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Cross Educaiton Effect of Delorme Progressive Resistance Exercise on Quadriceps Femoris

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CROSS EDUCATION EFFECT OF DELORME PROGRESSIVE RESISTANCE EXERCISE ON QUADRICEPS FEMORIS

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This Thesis submitted by Thomas E. McDonald in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This project was conducted in order to determine if strengthening the knee extensors of one leg using dynamic contractions would result in an increase in the knee extensors of the opposite (contralateral) leg.

The experiment consisted of a pretest to determine the maximum amount of weight that could be lifted by each leg for all subjects. The preferred leg of each subject was then subjected to a five-week progressive resistance exercise program conducted on a daily basis. A post-test was then given in a similar manner to the pretest.

The participants were fourteen University of North Dakota Junior Physical Therapy students.

A "t" test was applied to the data to determine if a significant difference existed between means of the pretest and post-test for the nonexercised leg. This "t" test yielded significance at the .01 level. The nonexercised limb showed a mean increase of 4.64 pounds while the exercised limb showed a mean increase of 14.28 pounds.

CHAPTER I

INTRODUCTION

This project has implications for two fields; namely, Health, Physical Education and Recreation, and Physical Medicine and Rehabilitation. In the former, these implications deal particularly in the area of Adapted Physical Education. Disagreement in the literature concerning the phenomenon of cross education helped stimulate this writer's curiosity in this area of exercise.

Rose, Radzyminski and Beatty (1) used the quadriceps femoris for knee extension. Their subjects performed a single dynamic contraction from 90 degrees of knee flexion to 180 degrees of knee extension and held at 180 degrees for five seconds. It was determined that the strength of the nonexercised quadriceps increased almost exactly the same as in the exercised leg. It was interesting to note that their evidence showed that the cross education effect was nullified when the extremity was prevented from developing the normal proprioceptive feedback to the central nervous system by immobilization of the part.

Panin, _et al._ (2) used the quadriceps as well as other muscles in their research into cross education. They did not test for strength per se. Instead, a particular muscle or muscle group was exercised in order to obtain electromyographic potentials. For instance, the quadriceps exercise consisted of extending the knee from 90 degrees flexion. The first repetition was against gravity alone. Dynamic extension was then repeated three more times with loads of 10, 20, and 30 pounds, followed by a static contraction with the knee flexed at 90 degrees. The limit of 30 pounds for the quadriceps was found to be the maximum which could be lifted without gross compensatory movements in other parts of the body.

It was shown that the contralateral quadriceps did not show the highest amplitude of all the nonexercised muscles. In fact, the potentials registered from the nonexercised quadriceps were never greater than twenty per cent of the amplitude of the potentials in the exercised knee extensors. The investigators felt this would not be enough to cause an increase in strength in the nonexercised limb.

In his study on the bilateral effects of unilateral exercise, Coleman (3) tested twenty-one college males before and after twelve weeks of strength training. Dynamic strength was determined as the maximum amount of weight that could be lifted one time. The training sessions involved two sets of five forearm flexions with a weight that could be lifted only five times. When a subject was able to perform more than five repetitions, more weight was added in 2½ pound increments. A "t" test for the difference between means of the pretest and post-test yielded significance for both exercised and nonexercised limbs.

Kruse and Mathews (4), on the other hand, found no statistically significant increase in strength and endurance of the contralateral muscles of sixty male college students who performed ergometric exercises of the left forearm flexors for four weeks.

In another project utilizing electromyography, Gregg, Mastellone and Gersten (5) employed twenty healthy adult subjects for an experiment on the biceps brachii muscle.

The exercise procedure consisted in having each subject complete four cycles of right elbow dynamic flexion and extension. Each cycle consisted of four bouts of three repetitions each, using no weight, 10 pounds, 20 pounds, and static contractions against a supermaximal load.

They reported that electromyographic evidence of overflow to the nonexercised contralateral muscle was not observed during simple, non-resistive exercise. Left biceps activity appeared only when exercise stress was severe. This was first observed in the third cycle, third exercise bout (20 pound load). Positioning of the contralateral non-exercised arm and stabilizing the body with straps did not influence the appearance or distribution of the overflow.

It was interesting to note that the above-mentioned investigators found no evidence of overflow to the contralateral limb during static or so-called "isometric" contraction of the biceps brachii. Also, there was a complete disappearance of contralateral overflow when the exercising limb changed from isotonic to static contractions.

In regard to the preceding reference, the term overflow should not be confused with cross education. As used above, overflow refers to electromyographic evidence of action potentials in the contralateral limb, whereas cross education refers specifically to evidence of strength increase in a contralateral limb. Overflow of action potentials would be necessary, however, for an increase in strength to occur.

Using manual exercise as opposed to weights, Wellock (6) performed manual exercise for the right knee flexors of twenty Physical Therapy students at Northwestern University Medical School. The subjects were exercised in the prone position with ten repetitions at each of thirty-six exercise periods. Testing was accomplished with a cable tensiometer. In this experiment the contralateral knee flexors showed an increase in strength. The increase was found to be of practical significance (an increase of 24 per cent) but was not statistically significant.

In their experiment employing a progressive resistance exercise program for knee extensors, Logan and Lockhart (7) used a spring device designed to apply the greatest resistance at 115 degrees. This caused the greatest increase in strength of the exercised knee extensors at that specific angle. The strength gain in the nonexercised knee was not at one specific angle. It was theorized that this was probably a result of irradiation of impulses causing a diffused contralateral transfer. The conclusion reached was that specific strengthening at one angle results in a gross, nonspecific transfer to the contralateral knee extensors.

The Problem

As was seen in the preceding review of literature, there exists some disagreement in regard to the presence of the phenomenon of cross-education. Research in this area has been going on for several decades, seemingly without accord being reached. The literature cites studies involving both dynamic and static exercise as they relate to cross education. This investigator wished to make a determination for himself regarding cross education since the writer's experience as a physical therapist has involved dynamic exercise primarily. This study was undertaken using that particular mode of exercise. Perhaps the use of cross education could add a new dimension to the traditional regimens of therapeutic exercise now being utilized by physical therapists.

The specific problem was to determine the effect of cross education on the quadriceps femoris muscle group subjected to a five-week progressive resistance exercise program.

A pretest and post-test were required for this problem in order to determine whether a difference existed between strengths before and after the experiment.

The study was delimited to junior students majoring in Physical Therapy at the University of North Dakota. Further delimitation was made regarding the type of strengthening program utilized. Specifically, this was a progressive resistance exercise program which involved the use of the ten-repetition-maximum popularized by DeLorme (8,9) twenty-five years ago.

The ten-repetition-maximum for this experiment was defined as the maximum amount of dead weight that could be lifted ten times using dynamic rhythmic contractions.

Strength as used here was defined as the ability to perform dynamic exercise against gradually increasing resistance.

The term cross education was defined as a strength increase which occurred in a nonexercised (contralateral) limb as a result of strengthening the opposite limb.

Progressive resistance exercise was described as a strengthening program in which the subject had to perform against gradually increasing resistance at each exercise session.

This study was limited in terms of time to five weeks. Also, the investigator was unable to be in attendance during the daily exercise sessions. A third limitation was the subjective element introduced in establishing a true ten-repetition-maximum.

CHAPTER II

METHODOLOGY

A nonprobability sample of fourteen junior students at the University of North Dakota were selected as subjects for this investigation.

Test Procedure

The purpose of the test was to measure the strength of the quadriceps femoris muscle group by reason of the DeLorme method of progressive resistance exercise.

A pretest was conducted on Wednesday, September 22, and Friday, September 24. The test consisted of establishing a ten-repetition-maximum resistance for the quadriceps femoris bilaterally. The weight was lifted slowly enough and returned so that a pendulum effect was avoided. One lift and return then lasted approximately three seconds. The ten-repetition-maximum was established in trial-and-error fashion with about four trials necessary for each subject. A ten-repetition-maximum was established for both knee extensor muscle groups for each subject.

This procedure was repeated five weeks after the pretest, on November 1.

Experimental Procedure

Following the pretest the subjects were instructed to exercise only one leg for five weeks on a daily basis. The daily exercise bouts followed the progressive resistance exercise routine originally established by DeLorme (8,9) and used since by physical therapists throughout the country. This consisted of performing ten repetitions with one-half the originally established ten-repetition-maximum resistance, then ten repetitions with three-fourths that amount, and finally, ten repetitions with the full ten-repetition-maximum resistance. The rest period between sets of repetitions was just long enough to permit changing of the weights.

The subjects were instructed to attempt to increase their ten-repetition-maximum resistance as their strength increased. The subjects also attempted, as much as their class schedules would allow, to perform their daily training bouts at the same time each day. This helped to eliminate variability due to the effects of fatigue which would have been a factor had a subject exercised early one morning and not until the evening the next day.

A score card was prepared which contained the following information: subject's name, age, date and initial (pretest) results for the exercised and nonexercised limb, and date and results of ten-repetition-maximum resistance for the exercised and nonexercised limb following the five-week training period. Also, there were dated boxes in which to write the weight lifted each day with the exercised limb.

The exercise apparatus employed for the experiment was a heavy-duty model N-K Exercise Unit manufactured by N-K Products Company of Santa Cruz, California, and sold through the J. A. Preston Corporation of New York, New York. This exercise table was specifically designed for giving progressive resistance exercise to the quadriceps or hamstring muscles and has been used by this investigator for approximately three years.

This unit was available at the time this study was conducted and so the lower extremity was chosen. Also, in the writer's own experience, most extremity strengthening programs have involved the lower extremity and specifically either the hip musculature or the quadriceps femoris.

The N-K Unit provided objective measurement of the amount of weight lifted through the use of marked weights which were interchangeable on the unit's weight arm. This weight arm was adjusted so that the starting point for the exercise was at 90 degrees of knee flexion. Full knee extension was the end point for the range of motion.

The subjects were oriented to the operation of the N-K Exercise Unit at the time of the pretest. There were no apparent problems encountered by the subjects who usually performed their daily training bouts in pairs.

Instruction in the concept and principles of progressive resistance exercise was also given to the subjects. It was of utmost importance that they understood these principles as well as the mechanics of operating the N-K Unit since each subject was responsible for carrying out his daily training bouts.

In order to insure standardization of the training bouts, further instructions were given regarding the position of the subjects on the exercise table. They were instructed to grasp the back edge of the table with their hands and to lean back on their hands. This position is shown in Figures I and II.

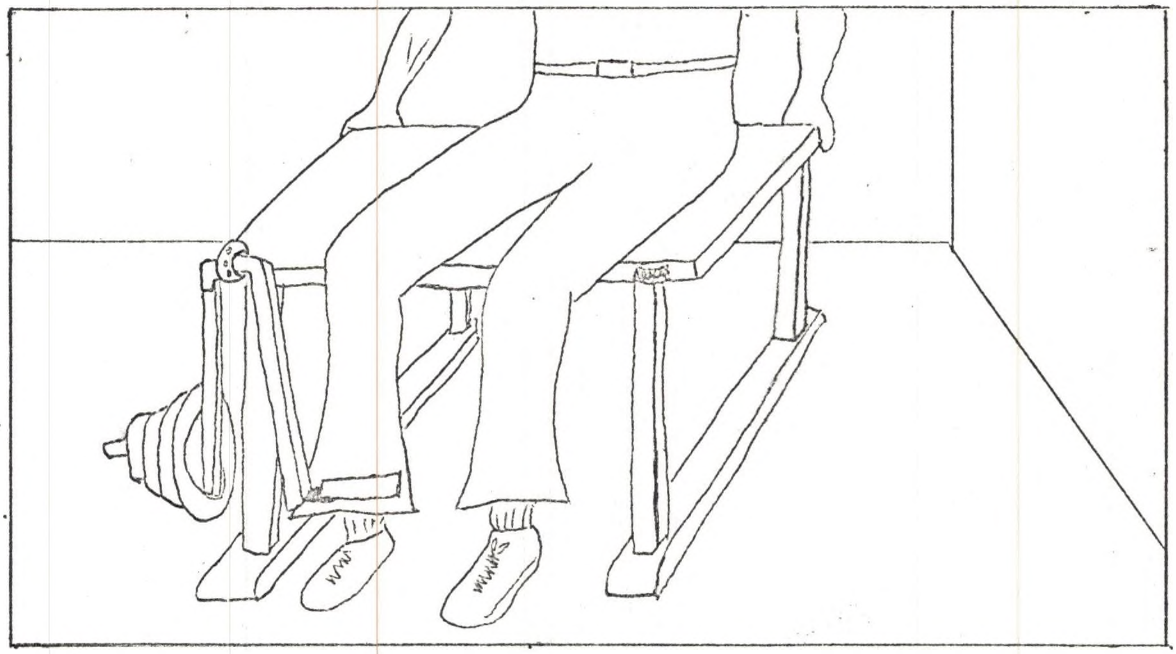

Figure 1. Starting Position for Dynamic Contraction of Quadriceps Femoris.

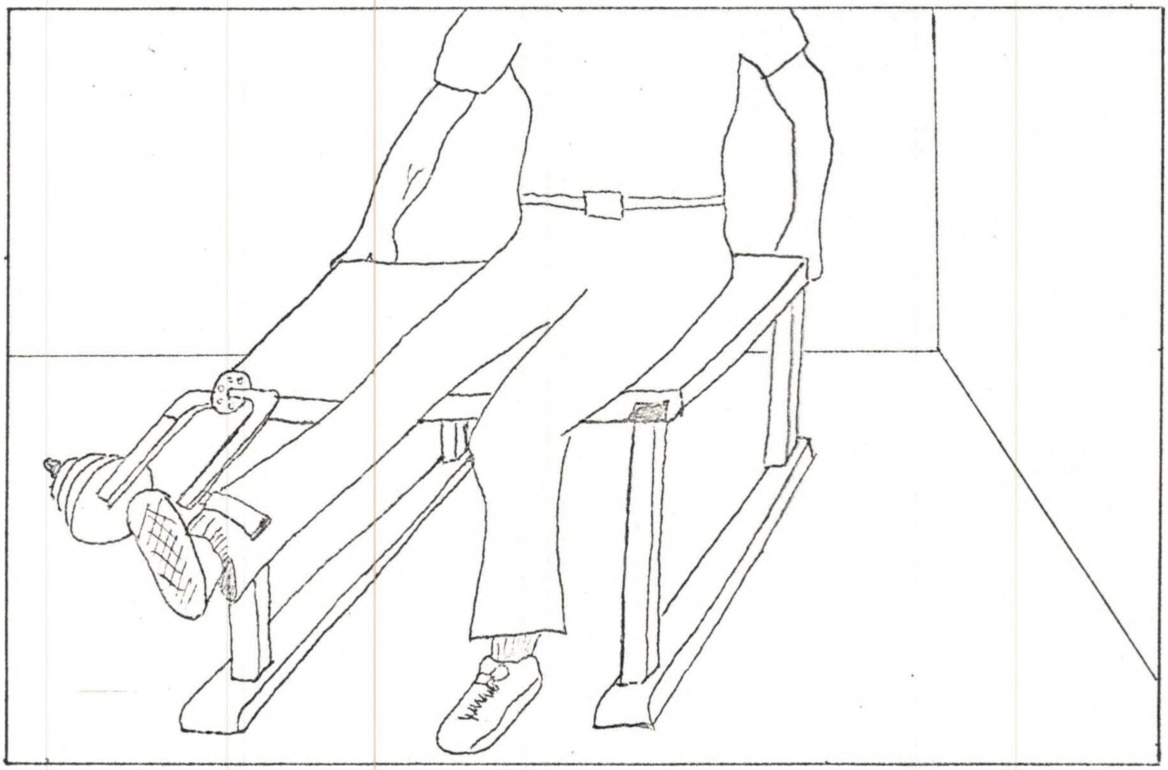

Figure 2. Full Extension of Knee During Dynamic Contraction of Quadriceps Femoris.

Experimental Design

A single group, nonprobability sample was employed in this study. The subjects were selected for convenience. A single group design seemed appropriate since this is the design of choice for an experiment involving a pretest, treatment for a specific period of time, and then a post-test. This design provided for each subject being his own control.

The data which were analyzed were the differences between the pretest and post-test scores. The type of data employed in this study were continuous. The unit of measurement was the dead-weight-pound.

It should be noted here that supplemental data were collected for the exercised limb merely for purposes of comparison. These data were not tested for significance.

A "t" test was applied to the data for the nonexercised limbs to determine the significance of the difference between means of the pretest and post-test. Significance was tested at the .01 level.

The following hypothesese were established:

H_o There was no difference between means of the pretest and post-test for the nonexercised limb.

H_1 There was a difference between the means of the pretest and post-test for the nonexercised limb.

CHAPTER III

ANALYSIS OF THE DATA

Results

The mean ten-repetition-maximum resistance for the pretest for the nonexercised limb was 45.89 pounds. The mean ten-repetition-maximum resistance for the post-test of the nonexercised limb was 50.53 pounds. The mean difference of 4.64 pounds, obtained after five weeks of resistance training on the preferred limb, was significant at the .01 level with thirteen degrees of freedom. Therefore, the null hypothesis was rejected.

The pretest and post-test resistance values for both limbs and the "t" value for the nonexercised limbs are shown in Table I, Page 13.

TABLE 1

INITIAL AND FINAL VALUES FOR TEN-REPETITION-MAXIMUM RESISTANCE FOR NONEXERCISED AND EXERCISED LIMBS WITH MEAN INCREASES AND "t" VALUE

SUBJECT	[a]NONEXERCISED LIMB PRETEST	[a]NONEXERCISED LIMB POST-TEST	[b]EXERCISED LIMB PRETEST	[b]EXERCISED LIMB POST-TEST
1	50	55	45	65
2	40	32.5	35	40
3	32.5	40	32.5	40
4	55	65	60	75
5	40	42.5	45	55
6	30	35	30	40
7	32.5	35	27.5	40
8	35	40	35	50
9	37.5	42.5	35	55
10	75	80	72.5	90
11	40	45	45	55
12	35	40	30	40
13	75	80	72.5	90
14	75	75	70	100

[a]Mean Increase for Non-exercised Limb = 4.64 Pounds

[b]Mean Increase for Exercised Limb = 14.28 Pounds

"t" Value = 7.320
Critical Value at .01 with 13 Degrees of Freedom = 3.012

CHAPTER IV

DISCUSSION

All subjects, except one, demonstrated an increase in the ten-repetition-maximum resistance they were able to lift with their nonexercised limb.

By observing the subjects during the pretest and post-test procedures, it was evident that they were indeed exerting considerable effort. In most cases, as the ten-repetition-maximum resistance was approached, they were seemingly using every muscle in their bodies to perform a single knee extension. But the question arises; did they try harder on the post-test than on the pretest? This question of putting forth effort represents a variable which would seem difficult to measure. Undoubtedly, some of the subjects did try harder on the post-test since the post-test gave them an opportunity to "have another chance to show what I can do."

In a pilot study conducted six months prior to this project, the mean increase in the nonexercised limb was shown to be approximately twice the value obtained in this project. It was of interest to the writer that the subjects in the pilot study knew the purpose of the study, whereas the subjects for this investigation were not given information regarding the purpose. This would seem to indicate that the results of the pilot study could have been biased by the subjects' knowledge of the purpose.

In her work in the area of cross education, Hellebrandt (10,11) alluded to the general agreement that the bulk of fibers which comprise the corticospinal tract (motor nerves) crossed over into the opposite lateral funiculus at the pyramidal decussation in the medulla oblongata. Therefore, the motor area of one side of the brain was primarily responsible for the innervation of muscles occupying the opposite half of the body. However, some of these fibers did not cross until they were farther down the spinal cord. Hellebrandt attributed a cross education effect to the possibility that the cascade of impulses descending from the motorcortex never flows exclusively to the lower motor neuron of one side. This could be a neurological pathway to explain the cross education phenomenon.

Hellebrandt (10,11) also observed that when a large quantity of energy was released, as in maximum volitional effort against maximal resistance, copying movements tended to occur in the so-called resting (contralateral) limb. These copying movements had a large tonic component. During severe exercise all four extremities participated in what initially was an exercise limited to the musculature of a single joint.

As was mentioned previously, participation of the entire body musculature was readily apparent in the subjects for this project. This was especially observed as the subjects reached their maximal output in terms of extending the exercised limb. Perhaps this so-called overflow of irradiation of impulses could be partially responsible for cross education. The writer, on many occasions, has observed the irradiation of impulses in the practice of Physical

Therapy. In applying strong resistance to strengthen a wrist, for example, the entire upper extremity could be seen to take part in the exercise as more motor units were recruited due to the increasing resistance.

Whether or not the bilateral course of efferent impulses from the motor cortex down the corticospinal tract could cause a training effect in an nonexercised limb resulting in cross education remains questionable to this investigator.

The possibility that the subjects put forth a greater effort on the post-test must also be considered as an explanation for the highly significant increase in the nonexercised limb. In this regard objectivity was a problem. The amount of weight on the exercise unit during an exercise bout was easily identified since the weights were stamped with the poundage. However, determining the exact ten-repetition-maximum with the variables of number of trials and fatigue and duplicating this for the post-test seemed to introduce a subjective element into the test procedure.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

University of North Dakota Junior Physical Therapy students were tested to determine the maximum amount of weight they could lift ten times with their knee extensors. When this determination was made for both lower extremities, the preferred limb was then subjected to a five-week progressive resistance exercise program. At the conclusion of the exercise program, which was performed daily, except for weekends, the nonexercised limb was given a post-test to determine if an increase in strength occurred. The exercised limb was also given a post-test.

Conclusions

On the basis of the results obtained from the post-test for this project and the analysis of those results, it was concluded that:

1. a significant increase in strength of the nonexercised limb occurred,

2. this increase was approximately one-third the increase of the exercised limb.

Recommendations

In regard to the results and conclusions of this project, the following recommendations appear feasible:

1. A follow-up project to this study should be carried out with perhaps more rigid controls applied to the testing procedure.

2. A similar project could be designed to test for cross education in the area of endurance training.

3. It would be interesting to retest the subjects of the study just completed after a specified length of time to determine the length of time the cross education effect persists.

4. The study should be repeated by varying such things as sample size, length of training sessions, and number of training bouts each week.

APPENDICES

APPENDIX A

TABLE 2

CALCULATION OF "t" TEST

SUBJECT	PRETEST	POST-TEST	D	D^2
M.Z.	50	55	5	25
G.P.	30	32.5	2.5	6.25
M.M.	32.5	40	7.5	56.25
E.H.	55	65	10	100
K.C.	40	42.5	2.5	6.25
D.K.	30	35	5	25
M.J.M.	32.5	35	2.5	6.25
V.S.	35	40	5	25
L.J.	37.5	42.5	5	25
W.R.	75	80	5	25
E.L.	40	45	5	25
D.S.	35	40	5	25
L.O.	75	80	5	25
M.M.	75	75	0	0
	642.5	707.5	$\Sigma D = 65$	$\Sigma D^2 = 375$

(a) $\Sigma d^2 = \Sigma D^2 - \frac{(\Sigma D)^2}{N}$

$= 375 - \frac{65^2}{14}$

$= 375 - 301.785$

$\Sigma d^2 = 73.214$

(b) $S_D = \sqrt{\frac{\Sigma d^2}{N}}$

$= \sqrt{\frac{73.214}{14}}$

$S_D = 2.286$

(c) $S_{\overline{D}} = \frac{S_D}{\sqrt{N - 1}}$

$= \frac{2.286}{\sqrt{13}}$

$= \frac{2.286}{3.605}$

$S_{\overline{D}} = .6342$

(d) $t = \frac{\overline{D}}{S_{\overline{D}}}$

$= \frac{4.64}{.6342}$

$t = 7.320$

Critical Value at .01 = 3.012

APPENDIX B

SCORE CARD FOR COLLECTING DATA

NAME:	AGE:	PRETEST: LEFT --- LBS.	PRETEST: RIGHT --- LBS.	POST-TEST: EXERCISED RIGHT --- LBS.	POST-TEST: NONEXERCISED LEFT --- LBS.

9/27	9/28	9/29	9/30	10/1	Weekend	10/4	10/5	10/6	10/7
10/8	Weekend	10/11	10/12	10/13	10/14	10/15	Weekend	10/18	10/19
10/20	10/21	10/22	Weekend	10/25	10/26	10/27	10/28	10/29	

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