Learning Through Research in Introductory Physics

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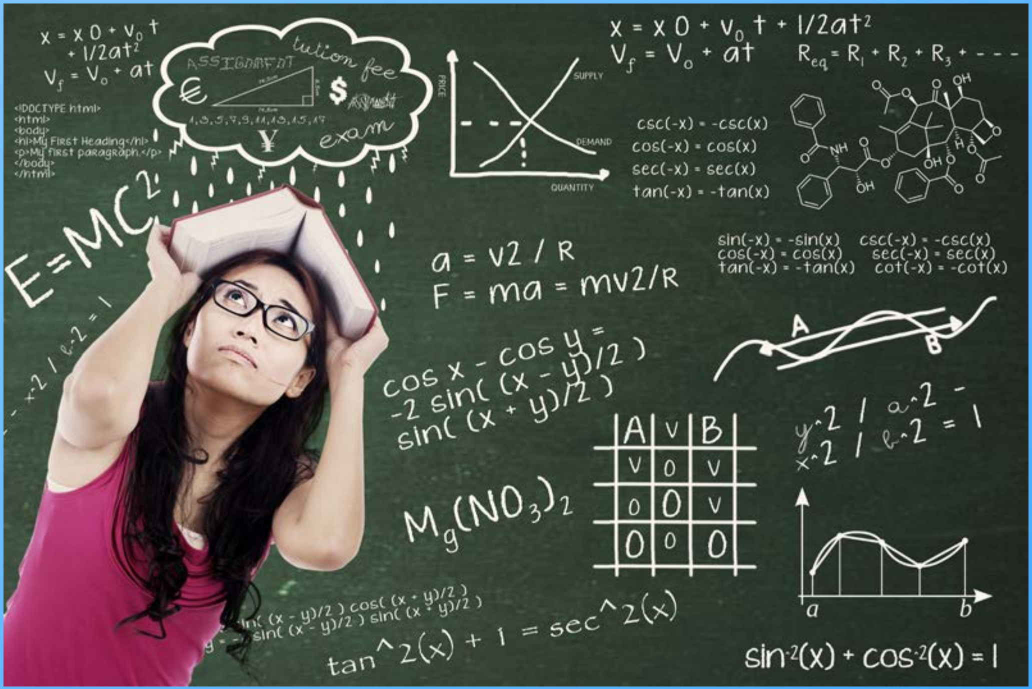


Outline

- Why introduce research into an introductory physics course?
- Learning Objectives
- Implementation
- Examples
- Assessment of the learning effectiveness
- Challenges with implementing research in an introductory course

Why Introduce Research into an Introductory Physics Course?

- **Started with GE assessment**
- **Active learning**
- **Applying physics knowledge and scientific methods**
- **Positive side effects: benefits to instructors**

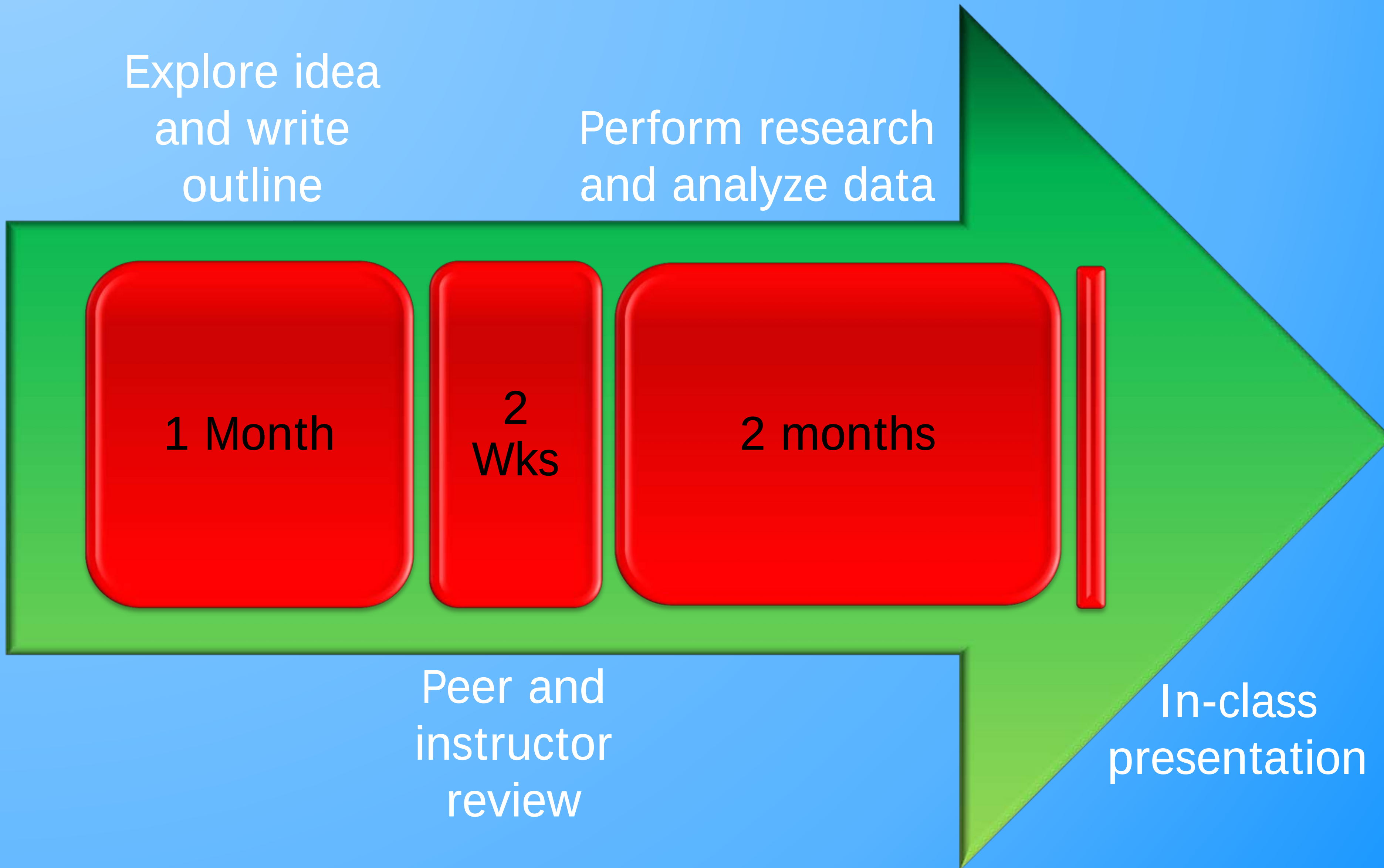
Learning Objectives

1. Investigate the physics underlying an everyday experience or an area of study.
2. Design and conduct a scientific experiment.
3. Analyze the measured data.
4. Draw conclusions based on data and observations.
5. Create a scientific poster and present it to peers.

Implementing the Project

1. Exploring the research idea.
2. Writing a project outline.
3. Peer-review of project outlines.
4. Instructor’s comments and suggestions.
5. Revising the project outline.
6. Conducting the research.
7. Making a scientific poster
8. In-class presentation.

Timeline


Explore idea and write outline
Perform research and analyze data
1 Month
2 Wks
2 months
Peer and instructor review
In-class presentation

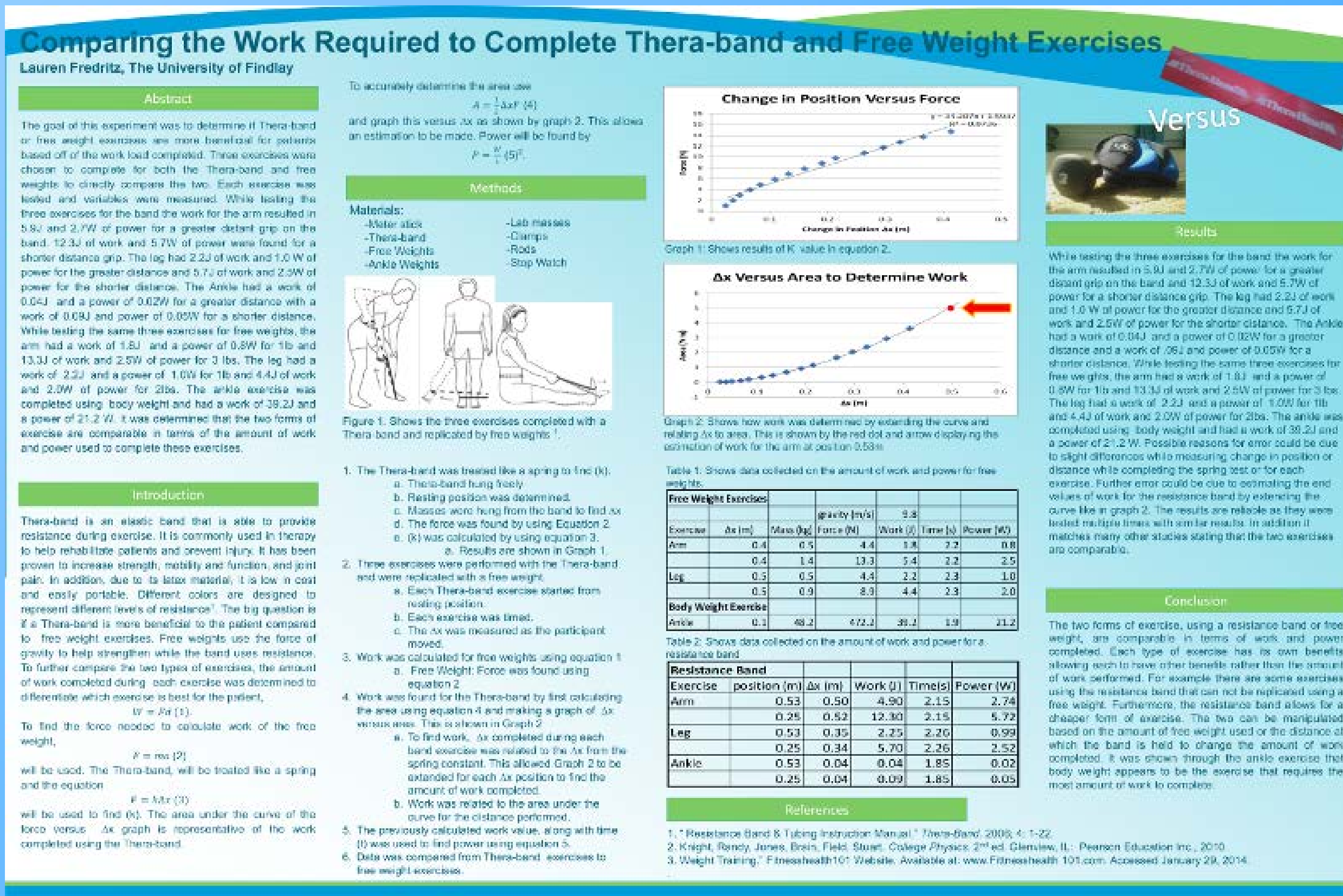
Example Research Ideas

1. Pressure on the forefoot when wearing different types of high heels
2. Effect of tire pressure on the gas mileage of a car
3. Jumping into tension: exploring the forces on the foot and knees while jumping
4. Tractor pulling competitions
5. Centripetal force in barrel racing
6. Active vs. passive recovery in swimming

Example Reviews

- Peer Reviews
  - Review 1
  - Review 2
- Instructors' comments/suggestions
  - Balancing a Backpack
  - The effect of tire pressure on the mileage of a car
  - Optimizing the Serve of a Volleyball

Example Poster



Comparing the Work Required to Complete Thera-band and Free Weight Exercises

Lauren Fredritz, The University of Findlay

Abstract

The goal of this experiment was to determine if Thera-band or free weight exercises are more beneficial for patients based off of the work load completed. Three exercises were chosen to complete for both the Thera-band and free weights to directly compare the two. Each exercise was tested and variables were measured. While testing the three exercises for the band the work for the arm resulted in 5.9J and 2.7W of power for a greater distant grip on the band. 12.3J of work and 5.7W of power were found for a shorter distance grip. The leg had 2.2J of work and 1.0 W of power for the greater distance and 5.7J of work and 2.5W of power for the shorter distance. The Ankle had a work of 0.04J and a power of 0.02W for a greater distance with a work of 0.09J and power of 0.05W for a shorter distance. While testing the same three exercises for free weights, the arm had a work of 1.8J and a power of 0.8W for 1lb and 13.3J of work and 2.5W of power for 3 lbs. The leg had a work of 2.2J and a power of 1.0W for 1lb and 4.4J of work and 2.0W of power for 2lbs. The ankle exercise was completed using body weight and had a work of 39.2J and a power of 21.2 W. It was determined that the two forms of exercise are comparable in terms of the amount of work and power used to complete these exercises.

Introduction

Thera-band is an elastic band that is able to provide resistance during exercise. It is commonly used in therapy to help rehabilitate patients and prevent injury. It has been proven to increase strength, mobility and function, and joint pain. In addition, due to its latex material, it is low in cost and easily portable. Different colors are designed to represent different levels of resistance[1]. The big question is if a Thera-band is more beneficial to the patient compared to free weight exercises. Free weights use the force of gravity to help strengthen while the band uses resistance. To further compare the two types of exercises, the amount of work completed during each exercise was determined to differentiate which exercise is best for the patient.

$W = Fd$ (1).

To find the force needed to calculate work of the free weight,

$F = ma$ (2)

will be used. The Thera-band, will be treated like a spring and the equation

$F = k\Delta x$ (3)

will be used to find (k). The area under the curve of the force versus Δx graph is representative of the work completed using the Thera-band.

To accurately determine the area use

$A = \frac{1}{2}\Delta x F$ (4)

and graph this versus Δx as shown by graph 2. This allows an estimation to be made. Power will be found by

$P = \frac{W}{t}$ (5)[2].

Methods

Materials:

- -Meter stick
- -Thera-band
- -Free Weights
- -Ankle Weights
- -Lab masses
- -Clamps
- -Rods
- -Stop Watch

Figure 1. Shows the three exercises completed with a Thera-band and replicated by free weights [1].

1. The Thera-band was treated like a spring to find (k).
   a. Thera-band hung freely
   b. Resting position was determined.
   c. Masses were hung from the band to find Δx
   d. The force was found by using Equation 2
   e. (k) was calculated by using equation 3.
      a. Results are shown in Graph 1.
2. Three exercises were performed with the Thera-band and were replicated with a free weight
   a. Each Thera-band exercise started from resting position.
   b. Each exercise was timed.
   c. The Δx was measured as the participant moved.
3. Work was calculated for free weights using equation 1
   a. Free Weight: Force was found using equation 2
4. Work was found for the Thera-band by first calculating the area using equation 4 and making a graph of Δx versus area. This is shown in Graph 2.
   a. To find work, Δx completed during each band exercise was related to the Δx from the spring constant. This allowed Graph 2 to be extended for each Δx position to find the amount of work completed.
   b. Work was related to the area under the curve for the distance performed.
5. The previously calculated work value, along with time (t) was used to find power using equation 5.
6. Data was compared from Thera-band exercises to free weight exercises.

Change in Position Versus Force

Graph 1: Shows results of K value in equation 2.

Δx Versus Area to Determine Work

Graph 2: Shows how work was determined by extending the curve and relating Δx to area. This is shown by the red dot and arrow displaying the estimation of work for the arm at position 0.53m

Table 1: Shows data collected on the amount of work and power for free weights.

Free Weight Exercises						
			gravity (m/s)	9.8		
Exercise	Δx (m)	Mass (kg)	Force (N)	Work (J)	Time (s)	Power (W)
Arm	0.4	0.5	4.4	1.8	2.2	0.8
	0.4	1.4	13.3	5.4	2.2	2.5
Leg	0.5	0.5	4.4	2.2	2.3	1.0
	0.5	0.9	8.9	4.4	2.3	2.0
Body Weight Exercise						
Ankle	0.1	48.2	472.2	39.2	1.9	21.2

Table 2: Shows data collected on the amount of work and power for a resistance band

Resistance Band					
Exercise	position (m)	Δx (m)	Work (J)	Time(s)	Power (W)
Arm	0.53	0.50	4.90	2.15	2.74
	0.25	0.52	12.30	2.15	5.72
Leg	0.53	0.35	2.25	2.26	0.99
	0.25	0.34	5.70	2.26	2.52
Ankle	0.53	0.04	0.04	1.85	0.02
	0.25	0.04	0.09	1.85	0.05

Versus

Results

While testing the three exercises for the band the work for the arm resulted in 5.9J and 2.7W of power for a greater distant grip on the band and 12.3J of work and 5.7W of power for a shorter distance grip. The leg had 2.2J of work and 1.0 W of power for the greater distance and 5.7J of work and 2.5W of power for the shorter distance. The Ankle had a work of 0.04J and a power of 0.02W for a greater distance and a work of .09J and power of 0.05W for a shorter distance. While testing the same three exercises for free weights, the arm had a work of 1.8J and a power of 0.8W for 1lb and 13.3J of work and 2.5W of power for 3 lbs. The leg had a work of 2.2J and a power of 1.0W for 1lb and 4.4J of work and 2.0W of power for 2lbs. The ankle was completed using body weight and had a work of 39.2J and a power of 21.2 W. Possible reasons for error could be due to slight differences while measuring change in position or distance while completing the spring test or for each exercise. Further error could be due to estimating the end values of work for the resistance band by extending the curve like in graph 2. The results are reliable as they were tested multiple times with similar results. In addition it matches many other studies stating that the two exercises are comparable.

Conclusion

The two forms of exercise, using a resistance band or free weight, are comparable in terms of work and power completed. Each type of exercise has its own benefits allowing each to have other benefits rather than the amount of work performed. For example there are some exercises using the resistance band that can not be replicated using a free weight. Furthermore, the resistance band allows for a cheaper form of exercise. The two can be manipulated based on the amount of free weight used or the distance at which the band is held to change the amount of work completed. It was shown through the ankle exercise that body weight appears to be the exercise that requires the most amount of work to complete.

References

1. "Resistance Band & Tubing Instruction Manual." *Thera-Band*. 2005; 4: 1-22.
2. Knight, Randy, Jones, Brain, Field, Stuart. *College Physics*. 2nd ed. Glenview, IL: Pearson Education Inc., 2010.
3. Weight Training." Fitnesshealth101 Website. Available at: www.Fitnesshealth 101.com. Accessed January 29, 2014.

Example Poster

The Effects of Active vs. Passive Recovery on Power Output while Swimming

Introduction

Active Recovery is the term used for cooling down after a workout, through slow or moderate exercise. Passive Recovery is the cessation of any exercise after a workout.

When exercising, in the first 10-120 seconds, the energy produced by the body is mainly anaerobic. This type of energy production produces lactic acid. Once you stop, blood and lactic acid pool in active muscles. This stopping hinders the transport of nutrients needed to aid muscle recovery. Active recovery allows the blood to transport these nutrients as well as taking negative by-products away from the muscles, including the lactate acid.

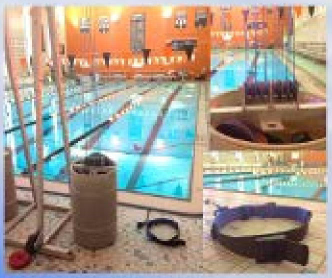
Lingering lactic acid in the muscles results in a heavy feeling, muscle soreness, and stiffness. This can negatively affect repeat performances.

Purpose

This experiment was done to discover the benefits and costs associated with active and passive recovering. I wanted to determine the best form of recovery for athletes, to allow repeat optimal performances.

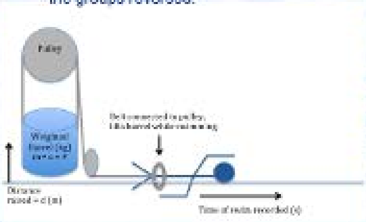
Materials

Test subjects, stopwatch, pulley system, weights, measuring device



Method

- 6 University swimmers chosen
  - All from the sprinting type group
  - Divided into passive & active groups
- A belt is worn around the waist, connected to a pulley and weighted barrel
- The weight in the barrel is set
- Each swimmer sprints for between 15-30 seconds, down a 25-meter pool. The distance the barrel moves vertically, is measured at the end of the time
- Then the active group recovers actively and the passive group sits still
- The trial is repeated after a time of full recovery
- This test was repeated 3 days later with the groups reversed.



Calculations

Table 1: Use of equations W = F * d and P = W/t. While also observing the variables a (m/s^2), m (kg), F (N), d (m), and t (s).

a (g) =	$9.8\frac{m}{s^2}$
m =	Mass of weighted pulley
F =	m • a
d =	Distance mass is moved
t =	Time taken during swim

F (m · a) W = F/d (N/m) P = W/t (W)

Data

Table 2. Using the equation for Power given below, the calculated power for both trials and both recovery types are given (other data not shown)

P = W/t (W)

	Trial 1	Trial 2
Passive Recovery	13.27	11.2
	19.22	16.2
	19.22	16.26
	17.22	12.44
	24.02	21.88
	25.71	23.24

	Trial 1	Trial 2
Active Recovery	16.06	16.96
	17.94	18.56
	17.96	17.44
	19.13	17.81
	22.98	21.18
	16.96	16.20

Passive Recovery	Active Recovery
% Change in P	% Change in P
-17.0%	5.5%
-17.0%	3.4%
-16.6%	-2.9%
-32.2%	-6.8%
-9.3%	-8.1%
-10.1%	-4.6%
Average: -15.9%	Average: -2.6%

Figure 1. Data from table 2. Percent difference in Power between 2 trials is displayed for all 6 participants. Passive recovery data is displayed on the left, with active recovery data displayed on the right.

Literature Cited

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Expected Results

It has been said that slowing your intensity at the end of a workout, and continuing to move around for about 5 to 10 minutes after, is very beneficial during repeat performances.

Discussion

The average power output in trial 1 was 19.7 W and 18.5 W, for passive and active recovery, respectively. After trial 2 the power was computed for passive and active recovery to be 16.9 W and 18.0 W, respectively. When passively recovering there was a 15.9% loss in power versus active recovery, which showed a 2.6% loss in power. These results agree with my hypothesis and lead me to believe active recovery is much more beneficial than passive recovery.

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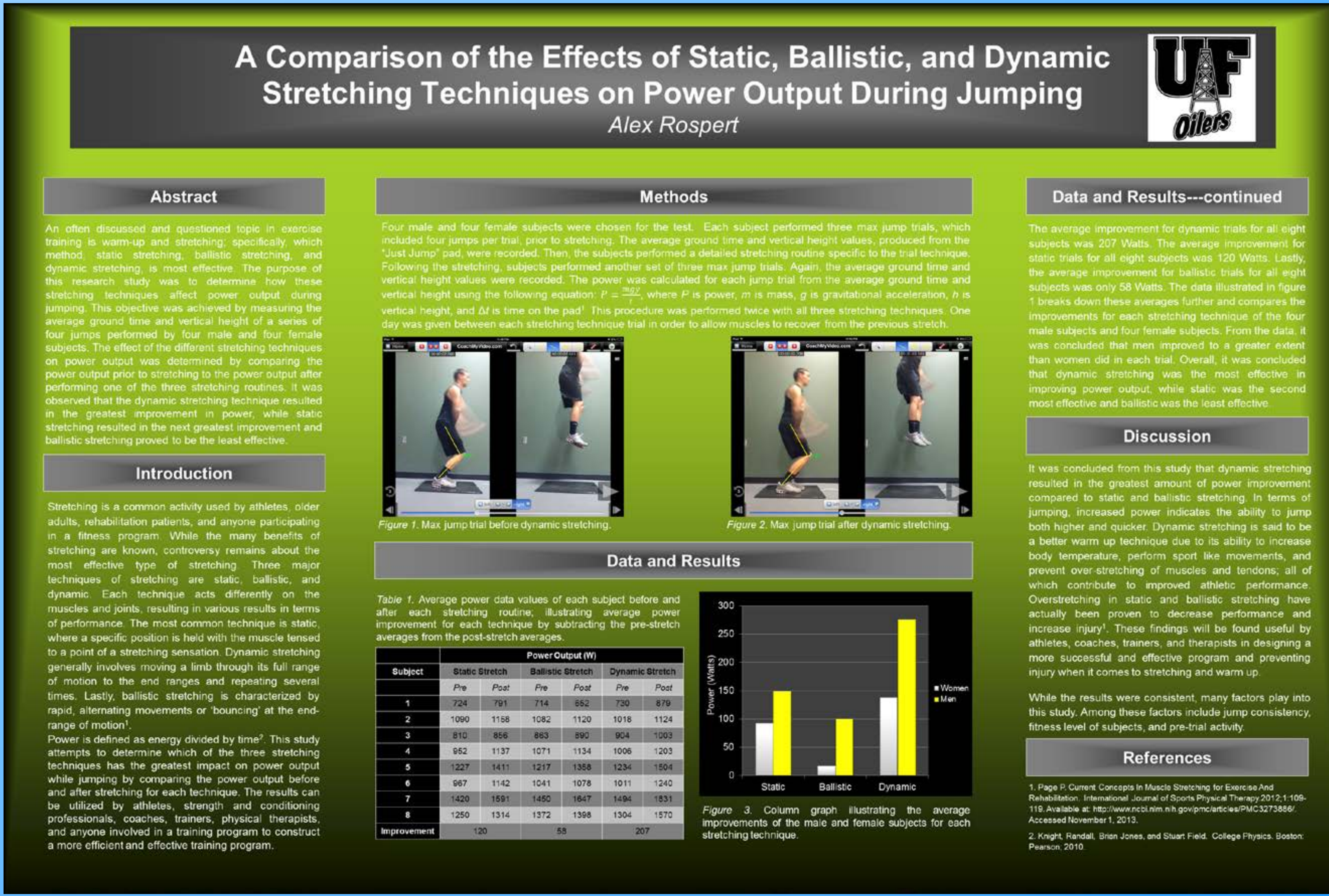
Example Posters



A Comparison of the Effects of Static, Ballistic, and Dynamic Stretching Techniques on Power Output During Jumping

Alex Rospert

Abstract

An often discussed and questioned topic in exercise training is warm-up and stretching; specifically, which method, static stretching, ballistic stretching, and dynamic stretching, is most effective. The purpose of this research study was to determine how these stretching techniques affect power output during jumping. This objective was achieved by measuring the average ground time and vertical height of a series of four jumps performed by four male and four female subjects. The effect of the different stretching techniques on power output was determined by comparing the power output prior to stretching to the power output after performing one of the three stretching routines. It was observed that the dynamic stretching technique resulted in the greatest improvement in power, while static stretching resulted in the next greatest improvement and ballistic stretching proved to be the least effective.

Introduction

Stretching is a common activity used by athletes, older adults, rehabilitation patients, and anyone participating in a fitness program. While the many benefits of stretching are known, controversy remains about the most effective type of stretching. Three major techniques of stretching are static, ballistic, and dynamic. Each technique acts differently on the muscles and joints, resulting in various results in terms of performance. The most common technique is static, where a specific position is held with the muscle tensed to a point of a stretching sensation. Dynamic stretching generally involves moving a limb through its full range of motion to the end ranges and repeating several times. Lastly, ballistic stretching is characterized by rapid, alternating movements or 'bouncing' at the end-range of motion[1].

Power is defined as energy divided by time[2]. This study attempts to determine which of the three stretching techniques has the greatest impact on power output while jumping by comparing the power output before and after stretching for each technique. The results can be utilized by athletes, strength and conditioning professionals, coaches, trainers, physical therapists, and anyone involved in a training program to construct a more efficient and effective training program.

Methods

Four male and four female subjects were chosen for the test. Each subject performed three max jump trials, which included four jumps per trial, prior to stretching. The average ground time and vertical height values, produced from the "Just Jump" pad, were recorded. Then, the subjects performed a detailed stretching routine specific to the trial technique. Following the stretching, subjects performed another set of three max jump trials. Again, the average ground time and vertical height values were recorded. The power was calculated for each jump trial from the average ground time and vertical height using the following equation: $P = \frac{mgh}{\Delta t}$, where P is power, m is mass, g is gravitational acceleration, h is vertical height, and Δt is time on the pad[1]. This procedure was performed twice with all three stretching techniques. One day was given between each stretching technique trial in order to allow muscles to recover from the previous stretch.

Figure 1. Max jump trial before dynamic stretching.

Figure 2. Max jump trial after dynamic stretching.

Data and Results

Table 1. Average power data values of each subject before and after each stretching routine; illustrating average power improvement for each technique by subtracting the pre-stretch averages from the post-stretch averages.

	Power Output (W)					
Subject	Static Stretch		Ballistic Stretch		Dynamic Stretch	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*
1	724	791	714	652	730	879
2	1090	1158	1082	1120	1018	1124
3	810	856	863	890	904	1003
4	952	1137	1071	1134	1006	1203
5	1227	1411	1217	1358	1234	1504
6	967	1142	1041	1078	1011	1240
7	1420	1591	1450	1647	1494	1831
8	1250	1314	1372	1398	1304	1570
Improvement	120		58		207	

Figure 3. Column graph illustrating the average improvements of the male and female subjects for each stretching technique.

Data and Results---continued

The average improvement for dynamic trials for all eight subjects was 207 Watts. The average improvement for static trials for all eight subjects was 120 Watts. Lastly, the average improvement for ballistic trials for all eight subjects was only 58 Watts. The data illustrated in figure 1 breaks down these averages further and compares the improvements for each stretching technique of the four male subjects and four female subjects. From the data, it was concluded that men improved to a greater extent than women did in each trial. Overall, it was concluded that dynamic stretching was the most effective in improving power output, while static was the second most effective and ballistic was the least effective.

Discussion

It was concluded from this study that dynamic stretching resulted in the greatest amount of power improvement compared to static and ballistic stretching. In terms of jumping, increased power indicates the ability to jump both higher and quicker. Dynamic stretching is said to be a better warm up technique due to its ability to increase body temperature, perform sport like movements, and prevent over-stretching of muscles and tendons; all of which contribute to improved athletic performance. Overstretching in static and ballistic stretching have actually been proven to decrease performance and increase injury[1]. These findings will be found useful by athletes, coaches, trainers, and therapists in designing a more successful and effective program and preventing injury when it comes to stretching and warm up.

While the results were consistent, many factors play into this study. Among these factors include jump consistency, fitness level of subjects, and pre-trial activity.

References

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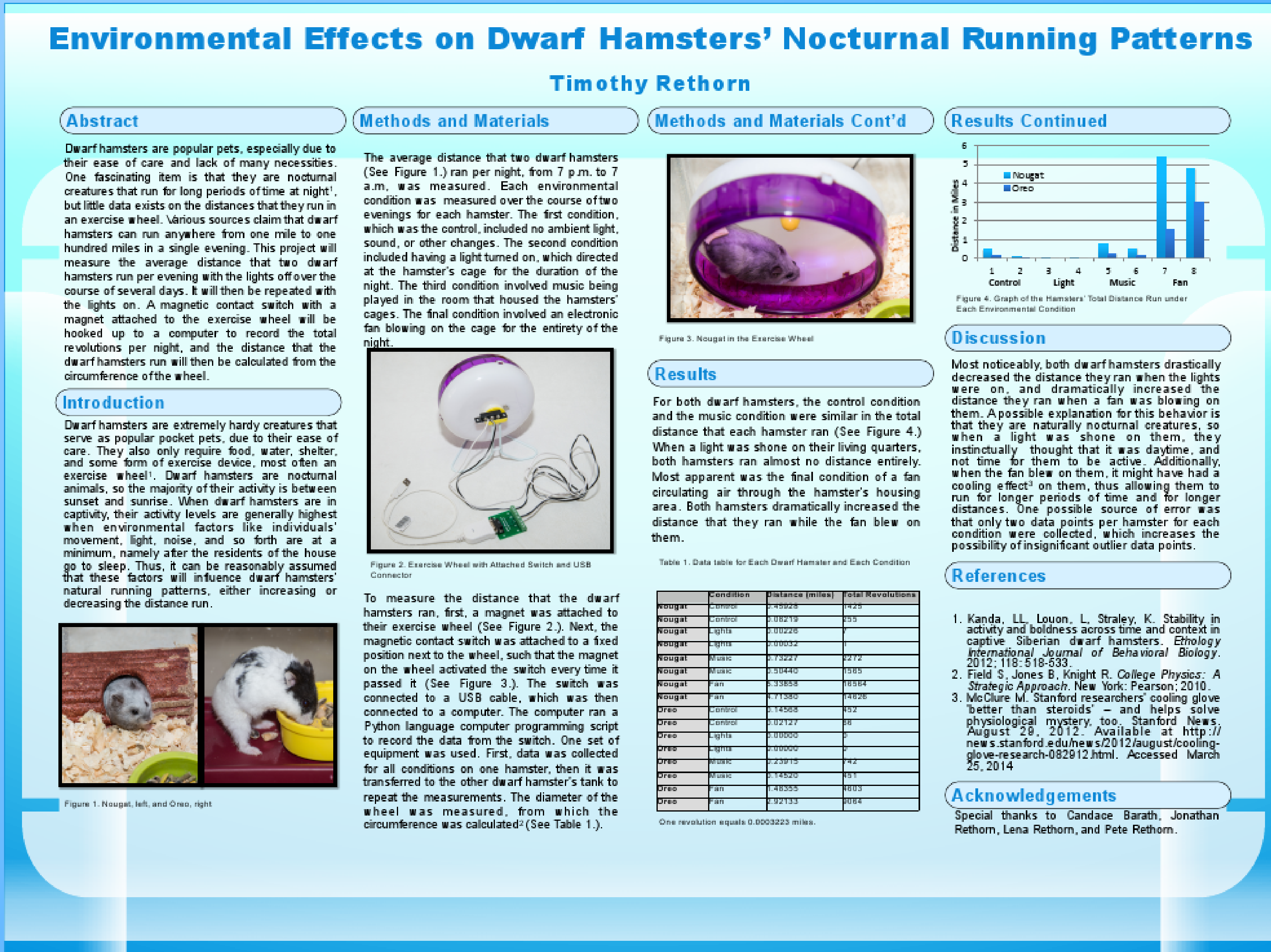
Example Poster



Environmental Effects on Dwarf Hamsters' Nocturnal Running Patterns

Timothy Rethorn

Abstract

Dwarf hamsters are popular pets, especially due to their ease of care and lack of many necessities. One fascinating item is that they are nocturnal creatures that run for long periods of time at night[1], but little data exists on the distances that they run in an exercise wheel. Various sources claim that dwarf hamsters can run anywhere from one mile to one hundred miles in a single evening. This project will measure the average distance that two dwarf hamsters run per evening with the lights off over the course of several days. It will then be repeated with the lights on. A magnetic contact switch with a magnet attached to the exercise wheel will be hooked up to a computer to record the total revolutions per night, and the distance that the dwarf hamsters run will then be calculated from the circumference of the wheel.

Introduction

Dwarf hamsters are extremely hardy creatures that serve as popular pocket pets, due to their ease of care. They also only require food, water, shelter, and some form of exercise device, most often an exercise wheel[1]. Dwarf hamsters are nocturnal animals, so the majority of their activity is between sunset and sunrise. When dwarf hamsters are in captivity, their activity levels are generally highest when environmental factors like individuals' movement, light, noise, and so forth are at a minimum, namely after the residents of the house go to sleep. Thus, it can be reasonably assumed that these factors will influence dwarf hamsters' natural running patterns, either increasing or decreasing the distance run.

Figure 1. Nougat, left, and Oreo, right

Methods and Materials

The average distance that two dwarf hamsters (See Figure 1.) ran per night, from 7 p.m. to 7 a.m., was measured. Each environmental condition was measured over the course of two evenings for each hamster. The first condition, which was the control, included no ambient light, sound, or other changes. The second condition included having a light turned on, which directed at the hamster's cage for the duration of the night. The third condition involved music being played in the room that housed the hamsters' cages. The final condition involved an electronic fan blowing on the cage for the entirety of the night.

Figure 2. Exercise Wheel with Attached Switch and USB Connector

To measure the distance that the dwarf hamsters ran, first, a magnet was attached to their exercise wheel (See Figure 2.). Next, the magnetic contact switch was attached to a fixed position next to the wheel, such that the magnet on the wheel activated the switch every time it passed it (See Figure 3.). The switch was connected to a USB cable, which was then connected to a computer. The computer ran a Python language computer programming script to record the data from the switch. One set of equipment was used. First, data was collected for all conditions on one hamster, then it was transferred to the other dwarf hamster's tank to repeat the measurements. The diameter of the wheel was measured, from which the circumference was calculated[2] (See Table 1.).

Methods and Materials Cont'd

Figure 3. Nougat in the Exercise Wheel

Results

For both dwarf hamsters, the control condition and the music condition were similar in the total distance that each hamster ran (See Figure 4.) When a light was shone on their living quarters, both hamsters ran almost no distance entirely. Most apparent was the final condition of a fan circulating air through the hamster's housing area. Both hamsters dramatically increased the distance that they ran while the fan blew on them.

Table 1. Data table for Each Dwarf Hamster and Each Condition

	Condition	Distance (miles)	Total Revolutions
Nougat	Control	0.45928	1425
Nougat	Control	0.08219	255
Nougat	Lights	0.00226	7
Nougat	Lights	0.00032	1
Nougat	Music	0.73227	2272
Nougat	Music	0.50440	1565
Nougat	Fan	5.33858	16564
Nougat	Fan	4.71380	14626
Oreo	Control	0.14568	452
Oreo	Control	0.02127	66
Oreo	Lights	0.00000	0
Oreo	Lights	0.00000	0
Oreo	Music	0.23915	742
Oreo	Music	0.14520	451
Oreo	Fan	1.48355	4603
Oreo	Fan	2.92133	9064

One revolution equals 0.0003223 miles.

Results Continued

Figure 4. Graph of the Hamsters' Total Distance Run under Each Environmental Condition

Discussion

Most noticeably, both dwarf hamsters drastically decreased the distance they ran when the lights were on, and dramatically increased the distance they ran when a fan was blowing on them. A possible explanation for this behavior is that they are naturally nocturnal creatures, so when a light was shone on them, they instinctually thought that it was daytime, and not time for them to be active. Additionally, when the fan blew on them, it might have had a cooling effect[3] on them, thus allowing them to run for longer periods of time and for longer distances. One possible source of error was that only two data points per hamster for each condition were collected, which increases the possibility of insignificant outlier data points.

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Assessment of Effectiveness in Learning

- **Project Outline, Peer Review, and poster**
- **Grading Poster**
  - **Creativity and experiment**
  - **Design of Methods**
  - **Realistic, appropriate data analysis**
  - **Effective presentation**
- **Incorporating GE rubrics into poster grading**
- **Class survey**

Class Survey: what did you learn the most from the research experience?

- The process of conducting research, such as the pre-planning and thought behind it
- How to conduct an experiment and learned how to present the information in a professional fashion.
- Learned that physics is really an aspect in a lot of different things that I would not have considered before.
- How to apply physics to daily life and to my major of physical therapy
- How to go about making a procedure to gather data
- How to format a scientific poster

Challenges for Students with Research

- Limited or no exposure to physics concepts related to their ideas.
- Some interesting ideas require physics knowledge beyond the introductory level.
- Students can become frustrated
- Not seeking enough advice from the instructor.
- Copying ideas/method, without modifications, from the internet.
- Student effort sometimes does not match the promise of their project proposal.

Challenges for Instructors in Implementing Research a Physics Course

- Guiding students toward non-trivial projects within their capabilities.
- Lack of student motivation
- Time consuming for instructors

Is It Worth It?

- **Experiential learning at an early stage**
- **Learn, develop, analyze, and present: some students have not been exposed to realistic data collection and analysis before**
- **Exposure to mistake and revision process in science: many never experience it**
- **Depends on the student's attitude**