1982

Periodization: a Hypothetical Training Model for Strength and Power.

Harold Stephen O'bryant
Louisiana State University and Agricultural & Mechanical College

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in

The School of Health,
Physical Education, Recreation, and Dance

by

Harold Stephen O'Bryant
B. S., Appalachian State University, 1972
M. A., Appalachian State University, 1974
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The purposes of this investigation were to: (a) examine strength and anaerobic power gains as well as selected local muscle endurance, maximum work output, and body composition adaptations resulting from short term training with traditional methods versus a theoretical model; (b) to provide a synergistic overview from a specifically constructed series of studies, each designed in a logical progression; and (c) to pool holdings of like data to generate a scaling procedure used to predict high and low gainers of power from initial measures.

Seven training studies utilized a total of 298 male and 45 female subjects divided into experimental and control groups. Training protocols consisted of free weight training 3 to 4 days per week, ranging from 6 to 12 weeks duration. Power was determined from a vertical jump procedure and the Lewis formula. Strength measures were taken from 1 RM parallel squat, bench press, and power clean. Local muscle endurance was measured from repetitions with 80% of 1 RM squat. In addition, ability to reproduce a ballistic task after fatigue was measured by a maximum leg ergometer ride and decrement of pre-post vertical jump. A progressive maximum leg ergometer ride to voluntary termination was used to measure maximum work output. Finally, body composition was appraised by both hydrostatic weighing and skin fold techniques.
The data for all variables were analyzed using a group by test ANOVA followed by contrast statements or Duncan's multiple range for specific test differences. Discriminant analysis was used in one experiment to identify group differences and provide a scaling model with functions that maximized group differences.

Training on the theoretical model generally produced greater increases in leg and hip strength and in power than the traditional method. Discriminant analysis procedures indicated that subjects who had the least initial lean body weight and were trained by the theoretical model gained the most power.
CHAPTER I

INTRODUCTION

It is not always the best athlete who wins, but often the one best prepared at the right moment. Having an athlete achieve his or her best performance for the season ending championships is a much pursued objective for both the athlete and coach. Achieving this objective may frequently be regarded as the measure of success for the entire season. One has only to look at the rash of world records by Eastern European athletes in the past Olympiads of Munich, Montreal, and Moscow, noting their relatively poorer performances in the immediately preceding and post-Games competition.

Much of the past and widely accepted research, particularly as related to the anaerobically trained athlete, has been limited to the examination and subsequent benefit from differences in volume and intensity of exercise. More recent interest in overall training concepts originated from the implication that prior training regimes led to optimal performance levels within a predetermined time lapse, creating what is often called a "peak".

The present lack of information and supporting data on training concepts result in little agreement toward a systematic approach to strength training. This series
of experiments was conducted in order to investigate a theoretical model for strength training.

**Statement of the Problem**

The purposes of this investigation were to: (a) examine strength and anaerobic power gains resulting from short term training with traditional methods and from a theoretical model; (b) to provide a synergistic overview from a specifically constructed series of studies, each designed in a logical progression from the previous; and (c) to pool holdings of data and submit to discriminant analysis for generation of a model that could be used to predict high and low gainers of anaerobic power from initial measurements.

**Review of Literature**

Among the essential physical qualities required for successful athletic performance are muscular strength and endurance. Furthermore, in many sport endeavors the athletes who exhibit the most anaerobic power have a clear-cut competitive advantage. Having recognized these attributes and noted contributions to performance, the sport scientist, athlete, and coach are challenged to design and implement specific developmental regimens to maximize performance. The following review of the literature concentrates on the physiological characteristics of strength and power, summarize training approaches, and ex-
amine training effects on body composition. Special attention is given to training protocols that attempt to optimize efforts and therefore result in timely performance peaking.

**Muscular Strength**

Muscular strength is the ability to exert force, or more specifically, the contractive power of muscles as a result of a single maximum effort (Clarke, 1974b). This is commonly measured by the amount of weight that can be lifted once (one repetition maximum: 1 RM). A sizeable number of experiments have demonstrated that significant strength gains are achieved through a variety of programs. The extent and rate of improvement may be genetically limited (Astrand and Rodahl, 1977) and may depend partially upon the initial level of strength (Mathews and Fox, 1976). Notably, a weak person will tend to gain strength more rapidly and to a greater relative extent than a person who already has a higher level of strength at the onset of training. Both isometric and isotonic forms of exercise improve muscular strength. Many studies do not favor one method over another, but in a review by Clarke, (1974a), several investigators are cited to have observed greater gains for the isotonic form, most notably weight training. Such exercise causing strength gains may also result in an increase in muscle
mass as well, along with improved anaerobic substrate utilization for a given workload (DeVries, 1974).

Muscular strength gains are best accomplished through a progressive resistance program as described by DeLorme and Watkins (1951) and later modified (Zinovieff, 1951) to include high resistance-low repetition training (Astrand and Rodahl, 1977; Brouha, 1962; Brown and Wilmore, 1974; Gettman, Ayres, Pollock and Jackson, 1978; O'Shea, 1966; Wilmore, 1975; Wilmore, Parr, Girandola, Ward, Vokdak, Barstow, Pipes, Romero, and Leslie, 1978). Precaution should be taken to avoid overtraining as it may lead to exhaustion of the neuromuscular apparatus and a subsequent decline in work capacity (Tschiena, 1973).

**Muscular Endurance**

Muscular endurance is often regarded as the ability of the muscles to perform work by holding a maximum contraction for a given length of time or by continuing to move a submaximal load (Clarke, 1974b). The present discussion is primarily concerned with the last point, dynamic endurance.

Unlike muscular strength, which must depend primarily on the ATP-ADP machinery and neural adaptations, muscular endurance must rely more on aerobic energy yield and consequently an abundant blood supply to the muscle in question (Astrand and Rodahl, 1977). Recent reports support
the general findings of earlier studies in that the isometric form of exercise is favored in the improvement of muscular endurance (Coleman and Hodges, 1972; Nobel and McCraw, 1973). It is generally accepted that optimal gains in muscular endurance result from a high repetition, low resistance program. However, care must be taken that the intensity is not too low (Stull and Clarke, 1970). Exercise consisting of prolonged repetitions with an extremely light load on the muscles have little effect on muscular endurance (Hellebrandt and Houtz, 1956).

**Anaerobic Power**

The term "muscular power" has been commonly used to indicate the ability to release maximum muscular force in the shortest possible time (Clarke, 1978). With speed being the chief component, there is composite interplay of both muscular strength and efficiency of the ATP-CP system (Mathews and Fox, 1976). The most common power test used is the vertical jump, so generally the legs have been used as a primary indication of one's power and potential (Clarke, 1974b; Costill, 1974). The recommended methods for power development are weight training and other strength-speed related activities, for the development of the anaerobic mechanisms involving enhanced neuromuscular function and greater efficiency of the ATP-ADP machinery (Astrand and Rodahl, 1977; Clarke, 1978;
DeVries, 1974). Significant increases in vertical jumping ability resulting from weight training have been reported (Bangerter, 1968; Ness and Sharos, 1956; Williams, 1965).

In a 12 year project, jumping ability emerged as the prime determinant of athletic ability on a battery of performance tests for both junior and senior high school aged boys (Clarke, 1971). Similarly, the vertical jump was found to be the best single test to predict basketball playing ability in elementary school boys (Everett, 1952). College athletes in baseball, basketball, football, gymnastics, and track and field were found superior to the normal population in muscular power (DiGiovanna, 1943). More recently, improvements were seen in both strength and power resulting from weight training of basketball team members (Moulds, Carter, Coleman and Stone, 1979; Ness and Sharos, 1956).

**Body Composition**

Body weight can be partitioned into the associated components of body fat and lean body weight by estimation of fat from skin folds (Durin, 1974; Sloan and Weir, 1970) or by hydrostatic weighing techniques (Brozek, Grande, Anderson and Keys, 1963; Katch, Michael and Horvath, 1967; Wilmore and Behnke, 1968).
A negative relationship exists between percent fat and maximum ability in performing most physical skills (Cureton, Hensley and Tiburzi, 1979). Likewise, a low percent of body fat is desirable for most athletes (Strauss, 1979). Fortunately, body composition can be altered through training. Some positive effects from weight training have been significant decreases in body fat and increases in lean body weight (Gettmen et al., 1978) even though total body weight may increase, decrease, or remain constant (Mayhew and Gross, 1974; Wilmore, 1974).

Training frequency, duration, and intensity have some degree of interaction as they determine the effect of exercise on body composition (Mathews and Fox, 1976; Wilmore, 1975). The alteration in body composition is greatest in the athlete whose competitive training program is very intense and least in the sedentary individual who has trained less frequently, for shorter periods, and at lower intensities (Astrand and Rodahl, 1977; Mathews and Fox, 1976).

Gains in muscular strength are usually accompanied by hypertrophy of individual muscle fibers (Goldberg, Etlinger, Goldspink and Jablecki, 1975). However, increases in muscle girth were far greater in males than in females (Brown and Wilmore, 1974; Sinning, 1973; Wilmore, 1974; Wilmore, 1975). With inactivity and subsequent atrophy of muscle tissue and/or increased body fat, the

**Peaking of Performance**

Optimum performance at a particular time range in a competitive period is best achieved from a systemized, well planned training schedule (Anonymous, 1975; Ozolin, 1975; Petrovsky, 1975; Volkov, 1975). Recognition of the value of such an approach has brought about a variety of systems with a broad spectrum of objectives, most of which involve manipulation of the volume and intensity of exercise during specified training phases (Falls, 1968; Mathews and Fox, 1976). Differences in objectives and specificity of training lead to diverse programs, some to maximize endurance as in distance running (Berg, 1978; Brooks, 1978; Groves, 1976; Jacobs, 1977; Jakalski, 1978), and others to develop strength and power for sprinting, jumping, and throwing events (Doherty, 1980; Gillespie, 1978; Jarver, 1980; Perrin, 1972; Werschoshanskij and Semjonow, 1973). More specific programs have been used for football (Riley, 1978) and soccer (Godik, 1976).

The major concern of the following discussion is limited to gains in strength and power. Collectively, programs aimed at such fall into one of two categories
and can be described as theoretical, being generally without supporting data, or lacking conformity to any systematic effort designed specifically to maximize performance at a prearranged time in the competitive season. However, English language scientific literature generally indicates that strength gains are most efficiently brought about with three sets using the maximum weight with which six repetitions can be done (3 x 6 RM) three times per week (Berger, 1962; Clarke, 1973; Mathews and Fox, 1976; O'Shea, 1966). However, it is known that competitive weightlifters rarely use this method of training especially as a year round program. Evidence of this may be found in a detailed examination of the training programs designed by Eastern European weightlifting coaches, whose athletes consistently win international competitions (Medvedev, Rodionov, Rogozyan and Melkonyan, 1979; Vorobyev, 1978).

Most of these training programs rely on the concept of "periodization" first examined by Matveyev in 1961 (Matveyev, 1972; Tschiene, 1973). A modified version of Matveyev's concept is shown in Figure 1. This concept of periodization embodies the principles of Selye's General Adaptation Syndrome (GAS), (1974). Application of the GAS to periodization theory proposes three phases of adaptation by the body to demands made on it in training (Miller, 1975; Garhammer, 1979). The first phase relates to the initial response to a stimulus. The
Matveyev's Model of Periodization.
second phase of adaptation corresponds to a preparation period in training when an athlete's body is adapting in such a way as to increase performance potential. The third phase of GAS corresponds to overtraining. A reasonable periodization of training should avoid the constant "pushing" of one's body which leads to chronic fatigue. An important concept in GAS is that demands on the body other than exercise can contribute to overtraining in much the same way as excessive physical exertion does.

As can be seen in Figure 1 the basic tenet of periodization is a shift from high volume and low intensity training during the early season (preparation phase) to an emphasis on high intensity but low volume of training (competition phase) during the late season. Technique training also increases during this latter part of the season. The competition phase is followed by a period of "Active Rest" during which the volume and intensity are both low and the athlete trains at a recreational level. Periodization is associated with 3 major objectives (Dick, 1975; Kruger, 1973):

1. Preparation of the athlete to achieve and optimal rate of improvement
2. Preparation toward a definite goal
3. Preparation for the main competitions associated with the ultimate goal.
In several branches of sport, most notably swimming and track and field, attempts have been made to accelerate performance improvement by establishing two competitive seasons. This double periodization is intended to produce multiple peaks in performance and exists as a variation of the basic periodization concept (Dick, 1976).

Training for a timely peak in strength performance has not been clearly understood nor adequately documented. Some previous attempts at strength research, conducted primarily during the late 1950's and early 1960's, suggested that 3 x 6 RM was the most efficient protocol for strength training. However, these investigations (Berger, 1962, 1965; Capen, 1956; McMorris and Elkins, 1975; and O'Shea, 1966) compared only various set and repetition combinations and did not investigate concepts of training. In order to test a true concept of performance peaking in a strength training context, a hypothetical model of training was developed which conformed to the basic tenets of periodization (Stone, 1979).

An important objective of periodization is the early development of muscle hypertrophy. Hypertrophy is best developed by three sets of 8-20 RM (MacQueen, 1954; McMorris and Elkins, 1975; O'Shea, 1976, 1966; Morehouse and Miller, 1976). Evidence of this can be gained by observing the training programs of elite body builders. However, the traditional approach to strength training (3 x 6 RM)
clearly does not provide the high volume of work necessary to promote efficient muscle growth. On the other hand, periodization provides an initial preparation phase of high volume and low intensity training which should produce hypertrophy and prepare the athlete for higher intensity work in the later season. Therefore, initial muscle hypertrophy can result in an enhanced ability to gain strength and power (Morehouse and Miller, 1976).

After hypertrophy occurs, strength development can be accelerated by using 3-5 sets of 2-6 RM during the later part of the preparation phase (Stone, 1979). Following Matveyev's concept, strength and power can be brought to higher levels using 3-5 sets of 1-3 repetitions during the first transition and competition phase. The training frequency may vary from 3 to 6 days depending upon individual characteristics of the athlete and the sport in question.

A hypothetical model of strength training is presented in Table 1. While this model was largely developed from observation and empirical evidence (Stone, 1979), it conforms to the basic concept of periodization.

A practical application of this hypothetical model is seen in an initial observation on unpublished data by Stone (1979). Six national caliber Olympic style weight lifters trained for 5 months prior to competition.
Table 1
Hypothetical Model of Strength Training
(Associated with Matveyev's Periodization Model)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Hypertrophy</th>
<th>Basic Strength</th>
<th>Strength &amp; Power</th>
<th>Peaking* or Maintenance</th>
</tr>
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<tbody>
<tr>
<td>Sets</td>
<td>3-5</td>
<td>3-5</td>
<td>3-5</td>
<td>1-3</td>
</tr>
<tr>
<td>Reps</td>
<td>8-20</td>
<td>2-6</td>
<td>2-3</td>
<td>1-3</td>
</tr>
<tr>
<td>Days/Wk</td>
<td>3-4</td>
<td>3-5</td>
<td>4-6</td>
<td>1-5</td>
</tr>
<tr>
<td>Times/Day</td>
<td>1-3</td>
<td>1-3</td>
<td>1-2</td>
<td>1</td>
</tr>
<tr>
<td>Intensity Cycle (weeks)**</td>
<td>2-3/1</td>
<td>2-4/1</td>
<td>2-3/1</td>
<td></td>
</tr>
<tr>
<td>Intensity</td>
<td>low</td>
<td>high</td>
<td>high</td>
<td>very high to low</td>
</tr>
<tr>
<td>Volume</td>
<td>high</td>
<td>moderate to high</td>
<td>low</td>
<td>very low</td>
</tr>
</tbody>
</table>

* Peaking for sports with a definite climax or maintenance for sports with long seasons such as football.

** Intensity Cycle - ratio of the number of heavy training weeks to light training weeks.
Three lifted according to the previously mentioned model of "periodization" and three trained the traditionally accepted three sets of six repetitions. Measures of performance determined for the two olympic lifts were made at 0, 12 wks and 24 wks. Results indicated that the group trained by the experimental model lifted more absolute weight at 12 and 24 wks, as well as more total poundage when normalized for differences in body weight.

Research Hypotheses

The following research hypotheses were tested during this series of studies and were discussed later with each individual experiment:

1. Training using traditional methods will result in a significantly greater increase in strength and leg power than training by the theoretical model during the preparatory phase.

2. The final strength and power gains resulting from short term training will be greater for the theoretical model than those obtained by traditional means (3 x 6 RM, 3 to 4 days per week).

3. Those subjects training by the theoretical model will experience greater increases in lean body mass and more reduction of body fat during the preparation phase than those training by traditional means.
4. Total body weight will remain approximately the same throughout training for both traditional and theoretical means, with no significant difference between groups.

5. Training will result in reduction of body fat, with no significant differences between groups at termination of the experiment.

6. Increases in maximum work output will be accomplished by both theoretical and traditional means, with no significant differences between the groups.

7. Training by both traditional means and the theoretical model will result in gains of absolute endurance, with no statistically significant differences between groups.

8. Training will result in similar performance on a power-fatigue task by both traditional and theoretical conditioned groups. There will be no statistically significant differences between the groups.

**Operational Definitions**

Terms used herein are defined as follows:

**Repetition Maximum.** Maximum amount of weight lifted for a specified number of repetitions (i.e. 1 RM as used in strength testing).

**Training Frequency.** Days trained per week.
Training Intensity. Mean weight lifted per repetition for a workout session

Training Load. Mean value computed for a workout session as a function of both volume and intensity.

Training Volume. Total repetitions performed for a workout session.

Assumptions

During this study the following assumptions were made:

1. Each subject put forth maximum effort in both training and testing sessions.

2. Subjects participating in this study did not participate in any other modes of training.

3. Subjects participation in this study underwent no significant dietary modifications during training.

4. Subjects had no expectations concerning effectiveness of the different treatments.

5. Initial levels of training were similar for subjects within individual experiments.

6. Subjects training with weights experience superior gains in strength and power as compared to those who do not train.

7. Strength performance scores reflected learning as well as physiologic adaptations.
Delimitations

1. No diet restrictions were imposed on subjects.
2. Speed of movement was not a controlled factor during performance of strength tests.

Significance of the Study

A general tendency in the methodology of sports training in recent years has been to markedly increase volume and intensity of training loads (Petrovsky, 1975). While this is true for most sports, it is particularly applicable to athletes who are involved in strength training, both weight lifters and the others who use weight training as a supplementary conditioning activity. It is probable that this is one of the elements responsible for the continued increased quality of sports performance. However, there are limits to the adaptability of the human organism and there is a very real danger of coaches and trainers falling into an "If a lot of work is good, more must be better!" pattern of thinking. Understanding of the third phase of Selye's (1974) General Adaptation Syndrome, exhaustion, could do much towards minimizing the occurrence of overtraining.

A task of the coach is to see that his athletes are stressed by as much conditioning work as they can readily adapt to without suffering from overtraining (Garhammer, 1979). One route toward achievement of this end is to
learn to monitor potential indices of overtraining. Another is to optimize performance at very specific times in the sport season (to peak for championships) by manipulating intensity and volume of training scientifically, according to the body's ability to adapt. The theoretical basis has been laid by Matveyev's (1972) study of training programs of elite athletes. If, through these experiments, that theory could be validated, among the benefits would be an improved efficiency of effort in training; avoidance of the fatigue, injuries, and mental staleness of overtraining; and optimized goal achievement. Rather than the small gains generally obtained by successful revolutionary training methods, it is felt that there is great potential benefit in application of periodization theory if indeed it proves to be valid. The possible value of this hypothetical model of training justifies this investigation of periodization theory.
CHAPTER II

METHODOLOGY

The purpose of this investigation was to develop and validate a theoretical training model for strength and power and to present supporting data from a specifically constructed series of experiments.

Subjects

Data were collected on healthy volunteer subjects from beginning weight lifting classes and from high school football and softball teams (Table 2). After signing informed consent statements, the subjects agreed to abstain from any additional form of training for the duration of the study. Each was randomly assigned to either an experimental group which was to follow a theoretical model, or to a control group which trained in the traditional manner. Data were pooled for Experiment 8 and included high school and college aged males who participated in Experiments 2, 3, and 6 (Table 3).

Data Collection

Strength. At the onset of each experiment, subjects were given instruction and adequate practice to acquire proficient technique in execution of initial strength measures. Measures for dynamic leg and hip strength were determined in Experiments 1-7 by performance of 1 RM parallel
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Group</th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Theoretical</td>
<td>n=11</td>
<td>x̄: 19.6</td>
<td>177.3</td>
</tr>
<tr>
<td></td>
<td>Traditional</td>
<td>n=8</td>
<td>x̄: 19.3</td>
<td>178.4</td>
</tr>
<tr>
<td>2</td>
<td>Theoretical</td>
<td>n=11</td>
<td>x̄: 20.5</td>
<td>176.7</td>
</tr>
<tr>
<td></td>
<td>Traditional</td>
<td>n=14</td>
<td>x̄: 19.2</td>
<td>178.5</td>
</tr>
<tr>
<td>3</td>
<td>Theoretical (E1)</td>
<td>n=11</td>
<td>x̄: 15.8</td>
<td>174.4</td>
</tr>
<tr>
<td></td>
<td>Theoretical (E2)</td>
<td>n=10</td>
<td>x̄: 15.8</td>
<td>171.1</td>
</tr>
<tr>
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<td>Traditional (C)</td>
<td>n=10</td>
<td>x̄: 16.0</td>
<td>172.3</td>
</tr>
<tr>
<td>4</td>
<td>Theoretical</td>
<td>n=10</td>
<td>x̄: 15.9</td>
<td>161.4</td>
</tr>
<tr>
<td></td>
<td>Traditional</td>
<td>n=10</td>
<td>x̄: 16.3</td>
<td>161.6</td>
</tr>
<tr>
<td>5</td>
<td>Theoretical</td>
<td>n=18</td>
<td>x̄: 19.9</td>
<td>179.6</td>
</tr>
<tr>
<td></td>
<td>Traditional</td>
<td>n=21</td>
<td>x̄: 19.8</td>
<td>177.5</td>
</tr>
<tr>
<td>6</td>
<td>Theoretical</td>
<td>n=46</td>
<td>x̄: 19.1</td>
<td>178.3</td>
</tr>
<tr>
<td></td>
<td>Traditional</td>
<td>n=44</td>
<td>x̄: 19.1</td>
<td>177.5</td>
</tr>
<tr>
<td>7</td>
<td>Theoretical (E1)</td>
<td>n=31</td>
<td>x̄: 19.9</td>
<td>175.5</td>
</tr>
<tr>
<td></td>
<td>Theoretical (E2)</td>
<td>n=27</td>
<td>x̄: 19.7</td>
<td>176.5</td>
</tr>
<tr>
<td></td>
<td>Traditional (C)</td>
<td>n=36</td>
<td>x̄: 19.3</td>
<td>180.1</td>
</tr>
</tbody>
</table>
Table 2
(continued)

<table>
<thead>
<tr>
<th>Experiment Group</th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical</td>
<td>n=15</td>
<td>x: 20.7</td>
<td>164.3</td>
</tr>
<tr>
<td></td>
<td>SD: ±2.2</td>
<td>±6.6</td>
<td>±6.9</td>
</tr>
<tr>
<td>Traditional</td>
<td>n=10</td>
<td>x: 19.5</td>
<td>165.1</td>
</tr>
<tr>
<td></td>
<td>SD: ±1.3</td>
<td>±4.3</td>
<td>±6.9</td>
</tr>
</tbody>
</table>

Table 3
Experiment 8 Group Means and Standard Deviations for Selected Variables (model data set: n = 55)

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>BWT (kg)</th>
<th>VJ (cm)</th>
<th>SQ (kg)</th>
<th>LBW (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Gainers</td>
<td>x: 17.1</td>
<td>173.32</td>
<td>70.25</td>
<td>52.1</td>
<td>111.59</td>
<td>56.68</td>
</tr>
<tr>
<td>(YD1) n=19 SD: ±3.6</td>
<td>±6.22</td>
<td>±7.79</td>
<td>±7.7</td>
<td>±18.10</td>
<td>±5.34</td>
<td></td>
</tr>
<tr>
<td>Low Gainers</td>
<td>x: 17.9</td>
<td>175.95</td>
<td>74.16</td>
<td>53.0</td>
<td>109.21</td>
<td>61.88</td>
</tr>
<tr>
<td>(YD2) n=39 SD: ±2.2</td>
<td>±6.41</td>
<td>±9.39</td>
<td>±6.3</td>
<td>±20.41</td>
<td>±7.85</td>
<td></td>
</tr>
</tbody>
</table>

Note: Group used for model set, numbered 55 subjects with a mean and standard deviation for specific power gain of 13.398 kg-m/sec and 5.645 kg-m/sec respectively.

squat where the bottom of the thigh must reach a horizontal position. Similarly, arm and shoulder strength was measured in Experiments 3-7 from 1 RM bench press executed in the conventional manner. In addition, Experiment 3 included
a measure of muscular strength for the shoulders and back as well as the legs was determined by execution of a 1 RM power clean. This power clean consists of a vigorous pulling action beginning with the loaded bar on the floor and ending with the bar in a resting position on the shoulders. Such a lift is similar to that required in competitive olympic weight lifting where the weight must be cleaned as done during the clean and jerk. The power clean is intended to closely approximate the mechanics and muscles used during the clean pull exercises required in training and therefore should measure strength gains specific to that exercise. Sufficient rest was given between exercises to insure a maximum effort. Care was taken during the strength measurements to insure that proper technique was maintained. Such 1 RM tests have been the preferred measure of dynamic strength (Berger and Harris, 1966; O'Shea, 1966; Wilmore, 1979; 1977; Withers, 1970), particularly if isokinetic devices are not available. Some have proposed variations in day to day measures of |10 to 20% (Astrand and Rodahl, 1977), although others have reported smaller variability in both females (1.5 to 11.6%) and males (5.3 to 9.3%) (DeVries, 1974). In order to minimize variation which could result from acute adaptations in the neuromuscular apparatus (Astrand and Rodahl, 1977) subjects performed a series of increasingly intense warmup lifts leading to the 1 RM attempts.
Power. Anaerobic power was determined in Experiments 1-7 using a vertical jump (VJ) procedure and the Lewis formula: power = \(\sqrt{4.9 \times \text{body weight (kg)} \times \sqrt{\text{VJ(M)}}}\) (Mathews and Fox, 1976). After a brief warmup and two practice jumps, each subject was given three trials for the VJ and the best score was used for data analysis. The VJ was performed immediately before measuring the squat. In addition, body weight was measured using a Health-O-Meter bar balance medical scale.

Body composition. Lean body weight and percentage of body fat were determined from data obtained by either hydrostatic weighing or estimated from skin folds (Figure 2). Hydrostatic weighing was used in Experiments 1, 2, and 6 while in 3, 4, 5, 6, and 7 skinfolds were employed.

Muscular endurance. Relative local muscle endurance of the legs was determined in Experiment 3 by the maximum number of repetitions performed during one set of parallel squats. After an initial warmup and rest, each subject was asked to parallel squat as many repetitions as possible with the bar loaded to 80% of the previously established 1 RM. To insure maximum efforts, the 80% RM was measured on the second day of a two day session while the 1 RM parallel squat was performed on the previous day. The initial 80% maximum load, once established, was kept constant on all subsequent tests.
I. Hydrostatic Weighing Techniques:

\[
\% \text{Fat} = \left(\frac{4.570}{\text{Density}} - 4.142\right) \times 100
\]

II. Skin Folds: (Men) | Skin Folds: (Women)
---------------------|---------------------
Tricep               | Tricep               
Subscapular sites** | Suprailiac sites***
Suprailiac           |                      

*Katch, Michael, and Horvath-1967 and modified by Wilmore and Behnke-1968 with subsequent application of specific gravity and density equations after Brozek, Grande, Anderson and Keys, 1963


Figure 2. Body Composition.
Work output. Maximum work output was determined in Experiment 6 by a progressive cycle test. Each subject pedaled a Monark leg ergometer at 60 rpm until voluntary termination or until proper cadence could no longer be maintained. Each ride began with a 3 minute warmup at 1 kp load followed by 1 minute stages with increases of $\frac{1}{2}$ kp increments each minute until termination criteria was met. Resistance values were recorded for the last stage completed by each individual and were used to determine the respective maximum work outputs.

Vertical jump decrement. A vertical jump procedure was used in Experiment 6 to evaluate the effect of fatigue on ballistic performance. A series of five vertical jumps was executed subsequent to the termination of the progressive cycle test and immediately following a warmdown and rest. Immediately after termination of the cycle ride, each subject rode an additional 60 seconds at 1 kp load prior to 30 seconds rest. Following the precisely timed warmdown and rest interval, each subject immediately executed a series of five vertical jumps. Each jump was recorded to achieve maximum as well as average values and compared to values obtained during a pretest. Measures of fatigue were represented as decrements in the vertical jump performance of both an average and maximum for each subject.
Test periods. Data were collected at various intervals over periods of time from 6 to 14 weeks (Table 4).

Table 4
Testing Periods for Experiments 1-7

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Tests administered after weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0, 3, and 6</td>
</tr>
<tr>
<td>2</td>
<td>0, 4, 8, and 11</td>
</tr>
<tr>
<td>3</td>
<td>0, 3, 7, 10, 12, and 14</td>
</tr>
<tr>
<td>4</td>
<td>0, 3, and 6</td>
</tr>
<tr>
<td>5</td>
<td>0, 3, 5, and 6</td>
</tr>
<tr>
<td>6</td>
<td>0, 4, 8, and 11</td>
</tr>
<tr>
<td>7</td>
<td>0, 1, 2, 3, 4, 5, and 6</td>
</tr>
</tbody>
</table>

Training Programs

Frequency. Subjects in Experiments 1, 2, 5, 6, and 7 trained three days per week, while those in Experiments 3 and 4 trained four times each week (Table 5).

Exercises. All subjects in all groups were required to warm up with light and then moderate weights at the beginning of each exercise. Exercises were selected on the basis of their overall contribution in the conditioning of the major muscles and on the basis of their spe-
Cificity to the physiologic parameters tested. Special emphasis was placed on multiple joint movements of the leg and hip extensors (Table 5).

**Table 5**

**Exercises Used in Training Programs**

<table>
<thead>
<tr>
<th>Experiments 1-2</th>
<th>Thursday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monday &amp; Friday</strong></td>
<td><strong>Wednesday</strong></td>
</tr>
<tr>
<td>1. parallel squats</td>
<td>1. clean pulls (from mid-thigh)</td>
</tr>
<tr>
<td>2. leg curls (1 set)</td>
<td>2. clean pulls (from floor)</td>
</tr>
<tr>
<td>3. bench press</td>
<td>3. shoulder shrugs</td>
</tr>
<tr>
<td></td>
<td>4. behind neck press</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiments 3-4</th>
<th>Thursday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monday &amp; Thursday</strong></td>
<td><strong>Tuesday &amp; Friday</strong></td>
</tr>
<tr>
<td>1. parallel squats</td>
<td>1. clean pulls (from floor)</td>
</tr>
<tr>
<td>2. bench press</td>
<td>2. clean pulls (from mid-thigh)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiments 5-7</th>
<th>Thursday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monday &amp; Friday</strong></td>
<td><strong>Wednesday</strong></td>
</tr>
<tr>
<td>1. parallel squats</td>
<td>1. clean pulls (from floor)</td>
</tr>
<tr>
<td>2. bench press</td>
<td>2. clean pulls (from mid-thigh)</td>
</tr>
<tr>
<td>3. hyperextensions</td>
<td>3. shoulder shrugs</td>
</tr>
<tr>
<td>4. sit-ups</td>
<td>4. behind neck press</td>
</tr>
<tr>
<td></td>
<td>5. sit-ups</td>
</tr>
</tbody>
</table>
Protocols. The traditional group in each experiment trained by using the maximum weight with which three sets of six repetitions (3 x 6) could be done (Table 6). Sets and repetitions were manipulated for the various theoretical groups, seeking optimal approaches for peaking. Data from Experiments 2, 3, and 6 were pooled for Experiment 8.

Data Analysis

Experiment 1. Data were analyzed using ANOVA, implementing a 2 (groups) x 3 (test periods) factorial design. Duncan's multiple range test was used to determine the location differences.

Experiment 2. Data were analyzed using a 2 (groups) x 4 (test periods) ANOVA. The completely randomized design utilized a split plot arrangement of treatments with the groups on the main plot and the test periods on the split plot. A follow-up test with single degree of freedom, contrast statements was used to determine differences between groups.

Experiment 3-7. Data were analyzed using a completely randomized design group by test ANOVA with repeated measures on the last factor. A follow-up test with single degree of freedom, contrast statements was used to determine differences between groups.

Experiment 8. A pre-post test for power was given and subjects were dichotomized into 2 groups (YD), as to low
### Table 6
### Training Protocols

#### Experiment 1

<table>
<thead>
<tr>
<th>Group</th>
<th>3 wks</th>
<th>4th wk</th>
<th>5th wk</th>
<th>6th wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical</td>
<td>5x10</td>
<td>5x5</td>
<td>3x3</td>
<td>3x2</td>
</tr>
<tr>
<td>Traditional</td>
<td>3x6</td>
<td>3x6</td>
<td>3x6</td>
<td>3x6</td>
</tr>
</tbody>
</table>

#### Experiment 2

<table>
<thead>
<tr>
<th>Group</th>
<th>4 wks</th>
<th>4 wks</th>
<th>3 wks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical</td>
<td>5x10</td>
<td>5x5</td>
<td>3x2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1x10)*</td>
<td>(1x5)*</td>
</tr>
<tr>
<td>Traditional</td>
<td>3x6</td>
<td>3x6</td>
<td>3x6</td>
</tr>
</tbody>
</table>

#### Experiment 3

<table>
<thead>
<tr>
<th>Group</th>
<th>3 wks</th>
<th>4 wks</th>
<th>3 wks</th>
<th>2 wks</th>
<th>2 wks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical (E₁)</td>
<td>5x10</td>
<td>5x5</td>
<td>3x3</td>
<td>3x2</td>
<td>detrain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1x10)*</td>
<td>(1x5)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theoretical (E₂)</td>
<td>5x10</td>
<td>3x5</td>
<td>3x3</td>
<td>3x2</td>
<td>detrain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1x10)*</td>
<td>(3x5)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional (C)</td>
<td>3x6</td>
<td>3x6</td>
<td>3x6</td>
<td>3x6</td>
<td>detrain</td>
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</table>

#### Experiment 4

<table>
<thead>
<tr>
<th>Group</th>
<th>3 wks</th>
<th>1 wk</th>
<th>1 wk</th>
<th>1 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical</td>
<td>5x10</td>
<td>5x5</td>
<td>3x3</td>
<td>3x2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1x10)*</td>
<td>(1x5)*</td>
<td>(1x5)*</td>
</tr>
<tr>
<td>Traditional</td>
<td>3x6</td>
<td>3x6</td>
<td>3x6</td>
<td>3x6</td>
</tr>
</tbody>
</table>
Table 6
(continued)

<table>
<thead>
<tr>
<th>Experiment 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
</tr>
<tr>
<td>Theoretical</td>
</tr>
<tr>
<td>Traditional</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
</tr>
<tr>
<td>Theoretical</td>
</tr>
<tr>
<td>Traditional</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group (males)</td>
</tr>
<tr>
<td>Theoretical (E₁)</td>
</tr>
<tr>
<td>Theoretical (E₂)</td>
</tr>
<tr>
<td>Traditional (C)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group (females)</td>
</tr>
<tr>
<td>Theoretical</td>
</tr>
<tr>
<td>Traditional</td>
</tr>
</tbody>
</table>
Table 6
(continued)

<table>
<thead>
<tr>
<th></th>
<th>3-4 wks</th>
<th>4 wks</th>
<th>2-3 wks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical Groups</td>
<td>5x10</td>
<td>3-5x5 (1x10)*</td>
<td>3x2-3 (1-3x5-10)*</td>
</tr>
</tbody>
</table>

Note: Numbers in parentheses represent a follow-up set with "lighter" weight*, with 70% of original maximum**, or with 75% of original maximum*** for each subject.

gainers (less than 8,000 kg-m/sec gain in power), and high gainers, (greater than or equal to 8,000 kg-m/sec gain in power). This cutoff value was used because it characterized a natural break in the data.

Discriminant analysis using 55 randomly selected individuals was employed to identify group differences and provide a scaling model with functions that maximize group differences. Classification procedures employing the remaining 25 subjects were used to validate the model. This holdout sample was used to determine whether the potential for high or low gain of power could be predicted.

Training loads. In Experiment 6, daily workout data for the parallel squat were recorded and subsequently used
to plot volumes and intensities by group. Total work was also calculated for each group. Differences between means of theoretical and traditional groups were evaluated for significance by t-test.

Criterion for significance. For determination of significance in all experiments an alpha level of $P < .05$ was employed.
CHAPTER III
RESULTS AND DISCUSSION

Experiment 1

This experiment was designed to test the concept of periodization on a short term basis (6 weeks) by comparing the theoretical model to the traditional program in which three sets of six repetitions were used throughout.

Body Composition

Hypertrophy phase. The high volume, low intensity training of the theoretical group over the first 3 weeks brought about significantly greater increases in LBW and decreases in percent fat (Figures 3 and 4). Considerations of the large difference in total work done by the two groups and the empirical evidence of body builders' similar success with high volume training make these changes in body composition an expected finding. An increase in muscle mass can be inferred from the greater LBW. Because muscle is a metabolically active tissue, even without the increased calorie cost of the higher volume work, metabolic turnover is greater for any level of activity and could contribute to the loss of body fat.

Peaking (6 wks). Although the volume of work done by the theoretical group dropped over the second 3 wks, the inferiority of the traditional method was maintained
Figure 3. LBW (kg Change), Experiment 1

Figure 4. Percent Fat (% Change), Experiment 1
(Figures 3 and 4). With the traditional group using twice as many repetitions in the 5th week and three times as many in the 6th, it would be expected that metabolic costs would be roughly proportionate. Whether an advantage by the theoretical group of about 2 kg LBW could compensate by an inherently higher metabolic rate is questionable. At any rate, it should be emphasized that the real changes occurred during the first 3 wks; the second three was a period of maintenance of the state of differences in body composition.

**Vertical Jump, Strength, and Power**

**Hypertrophy phase.** The group that trained by traditional methods was clearly superior to the theoretical group in VJ and in PWR after 3 wks, but there were no significant differences in SQ (Figures 5, 6, and 7). The deficiency in the theoretical group might be related to the chronic fatigue created by high volumes of work (Tschienne, 1973). Coaches and athletes who use periodization procedures should be taught to expect poorer sports performance during and immediately after the hypertrophy phase.

**Peaking (6 wks).** In terms of sports performance, peaking for strength, power, and jumping ability is critical. At termination of this experiment, significant differences in gains for SQ and PWR favored the theoret-
There were no differences between the groups in VJ or BWT. The reduction in volume and increase in intensity over this period is clearly valid. Apparently, the higher intensities provided an adequate stimulus for continued development, while the lower volumes removed the theoretical cause of poorer early performance, residual fatigue.
Figure 6. PWR (kg-m/sec improvement).

Experiment 1
The purpose of this experiment was to continue investigation of the theoretical model and its ability for producing strength and power gains by extending the training period to 11 weeks. A follow-up set with lighter weight was added during the last 7 weeks of training in order to determine whether LBW would be affected.

Data analysis revealed little agreement between Experiments 1 and 2. Unlike Experiment 1, there were no
differences between groups in LBW or percent fat. This discrepancy cannot be explained. Further, no significant differences appeared at any time in SQ or PWR, in contrast to the peaking performance of the theoretical group in Experiment 1. The obvious variance in the two training protocols (Table 6) suggests a rationale for those observations. In Experiment 1, there was clear weekly progression towards peaking by more frequent adjustments in volume and intensity. In Experiment 2, the hypertrophy and transition phases accounted for 8 of the 11 weeks of training, perhaps too long at high volume work, resulting in overtraining. There is no data to suggest whether 3 wks of high intensity (3 x 2) work could compensate for such a hypothetical problem. Another confounding factor was addition of follow-up sets with light weight to observe effects on LBW and percent fat. This had no observable influence on body composition, but added slightly to the volume of work at a time when perhaps theory dictated otherwise.

The only significant difference between groups in Experiment 2 was an advantage by the theoretical group in VJ (Figure 8). This is a factor critical to sports performance, and the fact that the significant difference occurred only after peaking is noteworthy. Thus, while strength and power increased in similar fashion for both
Figure 8. Means for VJ (cm), Experiment 2

Theoretical ○
Traditional △

** (P < 0.01)
groups, the theoretical model was validated by existence of the advantage in development of VJ performance.

**Experiment 3**

The purposes of this experiment were: (1) to determine the responses of younger subjects to periodization of training, (2) to examine two different transition phase procedures, and (3) to observe response to 2 wks of detraining.

**Strength**

The theoretical model with the sharper transition from the hypertrophy phase ($E_2$) was apparently the superior in terms of development of strength. Analysis of data for the power clean (CLN) revealed a significant difference only at 7 weeks with $E_2$ favored only over $E_1$ (Figure 9). It should be noted that a wide range in skill was exhibited during execution of the CLN, so lifting mechanics may be a confounding variable in this measure and consequently mask true strength gains to some extent. $E_2$ was significantly better than both $E_1$ and the control group (C) in BN after 10 weeks and at 12 weeks (Figure 10). $E_2$ also showed an advantage over C after 12 weeks in a measure of combined strength (SUM), which included data from SQ, BN, and CLN (Figure 11). The only departure from this pattern was in SQ, in which the strength development of $E_1$ was significantly superior to that of C after 12 weeks (Figure
Figure 9. Means for CLN (kg),
Experiment 3

Theoretical ◇ (E1)
Theoretical □ (E2)
Traditional △ (C)

* (P < 0.05)
Figure 10. Means for BN (kg),

Experiment 3
Figure 11. Means for SUM (SQ + BN + CLN), (kg), Experiment 3
In no case did the controls excel over either theoretical model group. These findings are in general agreement with Experiment 2 in that strength development results of theoretical models are at worst no different from traditional procedures, and show advantages in some measures of strength, particularly after the peaking phase. Conjecture that the long period of high volume work in Experiment 2 was responsible for the minimum advantage of the theoretical model was supported in this experiment. E₁, with a protocol similar to that in Experiment 2, was clearly only slightly better than C and obviously inferior to E₂, whose training involved a sharper departure from high volume lifting. Thus, it appears that overtraining can occur from too much work in a relatively short period, a most important concept for coaches and athletes.

**VJ, PWR, and Endurance**

While all groups improved performance across time in VJ, PWR, and the measure of muscular endurance (80% max SQ reps), there were no significant differences between groups. The fact that the low volume of training during the latter phases of the hypothetical program was not detrimental to endurance is important; a logical fear of loss of stamina upon reducing training volume is common.

Peaking by theoretical groups improved VJ in Experiment 1 and PWR in Experiment 2, contrary to the findings
Figure 12. Means for SQ (kg),
Experiment 3
of this experiment. A natural question arises as to whether the maturation level of the subjects in this experiment could possibly have been a factor, especially during the higher intensity phases of training that bring about peaking. Younger subjects with smaller muscle mass may need a modified approach to periodization.

Body Composition

There were no significant differences from training among any groups in BWT, LBW, or percent fat. This is in agreement with Experiment 2, but in Experiment 1, both LBW and percent fat underwent greater advantageous changes in the theoretical group. Examination of the three training protocols (Table 6) reveals no obvious solution to the controversy. Use of follow-up sets with lighter weights, as in Experiment 2, had no obvious effect on retention of LBW in the peaking phase.

Detraining

Only two significant differences between groups appeared following the 2 week detraining period. Retention of SQ strength was better for the control group compared to E_1 (Figure 12). Because the training protocols for E_1 and E_2 were identical for the final 5 weeks, the reason for the significant difference in SQ is observed. A greater reduction in fat by E_1 over E_2 during detraining cannot be explained and may be a function of unre-
stricted diet and/or error in measurement. In summary, none of the three protocols appears worthy of favor in terms of probability of better retaining gains from training.

Experiment 4

The purpose of this experiment was to test the periodization concept of strength training using females and employing the same protocol that the males in Experiment 1 used.

Strength

Both experimental and control groups developed highly significant increases in arm and shoulder strength and in strength of the legs and hips (Figures 13 and 14). Relatively large increases in strength were noted for such a short period of time, possibly as a result of subjects' low initial strength level (Mathews and Fox, 1976). Although no significant group differences were indicated, as was suggested in Experiment 3, the maturity level may be a factor in the quantitative response to high intensity training by the theoretical group. The mean ages were 15.9 and 16.3 years for the theoretical and traditional group, respectively. A consideration at this point may be that longer periods in development of basic strength might be needed for younger, less mature individuals before imposing the higher intensity phases of
Figure 13. Means for SQ (kg), Experiment 4

Figure 14. Means for BN (kg), Experiment 4
the hypothetical training protocol. This may be especially true for females who have less potential for gain in muscle mass (Brown and Wilmore, 1974; Sinning, 1973; Wilmore, 1974; Wilmore, 1975).

**Vertical Jump and PWR**

Impressive increases were seen in jumping ability (VJ) over the 6 weeks training period by both groups with mean increases of over 6 cm. Similar results were observed with respect to PWR, most improvements occurring during the first 3 weeks, with no significant differences between groups, in agreement with Experiment 3.

**Body Composition**

Increases in LBW and decreases in percent fat occurred as in Experiments 1-3. However, in agreement with Experiments 2 and 3 and contrary to Experiment 1, there were no significant differences between groups.

**Experiment 5**

The purpose of this experiment was to re-examine the effects of imposing a sharp decline in volume of exercise after the preparation period, a similar theoretical group in Experiment 3 having shown promising results by this approach in a 12 week program. In addition, following sets were controlled in this experiment as a percentage of original maximum strength.
Strength

As in Experiments 1-4, both theoretical and traditional groups increased significantly (\(P < .01\)) in SQ and BN after 6 weeks of training (Figures 15 and 16). There were significant differences between groups in SQ at 3, 5, and 6 weeks of training, favoring the theoretical group. On the other hand, BN showed a significant difference at 3, 5, and 6 weeks of training, favoring the traditional group. Whether training by the theoretical model can be expected to improve strength better than traditional procedures remains, through Experiments 1-5, problematic.

SQ scores favor the theoretical model in Experiments 1, 3, and 5, but BN performance is unclear. BN was not determined in Experiments 1 or 2, was superior by theoretical procedures in Experiment 3, no differences occurred in Experiment 4, and in Experiment 5, traditional procedures appear preferable. While no definitive resolution of the dilemma is possible, conjecture regarding muscle mass appears warranted. It was suggested in the discussions of Experiments 3 and 4 that muscle mass might be a factor to consider in judging the validity of the theoretical model. Inconsistent findings with respect to BN support this contention. A pattern has begun to emerge in SQ, favoring the need for sharper declines in training volume after the preparatory hypertrophy phase preceding high intensity training and is supported by the results in Experiments
Figure 15. Means for SQ (kg), Experiment 5
Figure 16. Means for BN (kg),
Experiment 5
An extension of this reasoning would lead to the recommendation that effects of longer periods of low intensity, high volume training for smaller muscle groups be examined.

**Power and Vertical Jump**

Results in anaerobic leg power (PWR), as well as jumping ability (VJ) after 6 weeks indicate that the theoretically trained group developed greater gains in PWR and VJ than the traditional group (Figures 17 and 18). PWR in Experiment 1, and VJ in Experiment 2 favored the theoretical model, supporting these findings. No differences were found in either measure in Experiments 3 or 4. The fact that VJ improvement was superior at week 5 in the traditional group is supported by similar data in Experiment 1 in which transient disadvantages in VJ and PWR by the theoretical group were attributed to the high volume of work in the preparatory phase. Critical to this discussion is the fact that the goal of periodization is toward peaking and that performances earlier in training are basically immaterial.

**Body Composition**

As in all previous experiments and as with other parameters, both training procedures continued to effect beneficial changes, in this case, increases in LBW and decreases in percent fat. In agreement with Experiments
Figure 17. Means for PWR (kg - m/sec),
Experiment 5
Figure 18. Means for VJ (cm),
Experiment 5
2, 3, and 4, no significant differences between groups were found in BWT, LBW, or percent fat.

**Experiment 6**

Purposes of this experiment were: (1) to examine the effectiveness of the theoretical model over a longer period, as in Experiments 2 and 3 (11 & 12 weeks, respectively), using much larger groups of subjects in a modified training protocol; (2) to determine whether training volume and intensity relationships were in accord with Matveyev's model (1972); and (3) to compare total work done in SQ by the two groups.

**Strength**

There was an overall test effect to indicate that both groups increased significantly ($P < .01$) in SQ after 11 weeks of training (Figure 19). Also, there was a highly significant difference between groups in SQ at 8 and again at 11 weeks, favoring the experimental group over the control. The bench press (BN) showed an overall test effect indicating that there was a highly significant ($P < .01$) increase for both groups at 11 weeks of training. However, there were no differences between groups at either 4, 8, or 11 weeks of training. This illustrates the greater ability of the model to produce strength gains in the large leg and hip muscles, reinforcing the findings in Experiments 1, 3, and 5. With specific ref-
Figure 19. Means for SQ (kg),

Experiment 6
erence to the other experiments that were of comparable length, these results are in general agreement. In Experiment 3 strength gains by the model were clearly superior, but no differences were observed to occur between groups in Experiment 2. However, just as in Experiments 4 and 5, the smaller arm and shoulder muscles did not respond in a parallel fashion. This recurring trend in BN lends further support to the supposition that such a smaller muscle mass may require a modified periodization approach, perhaps a longer duration of the preparation phase prior to exposure to higher intensity stimulation.

**Power and Vertical Jump**

Both PWR and VJ responded favorably to weight training, as was shown to be true in Experiments 1-5. However, no significant differences were shown between groups in this experiment. In the other two longer experiments, only VJ in Experiment 2 favored the theoretical model, other PWR and VJ comparisons showing no group differences. In 6 week experiments, results were split with PWR and/or VJ improvements favoring the model in Experiments 1 and 5, with no group differences whatsoever with the females in Experiment 4. With respect to male subjects, it appears that over longer periods, periodization yields no particular advantage over the traditional 3 x 6 protocol, with respect to PWR and VJ. The theoretical model,
however, appears preferable when shorter training periods are used. This trend might not hold for all protocols; certainly additional investigation of variations of the model are necessary in order to clarify this point.

**Body Composition**

No group differences in LBW, percent fat, or BWT appeared. This was true for the total sample (n=90) which was subjected to skinfold measures, and for the subset (n=31) which was evaluated by hydrostatic weighing procedures. It is clear that little, if any, additional advantage is offered by the model in altering body composition. Only Experiment 1 was characterized by significant group differences.

**Maximum Work Output**

There was an overall test effect for work capacity on the cycle ergometer, revealing that both groups increased significantly (P < .01) through the 11 weeks of training (Figure 20). Also, there was a highly significant difference between groups in maximum work output at 11 weeks, but no difference at 4 or 8 weeks. Although there is no basis for comparison in this series of studies, this finding is important as it relates to potential perception of the low volume work at peaking as being detrimental to endurance.
Figure 20. Sample Means for Maximum Work Output (kgm/min), Experiment 6
**VJ Decrement**

Measurement of VJ before and immediately after the maximum work output bouts yielded data, which, when analyzed, revealed no significant differences between groups. Besides the measures made after exhausting exercise, it would have been of interest to evaluate the decrement after a standardized submaximal bout. At any rate, the fact that there were no group differences is significant in itself. This data support maximum work output results, suggesting that the high intensity, low volume training of peaking is not particularly detrimental to endurance.

**Volume and Intensity**

SQ volume (total reps) and intensity (kg/rep) were plotted across time for comparison with Matveyev's model (1972) (Figure 21). Data for the traditional procedures show a constant volume with a steady increase in intensity. The inverse relationship between alterations in volume and intensity for the theoretical group is clearly according to plan (Figure 1).

**Total Work**

The total amount of work done in the parallel squat for the entire 11 weeks of training was found to be significantly different between groups, favoring the experimental group. The means and standard errors are shown in Table 7.
Figure 21. Means for Daily SQ Volume (reps) and Intensity (kg), Experiment 6
Table 7
Total Work for Parallel Squat in Experiment 6

<table>
<thead>
<tr>
<th>Group</th>
<th>Means (kg)</th>
<th>Std Error</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical</td>
<td>50605</td>
<td>1206</td>
<td>(P &lt; .01)</td>
</tr>
<tr>
<td>Traditional</td>
<td>30817</td>
<td>1233</td>
<td></td>
</tr>
</tbody>
</table>

Data for daily work (SQ Load) indicated that while the traditional group showed gradual increases throughout, the theoretical group achieved very high amounts of work initially, followed by sharp decreases (Figure 22). Consequently, periods of least work volume produced the greatest amount of strength and PWR gain for the theoretical group, supporting the concept of periodization. Further support of the lack of importance of total work done was found in the correlation of 1 RM SQ to SQ Load, where the highest correlation for the model occurred during initial training at the time of least strength, when strength had peaked (Table 8). Similar, but less conclusive results can also be seen for the traditional group. Therefore, strength gains were not primarily contingent on the amount of work done, but rather on the intensity of work. This may be an intrinsic advantage of the hypothetical model, which, by its design, allows
Figure 22. Means for Daily SQ Load (kg),

Experiment 6
Table 8
Correlation Coefficients of 1 RM SQ (kg) to SQ Load (kg) in Training for Experiment 6

<table>
<thead>
<tr>
<th>Group</th>
<th>4 weeks</th>
<th>8 weeks</th>
<th>11 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical</td>
<td>0.84</td>
<td>0.81</td>
<td>0.09</td>
</tr>
<tr>
<td>Traditional</td>
<td>0.75</td>
<td>0.69</td>
<td>0.60</td>
</tr>
</tbody>
</table>

for higher intensity work during latter phases of training when volume is restricted.

There is an obvious tradeoff inherent in the choice between traditional procedures and the theoretical model. Data in support of periodization has accumulated in these six experiments, but it is far from overwhelming. The decision must be made as to whether to use traditional methods, admittedly inferior in some respects while equally good in others, or the theoretical model, the success of which is dependent on the accomplishment of much more total work.

**Experiment 7**

Purposes of this experiment were: (1) to examine the concept of periodization during attempts to achieve multiple peaks in the development of strength and power in males, and (2) to examine the responses of college aged females to the theoretical model.
Strength (males)

There was a highly significant, \((P < .01)\), overall test effect for SQ and BN, indicating that all three male groups increased in leg and hip strength and in arm and shoulder strength after 6 weeks of training. E₁ was significantly better in SQ at 3 weeks than either of the other groups, but there were no other significant differences among groups (Figure 23).

![Graph showing SQ (kg) Means for Male Groups, Experiment 7](image-url)
For SQ, the first peak was achieved as planned; however, in no other strength measure was the single or double peaking model effective. Finding that periodization can be condensed effectively into a 3 week period is particularly meaningful, there being obvious applications in sports. Whether theory is correct that multiple peaks in strength can be achieved is moot; further investigation is warranted.

**Power and Vertical Jump (males)**

The results indicate the clear superiority of the double periodization group ($E_1$) for development of PWR, compared to the single periodization ($E_2$) or control groups (Figure 24). Furthermore, jumping ability was improved overall, with $E_1$ and $E_2$ both superior to the traditionally trained group (Figure 25).

The only failure of $E_1$ to fit expectations with respect to these measures was at the end of the first peaking cycle when there were no significant differences in VJ between groups. The findings of positive PWR and VJ responses to double periodization support the data on SQ, pointing to the efficacy of a short-term (3 wk) training cycle that contains all of the elements of the basic model. Weekly means for the double periodization group are presented in Figures 26 and 27 to provide a more complete picture of trends occurring over the entire
Figure 24. PWR (kg - m/sec) Means for Male Groups, Experiment 7
Figure 25. VJ (cm) Means for Male Groups, Experiment 7
Figure 26. Weekly Means for Experiment 7,
Double Periodization Group in PWR (kg - m/sec)
Figure 27. Weekly Means for Experiment 7,
Double Periodization Group in VJ (cm)
6 week training period. Responses in PWR were perfectly representative of theoretical expectations. The initial high volume preparation phase brought about a drop in PWR. During subsequent transition, small gains occurred, but PWR was still short of beginning levels. The first peaking caused a marked increment. The return to high volume, low intensity work then resulted in only a very slight dropoff in performance, with transition and peaking then bringing PWR to the highest level. Such requirements for double peaking are not uncommon. A typical example might be a regional high school competition from which winners would be selected to enter the state championship contest within 2 or 3 weeks.

While VJ responses were not as predictable as PWR, double peaking benefits are obvious in Figure 27. Of note is that at 2 wks performance is no better than at the outset, but the first peak at 3 wks is clear. From 3 wks to 6 wks, the model is perfect, first the high volume decrement and then the transition and peaking responses being picture-perfect with respect to theory-practice matching.

Body Composition (males)

This is the only experiment of the series in which BWT changed. Significant increases favoring the double peaking group over the controls occurred at 3 and at 5
weeks (Figure 28). The explanation might be expected to lie in extraordinary increments in LBW, but no such change occurred. There were no significant differences between groups in LBW. Reduction in percent fat was significantly greater in the traditional group than in the theoretical group after 5 weeks (Figure 29), contributing to the aforementioned differences in BWT. No mechanism lends itself to ready explanation of these changes.

**Strength (females)**

In agreement with the results of Experiment 4 on female subjects, the females in Experiment 7 obtained no advantage over traditional procedures by using the model. While there were highly significant increases in SQ and BN from training, there were no significant differences between groups.

**Power and Vertical Jump (females)**

Both female groups increased in PWR and VJ as indicated by an overall test effect for the 6 weeks training period (Figures 30 and 31). Significant differences between groups, in favor of the theoretical group, occurred at 6 weeks for PWR and at 3 and 6 weeks for VJ. The test effect results are in agreement with results of the female subjects in Experiment 4, but no PWR and VJ differences were found in the earlier study. These results support the earlier supposition that more mature subjects
Figure 28. BWT (kg) Means for Male Groups, Experiment 7

Theoretical (E1)
Theoretical (E2)
Traditional (C)

* (P<.01)
** (P<.01)
Figure 29. Percent Fat (%) Means for Male Groups,

Experiment 7

* (P<.05)
Figure 30. PWR (kg - m/sec)
Means for Female Groups, Experiment 7

Figure 31. VJ (cm)
Means for Female Groups, Experiment 7
might respond better to the very high intensity work required by the theoretical model because of the generally larger muscle mass. However, this is conjecture and not supported by data.

Body Composition (females)

No significant differences between groups were found for BWT, LBW, or percent fat. This is in agreement, both with data from Experiment 4 on females and with all experiments in the series on males, with the exception of the initial study.

Experiment 8

The purpose of this experiment was to identify and evaluate selected characteristics of subjects from Experiments 2, 3, and 6 who gain the most or the least PWR by use of the theoretical model.

Discriminant analysis procedures were employed to identify group differences among high and low gainers of power (n=55) and to provide a scaling model having functions that maximize group differences. A holdout sample (n=25) and subsequent classification procedures were used to validate the model. The means and standard deviations for selected variables in the model set (n=55) appear in Table 3. Intercorrelation among variables in the model set with specific power indices revealed $R = .77$ for BWT and LBW, a possible source of nonsignificance in subse-
quent analyses because it might cause multicollinearity problems and therefore result in difficulties of Beta interpretation.

A test of variance-covariance matrices, Box's (M), indicated that the two groups of subjects (YD₁ and YD₂) were homogeneous (F=3.2229 and 6.339.9 degrees of freedom; P<.05) which showed that the group differences were due to the vectors of means and not to variance-covariance differences.

Discriminant analysis showed that only one discriminant function was significant (P<.05). The raw score and standardized weights of both functions are provided in Table 9. This function accounted for 100% of variability among groups. The standardized discriminant weights provide an index of each variable's relative importance in the discriminant function. Since only one function was significant, and lean body weight (X6) was the only variable retained, its standardized canonical discriminant function coefficient was 1.0. This discriminant function separated the high gainers from the low gainers of power as demonstrated by differences between group centroids (Figure 32), and the significance demonstrated by an Hottelling T² (F=6.6573 and 53 df; P<.05). This classification technique employed on the model data (n=55) is illustrated by the confusion matrix in Table 10.
Table 9

Raw Score (Y) and Standard Weights of Discriminant Scores, Experiment 8

<table>
<thead>
<tr>
<th>Variable</th>
<th>Discriminant Function*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Group 1</td>
</tr>
<tr>
<td>X6</td>
<td>1.1247</td>
</tr>
<tr>
<td>Constant</td>
<td>-32.9385</td>
</tr>
</tbody>
</table>

Group 1: \( Y = -32.9385 + 1.1247 \times X6 \)

Group 2: \( Y = -38.4988 + 1.2277 \times X6 \)

*Wilk's Lambda = 0.8884 (Chi square = 6.212; df = 1; P < .05)

Figure 32. Illustration of Group Centroids, Experiment 8
Table 10
Confusion Matrix for Model Data (n=55), Experiment 8

<table>
<thead>
<tr>
<th>Actual # of Cases</th>
<th>Predicted Group Membership</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>group 1</td>
</tr>
<tr>
<td></td>
<td>cases</td>
</tr>
<tr>
<td>group 1 = 19</td>
<td>(10)</td>
</tr>
<tr>
<td>group 2 = 36</td>
<td>(7)</td>
</tr>
<tr>
<td>total</td>
<td>55</td>
</tr>
</tbody>
</table>

Overall percent of grouped cases correctly classified

\[
\frac{10 + 29}{55} = 70.91\%
\]

Maximum chance criteria = 65.5%

Proportional chance criteria = 55.0%

In order to combat the upward bias problem, a holdout sample (n=25) was used to validate the model. Means and standard deviations of selected variables for the holdout sample (n=25) are available in Table 11. Discriminant analysis was used to validate the model, yielding the confusion matrix presented in Table 12.
Table 11
Means and Standard Deviations of Selected Variables for Holdout Data (n=25), Experiment 8

<table>
<thead>
<tr>
<th></th>
<th>Age (yrs)</th>
<th>HT (cm)</th>
<th>BWT (kg)</th>
<th>VJ (cm)</th>
<th>SQ (kg)</th>
<th>LBW (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X:</td>
<td>19.8</td>
<td>177.7</td>
<td>75.1</td>
<td>53.5</td>
<td>105.4</td>
<td>65.73</td>
</tr>
<tr>
<td>SD:</td>
<td>±2.5</td>
<td>±5.8</td>
<td>±8.5</td>
<td>±7.0</td>
<td>±17.8</td>
<td>±5.85</td>
</tr>
</tbody>
</table>

Table 12
Confusion Matrix for Holdout Sample (n=25), Experiment 8

<table>
<thead>
<tr>
<th>Actual # of Cases</th>
<th>Predicted Group Membership</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>group 1 cases</td>
</tr>
<tr>
<td>Group 1 = 5</td>
<td>(1) 20.0</td>
</tr>
<tr>
<td>Group 2 = 20</td>
<td>(0) 0.0</td>
</tr>
<tr>
<td>total</td>
<td>25</td>
</tr>
</tbody>
</table>

overall percent of grouped cases correctly classified

\[
\frac{1 + 20}{25} = 84 \%
\]

maximum chance criteria = 80 %
proportional chance criteria = 96 %
The scaling model based on LBW as a single function appears to be a good classifier of high and low gainers of power with the given constraint in type of subjects and the variables recorded. It appears that this model could be used to classify subjects for assignment into experimental and control groups for a blocking effect when in pursuit of more homogenous grouping and better research design. A basic interpretation of the results of this experiment is that subjects with the least initial LBW respond best in PWR production while training on the theoretical model.

**Summary and Conclusions**

A consistent finding throughout the entire series of experiments was that traditional weight training procedures and all modifications of the theoretical model consistently provided significant increases in strength and power as well as desirable changes in lean body weight and percent fat. Judgement of the validity of periodization was difficult and must rely largely on subjective evaluation of pooled results. In only four of the 63 separate analyses in seven experiments did the traditional method prove better. In 40 cases, there were no significant differences between groups, while in 19 tests the theoretical model proved superior. A summary of findings, by category, should provide clarification:
1. In one experiment, LBW and percent fat changes favored the theoretical model. In one experiment, percent fat loss was greater in the traditional group. There were no significant differences in other comparisons between groups, leading to the conclusion that body composition modification is not more favorably affected by either method of training.

2. In five of the seven experiments, SQ performance favored the theoretical group. On the other hand, in the five experiments in which BN was evaluated, one favored the model, one favored the traditional method, and three were inconclusive, showing no significant differences between groups. Apparently, periodization procedures and exercises used in these experiments were quite valid for the larger muscle mass involved in SQ, but inappropriate for smaller muscle groups.

3. In five of the seven experiments, VJ and/or PWR developments were superior in the theoretical model groups. There were three instances, immediately following the high volume hypertrophy (preparation) phase, in which transient advantages were shown by traditional groups. Week-by-week plots of VJ and PWR in Experiment 8 revealed temporary losses in performance that characteristically followed the high volume phase. However, subsequent to application of peaking procedures, VJ and PWR clearly favor periodization theory.
4. Comparisons of maximum work output, 80% max SQ reps, and relative decrement in VJ following maximum work in Experiment 6 were equivocal. MWO favored the theoretical model, but there were no significant differences in the other two measures. Interpretation of these results would lead to the logical conclusion that, for these tasks, the low volume, high intensity work in peaking is not accompanied by a decrement in endurance in the periodization model group.

5. Two experiments involved female subjects and some of the results are equivocal. While one experiment was characterized by absolutely no significant differences between groups, the other showed clear advantages by theoretical model procedures in VJ and PWR, while SQ, BN, BWT, LBW, and percent fat were not significantly different. One might speculate that the differences could be a function of age or maturity, the only obvious discrepancy between subjects or programs.

It is concluded from these experiments that the proposed theoretical model of training, based on the concept of periodization, is superior to traditional methods for achieving increased strength and power.
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VITA

Harold S. O'Bryant was born on July 23, 1950 in Reidsville, North Carolina. Upon matriculation from Reidsville High School in June, 1968 he later attended Rockingham Community College (RCC) at Wentworth, North Carolina from 1968 to 1970 when he then transferred to Appalachian State University in Boone, North Carolina. He received a Bachelors of Science degree in 1972 and later in 1974 a Masters of Arts in Health, Physical Education, and Recreation from Appalachian State University (ASU).

Harold has had a variety of part time employment as an RCC assistant gymnastic instructor, a Y.M.C.A. age group gymnastic director, a prison recreational director, and ASU assistant men's gymnastic coach, all diversely related to professional goals. He preformed duties as a graduate teaching and laboratory assistant at ASU from 1973 to 1974, to later become employed by Jacksonville State University at Jacksonville, Alabama for 5 years as head men's gymnastic coach and member coach of both N.A.I.A. and N.C.A.A. While at Jacksonville he taught kinesiology, health problems, gymnastics, and scientific principles of coaching within the physical education curriculum.

During his tenure at Jacksonville he earned graduate credit not only from Jacksonville State University, but from the University of Alabama in Tuscaloosa and Birmingham
as well, later to transfer to Louisiana State University in Baton Rouge to continue graduate studies in 1979. While at L.S.U., Harold was employed as a graduate teaching assistant and taught first aid, anatomy, weightlifting, and exercise physiology laboratory. Harold has fulfilled all course requirements for a Ph.D. in Health, Physical Education, Recreation, and Dance with a minor in Physiology. Upon completion of the dissertation he will plan to graduate from L.S.U. at the summer commencement on August 7, 1982.
EXAMINATION AND THESIS REPORT

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Major Field: Health, Physical Education, Recreation, and Dance

Title of Thesis: Periodization: A Hypothetical Training Model for Strength and Power

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