

THE EFFECTS OF BALLET TRAINING ON ISOKINETIC
STRENGTH, POWER, AND MUSCULAR ENDURANCE

by

Shira Loree Caldwell Hedgepeth

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APPROVED:

Dr. Don Sebolt, Chairman

Dr. Richard Stratton

Dr. Michael Dumin

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Shira C. Hedgepeth

Committee Chairman: Don R. Sebolt

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(Abstract)

An experimental group of nine dancers between the ages of 18 and 23 who were participating in dance technique classes were compared to a group of nine dancers who were participating in an eight week weight training program and technique class and a control group of sedentary females of the same age.

Each group was tested for isokinetic strength, power, and muscular endurance on the Cybex II+ before and after the eight week training program of ballet and weight training. Each subject in the two experimental groups attended at least three ballet technique classes a week. The nine members of the weight training group lifted weights three times a week and performed exercises on the leg press, leg curls, and leg extension. Initial and final 1-RM's for the leg press, leg curl, and leg extension were also measured for the weight training group.

Data were analyzed by a nonparametric Kruskal-Wallis test to determine initial and final differences between the three groups in all isokinetic strength measurements. A Wilcoxon Analysis of Variance test was also used to determine differences between pretest and posttest isotonic strength scores.

No statistical difference was found between the three groups on posttest isokinetic strength, power, or muscular endurance of the quadricep or hamstrings after training. However, significant isotonic strength gains were found in the weight lifting group on leg press, leg curls, and leg extension exercises after the training sessions.

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CHAPTER I

Introduction

As early as 300 BC, people began to note the physical demands of classical ballet. Socrates wrote, "the best dancer was also the best warrior." In 1662, others wrote to the French Royal Academy of Dance and also noted that dance was the "...most suitable and necessary arts for physical development (Widdap, 1967). He noted that movements in ballet were similar to the sport of fencing and recommended ballet as a suitable and necessary form of exercise for physical development. Throughout the years, various athletes have added ballet exercises to their regular training programs. Gymnastics, track, football, and basketball are only a few sports that have recognized ballet's potential for physical improvement (Miller, et al., 1975).

Dance is a complex art form requiring expression through human motion. Unlike other art forms, dance must rely solely on the human body and its capabilities for artistic and aesthetic development. Shapes in dance are sculpted by dancers, requiring them to develop strength, power and flexibility to reach and maintain necessary positions in choreography. It is important for them to train their bodies as if they were professional athletes in competition. Most professional dancers begin training as early as ten years of age and train six or seven hours daily throughout their career (Sammarco & Miller, 1982).

Ballet re-educates the muscles of the body as the dancer learns to move more gracefully. Exercises executed at the barre or performed in the center of the floor are derivatives of "turn out." Turned out positions are necessary for the aesthetic development of balletic movements, although they are unnatural and stress the muscles and ligaments of the hips and pelvic regions. Dancing must also reach and maintain extremely pointed and flexed positions of the foot and ankle (Hardaker, et al., 1985) and learn to lengthen or fully stretch not only their legs but their spine, neck and arms. A dancer's stance alone is foreign to a nondancing individual (Newman, 1982). Therefore, dance training becomes a unique process, challenging individuals to perform almost physically impossible movements smoothly and gracefully (Laws, 1984).

Although dance is an art form and should not be thought of as solely a movement science, a dancer's movement could be enhanced by the performer's knowledge in scientific areas such as exercise physiology, biomechanics and kinesiology. This investigation focused on the concepts of power, strength, and muscular endurance and their relationship to dance training. It is evident that these components are necessary for proper and successful ballet dance technique.

In reference to athletic demand, classical ballet was ranked second out of 61 sports in a survey conducted by the Institute for Sports Medicine (Pepper, 1984) in New York, when speed, strength, balance, coordination, and accuracy were considered necessary components of neuromuscular and physical activities. Ballet was of special interest because of its adagio combinations which required isometric contractions

of the muscle to hold many extended positions coupled with allegro movements which consisted of rapid dynamic activity. This survey suggested that ballet training could enhance the performance of other high ability athletes.

Strength has been defined as the maximum ability for a muscle to exert force in a contraction (Wilmore, 1985). It is affected by sex, age, test position, and type of contraction tested. Strength is an essential measurement of muscular function in the normal performance of physical activity (Murray, 1980). Until recently, it has been defined by measuring the greatest amount of weight that can be moved through a full range of motion. However, this process only measured maximum strength at the joint's weakest angle (Novak, et al., 1978). Isokinetic testing has made it possible "...to load dynamically contracting muscle to its maximum capabilities at all points throughout the full range of motion and to test for strength at different functional speeds" (Kirkendal, 1984).

Dancers' training, like other sports, utilizes many functional speeds during one performance. It has been determined in several studies that strength changes may be limited to the speed at which training occurs (Lemes, et al., 1978).

Isokinetic testing devices have been reported as very useful in rehabilitation and research settings. The Cybex II device has been used in professional football, sports medicine clinics, and research laboratories. It has been utilized in occupational injury evaluation, athletic screening and verification of treatment (Medical News, 1978). It allows researchers and technicians to determine areas of weakness and to prescribe treatment for training. It is a method which has been

determined to be both reliable and valid. The Cybex II allows researchers to determine such components as strength, power, and muscular endurance more efficiently. Studies in which strength and power have been measured dynamically and isokinetically have reported high intercorrelations (Genuario & Balturaites, 1980).

Power has been defined in many ways. It is the ability to maintain tension at velocities which are specific to functional activities (Halling & Dooley, 1978). Contractile power is related closely with physical performance, training and principles of muscle mechanics. Power has also been defined as the time it takes for a muscle to develop force and to sustain this force through a full range of motion (ROM) (Halling & Dooley, 1978). Power and strength are both thought to be essential components of dance.

Statement of the Problem

Dancers perform many exercises that are believed to increase flexibility, strength, power, and muscular endurance of the quadriceps and hamstrings. For example, performing many rond de jambe en l'air in succession during a single phrase of music or performing slow developpes to isometrically held positions. Classical ballet instructors seldom question the potential muscular benefits of these exercises and few investigators have focused on the muscular changes seen during dance training. Additional knowledge would enhance the training of individuals who teach and participate in ballet technique class.

Another question not addressed in previous research is whether ballet training can be enhanced by supplementing technique class with a

weight training program designed to strengthen related muscle groups utilized in dance performance and training. Additional strength could possibly allow the dancer to concentrate more on the quality of his or her movement when performing. Also a weight training program could enhance such parameters as power and anaerobic endurance. As indicated in a study utilizing the Cleveland ballet, power is an important factor in dance training (Kirkendal, 1984), and increases in power could only enhance the dancer's performance.

The purpose of this study was to evaluate the muscular changes recorded during ballet dance training. Specifically, this study was designed to measure isokinetic strength, power, and muscular endurance changes in knee flexion and knee extension of dancers who were participating in ballet dance and with individuals who were participating in dance and in a supplementary weight training program.

Significance of the Study

Dancers are highly motivated individuals who strive for perfection in their art even if it begins to take preference over their physical condition (Sammarco & Miller, 1982). Therefore, many researchers have reported a need to investigate injuries associated with dance training. Most dance research has been reported by orthopedic surgeons who have limited knowledge of ballet and fail to understand a dancer's training and motivational drive (Washington, 1978). Elite dancers tend to avoid physicians because they are often advised to stop dance training (Medical, 1978). Because the potential benefits of dance have not been fully

investigated, some physicians are not aware of these benefits and maintain that the known hazards of dance outweigh the benefits.

In 1965, 37 dance companies were eligible for grants from the National Endowment for the Arts, and by 1978, there were over 200 (Medical, 1978). With this increased interest in dance and with more people taking ballet at universities and private schools of dance, it has become increasingly necessary for practitioners and teachers to familiarize themselves with the problems associated with dance. It is suggested that if dancers were compared to other athletes, the results might provide insight to the dancers' capabilities (Kirkendal, 1984). Studies which evaluate muscular changes during dance can also provide insight to a dancer's strengths and weaknesses. These factors could help dancers train more efficiently.

This researcher has located only one study focusing on strength related to dance performance--Kirkendal, 1984. This investigation of isokinetic strength reported the changes that occur when one performs in a professional dance company. In college, dancers spent less time in ballet class and rehearsals because of other requirements for graduation. Therefore, they may be lacking sufficient strength, power, and muscular endurance to perform efficiently.

Dancers do not usually lift weights because of lack of time and the belief that it will cause bulky muscles which are not aesthetically pleasing in dance (Mostardi, et al., 1983). The addition of a weight program to dance training could possibly increase the college dancer's strength, power, and muscular endurance, and in return may enhance

performance. This has been demonstrated in numerous studies involving other physical activities or sports.

It is accepted that specific strength is necessary to achieve and maintain positions in choreography and ballet dance. For example, developpes' require the quadricep muscles to be stressed by lifting and extending the leg fully in the air. Although a dancer may increase the strength of their quadriceps by repeating this movement several times in one class, a greater increase might be observed if the muscle group was progressively loaded. Overloading is the primary technique used in weight lifting. When an individual is able to move a certain load with ease, weight is added to increase the strength of the working muscle group. If dancers were to participate in a weight training program, their strength gains may increase and therefore increase the dancers' ability to reach and maintain needed positions in adagio combinations.

The concepts of isokinetic muscular endurance and power related to dance have not been fully investigated. Kirkendal (1984) reported a greater increase in strength and power at faster exercise speeds. However, this investigation only utilized exercise speeds of 45, 90, and 180 deg/sec. He reported a significant strength gain only at 180 deg/sec, therefore, power may be an important variable in dance training. If these findings were supported by similar investigations, practitioners would have a greater understanding of necessary components in dance and therefore could enhance the dancer's training program.

Muscular endurance in dance has not yet been investigated. Although ballet dance requires performers to maintain extended positions such as developpes for several counts in a musical phrase and to move slowly

through extensions in adagio combinations, it is not known whether muscular endurance is increased by ballet dance training. If the relationship between traditional ballet training, supplemental weight training, and muscular endurance is firmly established, dancers could possibly enhance their performance by supplementing their dance training with a weight training program designed to increase muscular endurance.

Other athletes who utilize anaerobic conditioning have benefited from weight lifting, but dancers seldom consider combining the two training programs. It has been determined that strength, power, and muscular endurance are important for every type of athlete (Wilmore, 1982). Although ballet is not considered a sport, it demands many of the same qualities in performance as other athletic activities. Athletes have added weight lifting to their training to increase muscular strength and endurance and therefore improved their performance. The results of this study may provide information regarding the value of supplementing ballet training with a properly designed weight training program.

Research Hypothesis

The following null hypotheses were tested:

1. There is no significant difference in peak torque of knee flexors and extensors at the joint angle velocity of 60 deg/sec in individuals who were participating in a ballet training program and those who were participating in a ballet training program supplemented with a weight training program.
2. There is no significant difference in peak torque to body weight ratio of knee flexors and extensors at the joint angle velocity of 60

deg/sec in individuals who were participating in a ballet training program and those who were participating in a ballet training supplemented with a weight training program.

3. There is no significant difference in average power of knee flexors and extensors at the joint angle velocity of 240 deg/sec in individuals who were participating in a ballet training program and those who were participating in a ballet training supplemented with a weight training program.

4. There is no significant difference in muscular endurance of knee flexors and extensors at the joint angle velocity of 240 deg/sec in individuals who were participating in a ballet training program and those who were participating in a ballet training program supplemented with a weight training program.

Delimitations

The following delimitations were imposed by the investigator:

1. Subjects were limited to females between the age of 18 and 35, who had studied ballet technique for at least two years, and who were currently participating in ballet technique classes at least three times weekly.

2. Strength of knee flexor and extensors were measured only at the joint angle velocity of 60 deg/sec.

3. Power of knee flexors and extensors were measured only at the joint angle velocity of 240 deg/sec.

4. Muscular endurance of knee flexors and extensors were measured only at the joint angle velocity of 240 deg/sec.

Limitations

The following restrictions were recognized by the investigators:

1. The Cybex II+ only measured functional speeds up to 300 deg/sec.

The functional speeds of selected ballet combinations may be much greater than could be measured with the Cybex II system.

2. Cybex II+ only measured joint strength and power on an uniaxial plane and ballet consists of multiaxial movement (Mostardi, et al., 1983).

3. Due to the sampling techniques employed by the investigator, results of this study are only applicable to female ballet dancers who participated in this investigation.

Basic Assumptions

The following assumptions were made by the investigator:

1. It was assumed that all subjects attended the ballet technique class and the supplementary weight training sessions regularly.

2. It was assumed that subjects only participated in the physical activities outlined in the two experimental conditions.

3. It was assumed that subjects gave maximal efforts during all experimental testing.

4. All statistical assumptions were met.

Definitions

1. ADAPIO: A French term meaning at lease or leisure. A series of exercises which consist of slow and graceful movements. Principle steps are plies, developpes, grand fautte en tournant attitudes and arabesque. These exercises are performed to develop a sense of line, fluidity, a sense of ease and to develop power.

2. ALLEGRO: A French term meaning brisk and lively. Principle steps are steps of elevation or light jumps.

3. AVERAGE POWER: The time it takes for a muscle to develop force and to sustain this force through a full range of motion (ROM). It is the total work done in the test repetitions divided by the total contraction time. This time was computed separately for knee flexion and knee extensions.

4. BARRE: The horizontal wooden bar fastened to the walls of ballet classrooms or rehearsal halls which the dancer holds for support. Most ballet classes begin with barre exercises.

5. BATTEMENT DEGAGE: Similar to battement tendu but the foot disengages.

6. BATTEMENT GRAND: large battement. The leg is brushed from fifth position and raised into the air. Can be performed to the front, side or back.

7. BATTEMENT TENDU: The working foot slides from fifth position and fully extends to the front, side, or back without raising the toes from the floor.

8. ENDURANCE RATIO: The ratio calculated by dividing the total work generated from the last six trials by the total work generated by the first six trials.

9. FONDU: Sinking down or plieing with one leg.

10. FRAPPE: Struck battement: An exercise where the dancer forcefully extends the leg from cau-de-pied (about the ankle of the supporting foot).

11. ROND DE JAMBE: A circular movement of the leg that is performed at the barre and in adagio combinations.

12. PEAK TORQUE: Peak torque is the maximum force that a muscle can produce at any given angle and is a measurement of isokinetic strength.

Summary

Dance is a complex art form which requires much dedication and discipline. Like many other physical activities or training programs, dance training can be influenced and improved by scientific studies investigating muscular changes that occur during training. This investigation was designed to measure isokinetic strength, power, and muscular endurance changes in knee flexors and knee extensors of individuals who were participating in ballet training and individuals who were participating in ballet and a supplementary weight training program.

CHAPTER II

Review of Literature

This chapter will focus on literature concerning the general isokinetic components of strength, power, and muscular endurance and selected muscular function parameters related to dance.

Isokinetic Measurements: Strength, Power, and Muscular Endurance

Isokinetic exercise has been used in training, rehabilitation, and research. Introduced by Hislop and Perrine in 1967, isokinetics is uniquely different from previously introduced resistance training and strength measurements. Isokinetic devices allow one to control the speed of movement during muscular performance and maximal loading of the muscle throughout the full range of motion. Through the use of isokinetics, the muscle can develop the highest power output, the most work possible per repetition and maximum peak torque at an optimal angle in the range of motion. Isokinetics have been reported to be both reliable and valid when utilized as a research tool. From previous studies on athletic and nonathletic populations, researchers are able to establish reproducible normative data, which enables coaches, trainers, and physical therapists to diagnosis, treat, and prevent injuries during training.

One parameter commonly measured in isokinetic strength research is peak torque. Wyatt, et al. (1981) reported that peak torque of the quadriceps for nonathletes was approximately 135 and 79 foot pounds for males and females respectively at 60 deg/sec. He reported that hamstring peak torque values were significantly less than quadricep torque and that

both torque values decreased as velocity increased. Peak torque of nonathletic high school students was reported by Holmes and Alderink (1984) at 60 deg/sec. Although the subjects were younger in this study, reported torques of both males and females were greater than those reported by Wyatt for both the quadriceps and hamstrings. Nondominant limbs were reported to be similar to dominant, but one to four foot pounds of difference was reported.

Reported torque measurements of athletic populations have been assessed by numerous researchers in all types of sports. Gilliam, et al. (1979), Davis, et al. (1981), and Rankin (1983) reported peak torques of high school, college, and professional football players. Gilliam (1979) reported that peak torques of the quadriceps in high school football players were unique to the positions they played and that defensive linemen were reported to have an average of 1.6 kg-m greater torques than any other position investigated. This observation was reproduced by Davis and Rankin (Davis, et al. 1981; Rankin & Thompson, 1985).

Gilliam also investigated the relationship between peak torque of the quadriceps and hamstrings to body weight. He reported a high correlation between these two variables. Davis (1981) reported similar results when he investigated peak torque values of quadriceps and hamstrings to body weight ratio of professional football players. He reported that defensive linemen scored a high of 74% while offensive linemen scored lower at 57%. Both ratios were determined at 300 deg/sec. Rankin and Thompson (1983) reported lower ratios for linemen, but differences between offensive and defensive positions were not investigated. Agre and Baxter (1981) investigated peak torque to

quadricep ratios of male soccer players and reported that at unspecific speeds body weight to peak torque of the quadricep ratios were 96% and 102% for the right leg and left leg respectively. These researchers also investigated hamstring to body weight ratios and reported similar, but lower values than reported quadricep ratios of 74% and 57% in Davis' study.

Others have compared differences in peak torque between male and female athletes. Wilmore (1974) reported that although peak torques were generally greater in male than in female athletes, females would score comparably higher if body weight was accounted for in the calculation of peak torque. Miyashita and Kaneshisa (1979) reported no significant difference between males and females between the ages of 13 and 17. Hoffman's (1979) investigation contradicted previous studies when reporting strength differences of male and female cadet basic trainees of similar ages. He reported that when controlling for lean body mass and height, peak torque differed significantly between the sexes on measures of isokinetic leg press. Recorded values were 591 and 799 foot pounds for females and males respectively.

Haymes, et al. (1980) investigated Olympic skiers and reported significant sex differences between alpine skiers. When comparing alpine, cross country, and Nordic skiers, it was reported that female alpine skiers had greater torque outputs than males or females of the other discipline. Lean body weight was accounted for in these calculations. Starkey and Peters (1981) results agreed with Haymes when investigating male and female marathon runners strength, power, and muscular endurance after a 100 mile run. Most recently, Kirkendal (1984)

investigated professional ballet dancers and reported similar results. He reported that male ballet dancers scored significantly higher in peak torque of the quadriceps at 45, 90, and 180 deg/sec than did female ballet dancers from the same company.

Age and its relationship to peak torque also has been investigated. Miyashita and Kaneshisa (1979) reported that peak torque of the quadriceps increased linearly with age from 13-17 in male subjects. Females did not increase between the ages of 14-17, but a significant strength difference was reported between the ages of 13-14 years. Gilliam, et al. (1979) reported quadricep torque differences between the ages of 15-17 years in high school football players. Differences in peak torque of the hamstrings were reported between 15 and 16 years at velocities of 30 and 180 deg/sec. No difference in hamstring torques were reported between 16 and 17 years of age. These reported differences were explained by the differences in relative body weight of each age group. When weight was held constant, the correlation of predicted torque outputs of the hamstring decreased.

Another important concept generally investigated relative to peak torque is flexion to extension ratios. Gilliam, et al. reported that defensive linemen had significant higher ratios (65%) than other positions investigated (59%). Other investigators have reported similar ratios when investigating football players. Parkers, et al. (1982) reported ratio of 56% and 57% when assessing torques of 84 high school players. Davis, et al. (1981) reported ratios of 60% at 45 deg/sec and 80% at 300 deg/sec, and Rankin and Thompson (1983) reported ratios of 64% at 60 deg/sec and 88% at 30 deg/sec in professional football players.

Wilkerson, et al. (1980) reported flexion to extension ratios of 140% at 30 deg/sec to 65% at 300 deg/sec in elite male marathon runners. Reported values of college athletes recorded by Osternig (1981) were markedly lower than Wilkerson's, scoring 57% at 50 deg/sec and 77% at 400 deg/sec recorded by means of an isokinetic dynamometer. Costain and Williams (1984) reported ratios of 61% at 30 deg/sec in female soccer players, and Holmes and Aldernik (1984) reported similar ratios with males between the ages of 15 and 18. All of the previously mentioned studies agree that at higher velocities, hamstrings will produce proportionally more force causing ratios to increase.

Morrow, et al. (1979) investigated the relationship between strength and predicted success in woman's intercollegiate volleyball by utilizing a Cybex leg press device. From this investigation, it was reported that most successful players had higher peak torques than less successful players. Reported torques were 155 foot pounds and 138 foot pounds for successful and nonsuccessful players respectively. Most successful players were determined partly from team success and were reported to be faster, taller, stronger, and leaner than the least successful players (Morrow, et al., 1979).

Miyashita and Kaneshisa (1979) investigated the relationship between various athletic events and peak torque. They reported significant correlations in 13, 14, and 15 year old males and 13, 15, 16, and 17 year old females between running (50 meters) and peak torque values. If age was not considered, correlations of $r = .69$ and $r = .37$ were observed in males and females. Significant correlations of peak torque of the extensors and swimming performance were observed in females in the same

study, but a negative correlation was reported in males (Miyashita and Kaneshisa, 1979).

From these investigations general conclusions concerning peak torque can be determined. Generally, torque output will decrease as isokinetic velocities increase, and in some populations, these decreases will be significantly different between testing speeds. Constain and Williams (1984) reported a significant difference between knee flexion and knee extension torque values at speeds of 30 and 300 deg/sec. Wyatt and Edward (1981) demonstrated significant differences in quadriceps and hamstrings torques between speeds of 60 and 180 deg/sec, 180 and 300, and 60 and 300 deg/sec in both males and females. Differences were greater between between velocities of 180 and 300 deg/sec. Wilkerson, et al. (1980) also reported that torque values declined in the quadriceps and the hamstrings in 13 elite marathon runners. Tests were performed at 30, 60, 120, 180, 240, and 300 deg/sec.

Endurance of the quadriceps and hamstrings has been investigated less frequently than peak torque, but normative values have been reported by various investigators. Wilkerson, et al. (1981) reported an average endurance ratio of the quadriceps of 90% in marathon runners. Endurance in this investigation was determined by a 40 second work bout by comparing the strength in the first repetitions to the decrement of strength in the last.

Endurance was assessed differently in Haymes', et al. (1980) study by determining the number of contractions performed to produce a 50% decrement in torque. He reported that when using this method that Olympic skiers were comparable to other athletes in endurance and that males and

females did not differ from the other. Mostardi, et al. (1983) utilized the same method as Haymes and reported no difference between male and female dancers or between the right and left legs in endurance.

Starkey (1981) compared endurance ratios of male and female runner after a 100 mile race and reported decreases in average quadricep strength at 30.8% overall. An average of 46% was reported in females and 19% decrease was reported in males. Decreases in hamstring endurance was reported to be 27% and 25% in the same study (Starkey, 1981).

Meadors, Crews, and Adeyamjier (1983) investigated endurance ratios between ratio nonathletic females and reported lower ratios than those of nonintercollegiate athletic populations. Reported ratios of knee extension and knee flexion was 20% and 26% respectively.

The last parameter commonly investigated during isokinetic assessment is average power. Hosler, Morrow, and Jackson (1978) reported the mean average power leg press score of 180 college female volleyball players. An average of 318 pounds was reported with a range of 176-459 pounds. When considering fast twitch fibers as a dependent variable, it was reported that greater leg press power was seen in males with 50% fast twitch fiber. Reported values were 11, 16, 23, and 47% at velocities of 115, 200, 287, and 400 deg/sec (Colye, Costil, & Lessmes, 1979).

Starkey (1981) reported a decrease in quadricep power of 26% and 15% at 180 deg/sec for males and females after completion of a 100 mile race. Starkey reported similar results in average power of the hamstring, reporting a decrease of 18% and 17% in males and females after competition.

Wilkerson, et al. (1981) reported increases in average power with increases in velocities in both knee flexors and extensors. Knee flexors have been reported to produce significantly greater power than the extensors at speeds greater than 120 deg/sec. Below speeds of 60 deg/sec, the reverse was seen.

Isokinetic Strength Related to Dance

A study utilizing the Cleveland Ballet compared strength changes from pre to post season. It was reported in pre season test that females decreased in peak torque of the quadriceps when doubling of speed. A 16% decline in torque during extension was reported from 45 deg/sec to 90 deg/sec, and a 42% decline was reported from 45 deg/sec to 90 deg/sec. The males' scores were similar but a significant sex difference was found. After training, this decline decreased all all speeds in the female participants, but the greatest improvements were seen from 90 deg/sec to 180 deg/sec. Quadricep torque increased with training. Females increased their torque by 4, 9, and 16% at functional speeds of 45, 90, and 180 deg/sec, but significant changes only occurred at a speed of 180 deg/sec. Although this study provides additional knowledge of dance training, it did not focus on average power or muscular endurance measurements (Kirkendal, 1984).

Other researchers have compared dancers to other athletes. Haymes and Dickenson (1980) also reported that alpine ski racers scored greater torques and peak torques for quadriceps than dancers. Chambers (1981) reported that dancers were more flexible in both the hamstring and shoulder than various varsity athletes, but scored lower in hamstring

strength. On the average, dancers were strong in the quadriceps and hip flexion. Mostardi, et al. (1983) tested dancers with the Cybex II and reported that female dancers scored lower than female basketball players of the same age on knee flexion and knee extension. Peak torque scores for quadriceps of dancers were 55 N-meters and 54 N-meters for the right and left leg respectively. Basketball scored an average of 86 foot pounds and 82 foot pounds for right and left leg.

Several studies have investigated the relationship between isokinetic torque and vertical jump ability. Many jumps are utilized in allegro combinations in dance, and although all jumps performed in ballet require "turn out," many of them use mechanics similar to that of vertical jumps. Conflicting results have been reported. Studies in the late 60's reported that dynamic leg strength was not correlated to strength and power (Bell, Rich, & Wallis, 1964; Eckert, 1964; Costill, Miller, Myers, Kehae, & Hoffman, 1968), but Genuario (1980) reported a significant relationship between torque at a functional velocity of 180 deg/sec and vertical jump. Weight was also reported to be a significant factor in the vertical jumps. Pipes and Wilmore (1975) reported no significant improvements as isotonic and isometric strength increased, but did report a significant improvement in vertical jump when isokinetic strength increased.

Summary

Peak torque is commonly used in research as a measure of strength. From previous research, it has been determined that quadriceps produce significantly more torque than do hamstrings and that peak torque values

decrease as velocity increases. It has also been determined that nondominant limbs produce one to four foot pounds less torque than the dominant limbs. Reported torque values also differ between athletic and nonathletic populations. Peak torque of the quadriceps and hamstrings are also highly correlated with body weight and differ from groups of athletes. Significant differences in peak torque of the quadriceps and the hamstrings have been reported between males and females of the same age and between the same sex of different ages. Reported flexion to extension ratios of peak torque ranged from 56 to 140%.

Endurance has been investigated less frequently than peak torque, but normative values have been reported for marathon runners, Olympic skiers, and ballet dancers. Each have been reported to be comparable to the others.

Average power has been reported by Hosler, et al. (1978), Calye, et al. (1979) and Wilkerson. From these investigations, it has been reported that knee flexors produce significantly greater power than the the extensors at speeds greater than 120 deg/sec and the reverse is observed below 60 deg/sec.

From studies focused in dance, it has been determined that greater increases in strength occurred at functional speeds of 180 deg/sec (Kirkendal, 1984), and that dancers will typically score lower on peak torque in comparison with other athletes (Kirkendal, 1984; Haymes & Dickerson, 1980).

CHAPTER III

Introduction

Dance is a complex art form which requires expression through human movement. Dancers are required to train as professional athletes to enable them to develop strength, power, and muscular endurance to reach and maintain static positions in choreography. Most professional dancers begin training as early as age ten and train daily for six to eight hours (Sammarco, 1980). Dance training is a unique process, challenging individuals to perform almost physically impossible movements smoothly and gracefully (Laws, 1984).

In terms of athletic demand, classical ballet was ranked second out of 61 sports in a survey conducted by the Institute for Sports Medicine (Pepper, 1984) in New York when speed strength, balance, coordination and accuracy were considered necessary components of neuromuscular and physical activities. One study has examined the concept of isokinetic strength and power in professional dancers. Kirkendal (1984) reported significant changes in quadricep peak torque only at functional velocities of 180 deg/sec in female dancers of the Cleveland Ballet Company. Therefore, this investigation suggests that power is an important part of a dancer's training because peak torque only significantly increased between pre and post season at a functional velocity of 180 deg/sec.

Dance training is not fully understood, and many dancers train daily without questioning the benefits of their training. It has not been determined what muscular changes are beneficial to dance training.

Extreme flexibility is evident but other physical aspects have not been fully examined.

Another question that has not been addressed is whether dancers can benefit from a supplementary weight program. If strength and power are important to a dancer, more improvement in strength and power may be seen when a weight training program is designed to enhance the strength of muscles utilized in dance.

The purpose of this study was to determine the effects of ballet dance training on isokinetic strength, power, and muscular endurance. Specifically, this study was designed to determine isokinetic strength, power, and muscular endurance in knee flexors and knee extensors of individuals who were participating regularly in ballet and those who were participating in dance and a supplementary weight training program.

Methodology

Two experimental groups were formed from dancers 18-35 years of age who had studied ballet for at least two years prior to the study and who were enrolled in ballet class. The first group, ballet (B), participated in at least three ballet technique classes per week, and a second group, ballet and weight training (BW), participated in the same ballet technique classes but supplemented their dance training with a twenty minute weight training program three times a week. A control group (C) consisted of females with similar characteristics who were not participating in any regular exercise program. All subjects gave written informed consent prior to participation in this investigation.

Pretest

Strength, power, and muscular endurance of knee flexors and extensor were measured on the Cybex II+ isokinetic testing device. Each subject was seated for testing and the preferred limb was secured to the long arm input adaptor. The axis of the knee was aligned with the dynamometer. Subjects were given a warm-up of three to five submaximal repetition at 60 deg/sec and 240 deg/sec before testing. Peak torque was measured at 60 deg/sec and was determined as the highest score of three maximal trials. Peak torque to body weight ratio was also measured at 60 deg/sec and was determined by dividing peak torque by body weight. Muscular endurance and power were examined at a joint angle velocity of 240 deg/sec. This test consisted of 30 maximal repetitions of knee extensions and knee flexion exercises. Endurance was calculated by dividing the total work from the last six trials by the total work of the first six trials. Average power was measured by dividing the total work done in the test repetitions by the total time of contraction. This was computed separately for both knee flexion and knee extension.

This weight training group was also tested for initial isotonic strength using the universal machine. One repetition maximums (1-RM) were determined for leg extension, knee flexion, and leg press by starting with a submaximal load and increasing the weight until the subjects could only move the weight through full range of motion one time.

Both experimental groups participated in ballet technique classes. Each 1 1/2 hour class met three times per week. Each class began with typical barre exercises for 25-30 minutes, starting with plies and ending with grand battement. After three exercises, the subjects were instructed

to stretch before starting the center floor exercises. Both adagio and allegro combinations were performed for 45-50 minutes. Fourteen of the subjects were also involved with rehearsal for fall productions, including "The Nutcracker," "Hair," and various performances for a contemporary jazz dance company. Warm-ups similar to the barre exercises during class were performed before beginning rehearsals.

One experimental group (BW) also participated in an eight week weight training program consisting of leg extensions, leg press, and leg curl exercises. The weight training program was designed to increase strength, power, and muscular endurance and consisted of three different phases. The first phase, hypertrophy, lasted for two weeks and the loadings ranged from .65 to .75 of the subjects initial 1-RM. Three sets of 8-12 repetitions were performed each session. The second phase, basic strength, lasted for three weeks. Three sets of four to six repetitions were performed at loadings of .75 to 85 of their recalculated 1-RM. The third phase, strength and power, lasted for three weeks. Three sets of two to three repetitions at loadings of .85 to .91 of their recalculated 1-RM was performed during each workout (Stone, et al., 1982). The program was modified during the last two weeks because the dancers were unable to complete the required repetitions. Weight loadings were decreased.

A multifactor randomized control group repeated measures paradigm (Van Dalen, 1979) was used in the study. Data were analyzed by a nonparametric Kruskal-Wallis test to determine differences between the three groups in all strength measures on pretest and posttest scores. A Wilcoxon Analysis of Variance test was performed to determine differences between pretest and posttest strength scores within each group.

Reliability coefficients using the Cybex II+ isokinetic systems were previously reported by Johnson and Siegal (1978) and ranged from $r = .93$ to $r = .99$.

Results

Initial Scores on Isokinetic and Isotonic Tests. No significant difference was found between either of the treatment groups or the control group on initial isokinetic measurements of peak torque, peak torque to body weight ratio, average power, or muscular endurance in either the knee extensors (quadriceps) or the knee flexors (hamstrings).

Isotonic 1-RM measured on the leg press ranged from 140-345 lbs. Isotonic knee extension ranged from 20-110 lbs. The pretest scores on the leg curl ranged from 20-60 lbs.

Final Scores. No statistical difference was found between the three groups after the eight week training session on peak torque of either the quadriceps or hamstrings. The control group scored an average of 96.4 ft. lbs. on peak torque of the quadriceps, while the ballet group and the ballet and weight training groups scored an average of 80 ft. lbs. and 91 ft. lbs. respectively. Average scores of the hamstrings were lower. The control group scored an average of 52 ft. lbs. while the ballet and ballet and weight training group scored an average of 44 ft. lbs. and 49 ft. lbs. (See Figure 1.)

No statistical difference was found between the three groups after the eight week training session on peak torque to body weight ratio. The highest average of peak torque to body weight of the quadriceps was observed in the ballet and weight training group (77%). The ballet group

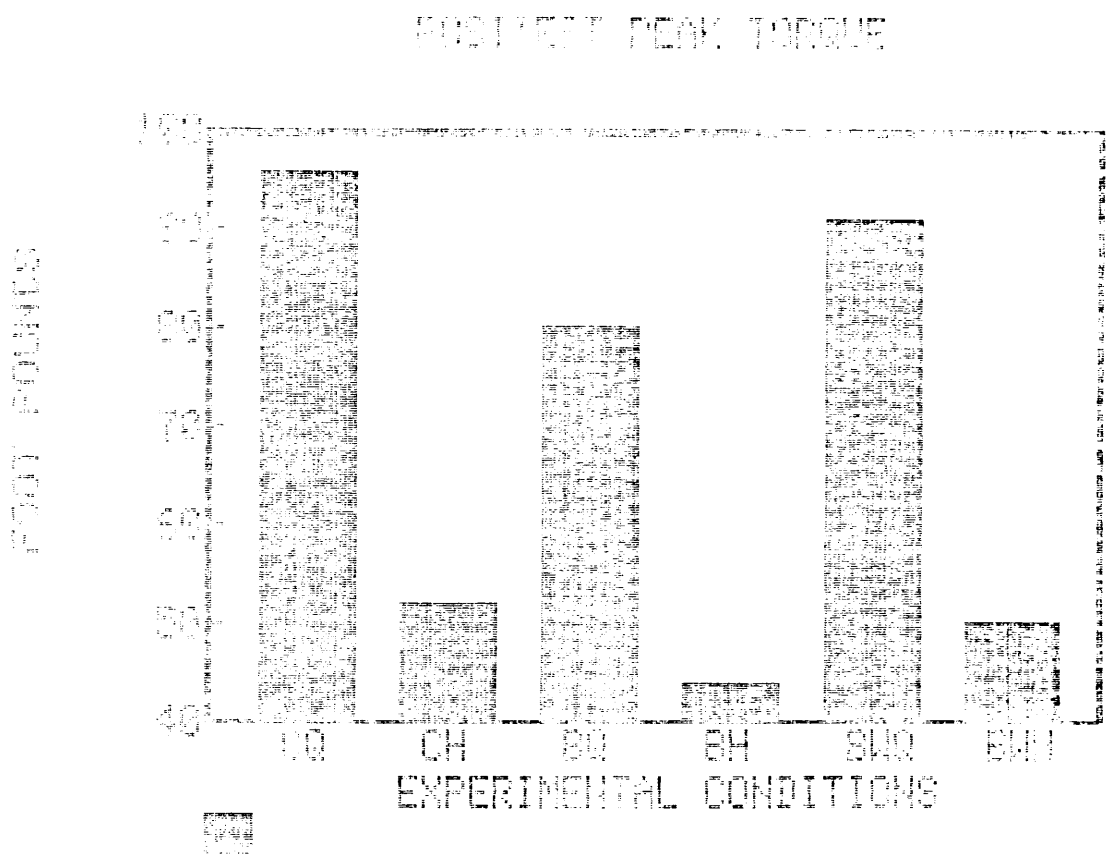


Figure 1. Posttest Means of Quadriceps and Hamstring Peak Torque

scored an average of 69% and the control group 71%. The highest average of the hamstrings was also observed in ballet and weight training group (41%). The ballet group scored an average of 38%, and the control group scored an average of 93%. (See Figure 2.)

No statistical difference was found between the three groups after the eight week training session on muscular endurance of the quadriceps and hamstrings. The largest endurance ratio in the quadriceps was observed in the ballet group (66%). The ballet and weight training group scored an average of 60%, and the control group scored an average of 59%. The highest average of the hamstrings was also observed in the ballet group (61%). The ballet and weight training group scored an average of 52.5%, and the control group scored an average of 51%. (See Figure 3.)

No statistical difference was found between the three groups after the eight week training session on average power of the quadriceps and hamstrings. The highest average power score of the quadriceps was observed in the control group (120 watts). The ballet and the ballet and weight training group scored an average of 112 and 115 watts. The highest average power score of the hamstrings was observed in the ballet and weight training group (74.5 watts). The control group scored an average of 71 watts, and the ballet group scored 61 watts. (See Figure 4.)

Isotonic Tests. Significant pretest to posttest differences were observed for both the leg press ($p > .01$) and leg extensions exercises ($p > .02$). Posttest scores for leg press after the eight week training program was 382 pounds and mean posttest scores for leg extension was 86 pounds. The posttest mean recorded for its leg curl was 49 pounds. There

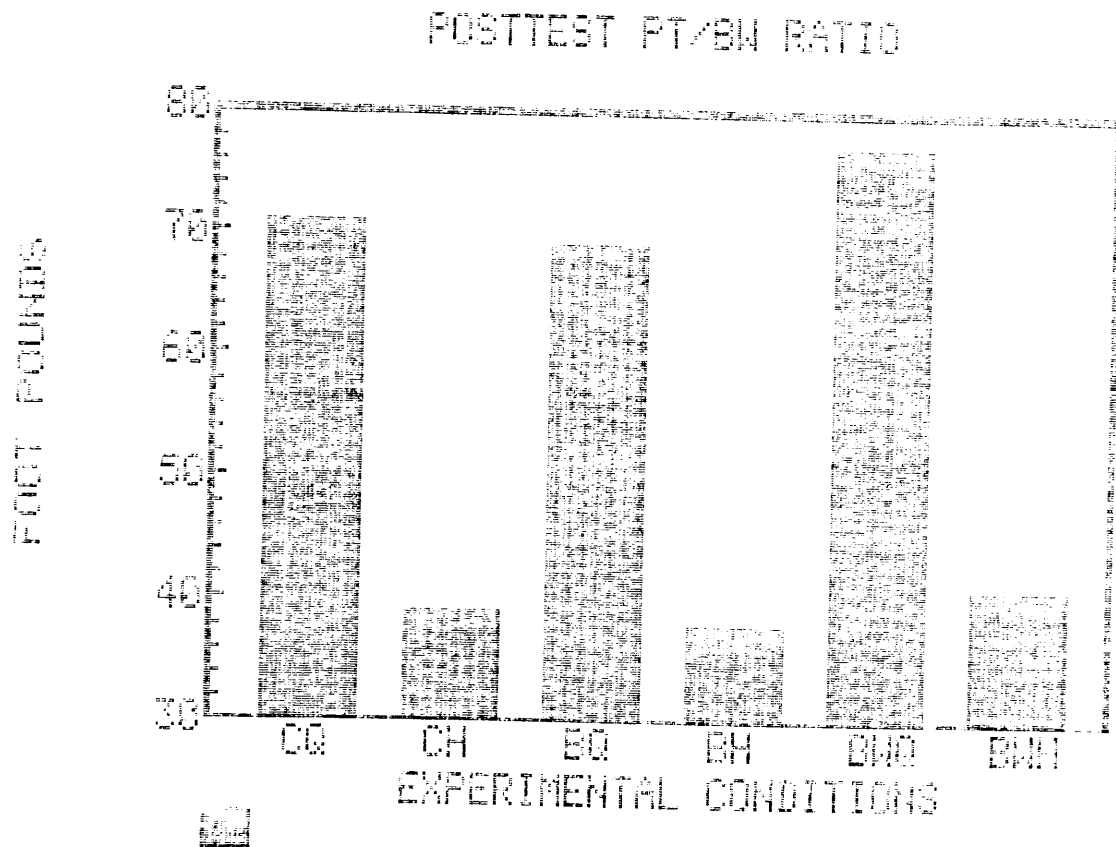


Figure 2. Posttest Means of Peak Torque to Body Weight Ratios

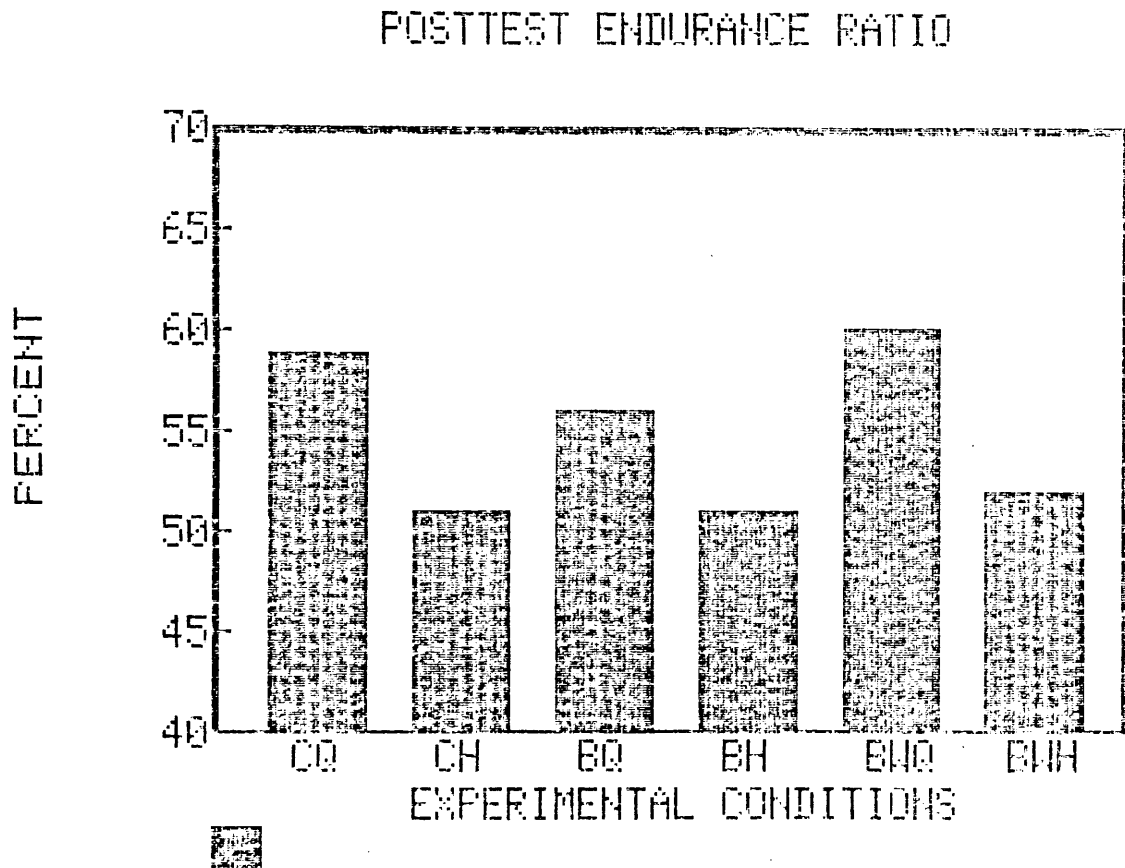


Figure 3. Posttest Means of Muscular Endurance of the Quadriceps and Hamstrings

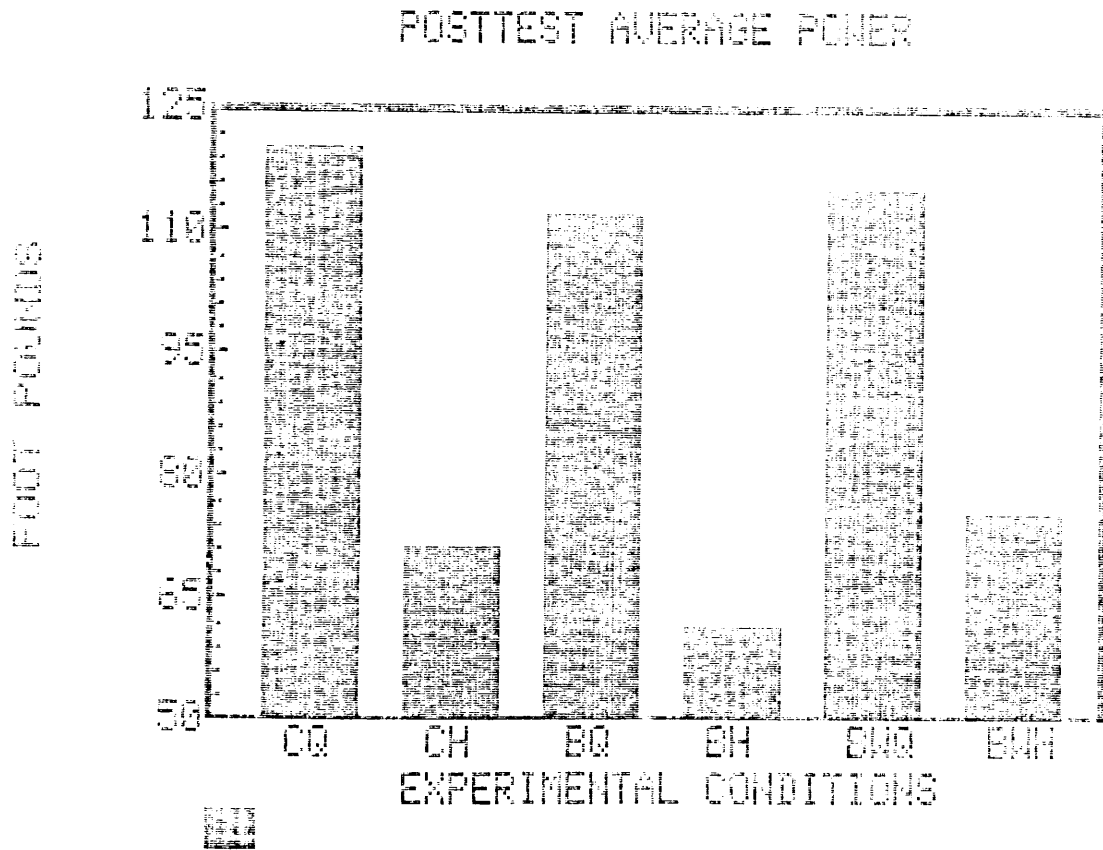


Figure 4. Posttest Means of Average Power of the Quadriceps and Hamstrings

was no significant difference between pretest and posttest strength scores on the leg curl exercise.

Discussion

The results of this study were consistent with those reported by Kirkendal (1984) who investigated peak torque at 45 and 180 deg/sec. He reported nonsignificant increases in peak torque and peak torque to body weight ratio in the quadriceps and the hamstrings at both speeds, but reported greater training responses at the higher velocity. This study investigated peak torque values and peak torque to body weight ratios at 60 deg/sec and demonstrated that ballet training did not enhance strength at this functional velocity. Therefore, it can be concluded that ballet dance alone does not significantly influence the strength of the muscle groups tested.

Another factor that should be considered is peak torque to body weight ratio. It is expected that at lower functional velocities that the quadriceps should exert approximately 100% of the individual's body weight. This study revealed that ratio of the ballet dancers were lower than the normative data described by Davis and agreed upon by Kirkendal (1981) who also reported lower than expected body weight ratios for professional ballet dancers. Kirkendal noted that male dancers of the same company were within the norm. Difference in training between the male and female dancer may explain part of the reported differences.

One factor which attributes to lower torque values is the training practices of the dancers. Dancers perform the same types of exercises daily and the muscles utilized in the technique classes are seldom

stressed with substantive overloads. Therefore, one can expect to observe strength increases proportional to the weight of the limb just as would be observed in the individual who is not participating in ballet. To observe further increases in strength, the muscle must continue to be stressed by an overload. Although the control group was not involved in a training program, each had to maintain sufficient strength in the quadriceps and the hamstrings for daily locomotion. It would follow that significant differences in isokinetic strength were not observed between the control and the ballet group, since the ballet group did not overload the quadricep and hamstring during the experimental sessions more than subjects in the control group.

Average power was influenced by the ballet training, more than peak torque. An increase of 32 watts in quadricep average power was observed in the ballet group and was statistically significant ($p > .05$). Dancers perform many exercises each day that requires fast movements and explosive power; for example, quick beats of the feet in the air and other allegro combinations. Because power is a function of both speed and strength, dance training may influence power training more than strength training.

Isotonic strength changes were observed in the weight training group which indicated the designed training program produced significant isotonic strength gains across the selected muscle groups; however, their strength gains were not sensitive to the isokinetic tests used in this investigation. It would appear as more appropriate to have had the weight training group actually train isokinetically, however, the experimental setting did not allow this to be incorporated into the research design.

It is therefore suggested that individuals participating in a ballet training program and those who are participating in a ballet dance program supplemented with a weight training programs will not experience significant isokinetic strength or muscular endurance changes in an eight week training session.

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CHAPTER IV

Summary of the Study

This study investigated isokinetic strength, power, and muscular endurance changes of ballet dancers who were participating in a ballet dance training program and those who were participating in the same program but also supplemented their dance training with a weight lifting program.

Eighteen female subjects participating in a ballet program at Radford University were randomly divided into two experimental groups: a ballet training group and a ballet and weight training group. Each subject was tested on the Cybex II+ device to determine initial and final measures of peak torque, peak torque to body weight ratios, average power and muscular endurance after an eight week training program. Each subject participated in ballet class at least three times per week and rehearsals, and the weight training group trained three times per week on Universal equipment performing leg press, leg curls, and leg extensions. Nine subjects who were not participating in a regular dance programs were selected as a control group.

Discussion

The results of this study were consistent with those reported by Kirkendal (1984) who investigated peak torque at 45 and 180 degrees. He reported nonsignificant increases in peak torque and peak torque to body weight ratio in the quadriceps and the hamstrings at both speeds, but reported greater training responses at the higher velocity. This study investigated peak torque values and peak torque

to body weight ratios at 30 deg/sec and found that ballet training did not enhance strength at this functional velocity. Therefore, it can be concluded that ballet dance alone does not significantly influence the isokinetic strength of the muscle groups tested.

One factor which attributes to lower torque values is the training practices of the dancers. Dancers perform the same types of exercises daily and the muscles utilized in the technique classes are seldom stressed with substantive overloads. Therefore, one can expect to observe strength increases proportional to the weight of the limb just as would be observed in the average individual who is not participating in ballet. To observe further increases in strength, the muscle must continue to be stressed by an overload. Although the control group was not involved in a training program, each had to maintain sufficient strength in the quadriceps and the hamstrings for daily locomotion. It would follow that significant differences were not observed between the control and the experimental groups, since the ballet group did not overload the quadricep and hamstring during the experimental sessions more than the subjects in the control group.

Isotonic strength changes were observed in the weight training group which indicated the designed training program produced significant isotonic strength gains across the selected strength measures, however, their strength gains did not significantly increase isokinetic strength. It would appear as more appropriate to have had the weight training group actually train isokinetically, however, the

experimental setting did not allow this to be incorporated into the research design.

Another factor that may have influenced the lack of strength gains in the quadriceps and hamstring associated with ballet training was that ballet training utilizes turned out positions. All jumps or leaps are performed in maximal turned out positions. This may alter kinesiological patterns of jumping, leaping, and running. By altering these common movements, other muscle groups not normally stressed may be utilized more. This hypothesis requires further investigation.

Currently accepted dance techniques also teach the dancer to control their ascents and descents, from jumps, leaps, and other movements by cushioning their fall and maintaining a feeling of being lifted throughout their movement. Many dance instructors stress controlling their descent by tightening the abdominal muscles and the gluteus maximum and minimums and by maintaining proper alignment throughout their movement. This enables the dancer to better control their jumps and may actually redistribute the stress usually seen observed in the quadriceps and the hamstring during jumps or leaps.

Average power was also influenced by the ballet training, more than peak torque. An increase of 32 watts in the quadricep average power was observed in the ballet group and was significant ($p > .05$). No significant difference in average power of the hamstrings or quadricep was observed in the ballet and weight training group or the control group. This also can be explained by the type of exercise performed in the dance technique class. Dancers perform many exercises each day that requires fast movements; for example, quick beats of the

feet in the air and other allegro combinations. Because power is a function of both speed and strength, dance training may enhance speed of the movement rather than strength, therefore increasing power.

Several reasons may explain the lack of isokinetic strength power and muscular endurance gains in this investigation. First, this investigation only observed dancers who had previously trained in dance, therefore, muscular function adaptation gains normally observed in dance training would have already existed prior to this study. Another important factor influencing these results was possible due to overtraining. The dancers were complaining of fatigue, and many of the dancers were dancing six to eight hours daily and were following low calorie diets. Weight loss was stressed and many of the subjects lost body weight. If the weight losses were characterized by the loss of lean body mass, strength gains may have been influenced.

Conclusions

Based upon the findings of this study, the following conclusions were made:

1. Traditional ballet technique classes or ballet classes supplemented with isotonic weight training will not produce significant changes in relative or absolute isokinetic strength of the quadriceps or the hamstrings.

2. Traditional ballet technique classes or ballet classes supplemented with isotonic weight training will not produce significant changes in isokinetic muscular endurance of the quadriceps or hamstrings.

3. Traditional ballet technique classes will produce significant changes in isoinetic average power of the quadriceps or the hamstrings.

Recommendations

The following recommendations are made for future investigators:

1. A similar study using higher exercise speeds would allow the comparison of ballet dancers to other athletic populations.

2. A follow-up study investigating quadriceps to hamstring ratios and lean body mass to peak torque would provide additional information regarding the relationship of opposing muscle groups and their role in dance performance.

3. A longitudinal study investigating weight loss, fatigue, and hours of dance training and their relationship to strength, muscular endurance, and power would provide greater insight into its relationship between muscular function and dance.

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APPENDIX A

METHODSSubject Selection

Subjects selected for the experimental groups in this study were females between the ages of 18 and 35 and who had studied ballet for at least 2 years prior to the investigation. After written informed consent (Appendix B) was obtained from all participants, subjects were randomly assigned to experimental groups. The first group, ballet (B), participated in at least three ballet technique classes per week. The second group, weight training (BW), participated in at least three ballet technique classes per week and a twenty minute weight training program conducted three times per week. Members from both experimental groups also participated in out-of-class rehearsals. A third group, control, (C), was used as a control group and consisted of females with similar characteristics and who were not participating in any regular exercise program.

Pretesting Procedures

Initial strength, power, and muscular endurance of knee flexors and extensors were measured using the Cybex II+ isokinetic system (Appendix C). During the isokinetic tests, the subjects were seated and the preferred limb was secured to the input shaft. The axis of the knee was aligned with the dynamometer. The height of the dynamometer, shin pad, and number of cushions required for alignment were recorded and kept constant throughout all experimental testing. Prior to testing, subjects were familiarized with the equipment and were instructed to give maximal

contractions throughout the test. Three practice trials were given before each test. Peak torque was measured at a joint angle velocity of 60 deg/sec and was recorded as the highest score from the three maximal trials. Peak torque to body weight ratio was determined by dividing peak torque by the subject's body weight. Muscular endurance and power were examined at a joint angle velocity of 240 deg/sec. This test consisted of 30 maximal repetitions of knee extension and knee flexion exercises. Endurance was calculated by dividing the total work output from the last six trials by the total work output of the first six trials. Average power was determined by dividing the total work done in the test repetitions by the total contraction time which was computed separately for both flexion and extension.

The ballet and weight training group (BW) were also tested for initial isokinetic strength, power and muscular endurance (Appendix C). In addition, initial isotonic strength measured by one repetition maximums were determined for leg press, leg extension, and leg curls. The subjects started with a submaximal load. The loading was then gradually increased until the subject could only move the weight through the full range of motion one time (1-RM).

Experimental Procedures

Ballet Training. Both experimental groups participated in ballet technique classes. These classes began with barre exercises for 25-30 minutes per class, beginning with demi and grand plies in second, first, fourth, and fifth positions. Battement, tendue, Battement degage, passe, fondu, frappe, rond de jambe, rond de jambe en la aire, adagio combination

and grand battements were performed in succession from fifth and/or first positions. The subjects were instructed to stretch before starting combinations. Each subject performed the stretching exercises involving the quadriceps, hamstrings, abductor and adductors, and achilles tendon. Both adagio and allegro combinations were performed and practiced for 40-50 minutes each day.

Fourteen of the subjects also participated in rehearsals (Appendix D) for all productions, which included "The Nutcracker," "Hair," and various performances for a contemporary Jazz dance company. This required extra out-of-class rehearsals. Group rehearsal began with a structured 15-20 minute warm-up at the barre. Rehearsals for soloist and duets were individualized. Other rehearsals were held directly after class. Warm-ups included: plies, battement tendues, and stretching. Rehearsal time for each subject varied in intensity depending upon the specific choreography and purpose for the rehearsal.

Weight training. In addition to the ballet training as described above, the BW group was required to perform the following weight training exercises: leg extension, leg curls, and leg press. The weight training sessions were scheduled three days per week. The weight program was designed to increase strength, power, and anaerobic endurance, and consisted of three different phases. The first phase, hypertrophy, lasted for two weeks. The loadings for the weight training exercises ranged from .65 to .75 of the subject's initial 1-RM. Three sets of 8-12 repetitions were performed each training day. The second phase, basic strength, lasted for three weeks. The loadings ranged from .75 to .85 of the subject's new 1-RM which was recalculated upon completion of the

hypertrophy phase. Three sets of 4-6 repetitions were performed during each scheduled workout. (Stone, et al., 1982). The program was modified during the last two weeks because the dancers were unable to complete the required repetitions. Weight loadings were decreased. The third phase, strength and power, lasted three weeks. The loadings ranged from .85 to .91% of the subject's recalculated 1-RM. Three sets of 2 to 3 repetitions were performed during each workout.

Design

The research design used by the investigator was a multifactor randomized control-group repeated measures paradigm (Van Dalen, 1979). Prior to the experimental treatment, initial isokinetic strength, power, and endurance was recorded for all subjects across the three experimental conditions. Pretest measures of isotonic leg strength were also recorded for the weight training group.

Upon completion of all pretesting, the two experimental groups, (B) and (BW), received their assigned treatments. The control group, (C), did not participate in any structured physical activity between the pretest and posttest. After the completion of the eight week experimental training period, all subjects were posttested on the experimental variables. Between and within group comparisons were made for all dependent variables.

Statistical Analysis

A nonparametric Kruskal-Wallis test was used by the investigator to determine if initial differences existed between experimental groups in isokinetic strength, power, and muscular endurance (Appendix E). The same

statistical procedure was then used to test the research hypothesis of no significant difference between the experimental conditions on the posttest scores of all dependent variables (Appendix E).

Analysis of Variance (Wilcoxon) was then performed to determine the within group difference between pretest and posttest measures of isokinetic strength, power, and muscular endurance (Appendix E). The Wilcoxon procedure was also used to determine if there was a significant difference from pretest to posttest within the BW group in isotonic strength. Reliability estimates for experimental tests also appear in Appendix E.

APPENDIX B

5

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Informed Consent

I, _____, do hereby voluntarily agree and consent to participate in a testing program conducted by Shira Caldwell Hedgepeth for her master's thesis project for the Division of Health, Physical Education, and Recreation of Virginia Polytechnic Institute and State University.

The purposes of this test include: to measure peak torque, work, power, and endurance of the knee flexion/extensions of female dancers who are participating in ballet technique classes regularly and of those who are supplementing their training with a weight training program. I voluntarily agree to participate in this testing program. It is my understanding that my participation will include:

1. Cybex isokinetic knee extension/flexion and plantar-dorsal flexion strength, power, and endurance test.
2. Test speeds include 60 deg/sec @ 3 reps; 240 deg/sec @ 3 reps; and, endurance 30 reps.
3. Tests were given on preferred limb.

I understand that participation in this experiment may produce certain discomforts and risks. These risks include: possible muscular fatigue; strain, local delayed muscle soreness; elevated systolic blood pressure.

Certain personal benefits may be expected from participation in this experiment. These include:

1. Diagnostic evaluation of knee flexors and extensors and plantar-dorsal flexion.
2. Opposing muscle group ratios will be calculated. Subject data will be applied to normative data.

Date _____

Signed _____

Witness _____

APPENDIX C

Table 1

One Repetition Maximums for the
Weight Training Group

Subject	Pretest			Posttest		
	Leg Press	Knee Extensions	Leg Curl	Leg Press	Knee Extensions	Leg Curl
1	240	50	50	435	80	60
2	165	30	60	290	90	50
3	240	70	40	435	90	55
4	165	60	20	310	100	43
5	165	80	45	360	105	55
6	190	110	50	290	100	55
7	190	40	40	410	80	55
8	165	20	20	410	60	28
9	140	45	40	310	60	43

Table 2

Pretest and Posttest Isokinetic Measurements

S	G	Pretest									Posttest							
		PTQ	PTH	BWQ	BWH	EQ	EH	PQ	PH	PTQ	PHQ	BWQ	BWH	EQ	EH	PQ	PH	
1	B	101	53	72	39	.	86	44	83	53	61	61	39	.	.	114	35	
2	B	80	45	80	41	56	62	105	65	91	45	83	41	59	62	121	75	
3	B	50	30	54	33	.	.	.	.	51	34	57	38	67	54	70	55
4	B	57	25	56	25	.	96	72	34	78	38	76	37	56	57	100	60	
5	B	105	57	87	47	49	47	108	79	82	47	64	37	75	57	126	52	
6	B	88	31	62	22	38	91	85	39	111	53	76	36	63	73	154	112	
7	B	70	46	67	44	58	85	31	36	63	42	62	42	55	58	84	63	
8	B	51	47	42	39	88	44	78	50	71	41	62	36	77	68	120	48	
9	B	84	36	75	32	92	.	74	69	88	38	79	34	63	58	120	52	
1	BW	93	49	97	58	45	50	94	89	96	49	93	48	51	43	106	86	
2	BW	78	45	62	43	64	44	131	84	99	54	79	43	79	81	145	118	
3	BW	94	46	75	36	56	52	126	88	98	59	80	48	64	54	139	86	
4	BW	66	31	61	37	84	61	70	34	88	40	78	35	64	46	104	56	
5	BW	73	30	57	29	62	41	109	46	85	41	72	35	60	48	113	65	
6	BW	79	32	72	24	65	64	66	37	79	37	72	34	57	37	80	42	
7	BW	113	57	80	29	80	72	126	65	101	58	73	42	88	77	141	78	
8	BW	113	64	79	40	50	48	130	92	108	70	75	49	59	53	136	95	
9	BW	57	27	55	45	55	45	69	39	66	32	67	33	45	46	73	45	
1	C	64	33	55	28	64	49	104	46	68	36	59	31	62	42	101	42	
2	C	88	38	70	30	61	55	94	69	71	45	55	35	69	38	81	62	
3	C	98	43	68	30	.	.	71	48	99	50	68	34	50	44	109	68	
4	C	60	42	54	38	.	85	77	49	75	47	65	41	74	59	80	62	
5	C	92	43	73	34	53	58	103	71	107	57	88	47	59	56	133	102	
6	C	109	48	81	36	63	54	99	51	94	42	71	32	.	0	128	30	
7	C	92	50	59	32	46	50	120	93	105	58	66	37	63	78	141	89	
8	C	100	66	30	49	49	62	189	138	150	76	107	51	46	44	193	107	
9	C	84	46	52	28	56	65	105	59	99	59	60	36	61	44	118	71	

S = Subject; G = Group (C = control, B = Ballet, BW = Ballet and weight training; PTQ = peak torque quadriceps, PTH = peak torque hamstrings; WQ = peak torque to body weight ratio quadriceps; WH = peak torque to body weight ratio hamstrings; EQ = endurance ratio quadriceps; EH = endurance ratio hamstrings

APPENDIX D

Table 3

Training Activities of the Two Experimental Groups

Subject	Condition	Classes/Hours	Rehearsal Parts	Hours
1	B	ballet, modern 7	Snow, Waltz	9
2	B	ballet 4		0
3	B	ballet 4	Snow, Flower, Chinese	9
4	B	ballet 4		0
5	B	ballet, jazz 8	Parents, Snow, Flowers	9
6	B	ballet 4	Parents, Spanish, Flowers, Snow	9
7	B	ballet, modern 8		0
8	B	ballet 7	Party scene, Spanish, Waltz, Snow, Jazz Company	12
9	B	ballet, 4	Snow	9
10	BW	ballet, modern 7	Maid, Waltz	9
11	BW	ballet, jazz 7	Snow, Flowers	9
12	BW	ballet, jazz 7	Dolls, Waltz (lead), Snow, Jazz Company	12
13	BW	ballet, jazz 7		0
14	BW	ballet, modern 7	Snow, Waltz, Chinese	
15	BW	ballet, modern 7	(Four weeks only) Hair	12
16	BW	ballet, modern 9	Snow, Waltz, Spanish, Parents, Jazz Company, Hair (12 four weeks)	12
17	BW	ballet, modern 7	Waltz, Dolls, Snow, Jazz Company	12
18	BW	ballet, modern 9	Clara	9

B = Ballet

BW = Ballet and weight training

APPENDIX E

Table 4

Mean and Standard Deviations of Pre and Post Isotonic Measurements of the Ballet and Weight Training

Strength Variable	Pretest		Posttest	
	\bar{X}	(S)	\bar{X}	(S)
Leg Press	184.446	34.86	347.22	87.51
Leg Curls	40.56	13.333	49.156	10.0861
Leg Extensions	56.11	27.59	86.11	17.28

Table 5

Mean and Standard Deviations of Pre and Post Isokinetic Measurements

Variable	Group	Pre		Post					
		Quadricep \bar{X}	Hamstring (SD)	Quadricep \bar{X}	Hamstring (SD)				
Peak Torque	C	87.4	16.16	45.44	9.248	96.4	24.97	52.22	11.829
	B	77.1	20.93	40.00	11.005	79.78	17.24	44.20	6.1968
	BW	85.33	19.41	43.875	13.097	91.11	12.94	49.875	12.84
Peak Torque to Body Weight	C	60.22	14.99	34.1	6.29	71.0	16.49	38.50	7.25
	B	67.11	14.48	34.67	8.32	69.22	9.25	37.78	2.5
	BW	70.89	13.59	36.0	10.75	76.56	7.4012	40.78	6.629
Endurance	C	54.67	6.653	59.625	11.526	58.875	9.963	50.625	13.1686
	B	61.857	17.324	70.83	22.834	65.89	12.1906	60.875	6.468
	BW	63.67	15.37	53.00	10.4283	60.22	9.47	52.556	13.2581
Average Power	C	107.0	34.19	70.44	29.146	120.44	34.656	70.778	25.14
	B	79.88	23.82	50.75	18.56	112.11	24.65	61.33	21.92
	BW	102.33	28.057	65.11	25.30	114.89	26.4975	74.56	24.87

Table 6

Kruskal Wallis Test of Pretest
Quadriceps Scores

Strength Variable	Group	N	Sum of Scores	DF	X ²	Prob.
Peak Torque	C	9	143.50	2	1.63	.4416
	B	9	102.00	2		
	BW	9	132.50	2		
Peak Torque to Body Weight Rate	C	8	108.00	2	1.38	.5009
	B	9	121.50	2		
	BW	9	121.50	2		
Endurance Ratio	C	7	69.00	2	.72	.6967
	B	6	70.50	2		
	BW	9	113.50	2		
Average Power	C	9	144.00	2	3.53	.1714
	B	8	89.50	2		
	BW	9	144.50	2		

C = Control

B = Ballet

BW = Ballet and weight training group

Table 7

Kruskal Wallis Test of Pretest
Hamstrings Scores

Strength Variable	Group	N	Sum of Scores	DF	X ²	Prob.
Peak Torque	C	9	114.00	2	.53	0.7656
	B	9	117.00	2		
	BW	9	121.00	2		
Peak Torque to Body Weight	C	9	119.00	2	.13	0.9355
	B	9	130.50	2		
	BW	9	128.50	2		
Endurance	C	8	105.50	2	2.87	0.2381
	B	6	88.52	2		
	BW	9	82.00	2		
Average Power	C	9	143.00	2	2.86	0.2390
	B	8	78.50	2		
	BW	9	129.50	2		

C = Control

B = Ballet

BW = Ballet and weight training group

Table 8

Kruskal Wallis Test of Quadriceps
Posttest Scores

Strength Variable	Group	N	Sum of Scores	DF	X ²	Prob.
Peak Torque	C	9	146.50	2	3.11	0.2115
	B	9	92.00	2		
	BW	9	139.50	2		
Peak Torque to Body Weight	C	9	104.00	2	3.76	0.1524
	B	9	110.50	2		
	BW	9	163.50	2		
Endurance	C	9	106.00	2	.74	0.6903
	B	8	118.50	2		
	BW	9	126.50	2		
Average Power	C	9	131.00	2	.14	0.9335
	B	9	119.00	2		
	BW	9	128.00	2		

C = Control

B = Ballet

BW = Ballet and weight training group

Table 9

Kruskal Wallis Test of Hamstrings
Posttest Scores

Strength Variable	Group	N	Sum of Scores	DF	X ²	Prob.
Peak Torque	C	9	152.50	2	2.85	0.2400
	B	9	96.00	2		
	BW	9	129.50	2		
Peak Torque to Body Weight	C	9	109.50	2	.91	0.6342
	B	9	127.00	2		
	BW	9	141.50	2		
Endurance	C	8	80.00	2	5.44	0.0659
	B	8	143.50	2		
	BW	9	80.00	2		
Average Power	C	9	109.50	2	1.64	0.4394
	B	8	100.00	2		
	BW	9	141.50	2		

C = Control
 B = Ballet
 BW = Ballet and weight training group

Table 10

Wilcoxon Pre and Post Comparisons
of the Quadriceps

Strength Variable	Group	Pretest Sum of Scores	Posttest Sum of Scores	DF	X ²	Prob.
Peak Torque	C	75.00	96.00	1	.86	0.3533
	B	83.50	87.50	1	.03	0.8595
	BW	75.50	95.50	1	.78	0.3767
Peak Torque to Body Weight	C	72.50	98.50	1	1.32	0.2503
	B	80.00	91.00	1	0.24	0.6256
	BW	74.50	96.50	1	0.95	0.3296
Endurance	C	39.00	66.00	1	0.61	0.4366
	B	55.00	81.00	1	0.23	0.6333
	BW	88.50	82.50	1	0.07	0.7906
Average Power	C	71.50	99.50	1	1.53	0.2161
	B	49.00	104.00	1	4.90	0.0268
	BW	71.00	100.00	1	1.64	0.2002

C = Control
 B = Ballet
 BW = Ballet and weight training group

Table 11

Wilcoxon Pre and Post Comparisons of Hamstrings

Strength Variable	Group	Pretest Sum of Scores	Posttest Sum of Scores	DF	X ²	Prob.
Peak Torque	C	71.00	100.00	1	1.64	0.1997
	B	96.00	117.00	1	.83	0.3629
	BW	58.00	78.00	1	1.11	0.2929
Peak Torque to Body Weight	C	79.00	92.00	1	2.03	0.1541
	B	76.00	95.00	1	.71	0.4001
	BW	72.00	99.00	1	1.43	0.2325
Endurance	C	84.00	52.00	1	2.84	0.0919
	B	50.50	54.50	1	.51	0.4762
	BW	56.50	84.50	1	.01	0.9296
Average Power	C	81.00	90.00	1	.61	0.6906
	B	62.00	91.00	1	.93	0.3356
	BW	77.00	94.00	1	.56	0.4527

C = Control

B = Ballet

BW = Ballet and weight training group

Table 12

Wilcoxon Pre and Post Comparisons of
1-RM of the Weight Training Group

Strength Variable	Pretest Sum of Scores	Posttest Sum of Scores	DF	X ²	Prob.
Leg Curls	66.50	104.50	1	2.87	0.09
Leg Press	45.0	126.00	1	13.03	0.0003
Knee Extension	60.00	111.00	1	5.13	0.0235

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