $p = 0.001$; single twitch: +6% longer, $p = 0.015$.	A longer time to peak indicates a slower contraction time course.

How to read the statistics: $p < 0.05$ means the authors considered the difference statistically significant. The value d is a standardized measure of the difference between groups; $d = 1.44$ represents a large difference.

Source: Balshaw et al. (2022), Results 3.2-3.5 and Discussion.

Interpretation by the authors

> **Balshaw et al. - Discussion**
>
> *"substantially enhanced absolute explosive strength, but lower relative ability to express the available torque generating capacity"*

The authors therefore describe two findings at the same time: greater absolute explosive strength in the long-term trained group, but a poorer ability to use their own substantially higher maximum within a short time window.

> **Balshaw et al. - Perspective**
>
> *"resistance training slows the intrinsic contractile properties"*

In the Discussion, the authors link the lower relative results to slower muscle contractile properties. At the same time, they note that after many years, greater muscle size may increase absolute explosive force production even without an advantage in explosive-phase activation.

Source: Balshaw et al. (2022), Discussion and Perspective.

2. It's not about the speed of movement - it's about intention

Oranchuk et al. (2019) - the intent to develop force rapidly matters even when the joint does not move.

What kind of study was this?

This was a systematic review of 26 research outputs including 713 participants in total. The mean intervention duration was 8.4 +/- 3.6 weeks. Most studies involved untrained or recreationally active participants; none of the studies included in the review examined competitive athletes or well-trained participants.

The authors compared, among other variables, different joint angles, contraction intensities, and contraction intent. In the intent section, they compared gradually developed contractions with attempts to develop force as rapidly as possible.

> **What does ballistic intent mean?**
>
> It means being instructed to increase force as rapidly as possible from the start of the contraction. In an isometric action, joint movement velocity is zero, but the rate at which force rises can still be very high.

Pooled ranges reported by Oranchuk et al.

Measured outcome	Training with rapid-force intent	Gradual / sustained training	How the authors summarize it
Neuromuscular activation	Rapid-force intent: improvement of 1.04-10.5% per week; standardized effect size 0.02-0.31 per week.	Gradual / sustained contractions: improvement of 1.64-5.53% per week; standardized effect size 0.03-0.20 per week.	The authors summarize that ballistic intent produced greater neuromuscular adaptations.
Rapid force production	Rapid-force intent: improvement of 1.2-13.4% per week; standardized effect size 0.05-0.61 per week.	Gradual / sustained contractions: improvement of 1.01-8.13% per week; standardized effect size 0.06-0.22 per week.	The authors summarize an advantage of ballistic intent for rapid force production.

A standardized effect size expresses the magnitude of change after results are converted to a common scale. It is not a percentage. Oranchuk et al. reported it alongside percentage change per week.

> **Oranchuk et al. - comment in the RFD section**
>
> *“the intent of movement may be of similar value to actual external contraction velocity”*

Oranchuk et al. - Perspectives

“ballistic intent has been found to improve rapid force production even though movement velocity is zero”

If the goal is maximal strength or hypertrophy

The authors state that when muscle growth or maximal force production is the priority, the evidence shows little difference between contractions performed with ballistic intent and a gradual ramp to the prescribed intensity. The advantage of rapid intent is primarily relevant when rapid force production is the goal.

Source: Oranchuk et al. (2019), Abstract, Section 4.3.3 Rate of Force Development, Section 4.4, and Perspectives.

Specific studies comparing contraction intent

Study	How the training was compared	Gradual-training result	Rapid-intent training result
Balshaw et al. 2016	Gradual group: 1 s to 75% of the current maximum, then hold for 3 s. Rapid group: rise as fast as possible to at least 80% of the current maximum.	Gradual group: maximal strength +23.4%; force at 150 ms +12.1%.	Rapid group: maximal strength +17.2%; force at 50, 100, and 150 ms +14.4% to +32.6%.
Tillin & Folland 2014	Gradual group: 1 s to 75% of maximum, then hold for 3 s. Rapid group: rise as fast as possible to at least 90% of maximum.	Gradual group: maximal strength +20.5%; force at 50, 100, and 150 ms +3.09% to +7.39%.	Rapid group: maximal strength +10.6%; force at 50, 100, and 150 ms +13.1% to +53.7%.
Williams 2011	Isometric knee extension: gradual ramp versus contraction performed as explosively as possible.	Gradual group: force at 150 ms +14.3%; Oranchuk et al. marked this result as not statistically significant.	Rapid group: force at 150 ms +48.8%; voluntary activation at 150 ms +31.6%.

Source: Oranchuk et al. (2019), Table 3 and Section 4.3.3.

Around 80% of maximum - what do the protocols actually show?

In Balshaw et al. (2016), rapid contractions were instructed to reach at least 80% of the currently measured maximum voluntary torque. The actual mean peak measured during training was 81 +/- 4% of that maximum. In the Massey et al. (2018) analysis, the mean peak was also 81%.

This was not a universal threshold across all studies: Tillin & Folland targeted at least 90% of maximum, while Maffiuletti and Williams used 100% of the freshly measured maximum as the target. Where the authors did not report the mean value actually reached during training, the table states not reported.

Training protocols - 5 isometric studies

The table is split across two pages to keep the type readable. The actual measured peak column separates the prescribed target from the value actually reported during training.

Study	How maximum was established	Instruction for the rapid group	Target for each repetition	Actual measured peak	Volume, rest, and feedback
Balshaw 2016	At the start of each week, 3 maximal contractions were performed and the current maximum voluntary torque was re-established.	as fast and hard as possible - develop torque as rapidly as possible from the start.	At least 80% of the current maximum; contraction about 1 s.	81 +/- 4% of the current maximum.	12 weeks; 3 sessions/week; 4 x 10 per leg; 5 s between repetitions; 2 min between sets for the same leg; on-screen feedback showed the best rate of torque development so far and the 80% line.
Massey 2018	At the start of each week, 3 maximal contractions were used to update the current maximum and prescribed loading.	Maximize rate of torque development; as fast and hard as possible.	About 80% of the current maximum.	81% of the current maximum - based on analysis of repetitions from selected sessions in weeks 1, 6, and 12.	The same 12-week paradigm as Balshaw 2016; 4 x 10 per leg; 5 s between repetitions. The authors note that when maximizing RTD, the participant cannot precisely control peak torque.
Tillin & Folland 2014	Maximum force was established before training and re-established at the start of the first session of each week.	fast and hard for about 1 s.	Attempt to reach at least 90% of the current maximum.	No mean across all repetitions was reported; an example set shown in the figure reaches about 90%.	4 weeks; 4 sessions/week; 4 x 10; 5 s after each rapid contraction; 2 min between sets; force sampled at 2000 Hz.

Part 1/2. Balshaw 2016 and Massey 2018 describe the same / closely linked training paradigm, not two independent replications.

Training protocols - continued

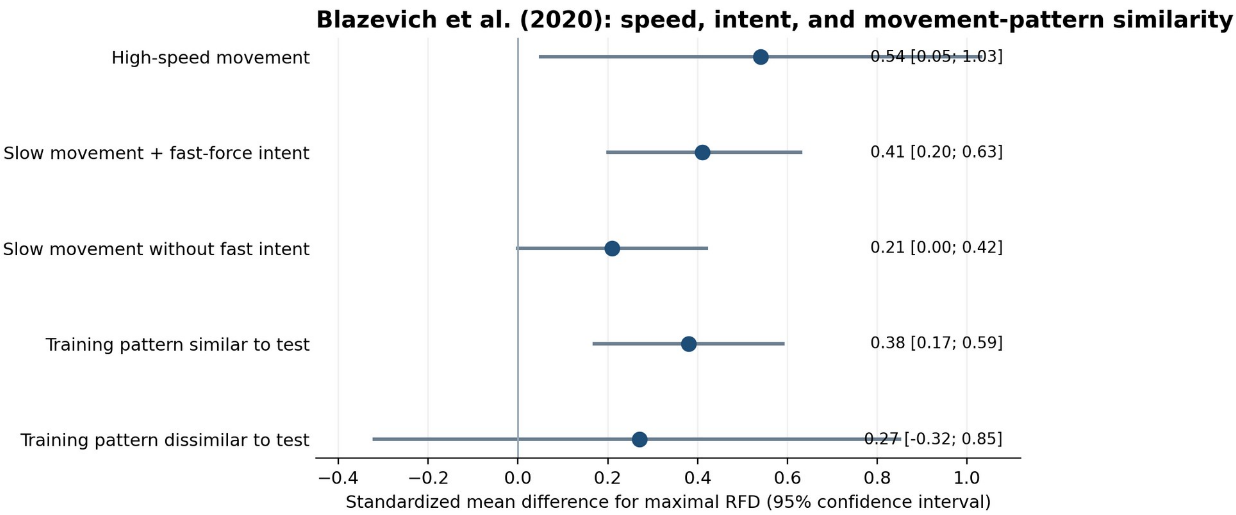
Study	How maximum was established	Instruction for the rapid group	Target for each repetition	Actual measured peak	Volume, rest, and feedback
Maffiuletti & Martin 2001	At the start of every session, participants performed 12 submaximal contractions from 30-80%, followed by a fresh maximum measurement.	climb as fast as possible to the MVC - reach the freshly measured maximum as rapidly as possible.	100% of the freshly measured maximum as the target.	No aggregate mean of the percentage of maximum actually reached was reported.	7 weeks; 3 sessions/week; 6 x 6; 18 s between repetitions; 3 min between sets; visual feedback; performance was monitored by the investigator.
Williams 2011	The target was specific to contraction type and updated before each set; if the target was exceeded, the newly measured value became the target for subsequent sets.	A maximal contraction performed as explosively as possible, followed by a 5-s hold.	100% of the current maximum as the target.	No aggregate mean of the percentage of maximum actually reached was reported.	6 weeks; 3 sessions/week; week 1: 3 x 6, week 2: 3 x 8, weeks 3-6: 3 x 10; 25 s between repetitions; 3 min between sets.

Source for both parts of the table: the supplied five-study RFD protocol extraction prepared from primary sources.

Blazevich et al. (2020) - rapid-force intent during slow movement

This was a systematic review with meta-analysis and meta-regression including 54 studies and 59 intervention groups. The authors examined actual movement velocity, intent to produce force rapidly, and similarity between the training movement pattern and the movement later used to test RFD.

> **Important data limitation**
>
> In the Blazevich et al. extract, sufficient data to analyze movement velocity, intent, and movement-pattern similarity were available for maximal RFD. These numbers should not automatically be applied to RFD during the first 50 ms.



A standardized mean difference is a common scale used in meta-analysis to compare results across different studies. A positive value indicated improvement relative to the control group.

Condition	Meta-analysis result	Interpretation reported in the extract
Movement performed at high actual velocity	0.54; 95% confidence interval 0.05 to 1.03.	Significant improvement in maximal RFD versus control.
Mechanically slow movement with intent to produce force as rapidly as possible	0.41; 95% confidence interval 0.20 to 0.63.	Significant improvement in maximal RFD despite low actual movement velocity.
Slow movement without rapid-force intent	0.21; 95% confidence interval 0.00 to 0.42; p = 0.05.	A borderline effect and weaker than in the two conditions above.
Training movement pattern similar to the tested movement	0.38; 95% confidence interval 0.17 to 0.59.	Significant improvement in maximal RFD.
Training movement pattern dissimilar to the tested movement	0.27; 95% confidence interval -0.32 to 0.85; p = 0.37.	No clear effect.

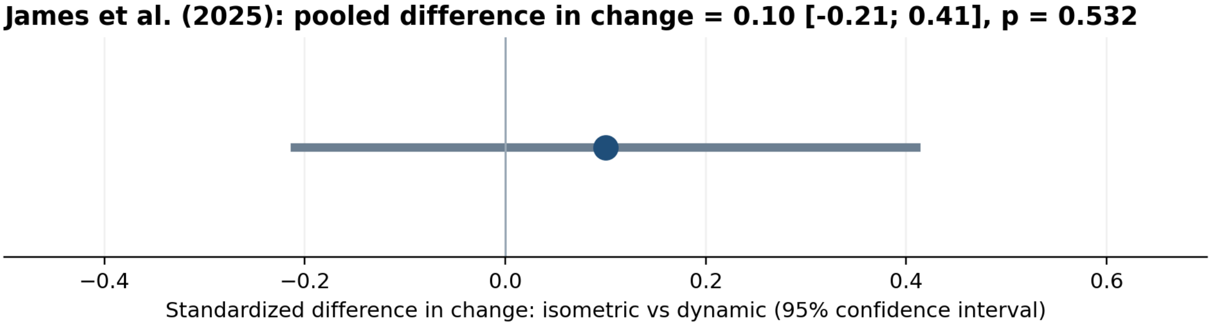
Source: Blazevich et al. (2020) - extract of publicly available data.

3. Be specific

James et al. (2025) - changes in isometric RFD and dynamic rapid-force performance do not necessarily move together.

What kind of study was this?

This was a systematic review and meta-analysis. It included 5 studies, 15 isometric-dynamic change comparisons, and 82 participants. Each study included at least 4 weeks of ballistic / explosive training and reported both an isometric measure of rapid force production and a dynamic test, such as a jump.



The pooled standardized difference in change was 0.10; 95% confidence interval -0.21 to 0.41; p = 0.532. The authors therefore did not find that ballistic training consistently produced a larger change in either type of test. At the same time, wide prediction intervals indicated substantial variability across specific settings.

Data and comments from the authors on transfer

Element	What the authors report	Meaning within their study
Shared information between isometric and dynamic tests	The authors note that, in most populations, shared variance is about 20% for very early epochs around 50 ms and about 40% for later epochs from approximately 150 ms onward.	Isometric and dynamic measures do not describe exactly the same quality.
Main meta-analysis result	No significant difference in the magnitude of change between isometric and dynamic measures following ballistic training.	At the group level, one cannot assume that one testing modality will always respond more strongly.
Subgroup analyses	Stretch-shortening cycle type, isometric test type, RFD time interval, and single- versus multi-joint testing did not show a consistent moderating effect.	The variability could not be explained by simply choosing one type of test.

James et al. - Key Points / Conclusion

“the transfer between rapid isometric and dynamic neuromuscular qualities is not uniform and should not be assumed”

Recommendation from the authors

The authors recommend matching the assessment modality to the primary performance outcome of interest and interpreting changes within the constraints of the testing method used.

Limitations identified by the authors

- Only 5 studies and 15 comparisons.
- The analysis could not establish a linear relationship or proportionality between changes in RFD and changes in ballistic performance.
- Most participants had limited training experience; only one of the five studies included a group with more than 2 years of resistance-training experience.

Source: James et al. (2025), Abstract, Introduction, Results, Discussion, Conclusion, and Table 2. Source status: manuscript draft.

Additional study in trained participants - Vanderka et al. (2016)

This study is one of the studies included in James et al. (2025). In Table 2, James et al. describe the sample as university students with at least 2 years of resistance-training experience. The Vanderka et al. full text describes them as moderately trained athletes with at least 2 years of strength-training experience.

Participants and protocol

Element	Description
Participants	68 men, mean age 21.9 +/- 2.5 years. Training group: 36; control group: 32. All had at least 2 years of resistance-training experience.
Duration	8 weeks, 3 sessions per week, 26 sessions in total.
Exercise	Loaded jump squat. During take-off, participants were instructed to jump as high and as fast as possible.
Load selection	The load that produced maximal mean power was determined individually. All repetitions were required to be performed at least 90% of maximal mean power.
Volume	13 sessions: 8 sets x 4 repetitions with the load that maximized mean power; 13 sessions: 4 sets x 8 repetitions with 80% of that load. Rest between sets: 3 min.
Feedback	Every repetition was measured, and the athlete received real-time feedback on force, velocity, and power.
Tests	Maximum force in an isometric half squat, RFD during the first 100 ms, countermovement-jump and squat-jump height, and 50-m sprint time.

Results

Parameter	Change in the first 4 weeks	Change in the next 4 weeks
Maximum force in the half squat	First 4 weeks: +14.4% in the training group vs +3.5% in control; between-group difference $p < 0.001$.	Next 4 weeks: +4.7% vs -0.1%; $p = 0.004$.
RFD during the first 100 ms	First 4 weeks: +27.2% vs +0.8%; $p < 0.001$.	Next 4 weeks: +17.2% vs +2.0%; $p = 0.005$.

Parameter	Change in the first 4 weeks	Change in the next 4 weeks
Countermovement-jump height	First 4 weeks: +10.0% vs -0.3%; $p < 0.001$.	From week 4 to week 8, there was no further significant improvement in the training group.
Squat-jump height	First 4 weeks: +15.6% vs -1.4%; $p < 0.001$.	From week 4 to week 8, there was no further significant improvement.
50-m sprint time	First 4 weeks: -1.0% vs +0.4%; $p = 0.002$.	Next 4 weeks: -1.9% vs -0.3%; $p = 0.002$. A lower time means better performance.

> **Vanderka et al. - summary by the authors**
> *“using jump squats … can simultaneously improve several different athletic performance tasks in the short-term”*

In this study, ballistic training improved both isometric RFD during the first 100 ms and several dynamic performance outcomes in participants with at least 2 years of resistance-training experience.

Source: James et al. (2025), Table 2; Vanderka M, Longova K, Olasz D, Krcmar M, Walker S. Journal of Sports Science and Medicine. 2016;15(3):492-500. PMID: 27803628; PMCID: PMC4974862.

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