STABILITY OF EXPERIENCED FEMALE LIFTERS' HEART RATES ACROSS DAYS DURING AND AFTER PYRAMID EXERCISES OF BENCH PRESS AND PARALLEL SQUAT

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ABSTRACT

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This investigation compared female weight lifters' heart rates (HR) across days for free weight pyramid lifting cycles. HRs during and after bench press and parallel squat free weight pyramid weight lifting cycles of 10, 8, 6, 4, 6, 8, and 10 repetitions at 50, 65, 75, 85, 75, 65, and 50 % of 1-RM respectively, were obtained on 25 experienced female weight lifters. HRs were determined using Polar Vantage XL Heart Watch monitors programmed to record HRs at 5 sec intervals, beginning with the initial lift and ending when the HR decreased during the recovery period after the final lift of the pyramid cycle. The exact time for each lift was determined. The HR during the last 5 sec was used to represent the HR during that lift. HRs obtained immediately after the lift represented the initial recovery HR. Peak recovery HR was the highest rate obtained during the recovery period. There were no significant ($p > .01$) differences in HRs reported during, immediately after, or at peak recovery between test days at the respective percentages for either bench or squat cycle. HRs for squats among the various repetitions were significantly ($p < .01$) higher than corresponding bench HRs. There were no significant ($p > .01$) differences between days in the total time to complete either bench or squat cycles. The total time to complete the squat cycle was significantly ($p < .001$) longer than the bench cycle. Self-reported resting HRs were not significantly different ($p > .01$) between days. HRs measured during, immediately after, and at peak recovery for pyramid lifting cycles remained stable across days in experienced female weight lifters.

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INTRODUCTION

It has been well documented that heart rate increases during weight lifting (Greer, Dimick, & Burns, 1984; Kuel, Haralambie, Bruder, & Gottstein, 1978; Rozenek, Rosenau, Rosenau, & Stone, 1993). While numerous studies have examined various physiological changes during and after weight lifting, few studies (Butts & Hoffman, 1992; Stone, Fleck, Triplett, & Kraemer, 1991) have addressed the effects weight lifting has on postexercise heart rate. Furthermore, even fewer studies (Alway, Grumbt, Gonyea, & Stray-Gundersen, 1989; Cureton, Collins, Hill, & McElhannon, 1988; Smith, Stokes, & Kilb, 1987) have examined the physiological responses to weight lifting in experienced female lifters.

In a recent study (Butts & Hoffman, 1992) male weight lifters' heart rates were examined for stability across days during and after bench press and squat pyramid free weight exercises. No significant differences in heart rates between any individual cycles across the two test days were found suggesting that the heart rate responses to weight lifting exercises in males are consistent. Recently McMillan et al. (1993) compared the physiological (i.e., heart rates) responses of trained and untrained males to a single bout of weight training exercises of the same relative intensity. They determined the magnitude of the response to weight-training exercise is related to the subjects' state of training. The relationship between heart rate and oxygen uptake during weight lifting has also been studied (Collins, Cureton, Hill, & Ray, 1991). These authors concluded that using heart rate to prescribe the metabolic intensity of weight lifting exercise results in a substantially lower level of aerobic metabolism than during dynamic low-resistance exercise in 15 male subjects. In addition to examining heart rate, Ballor, Becque, and Katch (1987) also measured the metabolic responses in male subjects during a hydraulic resistance circuit, and found that the metabolic cost for each individual exercise is of sufficient intensity to cause a training effect. A review of the literature reveals that few studies have investigated the various physiological responses to resistance exercises in women.

The purposes of this investigation were two-fold. The initial goal was to determine if the heart rate responses of experienced female lifters were consistent during, immediately after, and at peak recovery, across two test days for the free weight bench press and parallel squat exercises using the same weight and percentages of their respective 1-repetition maximum (1-RM). The secondary purpose was to compare experienced female weight lifters' heart rates during, immediately after, and at peak recovery between bench press and parallel squat free weight exercises during pyramid lifting cycles.

METHODS

Subjects

Twenty-five female weight lifters volunteered to participate in the study. Written informed consent was obtained prior to any testing. All subjects were students at the University of Wisconsin-La Crosse, and were classified as experienced lifters (i.e., an individual who could perform the technique of parallel squat correctly in the judgement of the investigator). Criteria used to evaluate the lifter's ability were based on the technique for parallel squat as defined by Johnson (1989).

Methods

All testing was performed in the University of Wisconsin-La Crosse Strength and Conditioning Center. A standard bench with rack and squat rack were used.

Each subject completed three days of testing. A coin toss determined which test (bench press or parallel squat) would be performed first for the 1-RM testing as well as the for two following test days. The first day the subject's maximal bench and squat weights were determined based on the protocol for 1-RM testing defined by Stone and O'Bryant (1987).

The actual tests used a pyramid cycle (Fleck & Kraemer, 1987) which consisted of 7 sets of each exercise per day, with repetitions of 10, 8, 6, 4, 6, 8, and 10, at 50, 65, 75, 85, 75, 65, and 50% of the subject's 1-RM, respectively. Rest periods were controlled by the subject in order to better simulate their regular workout. The same lifting sequence was repeated on a second day which occurred no less than 24 and no more than 96 hours after the first test day. Self-reported resting heart rates were obtained for test days 1 and 2 prior to the pyramid testing for that day.

During all pyramid tests, two Polar Vantage XL Heart Watch monitors with transmitter (Polar USA, Inc., Stamford, CT) were used to continuously monitor heart rates. The transmitter, attached to an elastic strap, was worn snugly around the thoracic cavity with electrodes symmetrically placed slightly under the bra line. The heart watch monitors were programmed to record heart rates at 5-second intervals. Watches were worn on each wrist of the subject, with the one on the left designated as the back-up. A separate stop watch was coordinated with the heart rate watches in order to record the exact start and stop times of each set.

The stored heart rate data were downloaded to an IBM PC. This procedure permitted the determination of heart rates at the exact time of the lift. The heart rate during the last 5 seconds of the lift was recorded as the heart rate during the lift. The heart rate obtained during the 5 seconds after the lift was used as the immediate recovery heart rate. The peak recovery heart rate was defined as the highest rate obtained during the recovery period.

Statistical Analysis

A dependent t-test was calculated to determine differences in heart rates among the various repetitions, between exercises, and between days 1 and 2. A Pearson product correlation was calculated to establish reliability between all heart rates recorded on test day 1 compared to day 2. An alpha level of .01 was used for all significant results in order to decrease the probability of a Type I error commonly associated with dependent t-tests.

RESULTS

The subjects' physical characteristics and their bench and squat 1-RMs are presented in Table 1.

Table 1. Subject characteristics (N = 25)

Variable	Mean	Range	SD*
Age (yrs)	20.8	18-23	1.44
Height (cm)	166.6	149.9-175.3	6.59
Weight (kg)	62.0	43.2-74.5	7.33
1-RM (kgs)			
Squat	84.4	59.1-145.5	17.65
Bench	52.8	36.4-75.0	9.56
Resting HR (bpm)			
Day 1	61.2	48-76	6.28
Day 2	60.7	40-76	7.64

*SD = standard deviation

significantly (p > .01) different between test day 1 and day 2. There were no significant differences (p > .01) in heart rates during, immediately after, or at peak recovery between day 1 and day 2 at the respective percentages for either bench press or parallel squat. All correlations between day 1 and day 2 corresponding heart rates in the pyramid cycle were significant (p < .001) and ranged from a low of .73 to a high of .94. The heart rates obtained during, immediately after, and at peak recovery of the squats were significantly (p < .01) higher than the corresponding heart rates obtained for the bench press (see Figures 1 & 2). There were no significant (p > .01) differences between day 1 and 2 in the total time required to complete either bench press (16.2 min and 14.8 min) or squat (22.6 min and 21.4 min) pyramid cycles, respectively. The total time for completing the parallel squat pyramid cycle was significantly (p < .001) longer than the total time to complete the bench press pyramid cycle.

DISCUSSION

At the time of the present study, all 25 subjects were actively participating in some type of free-weight resistance training on a regular basis, although workouts varied. As can be seen in Table 1, there was a large range in body weight (43.2 to 74.5 kg). This may explain the variability in the 1-RMs for the bench press (36.0 to 75.0

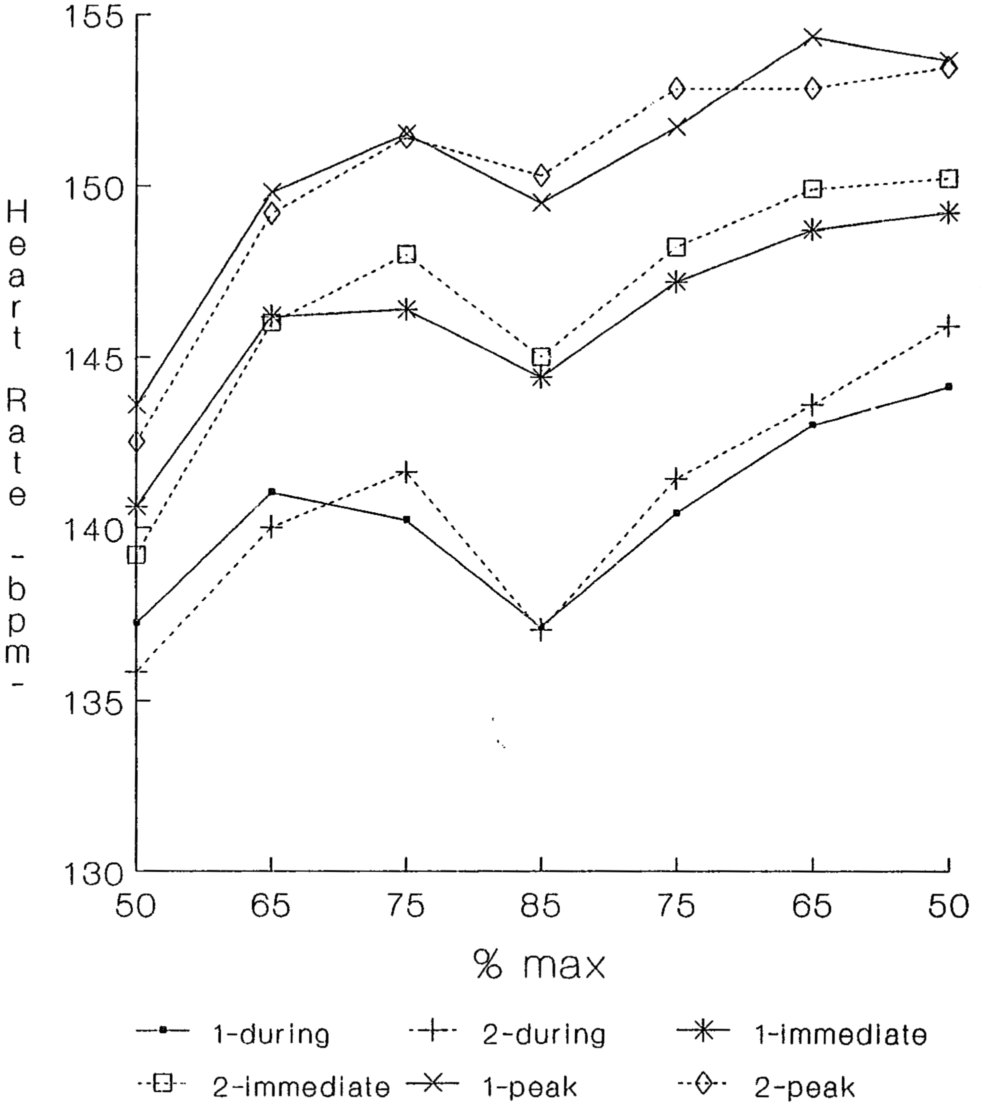

Figure 1. Bench press heart rates

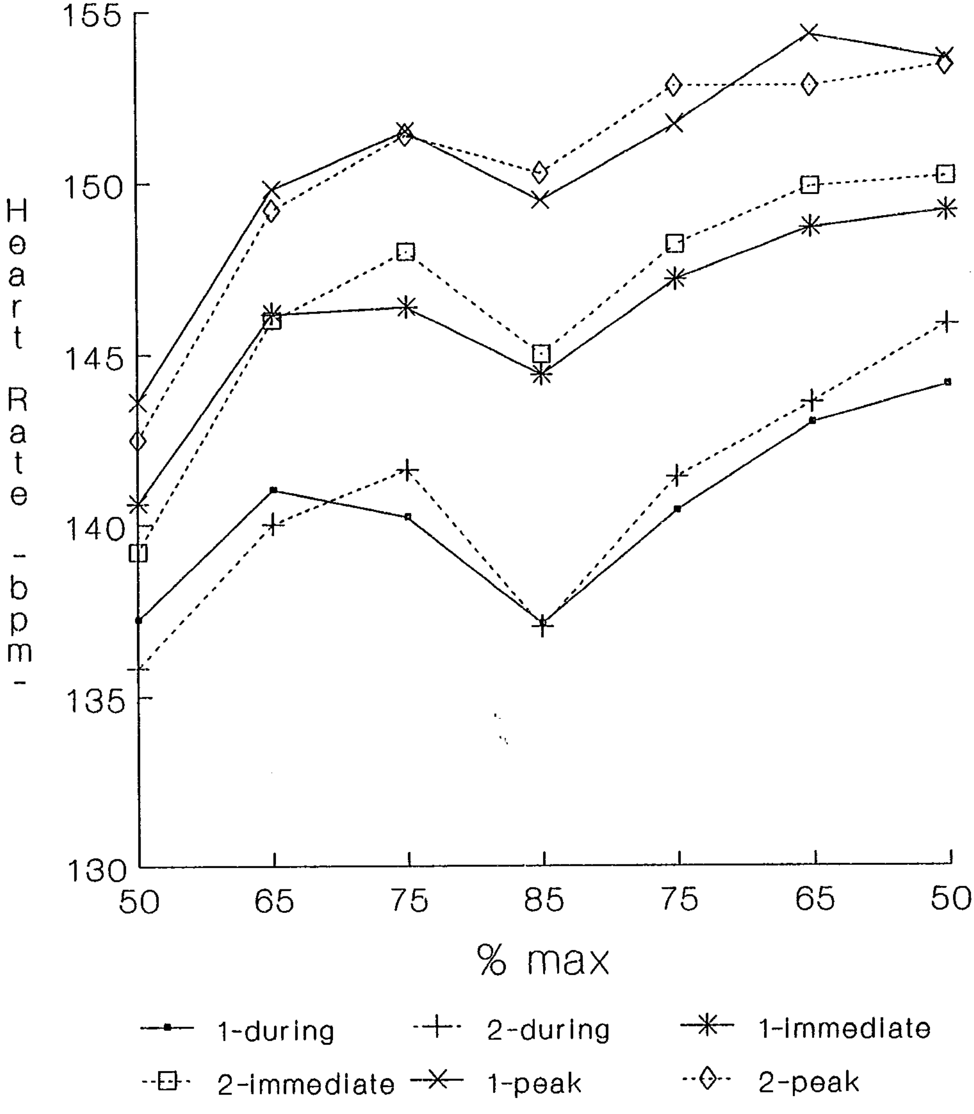

Figure 2. Parallel squat heart rates

kg) and parallel squat (59.1 to 145.5 kg). The subjects' mean body weight was similar to the weight of 66.7 kg reported for female collegiate volleyball athletes by Smith et al. (1987) and the 64.3 kg reported by Fry et al. (1991). The average bench press of 52.8 kg and parallel squat of 84.4 kg 1-RMs were higher than those reported for female starting collegiate volleyball athletes in 1991 (Fry et al.) of 45.7 and 73.0 kg, respectively, and higher than those reported by O'Shea and Wegner (1981) of 42.7 and 72.7 kg, respectively. Based on a body-weight classified norms chart for females developed by Kindig, Soares, Wisenbaker, and Mrvos (1984), the subjects in the present study placed in the 98th percentile for bench press 1-RM. Kindig et al. (1984) reported a standard for the half squat, not the full parallel squat as was performed in the present study, therefore no comparison of the squat 1-RM average could be made.

Self-reported resting heart rates of 61.2 and 60.7 bpm for day 1 and day 2, respectively, were lower than the 67.9 bpm reported for experienced male weight lifters by Knowlton, Hetzler, Kaminsky and Morrison (1987), but higher than the 59.6 bpm reported for experienced male weight lifters by Butts and Hoffman (1992). Little or no change in resting heart rates have been found to occur as a result of resistance training (Fleck, 1988). Similarly, Goldberg, Elliot, and Kuehl (1988) reported resting heart rate to be unaltered after 16 weeks of weight training. Conversely, Stone et al. (1991) suggested resistance training may result in bradycardia. The literature is inconclusive as to whether resting heart rate is influenced by resistance training alone.

Since there was no significant difference in the time required to complete the bench press or parallel squat pyramid cycle between days 1 and 2, the times were averaged. The average time required to complete the pyramid cycles for both the bench press (15.5 min) and squat (22.0 min) were similar to findings of Butts and Hoffman (1992) for 40 male subjects to complete the same pyramid cycles (14.5 and 19.6 min, respectively). The actual lift and rest times for the present study were left to the discretion of the subjects in order to more accurately simulate a regular workout. The lack of significant differences in total time to complete the pyramid cycles between days 1 and 2 suggests that experienced weight lifters can consistently monitor the lift and rest times required to complete the pyramid cycle.

This consistency is further exemplified by the lack of significant differences in lifters' heart rates observed across days 1 and 2 during the lift, as well as at immediate and peak recovery. This concurs with the findings of Butts and Hoffman (1992) of heart rates during pyramid cycle weight lifting on different days in experienced male weight lifters. Their subjects completed a bench and squat pyramid cycle with percentages of the subjects' 1-RM identical to those used in the present study. In that study, heart rates remained stable across days, with similar elevations occurring at immediate and peak recovery.

Similar findings were reported by Katch, Freedson, and Jones (1985) of reproducible heart rates on different days during hydraulic circuit resistance training in subjects with no prior experience with resistance training. In the study of Katch et al. (1985) the heart rates increased progressively between each set, but there was no significant difference in exercise heart rates between days.

The heart rate response to any exercise involves integration of the muscular, cardiovascular, and central nervous systems. "Activation of skeletal muscle afferent fibers by stretch, muscular contraction, or metabolites produced from increased cellular activity can result in modifications of the heart rate response" (Rozenek et al., 1993, p. 52). Muscular contraction capable of producing occlusion of the blood vessels in the exercising muscle can also stimulate a pressor response that can activate the sympathetic nervous system and influence the heart rate response (MacDougall, Tuxen, Sale, Moroz, & Sutton, 1985). The size of the muscle mass activated, as well as the activation of fast-twitch muscle fibers, may also influence the cardiovascular response to exercise (Petrovsky et al., 1981). In the present study, the parallel squat lift involved a larger muscle mass as compared to the bench press, thereby producing a comparatively higher heart rate response.

In resistance exercise, heart rate appears to continually rise during the recovery period. The present study's findings were similar to those of Butts and Hoffman (1992), where the average heart rates at immediate and peak recovery for all sets were higher than heart rates during the actual lift (see Figures 1 and 2). According to Stone et al. (1991), this immediate increase in postexercise heart rate is related to the amount of weight lifted as well as to the muscle mass and number of repetitions involved. In the present study, the number of repetitions performed for bench press and parallel squat were identical, but the amount of weight lifted and muscle mass utilized were greater for parallel squat. According to Lewis et al. (1985) the elevated recovery heart rates are in response to the continued elevation of plasma catecholamines initially released during the lift. Another potential mechanism for the continued rise of postexercise heart rate is the baroreceptor reflex inhibition of heart rate during the resistance exercise. Hypertension occurs during resistance exercise as a result of the large increase in peripheral resistance due to occlusion of blood vessels in the contracting muscle. One would expect a baroreflex-mediated decrease in sympathetic and increase in parasympathetic tone to the heart, resulting in an attenuated exercise heart rate. Once the lift is finished total peripheral resistance decreases, blood pressure lowers, and the baroreceptor reflex is diminished, causing an immediate rise in postexercise heart rate.

The interaction of these factors may explain the significant difference in heart rate response observed between the bench press and parallel squat, and between each different set of the pyramid cycle within each exercise. During the parallel squat, as well as during the higher percentages of the subjects' 1-RM during the pyramid cycle, subjects may have recruited additional muscles, especially as fatigue became evident with increasing repetitions and sets, to complete the lifts. Similarly, Rozenek et al. (1993) recently reported a significantly higher exercise heart rate at 70% 1-RM bench press than at 50%, with significantly elevated heart rate responses observed with increasing set number. Rozenek et al. further explains that this increased exercise heart rate effect at 70% 1-RM would have resulted in recruitment of a larger number of fast-twitch fibers as compared to the 50% trial. This, combined with an increased pressor response and greater metabolite production, may have led to the observed heart rate increases with increasing resistance. All the factors mentioned above may have contributed to the significantly higher exercise heart rates observed for parallel squats than for the bench press.

As with the heart rate response, the basic physiological responses to resistance exercise (i.e., muscular hypertrophy and muscular strength) are not gender specific. Holloway and Baechle (1990) reported female muscle tissue is similar in force output to male muscle tissue. Furthermore, there is evidence suggesting the occurrence of similar, proportional increases between the sexes in strength performance and hypertrophy of muscle fiber in response to resistance training relative to pretraining status (Holloway & Baechle, 1990). A 16-week weight training study, Cureton et al. (1988) investigated the relative changes in strength and muscle hypertrophy consequent to weight training in men and women. The results of their study indicated the changes in men and women as a result of resistance training were not significantly different. They concluded weight training responses are similar in men and women.

In conclusion, the present study showed stability of heart rates during, as well as immediately after and at peak recovery, across days of a pyramid lifting cycle for bench press and parallel squat. Heart rates continued to increase after the lift was completed across all sets of the pyramid for both bench press and parallel squat. The parallel squat lift resulted in significantly higher heart rates during, immediately after, and at peak recovery as compared to the heart rates for bench press across all sets of the pyramid cycle. When compared to the limited data on heart rate responses to weight lifting, the present results support previous data that heart rates remain stable across days, heart rates continue to peak after the lift is completed, and the parallel squat yields higher heart rates as compared to the bench press.

PRACTICAL IMPLICATIONS

Monitoring experienced female lifters' heart rate responses during free weight exercise can be accurately achieved using Polar Vantage XL Heart Rate monitors. There appears to be no gender differences in the response to weight lifting in that females respond in a similar fashion to pyramid cycles of resistance training as males. Weight lifters can periodically monitor heart rates to establish a baseline/norm for the individual. From this baseline, the lifter/coach can determine if the proper response is being achieved (i.e., if overtraining or undertraining is occurring).

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APPENDIX A

REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

Resistance, strength, and weight training all have become popular forms of recreation as well as methods to condition athletes. The terms strength, weight, and resistance training all have been used to describe a type of exercise which requires the body's musculature to move (or attempt to move) against some type of opposing force presented by various types of equipment (Fleck & Kraemer, 1987). Certain physiological responses occur as a result of such muscular bouts of exercise, which have been addressed in the literature over the years. Although attention to heart rate responses during resistance exercise has been limited (Butts & Hoffman, 1992; Stone, Fleck, Triplett, & Kraemer, 1991), even fewer studies (Alway, Grumbt, Gonyea, & Stray-Gundersen, 1989; Cureton, Collins, Hill, & McElhannon, 1988; Smith, Stokes, & Kilb, 1987) have examined the physiological responses to weight lifting in experienced female lifters.

A review of the muscular responses to resistance training, cardiovascular responses and adaptations, body composition/weight alterations, and sex differences in resistance training is presented below. An overview of heart rate monitors is also discussed.

Muscular Responses

Two schools of thought exist concerning how enlargement of the total muscle takes place. The first school of thought holds that hypertrophy, an increased cross-sectional area of existing muscle fibers, is responsible. The second method suggests hyperplasia, fibers split leading to an increase in the total number of fibers, is responsible for muscle growth (Fleck & Kraemer, 1987).

In laboratory animals muscle growth has been shown to occur due to hypertrophy alone (Gollnick, Timson, Moore, & Riedy, 1981; Timson, Bowlin, Dudenhoeffer, & George, 1985). Increased muscle size in strength-trained athletes also attributed to hypertrophy of existing fibers (Gollnick, Parsons, Riedy, & Moore, 1983). This increase in overall cross-sectional area is attributed to the increase in size and number of the actin and myosin filaments and addition of sarcomeres within existing muscle fibers (MacDougall et al., 1979).

Conversely, a study by Ho et al. (1980) found hyperplasia to be the main reason for increased muscle enlargement in laboratory animals. Criticism of this study suggest that damage to the muscle samples, as well as degenerating muscle fibers, account for the observed hyperplasia. Studies comparing body builders and power lifters conclude that the cross-sectional area of the body builders' individual muscle fibers was not significantly larger than normal, yet they possessed larger muscles than normal (MacDougall, Sale, Elder, & Sutton, 1982; Tesch & Larsson, 1982). This indicates that these athletes have a greater number of total muscle fibers and hyperplasia may be the reason for this increase. In contrast, another study by MacDougall, Sale, Alway, and Sutton (1984), concludes body builders possess the same number of muscle fibers as the control group but possess much larger muscles. This study suggested that the large muscle size of body builders is due to hypertrophy of the existing fibers, rather than hyperplasia.

Studies do indicate that it may be possible to selectively hypertrophy either the fast twitch (FT) or slow twitch (ST) fibers depending on the training regime. Power lifters who train predominantly with high intensity (i.e., heavy resistance) and low volume (i.e., small number of sets and repetitions) have been shown to have FT fibers with a mean fiber area of 79 m^2 x 100 in the vastus lateralis (Tesch, Thorsson, & Kaiser, 1984). Conversely, the same study also found body builders who train predominantly with a lower intensity but a higher volume have smaller FT fibers with a mean fiber area of 62 m^2 x 100 in the same muscle.

The increase in the number of capillaries in a muscle may also contribute to the enlargement of the entire muscle. The increase of capillaries appears to be linked to the intensity and volume of strength training, as with selective hypertrophy of FT fibers. Tesch et al. (1984) found that power lifters and weight lifters exhibit no change in the number of capillaries per muscle fiber. Due to hypertrophy of the fibers those same athletes showed a decrease in capillary density (i.e., the number of capillaries per cross-sectional area of tissue) when compared to nonathletic individuals. It has also been proposed that the training performed by body builders induces increased capilarization (Schantz, 1982). Thus, high-intensity/low-volume strength training appears to decrease capillary density whereas low-intensity/high-volume strength training has the opposite effect of increasing capillary density.

Physical activity also aids in the increase in size and strength of ligaments and tendons (Fahey, Akka, & Rolph, 1975), which may cause in part the apparent enlargement of a muscle due to weight training. Increased strength of the ligaments and tendons is a necessary adaptation to aid in preventing possible damage to these structures caused by the muscle's ability to lift heavy weights and develop more tension (Fleck & Kraemer, 1987).

With the effect of capilarization and the increase in size of ligaments and tendons, there is no concrete evidence to support the relationship of increased muscle size due to hyperplasia, although there are indications that hyperplasia occurs due to resistance training. Due to these conflicting results in studies on hypertrophy and hyperplasia, this topic remains controversial. Therefore, further research needs to be performed, possibly on elite competitive lifters.

Cardiovascular Responses and Adaptations

"The cardiovascular system serves to integrate the body as a unit and provides the muscles with a continuous stream of nutrients and oxygen so that a high energy output can be maintained for a considerable time period" (McArdle, Katch, & Katch, 1991, p.223).

Blood Pressure

Individuals experience hypertension during the performance of resistance type exercise (Fleck & Dean, 1987). A review published recently by Stone et al. (1991) suggest resistance training appears to reduce amount of elevation of the exercise blood pressure. The effects of long-term training may influence the level of increase in exercise blood pressure. Trained body builders, for example, show smaller increases in systolic and diastolic blood pressure with resistance exercise than novice and untrained (Fleck, 1988).

The pressor response, or valsalva maneuver, may be the cause of extremely elevated blood pressures during resistance training exercise. The effect of breath holding with a closed glottis has shown blood pressures to reach as high as 480/350 mmHg during the performance of a double leg press (MacDougall, Tuxen, Sale, Moroz, & Sutton, 1985). When breathing was allowed during the same contraction, blood pressure was reduced substantially. This demonstrates that the elevation of blood pressure during resistance training is much lower if breathing is performed during the lift as opposed to the performance of the valsalva maneuver during contraction.

Considering the effects of resistance training on resting blood pressure, research has shown there to be no long term effects in relation to elevated resting blood pressure in resistance trained athletes (Collinder & Tesch, 1988). In fact, a study on the cardiovascular responses to short-term Olympic style weight-training found there to be a decrease in resting blood pressure in the subjects tested (Stone, Wilson, Blessing, & Rozenek, 1983).

Heart Size

A moderate increase in heart size is often the result of exercise training in men and women. Morganroth, Maron, Henry, and Epstein (1975) were among the first to study the differences of heart adaptations in endurance training and resistance training. The data of this study demonstrated the hearts of endurance trained athletes possessed normal wall thickness with an increase in ventricular cavity size. Conversely, resistance trained athletes had a greater than normal wall thickness with a normal ventricular cavity size. It was speculated that the increase in wall thickness was because the hearts of resistance-trained athletes must pump blood at higher pressures (i.e., pressure overload), and the heart adapts to this stress by developing thicker than normal ventricular walls. The previous study was reaffirmed by the data presented by Fleck (1988), where resistance training caused increased left ventricular wall thickness and left ventricular mass. This study found little or no change in left ventricular internal dimensions.

There is a relationship between body size and heart size. A large individual may have a large heart (Alpert, Terry, & Kelly, 1985). A study accounting for body size found resistance trained males to have a significantly greater wall thickness but a nonsignificant ventricular volume as compared to sedentary males (Fleck & Kraemer, 1987).

Heart Rate

Studies on the effects of resistance training on heart rate have shown that heart rate decreases for maximal work and recovery from short-term weight training (Stone et al., 1991; Stone et al., 1983). In a 1988 study by Colliander and Tesch, the heart rates of age matched body builders were compared to medical students during resistance exercise. Body builders displayed lower heart rate at identical power outputs at a percent relative to their 1-RM as compared to the medical students.

Butts and Hoffman (1992) reported exercising heart rates two separate testing days during pyramid lifting cycles of bench press and parallel squat were consistent. Heart rates were measured during the lift, immediately after the lift, and at peak recovery on 40 experienced male weight lifters. "The lack of significant differences between days one and two heart rates during the actual lifts, as well as immediately after and at peak recovery, indicate the heart rate responses were consistently stable across days" (Butts & Hoffman, 1992, p. 221).

Similar findings were reported by Katch, Freedson, and Jones (1985) of heart rates on different days during resistance training in subjects with no prior experience with resistance training. The subjects completed three sets of 20 seconds performing the maximum number of repetitions possible, with 20 seconds rest in between sets on a three machine hydraulic circuit. In Katch's et al. study (1985) heart rates increased progressively between each set, but there was no significant difference in exercising heart rates between days.

The heart rate response to exercise involves integration of the muscular, cardiovascular, and central nervous system. "Activation of skeletal muscle afferent fibers by stretch, muscular contraction, or metabolites produced from increased cellular activity can result in modifications of the heart rate response" (Rozenek, Rosenau, Rosenau, & Stone, 1993, p. 52). Muscular contraction capable of producing occlusion of the blood vessels in the exercising muscle can also stimulate a pressor response that can activate the sympathetic nervous system and influence the heart rate response (MacDougall et al., 1985). The size of the muscle mass activated, as well as the activation of fast-twitch muscle fibers, may also influence the cardiovascular response to exercise (Petrovsky et al., 1981).

In resistance training, heart rate continues to rise in the recovery period. According to Stone et al. (1991), this immediate increase in postexercising heart rate is related to the amount of weight lifted as well as the muscle mass and number of repetitions involved. According to Lewis et al. (1985) the elevated recovery heart rates are in response to the continued elevation of plasma catecholamines initially released during the lift.

When comparing upper extremity exercises to lower extremity exercises, Fleck and Dean (1987) found there to be no difference in heart rate responses for specific circuit resistance exercises. Conversely, Butts and Hoffman (1992) found significantly ($p > .01$) higher heart rates during squat (lower extremity) as compared to bench press (upper extremity) free weight exercises. This study suggests experimental design to be one of the explanations for the discrepancy, as well as the larger muscle mass and higher amount of weight involved during the squat exercise. This may cause and elevated heart rate response when compared to the bench press exercise.

VO_2 Max

An individual's VO_2max provides a quantitative statement of the capacity for aerobic energy transfer (McArdle et. al., 1991). Maximal oxygen consumption (VO_2 max) may be increased through resistance training, but the increase is less than that caused by a running program (Fleck & Kraemer, 1987). An increase in VO_2 max during short-term Olympic style training was documented by Stone et al. (1983), while no change in VO_2 was observed as a result of high-intensity strength training (Hurley et al., 1984), and Gettman and Pollock (1981) found that a typical resistance training regimen of 8 to 9 weeks actually showed a decrease of 0.5 to 0.9% in VO_2 max. According to Stone et al. (1991) the mechanism by which weight training may lead to increases in VO_2 max is unclear.

In contrast, circuit weight training for a duration of 8 to 20 weeks has been shown to increase VO_2 max up to 5% in men and 8% in women (Gettman & Pollock, 1981). Circuit weight training consists of a series of exercises performed for 12 to 15 repetitions of each exercise at approximately 40 to 60% of the 1-RM, with a rest period of less than 30 seconds between exercises. As with circuit weight training, a study by Stone et al. (1983), demonstrated an increase of 5.5% in VO_2 max following an 8-week Olympic-style resistance training program. The program included several common resistance exercises, snatch and clean pull exercises, and vertical jump exercises. The results are significantly lower, however, than the 20% increase normally observed with running endurance programs of equal duration (Fleck & Kraemer, 1987).

To see maximal increases in VO_2max, heart rate must be maintained at a minimum of 70% of maximal for a minimum of 20 minutes (American College of Sports Medicine, 1991). The major reason why resistance training typically does not see maximal increases in VO_2 max is due to heart rate dropping below 70% of maximal during rest periods. Resistance training is not the optimal method of increasing VO_2 max, although increases may occur.

Body Composition/Weight Changes

Body compositional changes do occur in short-term resistance training programs (6 to 24 weeks). Ideally, a strength training program should increase lean body mass (LBM) and decrease fat weight and percent body fat. Studies support the notion of body compostititional changes with a decrease in percent body fat (Kraemer, Deschenes, & Fleck, 1988; Stone et al., 1983) and an increase in fat free weight (Hurley et al., 1984).

Body composition has important relationships to cardiovascular fitness, strength, and flexibility. It is likely that it can be affected and controlled by use of large body mass during exercise depending on training volume (Stone et al., 1991).

Sex Differences

Only recently have women been accepted into the resistance training world. Resistance training has been viewed as not being feminine. Basically many individuals felt that women would appear too muscular as a result of resistance training. In today's society, women are successfully competing in many sports, including resistance training without appearing masculine.

The basic gender difference appears to be the degree of hypertrophy achieved through resistance training. According to Laubach (1976), women's total body strength is approximately 63.5% of men's. Variation exists from one body part to the next in terms of strength. The study by Laubach (1976) found that upper extremity dynamic strength of women varies from 35 to 79% of men with an average of 55.8%. Women's lower extremity strength varies from 57 to 86% of men with an average of 71.9%. Possible reasons for the difference in strength are variations in muscle mass distribution and quality of the muscle tissue (Laubach, 1976). The difference may also be attributed to societal norms: males generally perform the majority of the heavy physical labor.

The difference in the levels of hypertrophy have been attributed to the 20 to 30 times higher testosterone levels in men, which exerts a strong anabolic or tissue-building effect (McArdle et al., 1991). Hypertrophic response to resistance training is similar for men and women, although absolute changes in size are greater for men, but the enlargement of muscle on a percentage basis is the same between genders (Cureton et al., 1988). More research is needed before definitive statements can be made concerning similarities and differences in resistance training responses of men and women. The data available from relatively short-term studies suggest that women can utilize conventional resistance training exercises without developing overly large muscles (McArdle et al., 1991). Research also to date suggests that resistance training is at least as beneficial, if not more so, to women as to men (Fleck & Kraemer, 1987).

Women gain strength at the same or greater rate than men due to resistance training (Wilmore et al., 1987). The greater relative increase in strength in women as compared to men is normally due to the relative lower level of fitness upon starting a training program.

The majority of the misconceptions of women in regard to strength training are virtually not true. Women will not develop large, bulky muscles due to the normally lower levels of testosterone and higher levels of estrogen. Any increase in muscle mass is typically balanced by a loss of adipose tissue, yielding no change or a slight decrease in total body weight (Fleck & Kraemer, 1987).

Women can become very strong as a result of resistance training. At the 1985 Women's National Powerlifting Championships, a 165 lb. contestant squatted 534 lbs., deadlifted 557 lbs., and bench pressed 270 lbs. (Fleck & Kraemer, 1987).

Heart Rate Monitors

The use of heart rate monitors has become popularized over the past few years with as a result of advanced technology. In recent years, conventional models using electrodes have been used and shown to be effective (Thivierge & Leger, 1988), but were quite unpractical in a strength center setting.

More modern heart rate monitors have proven effective in strength testing measurements. Burke and Whelan (1987) found heart rate monitors to rarely exhibit errors exceeding 2-3 beats per minute over a range of 30-240 beats per minute. However, in the same study, when tested with subjects walking or jogging at low speeds on a treadmill, 20-70% of the readings given by the monitors had errors of greater than 20 beats per minute.

Thirteen low cost heart rate monitors were compared to ECG heart rate on 10 adults at rest, work, and recovery of bicycle ergometer, step test, and treadmill exercises at 65-75% and 85-95% max heart rate (Thivierge & Leger, 1988). The study concluded that of the 13 monitors tested, the most valid heart rate monitors were also the most stable.

Hoffman (1991) concluded that monitoring heart rates using the UNIQ Heart Watch Monitor can be reliable. The study measured the stability of experienced male lifter heart rates over two consecutive test days of pyramid cycles of bench press and parallel squat. Stability was observed using the UNIQ Heart Watch Monitor across days in both the bench press and parallel squat.

Summary

The physiological responses to resistance training has been well documented in the literature over the years. Muscular responses to resistance training still remains controversial with some believing hypertrophy to be the main cause of muscular enlargement, while others believe hyperplasia to be mainly responsible.

Cardiovascular responses and adaptations include elevated blood pressure during resistance training, especially while performing the valsalva maneuver, and a lowered blood pressure as a result of prolonged resistance training. Heart size is thought to increase, while ventricular cavity size shows no increase in resistance trained athletes. A slight decrease in resting heart rate occurs, and exercising heart rates during free weight pyramid cycles remain stable across days. A minimal increase in VO_2 max and a decrease in percent body fat are also marked effects of resistance training.

With more research on heart rate, lifters will be able to monitor exercising heart rates to measure intensity of exercise compared to pervious bouts of the same exercise at the same relative intensity.

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APPENDIX B

INFORMED CONSENT FORM

INFORMED CONSENT FORM

University of Wisconsin-La Crosse
La Crosse, WI

STABILITY OF EXPERIENCED FEMALE LIFTERS' HEART RATES ACROSS DAYS DURING AND AFTER PYRAMID EXERCISES OF BENCH PRESS AND PARALLEL SQUAT

I, ______________________, volunteer to participate in the test-retest study of heart rate stability, while performing a series of muscular strength exercises wearing a POLAR Heart Watch Monitor. The transmitter is to be worn around the thoracic cavity just below the bra line, with watches worn on each wrist. The purpose of this study is to measure the stability of lifters' heart rates during, immediately after and at peak recovery of two different pyramid lifting cycles.

I understand this study will involve 3 visits to the strength center. The first visit will involve a test to determine a 1-RM weight for both the bench press and parallel squat. The two following visits will involve the lifting of weights at percentages of the predetermined maximum weight in both the bench press and parallel squat. As with any exercise, there exists the possibility of adverse changes (i.e., dizziness, fatigue, muscle soreness, etc.) to occur during the test. It is understood that if any abnormal observations are notes, testing will terminate immediately.

To my knowledge, I am in good health and not under the guidance of a physician prohibiting me from participating in such strenuous activities this study will entail.

The actual testing will be performed by Christine L. Ritzer, a graduate student in the Human Performance masters program at the University of Wisconsin-La Crosse. She will be under the supervision of Nancy Kay Butts, Ph.D.

I have read the foregoing and understand the procedures involved in the testing of this study. My questions have been fully answered to my satisfaction. Therefore, I volunteer to be a participant in this study.

Signed:____________________________________Date:____________

Witness:___________________________________Date:____________

APPENDIX C

RAW DATA

CASE	SubjNum	HtCm	WtKg	Age	BenchMax	SquatMax
1	1	175.3	62.7	19	85	130
2	2	167.6	68.2	19	95	205
3	3	165.1	53.6	22	145	195
4	4	157.5	64.5	21	105	155
5	5	172.7	71.4	19	115	195
6	6	165.1	52.3	21	120	175
7	7	157.5	59.1	23	120	165
8	8	172.7	63.6	18	80	175
9	9	160.0	63.6	21	100	200
10	10	165.1	55.9	21	115	165
11	11	167.6	57.3	21	135	220
12	12	166.4	63.6	21	105	175
13	13	172.7	66.8	23	125	185
14	14	167.6	57.3	21	125	210
15	15	175.3	68.2	21	100	200
16	16	154.9	56.8	21	140	165
17	17	149.9	43.2	21	110	135
18	18	172.7	61.4	19	95	165
19	19	165.1	50.0	22	110	145
20	20	175.3	65.0	23	105	185
21	21	170.2	68.2	22	165	225
22	22	165.1	68.2	20	95	135
23	23	170.2	69.1	18	130	205
24	24	167.6	74.5	22	150	320
25	25	166.4	65.9	21	135	210

*** DESCRIPTIVE STATISTICS ***

VARIABLE	MEAN	STD.DEV.	VARIANCE	STD ERROR OF MEAN	COEFF OF VARIATION
SubjNum	13.0000	7.35980	54.1667	1.47196	56.6139
HtCm	166.624	6.58947	43.4211	1.31789	3.95469
WtKg	62.0160	7.33068	53.7389	1.46614	11.8206
Age	20.8000	1.44338	2.08333	0.288675	6.93931
BenchMax	116.200	21.0297	442.250	4.20595	18.0979
SquatMax	185.600	38.8190	1506.92	7.76380	20.9154

VARIABLE	MINIMUM	MAXIMUM	RANGE	TOTAL
SubjNum	1	25	24	325.000
HtCm	149.9	175.3	25.4	4165.60
WtKg	43.2	74.5	31.3	1550.40
Age	18	23	5	520.000
BenchMax	80	165	85	2905.00
SquatMax	130	320	190	4640.00

VARIABLE	MEDIAN	MODE	SKEWNESS	KURTOSIS
SubjNum	13.0000	NONE	-3.09416E-13	1.79615
HtCm	167.600	165.1	-0.767651	3.12421
WtKg	63.6000	68.2	-0.671412	3.07533
Age	21.0000	21	-0.407294	2.43920
BenchMax	115.000	95	0.411506	2.60581
- HAS MULTIPLE MODES				
SquatMax	185.000	165	1.46541	6.84660

*** CORRELATION MATRIX ***

VARIABLES:		
BenchMax	1.00000	
SquatMax	0.58732	1.00000
	BenchMax	SquatMax

DATA SET HAS 25 VALID CASES

CASE	D1M1H1L1	D1M1H1L2	D1M1H1L3	D1M1H1L4	D1M1H1L5
1	101	104	104	104	103
2	129	132	128	127	127
3	144	157	149	129	147
4	93	90	89	89	76
5	91	95	107	110	90
6	70	84	79	71	73
7	72	77	78	72	78
8	111	115	115	124	118
9	107	108	104	95	97
10	117	101	118	128	139
11	128	141	140	151	153
12	123	116	115	120	127
13	130	130	143	118	129
14	138	131	138	135	108
15	118	110	116	124	125
16	96	100	108	110	101
17	83	95	97	113	108
18	125	113	133	106	100
19	87	90	90	92	80
20	88	109	111	91	106
21	86	85	93	94	116
22	125	115	107	111	115
23	93	87	99	114	95
24	128	138	137	143	142
25	143	157	169	165	165

CASE	D1M1H1L6	D1M1H1L7	D1M1H2L1	D1M1H2L2	D1M1H2L3
1	100	89	106	107	102
2	123	120	131	134	133
3	154	138	141	151	149
4	85	83	95	91	94
5	95	103	92	105	113
6	86	76	70	99	79
7	80	82	74	81	80
8	112	106	115	118	113
9	104	105	99	109	107
10	141	137	120	108	159
11	144	140	130	143	147
12	116	113	122	116	124
13	132	127	133	138	142
14	135	124	124	134	144
15	123	117	122	119	127
16	100	102	95	100	112
17	83	88	88	99	105
18	108	83	119	98	94
19	86	82	83	95	93
20	101	94	88	114	106
21	113	94	85	91	98
22	104	108	125	117	113
23	97	84	94	92	102
24	139	125	136	142	143
25	165	149	152	164	171

CASE	D1M1H2L4	D1M1H2L5	D1M1H2L6	D1M1H2L7	D1M1H3L1
1	98	100	105	92	127
2	140	130	126	122	131
3	141	154	157	137	142
4	95	85	89	85	99
5	116	108	104	105	93
6	71	73	86	80	91
7	78	79	85	84	79
8	130	116	114	112	133
9	104	104	102	110	99
10	131	151	145	135	120
11	156	155	155	142	130
12	134	129	124	121	122
13	153	136	134	133	133
14	149	141	135	128	127
15	132	130	129	123	122
16	115	107	102	104	104
17	113	119	95	95	88
18	108	104	105	123	119
19	102	86	82	87	83
20	95	110	96	97	88
21	98	117	115	100	94
22	124	123	107	110	126
23	104	95	105	78	97
24	156	150	147	133	136
25	164	167	167	156	157

CASE	D1M1H3L2	D1M1H3L3	D1M1H3L4	D1M1H3L5	D1M1H3L6
1	120	121	117	116	117
2	134	133	140	130	130
3	155	149	151	154	157
4	97	96	118	93	93
5	105	113	116	112	104
6	110	101	101	96	104
7	87	87	86	91	94
8	133	130	130	133	125
9	109	107	104	99	102
10	119	159	159	161	154
11	143	148	156	155	155
12	116	124	134	129	124
13	138	142	153	144	135
14	134	144	149	141	135
15	126	133	146	134	143
16	108	112	115	109	110
17	99	105	113	119	100
18	106	107	112	106	112
19	95	93	105	86	82
20	114	106	107	110	97
21	91	98	98	117	115
22	125	122	139	127	107
23	105	102	104	103	105
24	144	154	166	158	153
25	164	171	164	167	167

CASE	D1M1H3L7	D1M2H1L1	D1M2H1L2	D1M2H1L3	D1M2H1L4
1	121	149	149	151	135
2	125	157	164	170	163
3	137	147	154	155	146
4	100	115	118	106	101
5	107	119	124	123	105
6	95	113	119	123	116
7	92	96	88	89	87
8	127	147	153	153	152
9	110	141	149	144	139
10	146	164	170	171	174
11	142	148	147	152	164
12	121	150	145	150	156
13	134	147	146	149	146
14	145	146	159	155	149
15	137	157	154	152	147
16	107	117	124	118	111
17	95	98	101	108	119
18	123	143	153	154	144
19	87	126	142	137	127
20	105	130	139	130	124
21	100	117	112	127	119
22	115	134	139	143	137
23	105	130	134	124	124
24	139	173	170	168	173
25	156	166	171	154	169

CASE	D1M2H1L5	D1M2H1L6	D1M2H1L7	D1M2H2L1	D1M2H2L2
1	143	147	146	151	153
2	161	161	159	157	166
3	156	151	152	148	155
4	112	118	122	119	122
5	128	125	129	125	132
6	116	91	130	116	123
7	96	92	98	101	99
8	155	156	161	152	158
9	135	147	150	143	151
10	170	180	179	172	176
11	160	153	156	154	154
12	156	156	155	150	154
13	147	151	149	148	150
14	143	157	149	155	163
15	152	156	156	159	164
16	132	129	125	122	131
17	113	116	114	102	108
18	146	155	159	145	162
19	129	139	134	128	138
20	130	138	139	131	142
21	125	126	128	122	123
22	144	152	150	136	141
23	129	138	136	135	139
24	169	172	167	179	176
25	163	169	160	166	175

CASE	D1M2H2L3	D1M2H2L4	D1M2H2L5	D1M2H2L6	D1M2H2L7
1	150	144	150	151	147
2	174	167	165	165	161
3	158	150	157	153	155
4	115	110	122	124	127
5	134	118	135	131	136
6	132	116	116	91	135
7	98	96	105	102	108
8	159	158	160	162	167
9	151	149	145	153	151
10	173	177	181	182	181
11	158	172	165	177	163
12	157	159	162	164	161
13	156	154	154	156	153
14	158	154	153	161	156
15	158	156	159	164	163
16	127	120	137	138	131
17	112	120	118	116	118
18	157	154	151	157	164
19	140	138	137	141	139
20	141	136	144	148	145
21	137	130	136	137	137
22	144	144	145	153	149
23	132	134	136	143	142
24	175	180	178	173	172
25	163	173	169	174	168

CASE	D1M2H3L1	D1M2H3L2	D1M2H3L3	D1M2H3L4	D1M2H3L5
1	154	156	150	144	150
2	157	167	174	167	166
3	148	155	158	150	157
4	124	129	130	122	132
5	133	136	138	134	138
6	121	125	132	130	131
7	107	112	110	105	112
8	153	161	162	164	164
9	143	151	156	154	152
10	177	178	179	179	183
11	154	157	162	174	169
12	150	157	161	159	165
13	150	152	157	156	159
14	158	166	159	158	156
15	160	169	168	165	168
16	132	143	144	130	142
17	104	110	112	120	118
18	156	164	163	162	168
19	128	138	140	138	137
20	132	142	143	140	150
21	124	134	140	135	137
22	137	147	148	147	145
23	141	144	151	150	146
24	180	177	179	181	179
25	166	175	171	174	169

CASE	D1M2H3L6	D1M2H3L7	D2M1H1L1	D2M1H1L2	D2M1H1L3
1	151	147	118	116	121
2	165	161	110	110	116
3	153	155	122	129	120
4	135	136	74	74	66
5	137	138	88	97	97
6	142	138	88	85	85
7	117	118	56	72	66
8	169	172	109	114	115
9	154	151	99	112	105
10	182	182	105	114	124
11	177	173	137	136	130
12	165	164	134	127	121
13	159	155	126	116	116
14	164	160	130	117	135
15	169	166	116	104	118
16	141	140	97	96	105
17	116	118	93	101	131
18	167	167	102	95	106
19	141	139	96	98	107
20	151	147	96	99	107
21	142	139	98	104	110
22	154	149	108	113	106
23	157	152	105	100	100
24	175	174	133	134	144
25	174	173	137	150	170

CASE	D2M1H1L4	D2M1H1L5	D2M1H1L6	D2M1H1L7	D2M1H2L1
1	114	125	116	113	118
2	117	113	116	107	111
3	91	144	136	146	114
4	71	68	71	74	74
5	95	94	87	89	92
6	90	92	85	81	88
7	65	72	68	76	66
8	121	111	117	115	111
9	94	104	103	102	94
10	108	112	127	115	109
11	141	143	138	132	137
12	133	131	132	116	137
13	123	138	131	135	121
14	130	132	129	130	135
15	95	117	116	117	115
16	102	103	99	98	101
17	113	118	97	103	100
18	102	79	115	95	103
19	119	90	86	108	86
20	95	96	97	95	93
21	121	124	119	108	102
22	102	105	109	119	113
23	102	128	92	96	103
24	141	134	130	133	138
25	160	172	162	148	145

CASE	D2M1H2L2	D2M1H2L3	D2M1H2L4	D2M1H2L5	D2M1H2L6
1	122	119	118	118	118
2	111	118	122	117	112
3	128	129	146	146	142
4	81	71	76	75	78
5	96	106	98	97	96
6	88	87	93	105	94
7	68	72	67	76	73
8	116	117	127	115	117
9	108	106	98	107	108
10	126	120	128	124	130
11	136	139	153	148	140
12	125	131	134	137	139
13	120	125	124	136	136
14	128	210	143	146	135
15	115	124	131	120	114
16	106	108	110	111	102
17	111	123	118	135	114
18	95	110	103	79	106
19	102	104	130	91	103
20	102	104	108	99	96
21	110	121	128	129	119
22	118	114	115	116	114
23	109	109	104	141	100
24	142	154	150	148	138
25	162	166	167	172	167

CASE	D2M1H2L7	D2M1H3L1	D2M1H3L2	D2M1H3L3	D2M1H3L4
1	114	126	131	135	130
2	108	118	122	120	122
3	146	114	128	129	146
4	75	83	91	89	86
5	92	92	96	106	108
6	88	92	98	102	102
7	77	75	89	79	82
8	114	130	128	126	129
9	103	95	108	106	98
10	125	112	126	130	147
11	134	137	140	143	153
12	127	137	125	131	134
13	142	127	128	129	135
14	128	135	129	210	150
15	116	116	115	124	131
16	99	104	108	108	110
17	105	100	111	123	118
18	115	105	102	110	109
19	82	100	109	104	130
20	99	101	103	106	108
21	117	102	110	122	128
22	124	118	118	121	121
23	95	111	109	109	105
24	135	139	143	158	155
25	152	155	163	166	167

CASE	D2M1H3L5	D2M1H3L6	D2M1H3L7	D2M2H1L1	D2M2H1L2
1	127	133	131	159	155
2	121	116	114	143	158
3	146	142	146	144	147
4	80	91	96	108	108
5	97	96	103	119	119
6	107	105	98	120	119
7	82	86	84	91	88
8	116	126	126	150	153
9	107	108	104	135	143
10	133	130	128	154	161
11	148	140	143	158	160
12	137	139	127	150	154
13	137	137	142	147	147
14	146	137	143	140	141
15	120	119	133	151	151
16	111	108	108	121	109
17	135	120	105	113	121
18	99	107	115	137	149
19	91	103	91	136	144
20	102	104	112	120	124
21	129	119	117	128	138
22	119	122	124	136	144
23	141	110	114	129	136
24	154	146	136	147	156
25	172	167	155	160	174

CASE	D2M2H1L3	D2M2H1L4	D2M2H1L5	D2M2H1L6	D2M2H1L7
1	150	141	149	154	158
2	158	157	158	160	160
3	142	139	143	147	157
4	106	96	108	113	108
5	127	120	120	123	128
6	132	132	128	125	134
7	84	75	88	88	92
8	146	146	147	159	163
9	137	137	140	149	150
10	177	183	186	189	187
11	156	161	161	157	152
12	154	160	155	153	162
13	154	155	147	149	152
14	148	151	153	152	153
15	157	139	142	153	151
16	126	110	128	127	123
17	118	108	121	114	120
18	149	126	143	151	146
19	152	147	150	136	149
20	137	112	134	139	137
21	135	138	134	138	140
22	146	139	148	152	156
23	131	122	131	140	143
24	156	160	162	160	162
25	160	170	159	162	162

CASE	D2M2H2L1	D2M2H2L2	D2M2H2L3	D2M2H2L4	D2M2H2L5
1	161	159	157	150	156
2	145	160	161	160	160
3	144	148	147	143	147
4	112	118	116	109	119
5	123	128	135	129	127
6	124	125	141	137	137
7	94	95	92	85	96
8	154	157	155	154	154
9	137	146	148	147	148
10	157	170	180	185	186
11	161	168	162	165	168
12	149	157	159	166	160
13	147	153	158	160	154
14	141	151	155	157	158
15	151	156	166	150	154
16	128	133	134	122	136
17	116	124	123	119	126
18	141	155	155	140	153
19	138	146	155	154	153
20	137	132	145	127	148
21	133	145	142	146	145
22	137	146	148	146	149
23	132	140	139	132	142
24	156	162	165	167	171
25	162	174	163	174	159

CASE	D2M2H2L6	D2M2H2L7	D2M2H3L1	D2M2H3L2	D2M2H3L3
1	159	158	163	163	162
2	162	161	145	160	162
3	149	157	144	148	147
4	122	119	121	126	124
5	132	135	129	136	140
6	133	141	124	127	142
7	98	102	110	103	107
8	163	171	154	161	161
9	153	151	137	146	151
10	189	189	161	174	180
11	163	158	161	170	167
12	160	165	149	157	159
13	155	155	147	154	160
14	157	158	144	157	158
15	159	156	151	156	166
16	136	132	131	134	136
17	124	126	116	124	123
18	156	151	149	155	155
19	143	152	138	146	155
20	146	141	146	146	146
21	145	144	136	148	143
22	154	158	143	146	149
23	146	147	140	152	152
24	168	166	161	167	172
25	174	162	162	174	169

CASE	D2M2H3L4	D2M2H3L5	D2M2H3L6	D2M2H3L7
1	159	159	160	164
2	161	160	162	161
3	143	147	149	157
4	122	126	128	130
5	134	137	135	140
6	137	143	140	141
7	99	105	108	110
8	163	164	164	175
9	147	149	153	154
10	185	186	189	189
11	166	172	166	166
12	166	160	164	165
13	162	160	158	157
14	158	167	162	164
15	158	160	160	156
16	133	141	138	138
17	122	126	125	126
18	148	154	156	154
19	154	153	146	152
20	148	148	150	147
21	146	152	145	147
22	150	152	155	158
23	148	159	164	153
24	173	175	169	167
25	175	164	174	165

*** DESCRIPTIVE STATISTICS ***

THERE ARE 84 VARIABLES AND 25 CASES IN THE DATA SET

VARIABLE	MEAN	STD.DEV.	VARIANCE	STD ERROR OF MEAN	COEFF OF VARIATION
D1M1H1L1	109.040	22.1124	488.957	4.42247	20.2791
D1M1H1L2	111.200	22.3028	497.417	4.46057	20.0565
D1M1H1L3	114.680	22.7847	519.143	4.55694	19.8681
D1M1H1L4	113.440	22.6423	512.673	4.52846	19.9597
D1M1H1L5	112.720	24.7563	612.877	4.95127	21.9627
D1M1H1L6	113.040	23.5770	555.873	4.71539	20.8572
D1M1H1L7	106.760	21.4015	458.023	4.28030	20.0463
D1M1H2L1	109.560	22.4222	502.757	4.48445	20.4657
D1M1H2L2	114.600	21.4087	458.333	4.28174	18.6813
D1M1H2L3	118.000	24.7572	612.917	4.95143	20.9806
D1M1H2L4	120.280	25.2711	638.627	5.05421	21.0102
D1M1H2L5	118.760	25.533	651.940	5.10662	21.4998
D1M1H2L6	116.440	24.3158	591.257	4.86315	20.8827
D1M1H2L7	111.680	21.4529	460.227	4.29058	19.2093
D1M1H3L1	113.600	21.2112	449.917	4.24225	18.6719
D1M1H3L2	119.080	20.1865	407.493	4.03729	16.9520
D1M1H3L3	122.280	23.0281	530.293	4.60562	18.8323
D1M1H3L4	127.320	23.4764	551.143	4.69529	18.4389
D1M1H3L5	123.600	23.7539	564.250	4.75079	19.2184
D1M1H3L6	120.800	23.5920	556.583	4.71840	19.5298
D1M1H3L7	118.840	19.4758	379.307	3.89516	16.3883
D1M2H1L1	137.200	20.5609	422.750	4.11218	14.9861
D1M2H1L2	140.960	21.5687	465.207	4.31373	15.3013
D1M2H1L3	140.240	21.0620	443.607	4.21239	15.0185
D1M2H1L4	137.080	23.4217	548.577	4.68434	17.0862
D1M2H1L5	140.400	19.2916	372.167	3.85832	13.7405
D1M2H1L6	143.000	22.2972	497.167	4.45945	15.5925
D1M2H1L7	144.120	18.3424	336.443	3.66848	12.7272
D1M2H2L1	140.640	20.3406	413.740	4.06812	14.4629
D1M2H2L2	146.200	20.6297	425.583	4.12593	14.1106
D1M2H2L3	146.360	19.6127	384.657	3.92253	13.4003
D1M2H2L4	144.360	22.2951	497.073	4.45903	15.4441
D1M2H2L5	147.200	19.1377	366.250	3.82753	13.0011
D1M2H2L6	148.640	22.5756	509.657	4.51512	15.1881
D1M2H2L7	149.160	17.5302	307.307	3.50603	11.7526
D1M2H3L1	143.560	19.3866	375.840	3.87732	13.5042
D1M2H3L2	149.800	18.6949	349.500	3.73898	12.4799
D1M2H3L3	151.480	18.2326	332.427	3.64651	12.0363
D1M2H3L4	149.520	19.6620	386.593	3.93240	13.1501
D1M2H3L5	151.720	18.0428	325.543	3.60856	11.8922
D1M2H3L6	154.280	17.3866	302.293	3.47732	11.2695
D1M2H3L7	152.560	16.9413	287.007	3.38825	11.1047
D2M1H1L1	107.080	20.0664	402.660	4.01328	18.7396
D2M1H1L2	108.520	18.3556	336.927	3.67111	16.9145
D2M1H1L3	112.840	21.9710	482.723	4.39419	19.4709
D2M1H1L4	109.800	21.8079	475.583	4.36157	19.8615

VARIABLE	MEAN	STD.DEV.	VARIANCE	STD ERROR OF MEAN	COEFF OF VARIATION
D2M1H1L5	113.800	24.4438	597.500	4.88876	21.4796
D2M1H1L6	111.120	22.5635	509.110	4.51269	20.3055
D2M1H1L7	110.040	20.0592	402.373	4.01185	18.2290
D2M1H2L1	108.240	20.1624	406.523	4.03248	18.6275
D2M1H2L2	113.000	19.7252	389.083	3.94504	17.4559
D2M1H2L3	119.480	28.2048	795.510	5.64096	23.6063
D2M1H2L4	119.640	23.5211	553.240	4.70421	19.6599
D2M1H2L5	119.520	24.9234	621.177	4.98468	20.8529
D2M1H2L6	115.640	21.6254	467.657	4.32507	18.7006
D2M1H2L7	112.480	21.1722	448.260	4.23443	18.8230
D2M1H3L1	112.960	19.4647	378.873	3.89293	17.2315
D2M1H3L2	117.200	17.3877	302.333	3.47755	14.8360
D2M1H3L3	123.440	26.4119	697.590	5.28239	21.3966
D2M1H3L4	124.160	21.8264	476.390	4.36527	17.5792
D2M1H3L5	122.280	23.2961	542.710	4.65923	19.0515
D2M1H3L6	120.440	19.2896	372.090	3.85793	16.0160
D2M1H3L7	119.800	18.7461	351.417	3.74922	15.6478
D2M2H1L1	135.840	17.5349	307.473	3.50698	12.9085
D2M2H1L2	139.960	20.1215	404.873	4.02429	14.3766
D2M2H1L3	141.520	19.3888	375.927	3.87777	13.7004
D2M2H1L4	136.960	24.4514	597.873	4.89029	17.8530
D2M2H1L5	141.400	19.7547	390.250	3.95095	13.9708
D2M2H1L6	143.600	20.3899	415.750	4.07799	14.1991
D2M2H1L7	145.800	20.0291	401.167	4.00583	13.7374
D2M2H2L1	139.200	16.7008	278.917	3.34016	11.9977
D2M2H2L2	145.920	18.2595	333.410	3.65190	12.5134
D2M2H2L3	148.040	18.3155	335.457	3.66310	12.3720
D2M2H2L4	144.960	21.9098	480.040	4.38196	15.1144
D2M2H2L5	148.240	18.1252	328.523	3.62504	12.2269
D2M2H2L6	149.840	18.6853	349.140	3.73706	12.4702
D2M2H2L7	150.200	17.8839	319.833	3.57678	11.9067
D2M2H3L1	142.480	14.6291	214.010	2.92582	10.2675
D2M2H3L2	149.200	16.9657	287.833	3.39313	11.3711
D2M2H3L3	151.440	16.6285	276.507	3.32570	10.9802
D2M2H3L4	150.280	18.8382	354.877	3.76763	12.5354
D2M2H3L5	152.760	17.0545	290.857	3.41090	11.1643
D2M2H3L6	152.800	17.2143	296.333	3.44287	11.2659
D2M2H3L7	153.440	16.4825	271.673	3.29650	10.7420

VARIABLE	MINIMUM	MAXIMUM	RANGE	TOTAL
D1M1H1L1	70	144	74	2726.00
D1M1H1L2	77	157	80	2780.00
D1M1H1L3	78	169	91	2867.00
D1M1H1L4	71	165	94	2836.00
D1M1H1L5	73	165	92	2818.00
D1M1H1L6	80	165	85	2826.00
D1M1H1L7	76	149	73	2669.00
D1M1H2L1	70	152	82	2739.00
D1M1H2L2	81	164	83	2865.00
D1M1H2L3	79	171	92	2950.00

D1M1H2L4	71	164	93	3007.00
D1M1H2L5	73	167	94	2969.00
D1M1H2L6	82	167	85	2911.00
D1M1H2L7	78	156	78	2792.00
D1M1H3L1	79	157	78	2840.00
D1M1H3L2	87	164	77	2977.00
D1M1H3L3	87	171	84	3057.00
D1M1H3L4	86	166	80	3183.00
D1M1H3L5	86	167	81	3090.00
D1M1H3L6	82	167	85	3020.00
D1M1H3L7	87	156	69	2971.00
D1M2H1L1	96	173	77	3430.00
D1M2H1L2	88	171	83	3524.00
D1M2H1L3	89	171	82	3506.00
D1M2H1L4	87	174	87	3427.00
D1M2H1L5	96	170	74	3510.00
D1M2H1L6	91	180	89	3575.00
D1M2H1L7	98	179	81	3603.00
D1M2H2L1	101	179	78	3516.00
D1M2H2L2	99	176	77	3655.00
D1M2H2L3	98	175	77	3659.00
D1M2H2L4	96	180	84	3609.00
D1M2H2L5	105	181	76	3680.00
D1M2H2L6	91	182	91	3716.00
D1M2H2L7	108	181	73	3729.00
D1M2H3L1	104	180	76	3589.00
D1M2H3L2	110	178	68	3745.00
D1M2H3L3	110	179	69	3787.00
D1M2H3L4	105	181	76	3738.00
D1M2H3L5	112	183	71	3793.00
D1M2H3L6	116	182	66	3857.00
D1M2H3L7	118	182	64	3814.00
D2M1H1L1	56	137	81	2677.00
D2M1H1L2	72	150	78	2713.00
D2M1H1L3	66	170	104	2821.00
D2M1H1L4	65	160	95	2745.00
D2M1H1L5	68	172	104	2845.00
D2M1H1L6	68	162	94	2778.00
D2M1H1L7	74	148	74	2751.00
D2M1H2L1	66	145	79	2706.00
D2M1H2L2	68	162	94	2825.00
D2M1H2L3	71	210	139	2987.00
D2M1H2L4	67	167	100	2991.00
D2M1H2L5	75	172	97	2988.00
D2M1H2L6	73	167	94	2891.00
D2M1H2L7	75	152	77	2812.00
D2M1H3L1	75	155	80	2824.00
D2M1H3L2	89	163	74	2930.00
D2M1H3L3	79	210	131	3086.00
D2M1H3L4	82	167	85	3104.00
D2M1H3L5	80	172	92	3057.00
D2M1H3L6	86	167	81	3011.00

D2M1H3L7	84	155	71	2995.00
D2M2H1L1	91	160	69	3396.00
D2M2H1L2	88	174	86	3499.00
D2M2H1L3	84	177	93	3538.00
D2M2H1L4	75	183	108	3424.00
D2M2H1L5	88	186	98	3535.00
D2M2H1L6	88	189	101	3590.00
D2M2H1L7	92	187	95	3645.00
D2M2H2L1	94	162	68	3480.00
D2M2H2L2	95	174	79	3648.00
D2M2H2L3	92	180	88	3701.00
D2M2H2L4	85	185	100	3624.00
D2M2H2L5	96	186	90	3706.00
D2M2H2L6	98	189	91	3746.00
D2M2H2L7	102	189	87	3755.00
D2M2H3L1	110	163	53	3562.00
D2M2H3L2	103	174	71	3730.00
D2M2H3L3	107	180	73	3786.00
D2M2H3L4	99	185	86	3757.00
D2M2H3L5	105	186	81	3819.00
D2M2H3L6	108	189	81	3820.00
D2M2H3L7	110	189	79	3836.00

VARIABLE	MEDIAN	MODE	SKEWNESS	KURTOSIS
D1M1H1L1	111.000	93	-0.110292	1.80921
- HAS MULTIPLE MODES				
D1M1H1L2	109.000	90	0.531916	2.43344
- HAS MULTIPLE MODES				
D1M1H1L3	111.000	104	0.438613	2.65515
- HAS MULTIPLE MODES				
D1M1H1L4	113.000	110	0.145305	2.88756
- HAS MULTIPLE MODES				
D1M1H1L5	108.000	108	0.248405	2.34133
- HAS MULTIPLE MODES				
D1M1H1L6	108.000	86	0.502596	2.30753
- HAS MULTIPLE MODES				
D1M1H1L7	105.000	82	0.341647	1.95156
- HAS MULTIPLE MODES				
D1M1H2L1	115.000	88	-0.0267520	1.91710
- HAS MULTIPLE MODES				
D1M1H2L2	109.000	91	0.604390	2.49311
- HAS MULTIPLE MODES				
D1M1H2L3	113.000	113	0.403061	2.24090
D1M1H2L4	116.000	95	-0.0276472	2.11030
- HAS MULTIPLE MODES				
D1M1H2L5	117.000	104	0.0648944	2.14470
- HAS MULTIPLE MODES				
D1M1H2L6	107.000	105	0.496200	2.18579
D1M1H2L7	110.000	110	0.126504	2.04972
- HAS MULTIPLE MODES				
D1M1H3L1	120.000	88	0.0239346	1.91489
- HAS MULTIPLE MODES				

D1M1H3L2	116.000	105	0.432746	2.42451
- HAS MULTIPLE MODES				
D1M1H3L3	121.000	107	0.404146	2.09684
- HAS MULTIPLE MODES				
D1M1H3L4	118.000	104	0.140856	1.73899
D1M1H3L5	119.000	NONE	0.239294	1.95609
D1M1H3L6	115.000	104	0.411523	2.03913
- HAS MULTIPLE MODES				
D1M1H3L7	121.000	95	0.142429	1.87413
- HAS MULTIPLE MODES				
D1M2H1L1	143.000	147	-0.326243	2.31711
D1M2H1L2	146.000	124	-0.702991	2.91462
- HAS MULTIPLE MODES				
D1M2H1L3	149.000	123	-0.639023	2.73811
- HAS MULTIPLE MODES				
D1M2H1L4	139.000	119	-0.229631	2.27104
- HAS MULTIPLE MODES				
D1M2H1L5	143.000	129	-0.390781	2.44310
- HAS MULTIPLE MODES				
D1M2H1L6	151.000	156	-0.805508	3.25568
D1M2H1L7	149.000	149	-0.549988	3.04977
- HAS MULTIPLE MODES				
D1M2H2L1	145.000	122	-0.208410	2.40134
- HAS MULTIPLE MODES				
D1M2H2L2	151.000	123	-0.508111	2.59146
- HAS MULTIPLE MODES				
D1M2H2L3	151.000	158	-0.681587	2.95105
D1M2H2L4	149.000	154	-0.315195	2.31026
D1M2H2L5	150.000	136	-0.335170	2.60903
- HAS MULTIPLE MODES				
D1M2H2L6	153.000	153	-0.900878	3.39274
D1M2H2L7	151.000	161	-0.443959	2.73935
- HAS MULTIPLE MODES				
D1M2H3L1	148.000	124	-0.192219	2.57246
- HAS MULTIPLE MODES				
D1M2H3L2	152.000	157	-0.456586	2.55142
D1M2H3L3	156.000	140	-0.603568	2.94713
- HAS MULTIPLE MODES				
D1M2H3L4	150.000	130	-0.319155	2.43102
- HAS MULTIPLE MODES				
D1M2H3L5	152.000	137	-0.364734	2.53433
- HAS MULTIPLE MODES				
D1M2H3L6	154.000	141	-0.543368	2.73697
- HAS MULTIPLE MODES				
D1M2H3L7	152.000	118	-0.287367	2.45996
- HAS MULTIPLE MODES				
D2M1H1L1	105.000	88	-0.403459	3.05586
- HAS MULTIPLE MODES				
D2M1H1L2	110.000	104	0.0921755	3.00849
- HAS MULTIPLE MODES				
D2M1H1L3	115.000	66	0.0271175	4.17496
- HAS MULTIPLE MODES				

D2M1H1L4	108.000	102	0.147772	2.98749
D2M1H1L5	113.000	NONE	0.108144	2.86378
D2M1H1L6	116.000	116	-0.0235142	2.63610
D2M1H1L7	108.000	95	0.0876943	2.39206
- HAS MULTIPLE MODES				
D2M1H2L1	109.000	103	-0.00285911	2.54129
- HAS MULTIPLE MODES				
D2M1H2L2	111.000	102	0.0698833	3.63343
- HAS MULTIPLE MODES				
D2M1H2L3	118.000	104	1.17964	5.85394
- HAS MULTIPLE MODES				
D2M1H2L4	122.000	98	-0.227322	2.89208
- HAS MULTIPLE MODES				
D2M1H2L5	118.000	146	-0.0933902	2.44232
- HAS MULTIPLE MODES				
D2M1H2L6	114.000	114	0.189071	2.90896
D2M1H2L7	114.000	99	-0.0158739	2.20435
- HAS MULTIPLE MODES				
D2M1H3L1	112.000	92	0.151395	2.45358
- HAS MULTIPLE MODES				
D2M1H3L2	115.000	128	0.547995	3.22092
D2M1H3L3	122.000	106	1.39900	5.98380
D2M1H3L4	128.000	108	-0.0274844	2.35111
- HAS MULTIPLE MODES				
D2M1H3L5	121.000	107	-0.00789964	2.39260
- HAS MULTIPLE MODES				
D2M1H3L6	119.000	108	0.306573	2.70292
- HAS MULTIPLE MODES				
D2M1H3L7	117.000	114	-0.00950485	2.12486
- HAS MULTIPLE MODES				
D2M2H1L1	137.000	120	-0.663515	2.90433
- HAS MULTIPLE MODES				
D2M2H1L2	144.000	119	-0.803047	3.13750
- HAS MULTIPLE MODES				
D2M2H1L3	146.000	137	-1.08329	4.59509
- HAS MULTIPLE MODES				
D2M2H1L4	139.000	139	-0.538576	3.18445
D2M2H1L5	143.000	128	-0.517202	4.09312
- HAS MULTIPLE MODES				
D2M2H1L6	149.000	149	-0.639905	4.07286
- HAS MULTIPLE MODES				
D2M2H1L7	151.000	162	-0.798743	3.91896
D2M2H2L1	141.000	137	-0.777802	3.42408
D2M2H2L2	148.000	146	-0.860963	3.63277
D2M2H2L3	155.000	155	-1.21106	4.92703
D2M2H2L4	147.000	146	-0.716848	3.68112
- HAS MULTIPLE MODES				
D2M2H2L5	153.000	154	-0.797369	4.49969
D2M2H2L6	154.000	146	-0.664048	4.06012
- HAS MULTIPLE MODES				
D2M2H2L7	155.000	158	-0.653284	4.02338
D2M2H3L1	144.000	161	-0.483059	2.54930

D2M2H3L2	152.000	146	-0.798758	3.51029
D2M2H3L3	155.000	155	-0.826831	3.57436
- HAS MULTIPLE MODES				
D2M2H3L4	150.000	148	-0.696178	3.67887
D2M2H3L5	154.000	160	-0.784498	4.10947
D2M2H3L6	156.000	164	-0.569194	3.59394
D2M2H3L7	156.000	147	-0.555966	3.81357
- HAS MULTIPLE MODES				