Applied Mathematical Science of Physical Training Part 4: Strength Potency

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1. Executive Summary

This work will detail how to determine the *strength* training potency from a given training set of repetitions. A physiological ability/attribute and its potency is a vector value based on three variables. In this paper, I will define those variables and how they relate specifically for the ability of strength.

The physiological Abilities and Attributes lie on a spectrum that consists of two separate but overlapping continuums. I will define these two continuums and detail why Maximum-Strength is the most fundamental ability and how it is the fulcrum between the two continuums.

I will comprehensively define what *strength* is. I will also define *absolute strength* and *maximum strength*. I will provide a complete list of the factors affecting strength.

I will detail how intensity is related to strength in barbell training and how the amount of reps done in a single set affects the adaptational level of strength development.

I will provide a polynomial equation for determining As Many Reps As Possible (AMRAP) with any intensity.

After determining AMRAP, I will provide an equation to determine the percentage of intensity-specific set level fatigue accumulated for a set with any amount of reps.

I will detail how we use intensity, AMRAP, and the % of set level fatigue to determine the strength potency of a set.

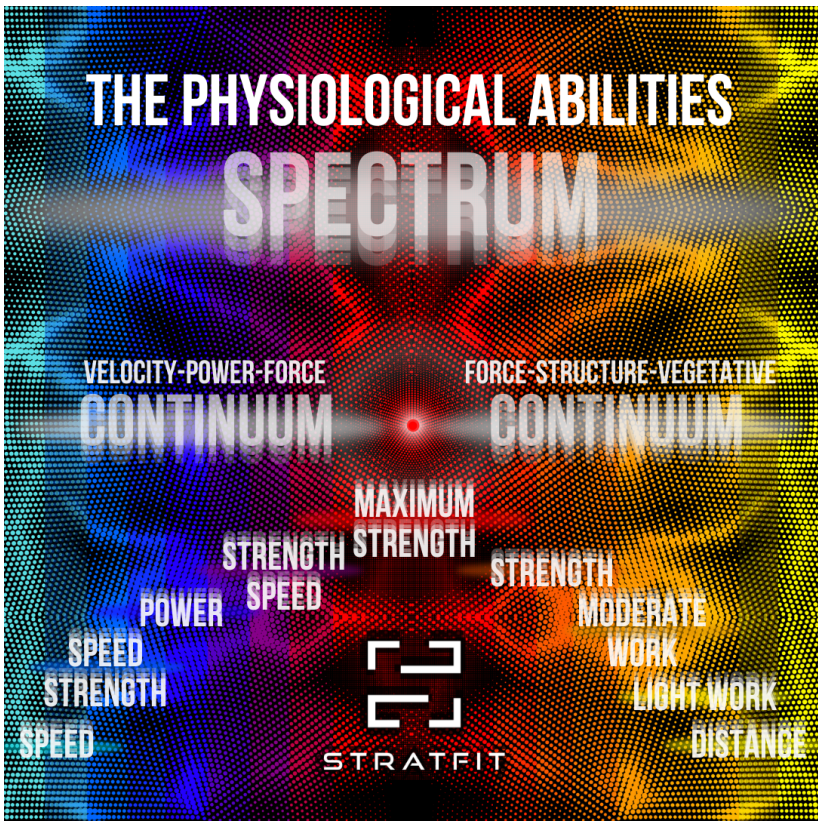
By the end of this paper, a rigorous and comprehensive method for determining and comparing the strength potencies of various training sets will be straightforward.

2. Introduction

The purpose of training is to cause adaptation(s). The amount and quality of adaptation relative to a specific purpose determines an individual's fitness. The components of fitness are the physiological abilities and attributes of training and performance. Developing these abilities is done through the training process. The optimization of this process is dependent on the efficiency of the training. The efficiency of training depends on the careful and skillful prescription of training loads and manipulation of the ability potencies across time according to a competitive schedule.

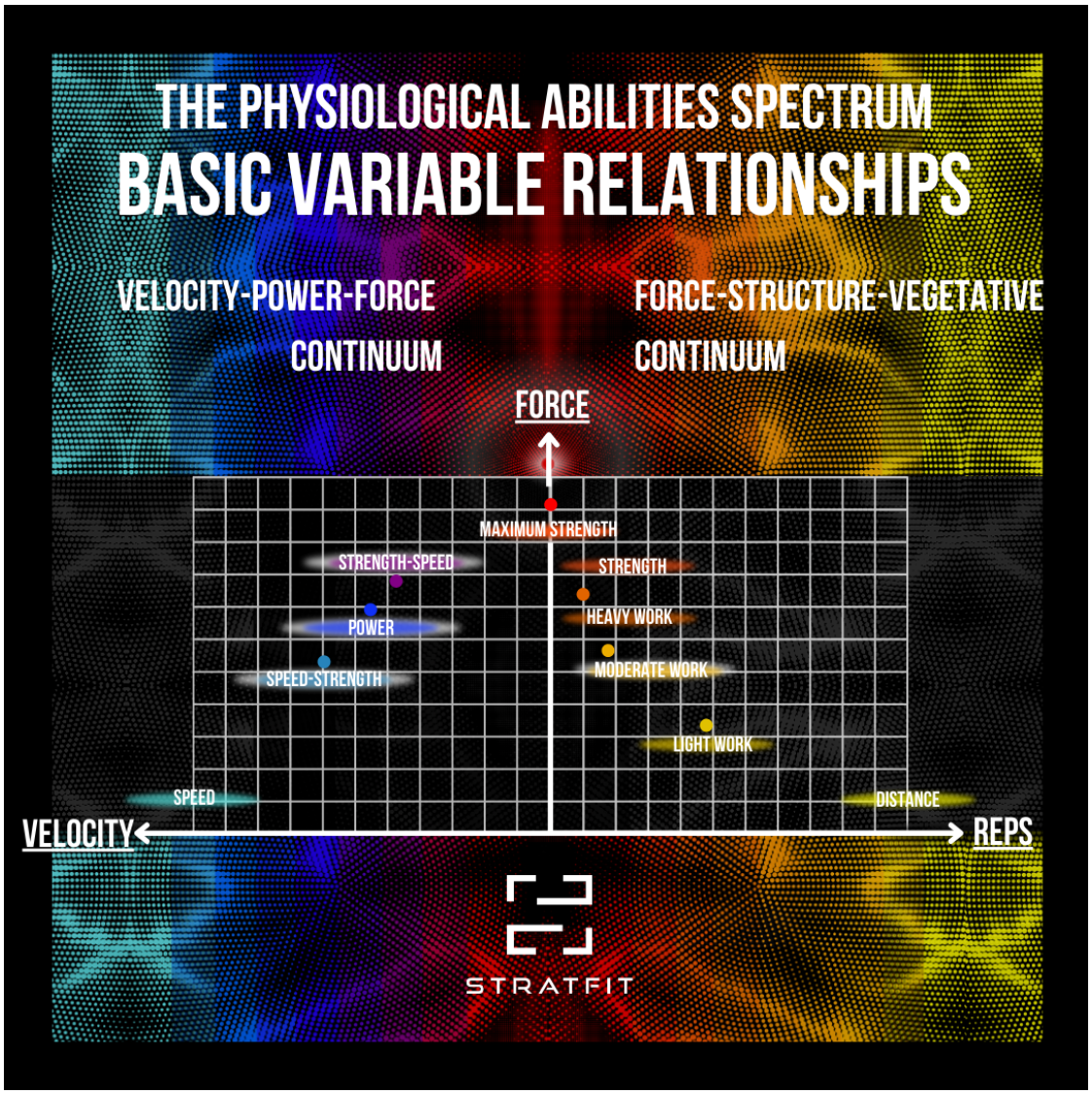
The physiological Abilities and Attributes lie on a spectrum that consists of two separate but overlapping continuums. The first continuum is the Velocity-Power-Force Continuum which includes Speed, Speed-Strength, Power, Strength-Speed, and Maximum-Strength. The abilities of the V-P-F continuum are essentially neurological in nature.

The second continuum is the Force-Structure-Vegetative continuum which consists of Maximum-Strength, Strength, Heavy Work Capacity, Moderate Work Capacity, Light Work Capacity, and Very-Light Work Capacity (which we call "Distance" as it relates to the ability to run, cycle, or swim a long-distance). The abilities/ attributes of this continuum are related to developing various types of endurance (strength endurance, muscular endurance, anaerobic, and aerobic endurance) and structural attributes like muscle mass.



Speed-Strength, Power, and Strength-Speed lie in between the two extremes. Maximum-Strength is the fulcrum ability of the spectrum between the two continuums. Velocity decreases as Force increases in the V-P-F continuum, from the very high velocity-low force ability of Speed to the very high force-low velocity ability of Maximum-Strength.

Force decreases, and the number of reps (or total distance the resistance is overcome) increases across the F-S-V continuum, from maximum strength to Very-Light Work Capacity (or Distance). General Strength, Heavy and Moderate Work Capacities (primary training zones for the development of Mass), and Light Work Capacities lie in between the extremities of this continuum.



The primary ability/attribute trained in a set is dependent on three factors-

1. The Intensity of the work (percentage of maximum)
2. The Amount of Work (Reps)
3. The level of volitional momentum applied

For the V-P-F continuum, the intensity increases from speed to maximum strength, while reps per set are kept low to prevent fatigue's negative effect on /velocity/power. For the abilities of this continuum, the lifter should apply maximum volitional velocity for all reps.

For the F-S-V continuum, intensity decreases from maximum strength to light work capacity. The reps per set are high relative to the intensity to purposively develop fatigue. Fatigue development is necessary for developing endurance and causing significant muscular protein degradation to induce the development of muscular hypertrophy. Volitional momentum is not a critical variable for this continuum as power is not a determinant for developing these abilities/attributes. We can even purposively keep momentum low during sets of this continuum to increase protein degradation in the working muscles. For sets in which the primary purpose is strength development, volitional momentum should be kept maximal since the weights will be heavy.

Strength and especially Maximum-Strength are the most fundamental of all the abilities since all lower intensity/force abilities of both spectrums depend on the athlete's maximum force capacity. This paper aims to clarify the protocol for determining the effectiveness of any training set for the development of strength.

3. Defining Strength

The first step in developing a mathematical method to determine strength potency is clearly defining strength.

Strength: The product of muscular action initiated and orchestrated by electrical processes in the Nervous (Central and Peripheral) System of the Body. It is the ability of a given muscle or a group of muscles to generate muscular force under specific conditions.

Several structural and functional factors determine strength-

Structural Factors

- The cross-sectional area of the muscle
- The density of muscle fibers per unit cross-sectional area
- The efficiency of mechanical leverage across the joint

Functional Factors

- The number of muscle fibers contracting simultaneously
- The rate of contraction of muscle fibers
- The efficiency of synchronization of the firing of the muscle fibers
- The conduction velocity in the nerve fibers
- The degree of inhibition of muscle fibers that do not contribute to the movement
- The proportion of large-diameter muscle fibers active
- The efficiency of cooperation between different types of muscle fiber
- The efficiency of the various stretch reflexes in controlling muscle tension
- The excitation threshold of the nerve fibers supplying the muscles
- The initial length of the muscles before contraction

To put it simply, strength is the ability to produce force. Although structural factors affect it, strength is not *primarily* a function of muscle size.

To illustrate this point, it is elucidative to look at the fundamental principle of strength training defined by Verkhoshansky and Siff in "Supertraining"-

The Fundamental principle of strength training: The production and increase of strength both depend on neuromuscular processes. Strength is not primarily a function of muscle size but one of the appropriate muscles (for the given movement) powerfully contracted by effective nervous stimulation. This is the foundation of all strength training.

The mathematical method for determining the strength potency of a training set I will detail in this paper is based on the reality of the neurological basis of strength. The equation will provide a value related to the potency for improving all the functional factors above.

3.1 Absolute Strength

An understanding of maximum strength and strength, in general, starts with the concept of Absolute Strength. Absolute strength is the total force capacity of an athlete as a mechanism. It refers to the amount of force the musculoskeletal structure of the organism could produce in non-volitional situations, such as under electro-stimulation in a laboratory or under a life-threatening fight or flight scenario.

Essentially absolute strength refers to the amount of force an athlete could produce if they were a robot and human volitional limitations were not a factor. Naturally, no human has complete voluntary control of their absolute strength. The percentage of control that one has of their absolute strength is maximum strength.

The difference in an athlete's absolute and maximum strength is known as the strength deficit. Research has shown that qualified weightlifters and powerlifters have much smaller strength deficits than average trainees due to the years of heavy barbell training they perform to compete at a high level in elite strength sports. The essential purpose of strength training for any athlete/trainee is to reduce the strength deficit. The strength potency of a training set is related to its effectiveness as part of a more extensive program to reduce the athlete's strength deficit.

3.2 Maximum Strength

An athlete's maximum strength is the fundamental determinant of their athletic capability. All athletic action begins with the production of force.

Maximum Strength: The maximum amount of external force that one can voluntarily produce.
*Athletic Example: Bench Press, Squat, and Deadlift in Powerlifting Competition.

Maximum strength is the maximum force an individual can produce for a particular spatial form; this is colloquially known as one rep maximum or 1RM. 1RM corresponds to 100% intensity.

The maximum force maximorum (maximum of all maximums) for the human neuromuscular/bio-mechanical system is the barbell deadlift. For the musculature of the upper body, it is the bench press.

Maximum strength at any given moment for a particular individual depends on the level of neural integration they can apply in the movement. Neural integration refers to the number of motor units recruited in an action (or hold).

The nervous system integrates to the level it is forced to by the amount of weight lifted. Therefore, performing a one-repetition maximum most effectively drives neural integration. One RM is the maximum weight an individual can lift in a given movement; this naturally requires and develops maximal neural integration. The maximum max strength potency for a single set occurs with 100% (99% in the StratFit Loading system) intensity for a single rep. Performing one RM to develop strength in training is known as the Max Effort Method.

While the max effort method is the most potent for developing strength, it is not the only effective method. Sets with multiple reps per set with intensities lower than 98-99% are also useful; this is known as the repetition method. The aim of the strength potency concept of this paper is to give strength coaches and athletes a greater handle on using the repetition method to increase strength.

4. Strength Potency

Naturally, the neural integration of a single rep relative to a particular movement corresponds precisely to the rep's intensity. 100% intensity for that specific movement corresponds to 100% neural integration (that is possible according to the individual's current level of adaptation). 80% intensity corresponds to 80% integration, 70% to 70%, 60% to 60%. Neural integration and maximum strength potency are equivalent.

To determine the max strength potency/neural integration for any set with more than a single rep, we must understand how increasing fatigue during a set affects neural recruitment.

4.1 AMRAP

The more repetitions a lifter performs in a set, the more motor units the motor cortex must recruit to finish the work. Pushing a set to AMRAP will force the maximum amount of neural recruitment possible with that intensity (weight). When a lifter performs AMRAP, the initial motor units fatigue as the set progresses, and new units must engage to finish the work. With this method, the last few reps in which a maximal number of motor units are recruited are the most useful. The term "No pain, no gain" originates from this fact.

So, a set's maximum and general strength potency is determined primarily by the intensity used and secondarily by the degree of intensity-specific fatigue accumulated. An equation that considers both variables but focuses more on intensity will provide the strength potency.

I established that a single rep's max strength potency was exactly the rep's intensity. The first rep of any set's max strength potency is equivalent to its intensity. To determine the whole set's max strength potency, we must determine the amount of neural recruitment developed by the rest of the reps according to fatigue. To determine the degree of fatigue developed by a given number of reps with a certain intensity, we must know how many reps are maximal for a set with the intensity. The following quintic polynomial provides the AMRAP value for any intensity:

173.5249 - 6.31*Intensity + 0.095759*Intensity^2 - 0.0006742*Intensity^3 + 0.00000174962*Intensity^4 + 9.927033E-17*Intensity^5

Table one shows the AMRAP values for various intensities.

Intensity	AMRAP	
	Raw	Rounded Down
99	1.26	1
90	4.57	4
85	6.32	6
80	8.06	8
75	9.85	9
70	11.80	11
65	14.04	14
60	16.71	16

Table 1: AMRAP Values for various intensities.

AMRAP for any intensity represents 100% set-level fatigue with that intensity. Now that the full fatigue rep amount for any intensity is known, we can determine the degree of fatigue accumulated from any non-AMRAP number of reps in a set.

4.2 Percentage of Fatigue Accumulated

Fatigue accumulates exponentially rather than incrementally during work. The following equation determines the percentage of intensity-specific fatigue accumulated in a set according to the relativity of the reps completed to AMRAP for the intensity.

(e^(-1/Reps*AMRAP))/(e^(-1/AMRAP*AMRAP)) = Intensity Specific Fatigue Accumlated

Where: e = Euler's Number, 2.718

Table 2 shows the degree of fatigue accumulated by various numbers of reps with 80% intensity.

Intensity	Reps	Fatigue Accumulated
80	8.00	100.0%
80	7.00	86.7%
80	6.00	71.7%
80	5.00	54.9%
80	4.00	36.8%
80	3.00	18.9%
80	2.00	5.0%
80	1.00	0.1%

Table 2: Intensity-specific fatigue accumulated for sets of various amounts of reps with 80% intensity

4.3 Fatigue and the Increase of Strength Potency

The next step is to determine how much working to 100% fatigue in a set adds to the initial strength potency of the first rep of the set (equivalent to the intensity).

For this purpose, I posit the idea the strength potency of an AMRAP set with any intensity can increase over the initial potency (equivalent to the intensity) by a maximum value that the following equation returns-

AMRAP * (Intensity/100) = Maximum Strength Potency Increase With Given Intensity

For 80% intensity the equation looks like this:

8 * (80/100) = 6.4

AMRAP * (Intensity/100) = Maximum Strength Potency Increase With Given Intensity

For an AMRAP set with 80% intensity, we add 6% (rounded) to the potency of the initial rep (80%) to bring the final strength potency of the set to 86%; this means that a set of 8 reps (AMRAP) with 80% intensity is roughly equivalent to a single rep with 86% intensity for increasing strength. An athlete with a 100 KG maximum on the Bench Press would get a similar strength effect from a set of 8 reps with 80 KG and a single rep with 86 KG. The muscular protein degradation-hypertrophy effect from the 80% x 8 reps set would be much more significant, but here we are only concerned with the neurological effect of neural recruitment for strength.

For sets that are <AMRAP, we simply factor in the percentage of fatigue accumulated from the number of reps completed using the Intensity Specific Fatigue Accumulated equation mentioned above. The final Strength Potency equation then looks like this-

Intensity + ((AMRAP * (Intensity / 100)) * % of Fatigue Accumulated) = Strength Potency

Table 3 shows the strength potencies of various sets with 80% intensity.

Intensity	Reps	Strength Potency
80	8	86.40%
80	7	85.55%
80	6	84.59%
80	5	83.51%
80	4	82.35%
80	3	81.21%
80	2	80.32%
80	1	80.01%

Table 3: Strength Potencies for various sets with 80% intensity.

Table 4 shows the same for sets with 90% intensity for further comprehension.

Intensity	Reps	Strength Potency
90	4	93.60%
90	3	91.36%
90	2	90.36%
90	1	90.01%

Table 4: Strength Potencies for various sets with 90% intensity. *4 reps is AMRAP with 90%.

It is further illustrative to look at different sets with various intensities performed for the optimal number of reps according to Prilepin's chart and the Abstract Internal Loading Equation (see my first paper, "Applied Mathematical Science of Physical Training Part 1: Barbell Loading"). The results are in table 5.

Intensity	Reps	Strength Potency
90	2	91.32%
85	3	86.88%
80	5	83.51%
75	6	79.09%
70	7	74.35%
65	9	70.22%
60	11	66.09%

Table 5: Strength Potencies for optimal sets with different intensities.

5. Implications

The strength potency equation provides a tool to increase precision in the design of progressive overload strength training programs. Typically, we simply increase the training intensity for a spatial form to increase/peak strength across a training period. Another basic (and somewhat less effective) protocol is to increase reps per set while keeping the intensity stable. Either method will cause progressive overload to a greater or lesser degree. We can make the prescriptions much more precise with the strength potency concept.

Table 6 shows how this can work in practice across eight microcycles.

Microcycle	Intensity	Reps	Strength Potency	Sets	Abstract Load
1	80	6	85%	3	0.78
2	85	5	89%	3	0.88
3	89	4	92%	3	1.03
4	70	5	72%	3	0.41
5	92	3	95%	3	1.15
6	95	2	97%	3	1.19
7	97	1	97%	3	0.96
8	82	2	83%	3	0.30

Table 6: An 8-week strength training progression. *Weeks 4 and 8 are deloads. Loads do not include warm-ups.

In table six, the work set intensity and strength potency increases chronologically from microcycle (week) to microcycle. The intensity of the work sets of each progressive microcycle is equal to the strength potency developed in the work sets of the previous microcycle (besides the deloads). A progressive prescription of strength potencies and intensities in this way allows the athlete to precisely prepare for the upcoming increase in intensity while using a lighter intensity; this ensures that the required structural and energetic adaptations for the increased neurological demand of the following microcycle are secured beforehand. This is just one theoretical example of using the strength potency concept to increase training programming precision.

Summary

In this paper, I detailed a comprehensive system for determining the effectiveness of training sets for increasing strength. This concept is known as Strength Potency.

I detailed the physiological abilities spectrum and its two constituent continuums. I defined strength and its fundamental modalities and showed why maximum strength is the fulcrum of the ability spectrum.

I listed all the factors that affect strength.

I also defined training intensity and how it relates to neural recruitment.

I provided the polynomial equation to calculate As Many Reps As Possible (AMRAP) for a set with any intensity.

I detailed how to determine the percentage of intensity-specific set-level fatigue accumulated based on AMRAP and the number of reps done; and how this is related to increased motor unit recruitment.

With intensity, AMRAP, and fatigue accumulated values in hand, I then posited the strength training potency equation.

Finally, I provided a practical example of how we can use the equation to prescribe training variables to create an effective progressive overload program.

Conclusion

This series of papers aims to develop a complete system of applied mathematical science for physical training. The first three papers detailed how to calculate the training load for various

training modalities and how to determine chronological preparedness according to the loading prescriptions across time. This paper is a crucial component of the supersystem since strength is the most fundamental of all physiological abilities. The strength potency provides another integrative mathematical tool to increase the precision of training variable prescription. I hope that other coaches and trainers will employ this equation as part of the greater loading-preparedness supersystem to increase creativity and effectiveness in their training program design processes.

Works Cited

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