Organization of Resistance Bands into a Linear Progression

ABSTRACT

This project will determine if and how latex resistance bands can be organized into a linear progress system for athletic training.

INTRODUCTION

Latex resistance bands have become a popular alternative to traditional barbells and weights or weight machines in a gym. They are typically available in sets of five to eight bands of verifying thickness and width and therefor resistance. No specific measurements are offered to define a bands strength so a typical linear progression training program can be difficult to establish, where in weight it a simple task of adding more weight.

This project will focus on a set of bands provided by Resistance Band Training. There are six bands of different strength, from low to high; orange, yellow, red, black, violet, green. Two bands of each color will be included in the test and were purchased through normal independent channels.

A setup will be created to measure the resistance characteristics of the bands and then an ordering system will be put together to provide linear progress through the bands.

OBJECTIVES

1. Measure the band resistances at various stretch lengths.
2. Determine if band resistance can be reliability measured.
3. Determine if band resistances can be added to provide resistance values between the singular bands
4. Develop a list of progressions between the bands and band combinations to provide as small of steps in resistance as possible.

MATERIALS

Resistance Bands

The bands are labeled Quantum Band and were purchased from www.resistancebandtraining.com. Six pairs of two bands each are included in this study. They are identified by color: orange, yellow, red, black, violet, and green. There are other sources of resistance type bands for exercise. Some of these seem to follow the same color scheme, but no verification has been done to indicate they are the same.

All of the bands are 41” in length in their idle state. The table below gives the cross section profile of each of the bands.

Color	*Width*	*Thickness*
Orange	0.0605	0.0955
Yellow	0.8380	0.1150
Red	0.5000	0.1860
Black	0.8225	0.1885
Violet	1.1410	0.1870
Green	1.7650	0.1880

These measurements were made with a Mitutoya 3.5 digit digital caliper with current calibration. The accuracy is suspect due to the flexibility of the bands in all directions.

The bands are a layered construction of latex like material.

Other Equipment

Stable End Points

Two stable end points capably of withstanding over 200lbs of lateral torsion and at least thirteen feet apart are needed to anchor the two ends of the measuring setup. The data collected in this report was collected in Cybertec's basement. A steel lally column and the steel I-beam supporting stairwell frame were used due to their convenience and stability to lateral torsion.

Maasdam Pow'R Pull 144S-6 1 Ton Capacity

This unit was purchased from Amazon based on reputation and price. Any tensioning device capable of over 200lbs could be used. In this paper it will be called by the slang name of "come along."

Crane660lb Hanging Scale, digital, heavy duty case

The scale was purchased on Amazon. The select was based on feedback from previous purchasers and budget. It is primarily used for weighing game for hunters and in healthcare for Hoyer Lifts. Any scale capable of measuring inline tension in pounds and capable of over 200lbs could be used.

Stanley 30' Measuring Tape

A standard carpenter measuring tape was used. These are available at any home improvement store.

Assorted carabiners and strapping

Strapping from climbing gear and carabiners were used to attach the come along, scale, and bands to the end points.

METHODS

Setup

The come along is anchored to one of the end points and the scale is anchored to the other. The band under test is connected between the come along and the scale. Carabiners were used for the actual connection to the bands to reduce any wear and wear on the band due to sharp edges. To start each test sequence the come along cable must be extended 70 to 80 inches to make it easier to connect the band without having to stretch the band.

The tare weight on the scale must be set to zero with the scale held in the horizontal position with no weight on the scale. The weight values are set to “pounds.”

Measuring

Each band will be measured at various specific lengths. The come combinations of all of these measurements will be called one dataset. The measured lengths will be 48, 54, 60, 66, 72, 78, 84, 90, 96, 102, and 108 inches. The 48-inch starting point is based on the lowest amount of stretch to actually create measurable tension on the band. The top length of 108 inches is based on the manufacturers published limitations.

A band will be placed in the measuring apparatus. The come along is tightened until the first length of 48” is reached. Due to band thickness and the distance between the pawls of the come along, all measurements are minimum and within a tolerance of 0.75 inches over the stated value.

Once the length has been measured and verified to be correct, the value of the digital scale is read and noted in the data collection forms.

This procedure is repeated for three complete datasets for each band. There are two bands of each color of orange, yellow, red, black, violet, green. An additional three datasets will be taken for the combination of both red bands measured together. The two bands of the same color will be measured alternating between the bands for each dataset. The red/red combination will obviously not be able to be alternated.

The data collection process will likely take multiple days to complete due to scheduling and priorities. Each data set will be marked with the day in which it was collected.

Data Processing

Data processing is required to resolve the multiple data sets down to a single set of values for each band. Two mathematical operations will be used in the process.

Average

In this document the common term, “average”, will be used synonymously with a statistical mean.

$$\bar{x} = \frac{\sum_{i=1}^{n} X_i}{n}$$

Where $\bar{x}$ is the mean, X_1 is the observed value and n is the quantity of values.

Standard Deviation

Standard deviation quantifies the amount of variation in the values of the data sets. The resulting standard deviation is expressed in pound, because the original datasets are measured in pounds.

$$\delta = \sqrt{\frac{\sum_{i=1}^{n} \left(X_1 - \bar{x} \right)^2}{n-1}}$$

Where δ is the standard deviation, X_1 is the observed value, $\bar{x}$ is the mean or average of all the values, and n is the quantity of values.

Slope

While the measured datasets are unlikely to be linear functions, some means of describing the rate of change in resistance over distance. The traditions calculation of rise over run will be used for the first and last values measured at 48 and 108 inches. The formula for the calculation is shown here.

$$Slope = \frac{X_{first} - X_{last}}{180 - 48}$$

The slope will be a rate of change of pounds per inch and can be used to compare the rate of change over elongation of the various bands.

Variation

Combining the datasets from each of the two color band involved only two values and a standard deviation doesn't work with a sample size this small. The term variation is used to indicate the value of difference between the two bands, measured in pounds.

$$Variation = \left| band_1 - band_2 \right|$$

Percent Deviation

Percent Deviation is simply turning the standard deviation into a percentage of the average. This will be used to compare the consistency of the repetitions of the bands to the tolerances of other exercise equipment.

$$PercentDeviation = \frac{\delta}{\mu}$$

Where δ is the standard deviation and μ is the mean or average of the samples.

Processing

The multiple datasets from each band will be averaged together to create a single dataset for that band. Standard deviations will be generated the band at the same time. Once a single dataset of each band has been created, the two like band's datasets will be averaged together to create a single dataset per band color.

The dual band measurement datasets will be averaged together and the standard deviation calculated.

Safety

The testing apparatus and methods will create tensions measured in the hundreds of pounds. Slippage, breaking, or other accidents can cause significant forces to be released. Appropriate safety equipment and procedures must be used for the operator's personal security.

RESULTS

Raw Data

	Band	*Set*	*48*	*54*	*60*	*66*	*72*	*78*	*84*	*90*	*96*	*102*	*108*	*Day*
Orange	***1***	***1***	4.1	5.7	7.2	8.1	9.2	10.1	11.0	11.6	12.3	13.0	13.8	1
		2	3.1	5.5	7.0	8.1	9.2	9.9	10.7	11.4	12.3	13.0	13.6	1
		3	3.7	5.5	7.0	8.1	9.0	9.9	10.5	11.4	12.1	12.1	13.6	1
	2	***1***	3.7	5.2	6.6	7.7	8.5	9.4	9.9	10.5	11.2	11.2	12.5	1
		2	3.5	5.0	6.3	7.4	8.3	9.2	9.9	10.5	11.2	11.2	12.5	1
		3	3.5	5.0	6.3	7.4	8.1	9.0	9.9	10.3	11.0	11.0	12.3	1
Yellow	***1***	***1***	5.5	8.5	11.0	12.7	14.3	15.8	16.9	18.2	19.3	20.4	21.8	4
		2	5.0	8.3	10.5	12.3	14.1	15.6	16.7	18.0	19.1	20.2	21.5	4
		3	5.0	7.7	10.1	12.1	13.8	15.2	16.3	17.6	18.7	19.8	20.9	4
	2	***1***	5.5	8.3	10.5	12.5	13.8	14.9	16.0	17.1	18.5	19.3	20.4	4
		2	4.8	7.7	9.9	11.6	13.2	14.5	15.8	16.9	17.8	18.7	19.8	4
		3	4.6	7.7	9.9	11.4	13.2	14.3	15.4	16.7	17.8	18.9	20.0	4
Red	***1***	***1***	3.7	6.3	8.8	10.5	12.1	13.4	14.7	15.8	16.9	18.0	19.1	2
		2	5.9	8.6	11.0	12.7	14.3	15.6	16.7	18.0	19.1	20.0	21.1	3
		3	5.5	8.1	10.3	12.3	13.8	15.2	16.5	17.6	18.7	19.8	20.9	3
	2	***1***	4.6	7.7	10.1	11.9	13.6	15.2	16.5	18.0	18.9	20.2	21.8	2
		2	6.3	9.4	11.9	13.8	15.6	16.9	18.2	19.6	20.7	21.8	23.1	3
		3	5.9	9.0	11.4	13.4	14.9	16.5	18.0	19.3	20.4	21.8	22.9	3
Black	***1***	***1***	10.7	16.9	21.8	24.6	27.9	30.6	33.2	35.9	38.3	40.3	42.5	4

		2	10.5	16.0	20.4	24.2	27.1	29.7	32.8	35.0	37.4	39.8	42.0	4
		3	10.3	16.0	20.4	23.5	27.1	29.9	32.8	34.3	37.4	39.4	41.8	4
	2	***1***	12.3	18.2	22.9	26.6	29.7	32.1	35.0	37.6	40.3	42.7	44.9	4
		2	11.6	17.6	22.0	25.1	28.6	31.5	34.3	36.5	39.2	41.6	44.3	4
		3	11.6	17.6	22.0	25.5	28.8	31.2	34.1	36.5	39.4	41.6	44.3	4
Violet	***1***	***1***	15.8	22.2	28.2	32.3	36.1	39.2	42.3	45.1	48.2	50.9	53.5	3
		2	14.3	21.8	27.1	31.2	35.0	37.9	41.2	44.3	47.1	50.0	52.4	3
		3	14.5	21.1	26.4	30.8	34.9	38.1	41.2	44.0	46.9	49.8	52.6	3
	2	***1***	16.7	24.4	29.9	33.9	38.1	41.8	44.9	47.8	50.4	53.1	55.7	3
		2	15.2	22.0	27.5	32.1	36.5	39.6	43.1	46.0	48.9	51.5	54.6	3
		3	14.1	21.1	27.5	31.7	35.9	39.4	42.5	45.6	48.9	51.7	54.8	3
Green	***1***	***1***	23.3	34.6	42.9	49.5	55.1	58.1	63.4	67.4	71.4	74.9	77.3	4
		2	21.7	32.0	40.4	46.1	52.1	56.9	61.6	66.0	70.2	73.5	77.6	4
		3	20.4	30.8	38.7	45.1	50.9	55.7	59.7	64.3	68.5	72.7	75.8	4
	2	***1***	23.3	34.3	42.9	49.5	55.3	30.1	65.0	68.5	72.9	76.4	80.4	4
		2	21.3	21.8	40.9	48.2	53.3	58.8	63.4	67.8	72.2	76.6	80.2	4
		3	20.4	31.9	40.5	47.8	53.3	58.6	62.5	67.2	71.8	75.5	79.7	4
Red/Red		***1***	11.9	18.5	23.5	27.1	30.4	33	35.4	38.1	40.5	42.5	44.9	2
		2	10.5	16.7	21.8	25.5	28.4	31.5	33.9	36.3	38.7	40.7	43.1	2
		3	9.4	15.6	20.4	24.2	27.5	30.4	33	35.4	37.9	40.3	42.3	2

PROCESSING

Orange

Band	Set	48	54	60	66	72	78	84	90	96	102	108	Day
1	1	4.1	5.7	7.2	8.1	9.2	10.1	11.0	11.6	12.3	13.0	13.8	1
	2	3.1	5.5	7.0	8.1	9.2	9.9	10.7	11.4	12.3	13.0	13.6	1
	3	3.7	5.5	7.0	8.1	9.0	9.9	10.5	11.4	12.1	12.1	13.6	1
Average		3.6	5.6	7.1	8.1	9.1	10.0	10.7	11.5	12.2	12.7	13.7	
Std Dev		0.5	0.1	0.1	0.0	0.1	0.1	0.3	0.1	0.1	0.5	0.1	
% Dev		14%	2%	2%	0%	1%	1%	2%	1%	1%	4%	1%	
2	1	3.7	5.2	6.6	7.7	8.5	9.4	9.9	10.5	11.2	11.2	12.5	1
	2	3.5	5.0	6.3	7.4	8.3	9.2	9.9	10.5	11.2	11.2	12.5	1
	3	3.5	5.0	6.3	7.4	8.1	9.0	9.9	10.3	11.0	11.0	12.3	1
Average		3.6	5.1	6.4	7.5	8.3	9.2	9.9	10.4	11.1	11.1	12.4	
Std Dev		0.1	0.1	0.2	0.2	0.2	0.2	0.0	0.1	0.1	0.1	0.1	
% Dev		3%	2%	3%	2%	2%	2%	0%	1%	1%	1%	1%	
	Average	3.6	5.3	6.7	7.8	8.7	9.6	10.3	11.0	11.7	11.9	13.1	
	Variation	0.0	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.8	0.6	

Yellow

Band	Set	48	54	60	66	72	78	84	90	96	102	108	Day
1	1	5.5	8.5	11.0	12.7	14.3	15.8	16.9	18.2	19.3	20.4	21.8	4
	2	5.0	8.3	10.5	12.3	14.1	15.6	16.7	18.0	19.1	20.2	21.5	4
	3	5.0	7.7	10.1	12.1	13.8	15.2	16.3	17.6	18.7	19.8	20.9	4
Average		5.2	8.2	10.5	12.4	14.1	15.5	16.6	17.9	19.0	20.1	21.4	
Std Dev		0.3	0.4	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	
% Dev		6%	5%	4%	2%	2%	2%	2%	2%	2%	2%	2%	

2	***1***	5.5	8.3	10.5	12.5	13.8	14.9	16.0	17.1	18.5	19.3	20.4	4
	2	4.8	7.7	9.9	11.6	13.2	14.5	15.8	16.9	17.8	18.7	19.8	4
	3	4.6	7.7	9.9	11.4	13.2	14.3	15.4	16.7	17.8	18.9	20.0	4
Average		5.0	7.9	10.1	11.8	13.4	14.6	15.7	16.9	18.0	19.0	20.1	
Std Dev		0.5	0.3	0.3	0.6	0.3	0.3	0.3	0.2	0.4	0.3	0.3	
% Dev		10%	4%	3%	5%	3%	2%	2%	1%	2%	2%	2%	
	Average	5.1	8.0	10.3	12.1	13.7	15.1	16.2	17.4	18.5	19.6	20.7	
	Variation	0.1	0.1	0.2	0.3	0.3	0.5	0.4	0.5	0.5	0.6	0.7	

Red

Band	***Set***	***48***	***54***	***60***	***66***	***72***	***78***	***84***	***90***	***96***	***102***	***108***	***Day***
1	***1***	3.7	6.3	8.8	10.5	12.1	13.4	14.7	15.8	16.9	18.0	19.1	2
	2	5.9	8.6	11.0	12.7	14.3	15.6	16.7	18.0	19.1	20.0	21.1	3
	3	5.5	8.1	10.3	12.3	13.8	15.2	16.5	17.6	18.7	19.8	20.9	3
Average		5.0	7.7	10.0	11.8	13.4	14.7	16.0	17.1	18.2	19.3	20.4	
Std Dev		1.2	1.2	1.1	1.2	1.2	1.2	1.1	1.2	1.2	1.1	1.1	
% Dev		23%	16%	11%	10%	9%	8%	7%	7%	6%	6%	5%	
2	***1***	4.6	7.7	10.1	11.9	13.6	15.2	16.5	18.0	18.9	20.2	21.8	2
	2	6.3	9.4	11.9	13.8	15.6	16.9	18.2	19.6	20.7	21.8	23.1	3
	3	5.9	9.0	11.4	13.4	14.9	16.5	18.0	19.3	20.4	21.8	22.9	3
Average		5.6	8.7	11.1	13.0	14.7	16.2	17.6	19.0	20.0	21.3	22.6	
Std Dev		0.9	0.9	0.9	1.0	1.0	0.9	0.9	0.9	1.0	0.9	0.7	
% Dev		16%	10%	8%	8%	7%	5%	5%	4%	5%	4%	3%	
	Average	5.3	8.2	10.6	12.4	14.1	15.5	16.8	18.1	19.1	20.3	21.5	
	Variation	0.3	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.1	

Black

Band	Set	48	54	60	66	72	78	84	90	96	102	108	Day
1	1	10.7	16.9	21.8	24.6	27.9	30.6	33.2	35.9	38.3	40.3	42.5	4
	2	10.5	16.0	20.4	24.2	27.1	29.7	32.8	35.0	37.4	39.8	42.0	4
	3	10.3	16.0	20.4	23.5	27.1	29.9	32.8	34.3	37.4	39.4	41.8	4
Average		10.5	16.3	20.9	24.1	27.4	30.1	32.9	35.1	37.7	39.8	42.1	
Std Dev		0.2	0.5	0.8	0.6	0.5	0.5	0.2	0.8	0.5	0.5	0.4	
% Dev		2%	3%	4%	2%	2%	2%	1%	2%	1%	1%	1%	
2	1	12.3	18.2	22.9	26.6	29.7	32.1	35.0	37.6	40.3	42.7	44.9	4
	2	11.6	17.6	22.0	25.1	28.6	31.5	34.3	36.5	39.2	41.6	44.3	4
	3	11.6	17.6	22.0	25.5	28.8	31.2	34.1	36.5	39.4	41.6	44.3	4
Average		11.8	17.8	22.3	25.7	29.0	31.6	34.5	36.9	39.6	42.0	44.5	
Std Dev		0.4	0.3	0.5	0.8	0.6	0.5	0.5	0.6	0.6	0.6	0.3	
% Dev		3%	2%	2%	3%	2%	1%	1%	2%	1%	2%	1%	
	Average	11.2	17.1	21.6	24.9	28.2	30.8	33.7	36.0	38.7	40.9	43.3	
	Variation	0.7	0.8	0.7	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.2	

Violet

Band	Set	48	54	60	66	72	78	84	90	96	102	108	Day
1	1	15.8	22.2	28.2	32.3	36.1	39.2	42.3	45.1	48.2	50.9	53.5	3
	2	14.3	21.8	27.1	31.2	35.0	37.9	41.2	44.3	47.1	50.0	52.4	3
	3	14.5	21.1	26.4	30.8	34.9	38.1	41.2	44.0	46.9	49.8	52.6	3
Average		14.9	21.7	27.2	31.4	35.3	38.4	41.6	44.5	47.4	50.2	52.8	
Std Dev		0.8	0.6	0.9	0.8	0.7	0.7	0.6	0.6	0.7	0.6	0.6	
% Dev		5%	3%	3%	2%	2%	2%	2%	1%	1%	1%	1%	
2	1	16.7	24.4	29.9	33.9	38.1	41.8	44.9	47.8	50.4	53.1	55.7	3
	2	15.2	22.0	27.5	32.1	36.5	39.6	43.1	46.0	48.9	51.5	54.6	3

	3	14.1	21.1	27.5	31.7	35.9	39.4	42.5	45.6	48.9	51.7	54.8	3
Average		15.3	22.5	28.3	32.6	36.8	40.3	43.5	46.5	49.4	52.1	55.0	
Std Dev		1.3	1.7	1.4	1.2	1.1	1.3	1.2	1.2	0.9	0.9	0.6	
% Dev		9%	8%	5%	4%	3%	3%	3%	3%	2%	2%	1%	
	Average	15.1	22.1	27.8	32.0	36.1	39.3	42.5	45.5	48.4	51.2	53.9	
	Variation	0.2	0.4	0.5	0.6	0.8	0.9	1.0	1.0	1.0	0.9	1.1	

Green

Band	***Set***	***48***	***54***	***60***	***66***	***72***	***78***	***84***	***90***	***96***	***102***	***108***	***Day***
1	***1***	23.3	34.6	42.9	49.5	55.1	58.1	63.4	67.4	71.4	74.9	77.3	4
	2	21.7	32.0	40.4	46.1	52.1	56.9	61.6	66.0	70.2	73.5	77.6	4
	3	20.4	30.8	38.7	45.1	50.9	55.7	59.7	64.3	68.5	72.7	75.8	4
Average		21.8	32.5	40.7	46.9	52.7	56.9	61.6	65.9	70.0	73.7	76.9	
Std Dev		1.5	1.9	2.1	2.3	2.2	1.2	1.9	1.6	1.5	1.1	1.0	
% Dev		7%	6%	5%	5%	4%	2%	3%	2%	2%	2%	1%	
2	***1***	23.3	34.3	42.9	49.5	55.3	30.1	65.0	68.5	72.9	76.4	80.4	4
	2	21.3	21.8	40.9	48.2	53.3	58.8	63.4	67.8	72.2	76.6	80.2	4
	3	20.4	31.9	40.5	47.8	53.3	58.6	62.5	67.2	71.8	75.5	79.7	4
Average		21.7	29.3	41.4	48.5	54.0	49.2	63.6	67.8	72.3	76.2	80.1	
Std Dev		1.5	6.6	1.3	0.9	1.2	16.5	1.3	0.7	0.6	0.6	0.4	
% Dev		7%	23%	3%	2%	2%	34%	2%	1%	1%	1%	0%	
	Average	21.7	30.9	41.1	47.7	53.3	53.0	62.6	66.9	71.2	74.9	78.5	
	Variation	0.1	1.6	0.4	0.8	0.6	3.9	1.0	1.0	1.1	1.2	1.6	

Red/Red

Set	***48***	***54***	***60***	***66***	***72***	***78***	***84***	***90***	***96***	***102***	***108***	***Day***

1	11.9	18.5	23.5	27.1	30.4	33	35.4	38.1	40.5	42.5	44.9	2
2	10.5	16.7	21.8	25.5	28.4	31.5	33.9	36.3	38.7	40.7	43.1	2
3	9.4	15.6	20.4	24.2	27.5	30.4	33	35.4	37.9	40.3	42.3	2
Average	10.6	16.9	21.9	25.6	28.8	31.6	34.1	36.6	39.0	41.2	43.4	
Std Dev	1.3	1.5	1.6	1.5	1.5	1.3	1.2	1.4	1.3	1.2	1.3	
% Dev	12%	9%	7%	6%	5%	4%	4%	4%	3%	3%	3%	

Summary Values

	48	***54***	***60***	***66***	***72***	***78***	***84***	***90***	***96***	***102***	***108***	***Slope***
Orange	3.6	5.3	6.7	7.8	8.7	9.6	10.3	11.0	11.7	11.9	13.1	0.158
Yellow	5.1	8.0	10.3	12.1	13.7	15.1	16.2	17.4	18.5	19.6	20.7	0.261
Red	5.3	8.2	10.6	12.4	14.1	15.5	16.8	18.1	19.1	20.3	21.5	0.269
Black	11.2	17.1	21.6	24.9	28.2	30.8	33.7	36.0	38.7	40.9	43.3	0.536
Violet	15.1	22.1	27.8	32.0	36.1	39.3	42.5	45.5	48.4	51.2	53.9	0.647
Green	21.7	30.9	41.1	47.7	53.3	53.0	62.6	66.9	71.2	74.9	78.5	0.946
Red/Red	10.6	16.9	21.9	25.6	28.8	31.6	34.1	36.6	39.0	41.2	43.4	0.547

DISCUSSION

Objective One

Measure the band resistances at various stretch lengths.

The bands were measures and the data is in the previous sections of this report. No unusual events occurrence during the measuring. Like many studies, additional sample would help solidify the understandings.

Objective Two

Determine if band resistance can be reliability measured.

It is obvious from reviewing the data that lower tension measurements were not very reproducible as compared to the higher tension measurements. There isn't enough data present to determine why. There could be many issues including the measurement process. The bands are a bilateral tension device and the alignment of the band with equal tension on both sides in low tension state is likely one of the problems with low tension measurement reproduction.

As a point of reference, York Barbell is a very reputable manufacturer of weight plates. They specify their metal training plates to be accurate within 2%. Using them as a high caliber standard, any of the measurement with a percent deviation under 2% is good.

Objective Three

Determine if band resistances can be added to provide resistance values between the singular bands

Comparing the ratings for the red bands and combination of two red bands shows an extremely linear match.

	48	***54***	***60***	***66***	***72***	***78***
Red	5.3	8.2	10.6	12.4	14.1	15.5
Red/Red	10.6	16.9	21.9	25.6	28.8	31.6
Difference	0.0	0.6	0.7	0.7	0.7	0.7

84	***90***	***96***	***102***	***108***	***Slope***
16.8	18.1	19.1	20.3	21.5	0.269
34.1	36.6	39.0	41.2	43.4	0.547
0.6	0.5	0.8	0.6	0.5	0.0

At each measuring point the difference in the projected two band resistance and the measured resistance is less than one pound. This proves that combining multiple bands does create a linear increase of the resistance consistent to the sum of the two bands.

Objective Four

Develop a list of progressions between the bands and band combinations to provide as small of steps in resistance as possible.

Combining two bands each of six colors presents 27 possible combinations of colors. There are eleven measuring points in the data sets, so the middle or 6^{th} position will be used for sorting the 27 combinations by resistance, low too high in the 78 in position.

All Possible Band Combinations

	48	*54*	*60*	*66*	*72*	*78*	*84*	*90*	*96*	*102*	*108*	*Slope*	*Inc*	*Inc %*
Orange	3.6	5.3	6.7	7.8	8.7	9.6	10.3	11.0	11.7	11.9	13.1	0.2		
Yellow	5.1	8.0	10.3	12.1	13.7	15.1	16.2	17.4	18.5	19.6	20.7	0.3	5.5	57.0%
Red	5.3	8.2	10.6	12.4	14.1	15.5	16.8	18.1	19.1	20.3	21.5	0.3	0.4	2.8%
Orange/Orange	7.2	10.6	13.5	15.6	17.4	19.2	20.6	21.9	23.4	23.8	26.1	0.3	3.7	23.9%
Yellow/Orange	8.7	13.4	17.1	19.9	22.5	24.6	26.5	28.4	30.2	31.5	33.8	0.4	5.5	28.5%
Red/Orange	8.9	13.5	17.3	20.2	22.8	25.1	27.1	29.0	30.8	32.2	34.5	0.4	0.4	1.7%
Yellow/Yellow	10.1	16.1	20.6	24.2	27.5	30.1	32.4	34.8	37.1	39.1	41.5	0.5	5.1	20.2%
Red/Yellow	10.4	16.2	20.9	24.5	27.8	30.5	33.0	35.5	37.7	39.8	42.2	0.5	0.4	1.4%
Black	11.2	17.1	21.6	24.9	28.2	30.8	33.7	36.0	38.7	40.9	43.3	0.5	0.3	1.0%
Red/Red	10.6	16.4	21.2	24.9	28.1	30.9	33.5	36.1	38.2	40.5	43.0	0.5	0.1	0.3%
Violet	15.1	22.1	27.8	32.0	36.1	39.3	42.5	45.5	48.4	51.2	53.9	0.6	8.4	27.2%
Black/Orange	14.8	22.4	28.3	32.7	36.9	40.4	44.0	46.9	50.4	52.8	56.4	0.7	1.1	2.8%
Black/Yellow	16.2	25.1	31.9	37.0	41.9	45.9	49.9	53.4	57.2	60.5	64.0	0.8	5.5	13.5%
Black/Red	16.5	25.2	32.2	37.4	42.3	46.3	50.5	54.0	57.8	61.2	64.8	0.8	0.4	0.9%
Violet/Orange	18.7	27.4	34.5	39.8	44.8	48.9	52.9	56.4	60.1	63.1	67.0	0.8	2.6	5.7%
Green	21.7	30.9	41.1	47.7	53.3	53.0	62.6	66.9	71.2	74.9	78.5	0.9	4.1	8.4%
Violet/Yellow	20.2	30.1	38.1	44.1	49.8	54.4	58.7	62.9	66.9	70.7	74.7	0.9	1.4	2.5%
Violet/Red	20.4	30.3	38.4	44.4	50.1	54.8	59.3	63.5	67.5	71.4	75.4	0.9	0.4	0.8%
Black/Black	22.3	34.1	43.2	49.8	56.4	61.7	67.4	71.9	77.3	81.8	86.6	1.1	6.9	12.5%
Green/Orange	25.3	36.2	47.8	55.5	62.1	62.6	72.9	77.8	82.9	86.9	91.6	1.1	1.0	1.5%
Green/Yellow	26.8	38.9	51.4	59.8	67.1	68.1	78.8	84.3	89.7	94.5	99.2	1.2	5.5	8.7%
Green/Red	27.1	39.1	51.6	60.1	67.4	68.5	79.4	84.9	90.3	95.2	100.0	1.2	0.4	0.6%
Violet/Black	26.3	39.2	49.4	56.9	64.3	70.2	76.2	81.4	87.1	92.1	97.2	1.2	1.7	2.4%
Violet/Violet	30.2	44.2	55.5	64.0	72.2	78.7	85.1	90.9	96.8	102.3	107.9	1.3	8.5	12.1%
Green/Black	32.9	48.0	62.6	72.6	81.5	83.9	96.3	102.8	109.8	115.8	121.8	1.5	5.2	6.6%
Green/Violet	36.8	53.0	68.8	79.7	89.4	92.4	105.1	112.3	119.6	126.1	132.4	1.6	8.5	10.1%
Green/Green	43.5	61.8	82.1	95.4	106.7	106.1	125.2	133.7	142.3	149.9	157.0	1.9	13.7	14.8%

This result can be used as it exists to provide a progressive resistance path through the band, providing increased resistance with each step. The two columns on the right show the increase in pounds and as a percentage. Some of the increases are for very little gain. Cutting all increased less than one percent gives a shortened progression.

All Possible Band Combinations

	48	***54***	***60***	***66***	***72***	***78***	***84***	***90***	***96***	***102***	***108***	***Slope***	***Inc***	***Inc %***
Orange	3.6	5.3	6.7	7.8	8.7	9.6	10.3	11.0	11.7	11.9	13.1	0.2		
Yellow	5.1	8.0	10.3	12.1	13.7	15.1	16.2	17.4	18.5	19.6	20.7	0.3	5.5	57.0%
Red	5.3	8.2	10.6	12.4	14.1	15.5	16.8	18.1	19.1	20.3	21.5	0.3	0.4	2.8%
Orange/Orange	7.2	10.6	13.5	15.6	17.4	19.2	20.6	21.9	23.4	23.8	26.1	0.3	3.7	23.9%
Yellow/Orange	8.7	13.4	17.1	19.9	22.5	24.6	26.5	28.4	30.2	31.5	33.8	0.4	5.5	28.5%
Red/Orange	8.9	13.5	17.3	20.2	22.8	25.1	27.1	29.0	30.8	32.2	34.5	0.4	0.4	1.7%
Yellow/Yellow	10.1	16.1	20.6	24.2	27.5	30.1	32.4	34.8	37.1	39.1	41.5	0.5	5.1	20.2%
Red/Yellow	10.4	16.2	20.9	24.5	27.8	30.5	33.0	35.5	37.7	39.8	42.2	0.5	0.4	1.4%
Black	11.2	17.1	21.6	24.9	28.2	30.8	33.7	36.0	38.7	40.9	43.3	0.5	0.3	1.0%
Violet	15.1	22.1	27.8	32.0	36.1	39.3	42.5	45.5	48.4	51.2	53.9	0.6	8.5	27.6%
Black/Orange	14.8	22.4	28.3	32.7	36.9	40.4	44.0	46.9	50.4	52.8	56.4	0.7	1.1	2.8%
Black/Yellow	16.2	25.1	31.9	37.0	41.9	45.9	49.9	53.4	57.2	60.5	64.0	0.8	5.5	13.5%
Violet/Orange	18.7	27.4	34.5	39.8	44.8	48.9	52.9	56.4	60.1	63.1	67.0	0.8	3.0	6.6%
Green	21.7	30.9	41.1	47.7	53.3	53.0	62.6	66.9	71.2	74.9	78.5	0.9	4.1	8.4%
Violet/Yellow	20.2	30.1	38.1	44.1	49.8	54.4	58.7	62.9	66.9	70.7	74.7	0.9	1.4	2.5%
Black/Black	22.3	34.1	43.2	49.8	56.4	61.7	67.4	71.9	77.3	81.8	86.6	1.1	7.3	13.4%
Green/Orange	25.3	36.2	47.8	55.5	62.1	62.6	72.9	77.8	82.9	86.9	91.6	1.1	1.0	1.5%
Green/Yellow	26.8	38.9	51.4	59.8	67.1	68.1	78.8	84.3	89.7	94.5	99.2	1.2	5.5	8.7%
Violet/Black	26.3	39.2	49.4	56.9	64.3	70.2	76.2	81.4	87.1	92.1	97.2	1.2	2.1	3.1%
Violet/Violet	30.2	44.2	55.5	64.0	72.2	78.7	85.1	90.9	96.8	102.3	107.9	1.3	8.5	12.1%
Green/Black	32.9	48.0	62.6	72.6	81.5	83.9	96.3	102.8	109.8	115.8	121.8	1.5	5.2	6.6%
Green/Violet	36.8	53.0	68.8	79.7	89.4	92.4	105.1	112.3	119.6	126.1	132.4	1.6	8.5	10.1%
Green/Green	43.5	61.8	82.1	95.4	106.7	106.1	125.2	133.7	142.3	149.9	157.0	1.9	13.7	14.8%

SUMMARY

The primary objective of finding a linear progression though the bands is accomplished the Flatted Progression list will work well more most users interested in progressing to stronger and strong band combinations.