HORMONAL RESPONSE TO FREE WEIGHT AND MACHINE WEIGHT RESISTANCE EXERCISE

Aaron Arthur Shaner

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APPROVED:

Jakob L. Vingren, Major Professor
David W. Hill, Committee Member
Disa Hatfield, Committee Member
Allen W. Jackson, Chair of the Department of Kinesiology, Health Promotion, and Recreation
Jerry R. Thomas, Dean of the College of Education
Mark Wardell, Dean of the Toulouse Graduate School

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No study has examined the effect of exercise modality (free weight vs. machine weight) on the acute hormonal response using similar multi-joint exercises. The purpose of this investigation was to examine the effect of resistance exercise modality on acute hormonal responses by comparing the squat and leg press which are multi-joint, and similar in action and lower-body muscle involvement. Ten resistance trained men (21-31 y, 24.7 ± 2.9 y, 179 ± 7 cm, 84.2 ± 10.5 kg) participated in the study. Sessions 1 and 2 determined the participants' 1-RM in the squat and leg press. During acute heavy resistance exercise testing visits (AHRET), sessions 3 and 4, participants completed 6 sets of 10 repetitions with an initial intensity of 80% of their 1-RM for the squat and leg press exercises. There was a 2 minute rest period between each set. Blood samples were collected before, immediately after, and 15 and 30 minutes after exercise via intravenous catheter during the AHRET visits and were analyzed for testosterone, cortisol, and growth hormone. Lactate, plasma volume change, heart rates and ratings of perceived exertion were also measured. Total work was calculated for external load only and for external load and the body mass used in the exercises. The 4 sessions were counterbalanced and randomized for exercise mode. Testosterone for the squat (Pre: 23.9 ± 8.7 nmol•L^{-1}; IP: 31.4 ± 10.3 nmol•L) and leg press (Pre: 22.1 ± 9.4 nmol•L^{-1}; IP: 26.9 ± 7.8 nmol•L) increased but more significantly after the squat. Growth hormone increased in both the squat (Pre: 0.2 ± 0.2 µg/L; IP: 9.5 ± 7.3 µg/L) and the leg press (Pre: 0.3 ± 0.5 µg/L; IP: 2.8 ± 3.2 µg/L). The increase was significantly higher after the squat compared to the leg press. Cortisol also increased after performing the squat (Pre: 471.9 ± 167.2 nmol•L^{-1}; IP: 603.2 ± 277.6 nmol•L) and leg press (Pre: 463.5 ± 212.4 nmol•L^{-1};

IP: 520.3 ± 270.3 nmol•L), but there was no significant difference between the two modes. The total work was significantly higher in the squat (60509 ± 10759 j) compared to the leg press (42875 ± 7010). The squat exercise is more effective at inducing an acute hormonal response. If the leg press exercise is used, the hormonal response may be reduced, which might lead to reduced training adaptations, especially when only a 90º knee angle ROM is used. To induce the maximal hormonal response to resistance exercise, free weight exercises should be used.

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INTRODUCTION

Resistance exercise provides strong stimuli that induce an acute response of the neuroendocrine system. These hormonal responses have a potential role in resistance training adaptations since hormones interact with skeletal muscle and other tissues that affect the development of muscle and adaptations, including enhanced strength and power of the muscle. Hormones can have an anabolic or catabolic effect on skeletal muscle. Anabolic hormones promote protein synthesis, whereas catabolic hormones promote protein degradation. Resistance exercise can cause both acute and chronic increases in circulating anabolic and catabolic hormones [19, 20, 41, 31, 38, 30, 47]. However, not all resistance exercise protocols have been effective at inducing a significant acute hormonal response [12, 36, 2, 4, 41, 37, 31, 50] suggesting that the appearance and magnitude of increase in these hormones appears to be dependent on factors such as the acute program variables (e.g., intensity, sets, exercise choice/mode, order of exercise, and rest period duration) [46]. Of these acute program variables, it appears few studies have investigated the effects of exercise modality/exercise choice (specifically free weight or machine exercises) on the hormonal response.

Resistance exercise causes an acute increase in testosterone, growth hormone (GH), and cortisol. These three hormones play an important role in muscle metabolism. Testosterone is an anabolic steroid hormone that provides both anabolic and anti-catabolic effects. In muscle tissue, testosterone stimulates protein synthesis [32] and inhibits protein degradation. Testosterone is considered the primary hormone that interacts with skeletal muscles for cell growth [49]. GH is also an anabolic hormone. GH has many functions including the growth and turnover of muscle, bone and collagen, and increased fat metabolism and the maintenance of a healthy body composition [7]. GH elevates in relation to the rise and fall of lactate [18] and may remain elevated for up to 30 minutes post-exercise for both men and women [18, 20]. Cortisol is a catabolic hormone whose catabolic effect appears stronger in type II fibers than in type I fibers [29]. Elevated cortisol levels promote fatty acid and protein catabolism [27].

Concentrations of testosterone, GH, and cortisol can acutely increase after a bout of resistance exercise [19-21, 30, 31, 38, 41-44]. The appearance and magnitude of the increase in these hormones post-exercise is affected by acute program variables including number of sets [20, 41, 8], intensity [40,36], volume [12, 41, 38], rest period duration [20, 1] exercise mode and choice [44, 14], as well as age [13, 24]. Larger increases in these hormones are observed when these acute program variables are manipulated to create hypertrophic workloads [13, 35]. Hypertrophic workloads, such as six sets of ~10-repetition maximum (RM) with 2-minute rest periods used by Ratamess and colleagues [37], are high in volume [12, 41, 37, 38], one moderate to high in intensity [40, 36], have short rest periods [20, 1], and are successful at inducing a significant acute response in testosterone, GH, and cortisol [41, 37].

Exercise choice significantly influences the hormonal response to a bout of resistance exercise because this variable affects the amount of muscle mass used and the volume of work performed. Exercise modality (free weight or machine weight) is one aspect of exercise choice. Many exercisers, especially those new to lifting or injured, choose machine exercises over their free weight counterparts. Two similar exercises are the back squat and the leg press. The squat and leg press engage the large muscles of the legs, are similar in lower body joint action, and many exercisers use them interchangeably even though the exercises are not equivalent. The squat is a closed kinetic chain functional exercise that incorporates the stabilizing muscles of the abdominals and lower back. The leg press is an open kinetic chain exercise that largely isolates the legs. Although the primary movers are the same for both exercises (quadriceps and gluteus), the squat incorporates more muscle mass than the leg press [48]. This is an important distinction because exercises that involve large muscle mass produce larger hormonal responses compared with smaller muscle mass exercises [24].

Very few studies appear to have directly examined the effect of exercise modality, specifically free weight versus machine exercises, on the hormonal response. Kang et al. [16] compared the GH release patterns of the back squat to the leg press following 3 workloads (3, 10, and 25-RM) to determine whether the mode of exercise could influence hormonal output. They found that the 10-RM workload gave the greatest increase of GH after performing the leg press, whereas 25-RM workload was the most effective in the squat. However, this study did not assess the effect of exercise modality on testosterone or cortisol response. Schilling et al. [39] examined hormonal responses (testosterone, GH, and cortisol) to a multi-joint free weight exercise (squat) to the responses to three single joint machine exercises (leg curl, leg extension, back extension) which combined involved the same major muscle groups as the squat. The authors found that less work was needed to stimulate similar hormonal response when using the multi-joint free weight exercise. Ahtianen et al. [1] investigated the acute hormonal and neuromuscular responses to and recovery from two different hypertrophic heavy resistance exercise protocols. The squat and leg press were used, but both exercises were performed as part of the same hypertrophic protocol and the hormonal responses of the exercises were not compared between modes. No study appears to have compared the acute testosterone, GH, and cortisol response to similar free weight and machine weight multi-joint exercises. Therefore, the purpose of the present study was to examine the effect of resistance exercise modality on the hormonal response using a multi-joint free weight exercise (squat) and a multi-joint machine exercise (leg press) that are similar in action and lower body muscle involvement.

METHODS

Experimental Approach to the Problem

This investigation used a 2 × 4 (Exercise Mode × Time Point) design to compare the hormonal responses of the squat and the leg press exercises in recreationally resistance trained men. All participants completed 4 sessions; 1 session per week for 4 weeks. During the first and second sessions, participants were familiarized with the squat and the leg press exercises and their one-repetition maximum (1-RM) was determined. On the third and fourth visits, participants performed 6 sets of 10 repetitions of the squat or leg press with 2 minutes rest between sets. The initial intensity was 80% of 1-RM. Participants performed only one exercise mode per session, i.e., participants who performed the squat exercise on the first visit performed the leg press exercise on the second visit. The order of exercise mode was randomized and counterbalanced; the order of exercise mode for Visits 1 and 2 was repeated for Visits 3 and 4. Fasted blood samples were collected before the warm up (Pre), immediately after exercise (IP), and 15 min (15) and 30 min (30) into recovery from exercise and analyzed for total testosterone, growth hormone (GH), cortisol, and lactate concentrations.

Subjects

Ten healthy recreationally trained men (21-31 y, 24.7 ± 2.9 y, 179 ± 7 cm, 84.2 ± 10.5 kg) completed the study. Participants were resistance trained for at least 6 months (≥ 2 times a week) prior to the study and performed the squat exercise on a regular basis. The participants completed a medical history questionnaire to help determine their eligibility for the study. Exclusion criteria included any musculoskeletal, cardiovascular, metabolic, endocrine, or neurological disorder that could inhibit involvement in exercise; previous orthopedic injuries that limited the range of motion of the hip, knee, or ankle joint; back injuries, such as herniated discs;

steroid use; or inability to meet the demands of the exercise protocol. Prior to participation, participants were informed of the protocols and risks associated with the study and provided written informed consent. The study was approved by the University of North Texas Institutional Review Board.

Procedures

Sessions 1 and 2: Anthropometric measurements, familiarization, 1-RM test for the barbell squat, and 1-RM for the leg press. After informed consent was given, height and weight were measured. Body composition was measured using dual-energy X-ray absorptiometry (DXA) (Lunar Prodigy General Electric Company, Madison, WI). Participants wore only light athletic clothing and no shoes during these measurements. Height and body composition were measured only in Session 1. Participants performed a standardized dynamic warm up (lunges, heel kicks, high knees, body weight squats, and shoulder circles) and were familiarized with the proper technique for performing the free weight barbell squat or leg press exercise (using an inverted leg press, Body Masters, Rayne, LA). The participant performed a squat to where the femur was parallel to the ground. The leg press was performed using an inverted leg press (45º) with a sled. The participant lowered the sled to a 90º knee angle and extended their knees to full knee extension (180º). Once participants demonstrated proper technique in the exercise, their 1-RM strength was measured using the methods described by Kraemer and Fleck [17].

Sessions 3 and 4: Acute heavy resistance exercise test (AHRET). On both AHRET visits, participants reported to the laboratory in the morning (0800-1000h) after a 12-hour fast and 48 hours without exercise. They were asked to provide a small urine sample and specific gravity of this sample was measured using urine refractometry (Reichert, Depew, NY) to ensure that participants were adequately hydrated (<1.020 g•ml^{-1}). Participants were asked to drink 0.5-1.0 L of water the night before and the morning of Visits 3 and 4 to aid with hydration. Once hydration levels were measured and recorded as normal, a teflon catheter was inserted into an antecubital forearm vein and kept patent with a 0.9% sodium chloride saline solution. The catheter remained in the vein for the duration of each session. If a participant was dehydrated, they were given water before exercise.

The standardized dynamic warm-up was then performed. After the warm up, participants performed a hypertrophic workload of 6 sets of 10 repetitions of the squat or leg press with 2 minutes of rest between sets. The initial intensity for both exercises was 80% of their 1-RM. The intensity was reduced after a set if the participant could not complete the 10 repetitions without assistance from the spotters.

In both AHRET sessions, blood was drawn prior to the warm up (pre), immediately after testing (IP), and 15 and 30 min into recovery from exercise. Prior to each blood draw 3 ml of blood was extracted and discarded to avoid inadvertent saline dilution of the blood sample. At Pre, immediately after each set and at each blood draw during recovery from exercise, heart rate (HR) was recorded. Heart rate was measured using a standard heart rate monitor (Polar, Lake Success, NY). Rating of perceived exertion (RPE) was recorded at Pre and immediately after each set using the category-ratio (CR-10) scale of perceived exertion [18]. The experimental design for the exercise protocol (Visits 3 and 4) is depicted in Figure 1.

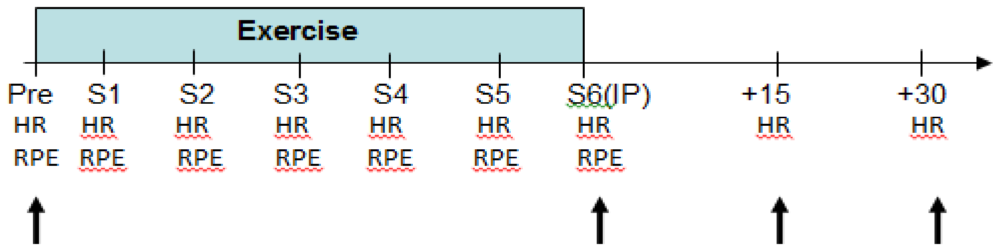

Figure 1. Time line for exercise protocol sessions (Visits 3 and 4).

HR= heart rate RPE= rating of perceived exertion S= set; ↑= blood draw

Calculation of work performed. The displacement of the bar (squat) and sled (leg press) during exercise were measured for each participant. The (positive) work performed during each set was calculated based on external load only (External Mass × *g* × Vertical Displacement × # of Repetitions) and external load and body mass moved during the exercise ((External Mass + Body Mass) × *g* × Vertical Displacement × # of Repetitions). For the squat, body mass above the knee (determined by DXA) was used; for the leg press, lower body mass (determined by DXA) was used; *g* is the acceleration caused by gravity ($9.8\ m \cdot s^{-2}$). The vertical displacement for the leg press was obtained as follows: Sled Displacement × Cos 45°. To obtain the total work performed for a session, the work for each of the six sets were added.

Experimental controls. Participants were asked to avoid alcohol and resistance or exhaustive exercise for the 48 h prior to all visits. The participants were advised to avoid engaging in sexual activity the night before or morning of testing. Participants recorded everything they ate or drank during the 3 days prior to Visit 3 and repeated the same diet for Visit 4. The participants were instructed to have consistent sleep the night before both sessions. Participants attested that they conformed to these guidelines. Sessions 3 and 4 were performed at the same time of day for a particular participant, to minimize any potential confounding effects of circadian rhythm.

Biochemical analysis. Blood samples were centrifuged at 1,500 *g* and the resultant serum and plasma were aliquoted and stored at -80 °C until analysis. Samples were analyzed for total testosterone, GH, and cortisol using commercially available enzyme-linked immunosorbent assays (Alpco, Salem, NH). The sensitivity and coefficient of variance (CV) for each assay was: testosterone 0.08 $nmol \cdot L^{-1}$ and7%; GH 0.5 $\mu g \cdot L^{-1}$ and 12%; cortisol 11.03 $nmol \cdot L^{-1}$ and 6%. Hemoglobin (Hemocue, Angelholm, Sweden) and lactate (Nova Biomedical, Waltham, MA) concentrations were measured in duplicate using automated analyzers. Hematocrit was measured in triplicate by centrifugation of heparinized micro-hematocrit capillary tubes (Fisherbrand®, Pittsburgh, PA). From hemoglobin and hematocrit values, plasma volume shifts were calculated using the methods of Dill and Costill [5]. Plasma volume was decreased immediately following exercise (squat: -14.3 ± 5.1%; leg press: -11.9 ± 9.6%) and gradually returned towards baseline at 15 minutes (squat: -5.1 ± 5.5 %; leg press: -2.3 ± 12.9%) and 30 minutes (squat: -2.5 ± 4.8%; leg press: -0.3 ± 14.1%) into recovery.

Statistical Analyses

Hormonal responses were analyzed using two-way ANOVA (Exercise Mode × Time Point) with repeated measures on both factors (PASW Statistics version 18, Chicago, IL). Where appropriate, Fisher's LSD *post-hoc* analysis was used to determine pair-wise differences. Alpha level was set at $p \leq 0.05$. Data is presented as mean ± standard deviation (SD).

RESULTS

For testosterone (see Figure 2) there was a significant ($p \leq 0.05$) main effect for time; testosterone concentrations were significantly increased immediately post-exercise (IP), and 15 and 30 minutes into recovery compared to Pre. There was a significant main effect for mode; testosterone was higher for the squat compared to the leg press condition. There was a significant interaction between mode and quadratic trend for time; post-hoc follow up revealed that testosterone was significantly higher for the squat compared to the leg press at IP.

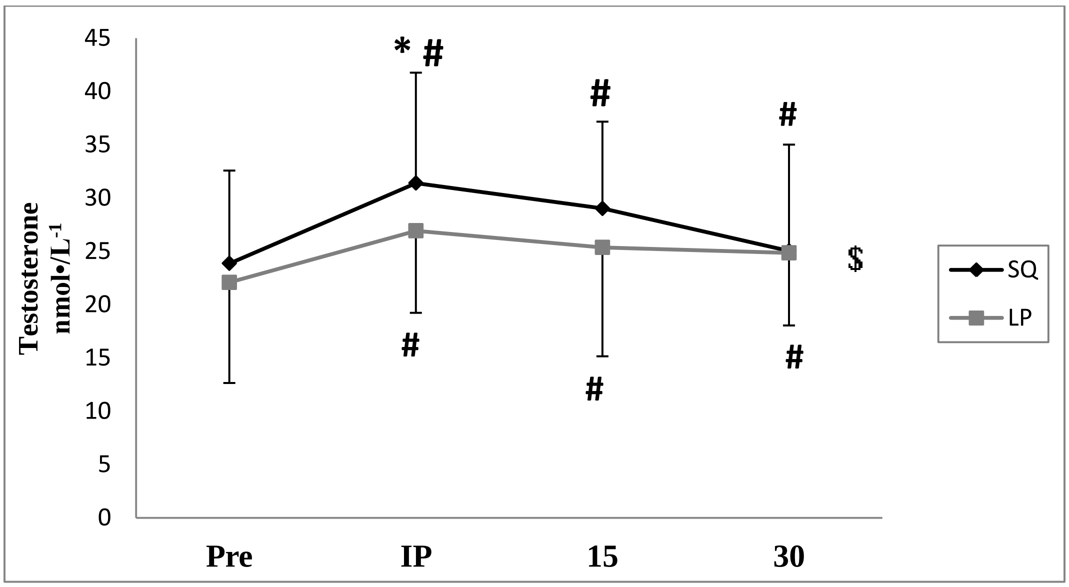

Figure 2. Testosterone concentrations before (Pre), immediately post-exercise (IP) and 15, and 30 minutes into recovery from exercise for the squat (SQ) and leg press (LP) exercises. # Significant ($p \leq 0.05$, main effect) difference from Pre. * Significantly different from corresponding time point for leg press. $ Significant main effect of mode. Mean ± SD.

For growth hormone (GH) (see Figure 3), there was a significant main effect for time; GH concentrations were significantly increased at IP, and 15 and 30 minutes into recovery compared to Pre. There was a significant main effect for mode; GH was higher for the squat compared to the leg press condition. There was a significant (Exercise Mode × Time) interaction effect; *post-hoc* follow up revealed that GH was significantly higher for the squat compared to the leg press at IP, and 15 and 30 minutes into recovery.

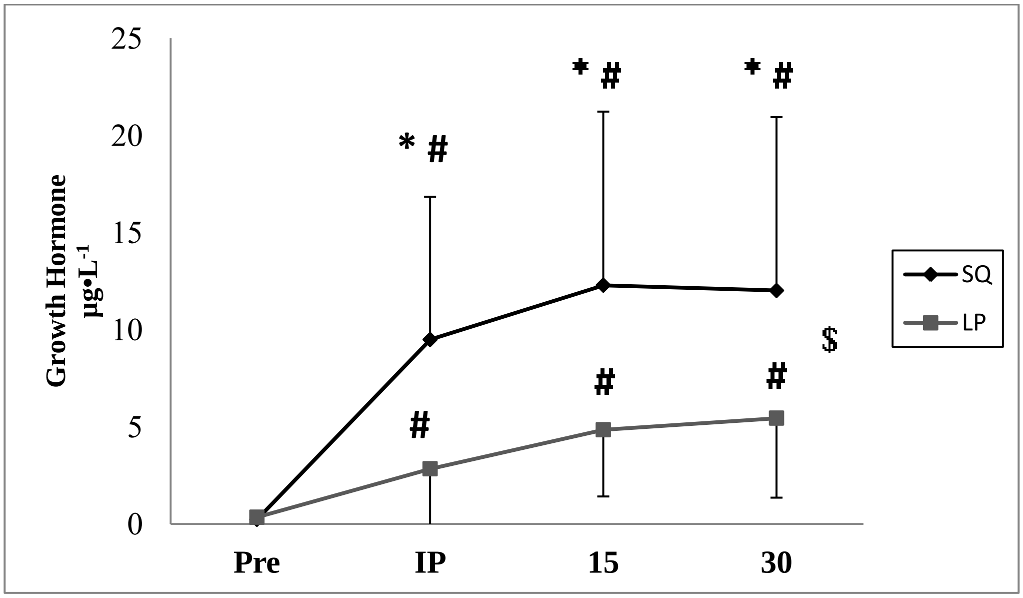

Figure 3. Growth hormone concentrations before (Pre), immediately post-exercise (IP) and 15, and 30 minutes into recovery from exercise for the squat (SQ) and leg press (LP) exercises. # Significant ($p \leq 0.05$, main effect) difference from Pre. * Significantly different from corresponding time point for leg press. $ Significant main effect of mode. Mean ± SD.

For cortisol (see Figure 4) there was a significant main effect for time; cortisol concentrations were significantly increased at IP, and 15 and 30 minutes into recovery compared to Pre. When sphericity was assumed there was a significant (Exercise Mode × Time) interaction effect; however, we did not meet this assumption. We therefore adjusted the degrees of freedom after which only a statistical trend ($p = 0.08$) for a (Exercise Mode × Time) interaction effect was found.

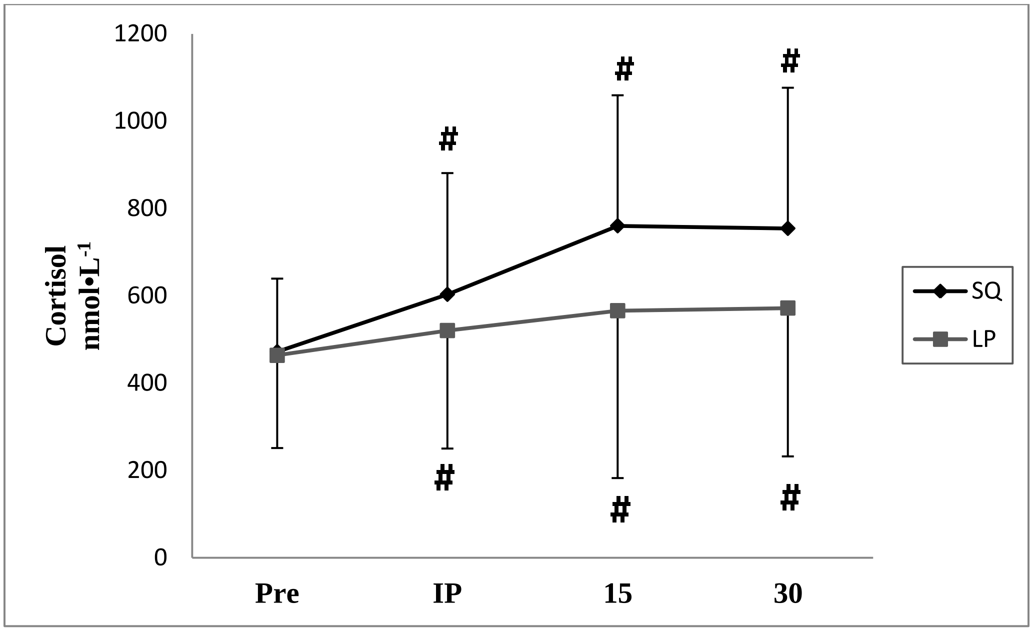

Figure 4. Cortisol concentrations before (Pre), immediately post-exercise (IP) and 15, and 30 minutes into recovery from exercise for the squat (SQ) and leg press (LP) exercises. # Significant ($p \leq 0.05$, main effect) difference from Pre. Mean ± SD.

For lactate (see Table 1) there was a significant main effect for time; lactate concentrations were significantly increased at IP, and 15 and 30 minutes into recovery compared to Pre. There was a significant main effect for mode; lactate was higher for the squat compared to the leg press condition. There was a significant (Exercise Mode × Time) interaction effect; *post-hoc* follow up revealed that lactate was significantly higher for the squat compared to the leg press at IP, and 15 and 30 minutes into recovery.

For heart rate (HR) (see Table 1) there was a significant main effect for time; HR was significantly increased at all time points after the onset of exercise compared to Pre. There was a significant main effect for mode; HR was higher for the squat compared to the leg press condition. There was a significant (Exercise Mode × Time) interaction effect; post-hoc follow up revealed that HR was significantly higher for the squat compared to the leg press for all time points following set 1.

For rating of perceived exertion (RPE) (see Table 1) there was a significant main effect for time; RPE was significantly increased following each set compared to Pre. There was no main effect for mode. There was a significant (Exercise Mode × Time) interaction effect; *post-hoc* follow up revealed that RPE was significantly higher for the squat compared to the leg press following Set 4.

Table 1

Lactate Concentration, Heart Rate (HR), and Rating of Perceived Exertion (RPE) for the Squat (SQ) and Leg Press (LP) Exercises

	Ex	**Pre**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6 (IP)**	**15**	**30**
Lactate $	SQ	1.1 ± 0.4						10.9 ± 2.3*#	8.0 ± 2.3*#	5.1 ± 1.4*#
	LP	1.1 ± 0.5						7.5 ± 2.6#	6.2 ± 2.1#	4.0 ± 1.6 #
HR $	SQ	71 ± 10	148 ± 18#	159 ± 17*#	164 ± 13*#	167 ± 14*#	165 ± 14*#	168 ± 12*#	98 ± 19*#	87 ± 14*#
	LP	68 ± 15	132 ± 14#	135 ± 16#	139 ± 14#	143 ± 14#	147 ± 13#	149 ± 15#	87 ± 17#	81 ± 14#
RPE	SQ	0.7 ± 0.7	7.0 ± 1.6#	8.2 ± 1.3#	9.0 ± 1.1#	9.4 ± 0.9*#	9.2 ± 0.9#	9.6 ± 0.7#		
	LP	1.0 ± 0.5	7.3 ± 1.6#	7.7 ± 1.3#	8.2 ± 0.9#	8.7 ± 0.7#	9.2 ± 0.6#	9.3 ± 0.5#		

Before exercise (pre), after sets 1-6 (S1-6), and 15 (15) and 30 (30) minutes into recovery. # Significant ($p \leq 0.05$, main effect) difference from Pre. * Significantly different from corresponding time point for leg press. $ Significant main effect of mode. Mean ± SD.

The total work performed for the external load did not differ between exercise modes; however, when the body mass moved during each exercise (squat: total body mass – shank mass; leg press: leg mass) was included in the load (added to external load), the work was significantly greater for the squat compared to the leg press exercise. It is not feasible to calculate actual work because different body parts move different distances throughout the exercise. Instead, the work was calculated using the displacement of the barbell (squat) and sled (leg press). The leg press displacement was adjusted for the angle. Results for work are presented in Table 2.

Table 2

One-Repetition Maximum (1-RM), Vertical Displacement, Total Work for External Load, and Total Work Including Body Mass Moved for the Squat (SQ) and Leg Press (LP) Exercises

	1 RM (kg) external load only	1 RM (kg) including body mass	Vertical displacement (m)	Total Work for external load (j)	Total Work including body mass (j)
SQ	140 ± 24*	215 ± 28*	0.58 ± 0.07*	35041 ± 7008	60509 ± 10759*
LP	366 ± 76	395 ± 72	0.22 ± 0.02	38372 ± 6600	42875 ± 7010

Mean ± SD.

DISCUSSION

This investigation appears to be the first study to directly compare the testosterone, growth hormone (GH), and cortisol responses of the squat and leg press exercises. The primary finding of this investigation was that differences exist between the acute hormonal and metabolic (based on heart rate and lactate) response to the squat and leg press exercises. The total external work performed was similar for the two exercise modes, but when work of moving body mass during exercise mode was included the total work was greater for the squat exercise which might explain the observed differences in the acute response to exercise.

Testosterone is important for muscle growth and strength due to its anabolic [32] and anti-catabolic effects [3]. Kvorning et al. [30] found that when testosterone was reduced to castrate levels in young men, increases in isometric strength from resistance exercise were not present, and muscle hypertrophy was attenuated. In the present study, both the squat and leg press acutely increased total testosterone. This finding is consistent with previous investigations which have reported that a high volume bout of heavy resistance exercise acutely increases testosterone in the circulation [12, 13, 24, 28, 30, 31, 38, 45, 41]. Testosterone concentration was significantly higher after performing the squat when compared to the leg press. This may be explained by the amount of muscle mass recruited for each exercise, because the magnitude of increase in testosterone is affected by the muscle mass involved. The squat incorporates more muscle mass [48] and therefore should induce a greater testosterone response [42].

Growth hormone is an anabolic hormone that supports muscular and skeletal growth [19]. GH concentration was significantly elevated following both modes of exercise; however, the increase was significantly greater for the squat exercise. As in previous studies [18], the increase in GH followed a similar pattern to the increase in lactate. Elias et al. [6] found that the anterior pituitary secretes GH in response to a reduction in pH associated with increased lactate concentration in the blood. Increases in circulating lactate and GH have also been observed when the rest period duration is abbreviated [20]. This suggests that increases in GH may be dependent on the metabolic demand of the exercise.

High volume protocols that use large muscle mass are effective for increasing circulating GH concentrations [12, 27, 31, 33, 41]. In the present study, the larger increases in GH after performing the squat are likely due to the amount of muscle mass recruited in the exercise and the increased lactate in the blood [48, 6]. The findings of this study are not consistent with those of Kang et al. [16]. Their study found that the leg press had a larger increase in GH than the squat when the intensity was set at 10-RM. This may have been due to the participants not performing enough sets of each exercise (they performed only three), or perhaps the response was affected by the body position of the participants during the lift. However, this does not explain the increase that was observed after the leg press and not the squat.

Cortisol is important to muscle metabolism because it stimulates protein degradation and inhibits protein synthesis. Protein synthesis is prevented by cortisol via blocking the AKT-mTor pathway [42]. Cortisol is increased acutely after a heavy bout of resistance exercise involving large muscle mass [10, 34, 11, 22, 23, 25, 26]. Furthermore, cortisol responds in the same manner as testosterone and GH in relation to the volume of work performed in an exercise session; a greater volume of work produces a greater increase in circulating cortisol [9, 12, 15, 41]. In the present study, cortisol was significantly elevated after both exercise modes. Statistically there was no difference between the two modes, but after adjusting the degrees of freedom, a statistical trend for (Exercise Mode × Time) interaction effect was found. The greater response for the squat exercise is likely due to a greater total work performed and a greater muscle mass involvement and activation than for the leg press [48].

The response of heart rate to exercise modality was similar to previous research [16]. Both modes of exercise produced similar patterns of increase in heart rate after sets of exercise and the pattern and magnitude of increase was similar to Kang et al. [16] All HRs were elevated from the Pre values for both exercises, and all HRs during exercise were greater for the squat. The attenuated HRs in the leg press may be due to the slightly inverted body position during exercise. In this position, venous return may be enhanced by gravity, resulting in increased stroke volume and thus reduce HR for the same cardiac output. However, it is also likely that the lower HR in the leg press was due to a lower metabolic demand during that exercise mode. Although HR was higher in the squat, the participants reported similar RPEs after sets of both exercise modes, suggesting that both exercise modes were equally demanding. This is interesting because although the squat was more work and more physiologically demanding, participants reported that both exercises felt equally demanding. Lactate was increased after both exercises, but the magnitude of increase was much larger after performing the squat protocol again suggesting a greater metabolic demand in the squat exercise. This may account for the greater response in GH after performing the squat [18].

Although the visits were initially counterbalanced, participant dropouts caused six participants to perform the leg press and four to perform the squat on Visit 3. This may have had an adverse effect on the results, but no effect was observed. Another limitation is that the participants only performed the leg press to a knee angle of 90º, while the knee angle for the full squat is less. This allows for greater range of motion (ROM) in the squat and greater muscle recruitment. The advantage of the shortened ROM for the leg press is that it does not allow the lower back to come off of the seat, and it does not load the spine in flexion. This leg press ROM is most commonly performed by people new to lifting and prescribed by physical therapists as a part of a rehabilitation program.

In the present study, greater testosterone and GH responses were observed after performing the squat exercise. Exercise lactate and HR were also greater after the squat. These findings are likely due to the amount of musculature involved in the squat and the fact that more work was performed in the squat exercise. Although not examined in this study, the addition of other large muscle exercises would have induced a much greater endocrine response. A greater range of motion in the leg press might have produced greater increases in hormone concentrations compared to a 90º ROM leg press. This finding suggests that the leg press when performed with a 90º knee angle will not produce the same adaptations as performing the squat.

Future research should further explore the effect of manipulating acute training variables such as exercise mode on the acute and chronic hormonal response to resistance exercise and training. Considering the results of the present study, it would be of great interest to further investigate the effect of exercise choice/mode on the hormonal response. There are other machine weight exercises that could be compared to free weight exercises. It would be interesting to compare the leg press at 120º ROM to the 90º ROM leg press and to the squat. It also would be of interest to compare the hormonal response of the squat and leg press using a protocol that is smaller in volume and more consistent with volume of exercise that is frequently used by exercisers.

PRACTICAL APPLICATIONS

When designing a resistance exercise protocol or program it important to consider the anabolic and catabolic hormonal responses it produces. The acute program variables have a strong influence on these responses. One such variable is exercise choice. Each day, trainers, coaches, and exercisers choose whether they will prescribe or perform free weight training or training with machine exercises, many without knowing there is a difference. If the leg press exercise is used, the hormonal response may be reduced, which might lead to reduced training adaptations, especially when only a 90º knee angle ROM is used. To induce the maximal hormonal response to resistance exercise, free weight exercises should be used.

APPENDIX A

IRB CONSENT FORM

University of North Texas Institutional Review Board

Informed Consent Form

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the purpose, benefits and risks of the study and how it will be conducted.

Title of Study: Hormonal Response to Free Weight and Machine Weight Resistance Exercise

Principal Investigator: Jakob Vingren Ph.D., University of North Texas (UNT) Department of Kinesiology, Health Promotion and Recreation.

Purpose of the Study: You are being asked to participate in a research study which involves testing the effects of exercise modality (free-weight or machine exercise) on the hormonal response.

Study Procedures: Before you can be approved for participation you must complete a medical history, nutrition & physical activity questionnaire, to ensure that you meet all the inclusion and none of the exclusion criteria.

Inclusion/exclusion criteria:
Inclusion: To meet inclusion criteria you must be: 1) male between the ages of 21-35 years; and 2) resistance trained for at least 6 months (training at least twice a week including the squat exercise).

Exclusion: Upon review of your medical history form (using attached medical questionnaire) we will exclude you if a pre-existing orthopedic limitations or medical condition may put you at risk during strength testing exercises. Such criteria will include, but may not be limited to, heart conditions or anomalies, respiratory conditions, blood pressure problems, musculoskeletal problems or previous orthopedic injuries that would limit the range of motion about the hip, knee or ankle joint. Special attention will be given to exclude potential volunteers with lower back problems including herniated inter-vertebral discs. You cannot participate in this study if you have recently taken, currently take, or plan to take any hormonal substances such as testosterone, anabolic steroids, and growth hormone. In addition if you have recently used (within the last 3 months) or currently use recreational drugs, tobacco products, or any hormonal medication you will be excluded from participation due to the potential interference with the outcome of the study. You will also be excluded if you currently or recently have used nutritional supplements, or adhered to an atypical diet that might confound the results of this study. We will reserve the right to dismiss you at any time if we believe you do not follow the instructions provided for this study.

Study overview:
You will be asked to complete two familiarization and one-repetition maximum (1-RM) determination visits and two exercise protocols. This is a total of four visits. Each visit should take about an hour. During the familiarization visits, you will be shown the proper technique for

completing the squat and leg press exercises. After a warm-up, you will perform either the squat or leg press exercise and your 1-RM will be determined. The following visit you will perform the other exercise and your 1-RM will be determined. For the two exercise protocol visits, you will perform the squat protocol on one visit and the leg press on the other. You will perform 6 sets of 10 repetitions at 80% your 1-RM for each exercise. You will have 2 minutes rest between sets. The order of these protocols will be random and you will not know which protocol you will be performing on the first visit. You will perform the other exercise on the next visit. For example, if you perform the squat on the first exercise protocol visit then you would do the leg press on the following visit.

On both exercise protocol visits (visits 3 and 4), you will report to the laboratory in the morning after a twelve hour overnight fast. Before the testing begins, a catheter will be inserted into an antecubital forearm vein. The catheter will remain in for the duration of each session and blood will be drawn prior to testing, immediately after testing, and fifteen and thirty minutes into recovery from exercise. EMG activities of the quadriceps muscle group will be recorded during all visits.

Visits:

Session 1 and 2: Anthropometric measurements, familiarization, and 1-RM test for the barbell squat and 1-RM for the leg press.

You will report to the Applied Physiology Laboratories (APL) (PEB 111) so that we can teach you correct technique for performing the squat using a modified Smith's Machine and the leg press. You will not perform both exercises on the same visit. You will be randomly assigned one exercise on the first visit and the other and the second. Once you can perform the squat exercise with correct technique, we will measure your one-repetition maximum (1-RM) strength in the squat and leg press. Additionally, we will measure your height, weight, and body composition using the dual-energy X-ray absorptiometry (DXA) machine at the first visit.

Session 3 and 4: Exercise testing for the squat and leg press.

All visits:

Each visit in this study will be separated by at least one week. You will report to the APL and a needle will be inserted into a forearm vein, the needle is then removed leaving behind a thin plastic tube (similar to an IV). Then a pre-exercise blood sample will be collected. You will then perform a warm-up on a stationary bike followed by dynamic stretches (e.g., heel kicks, lunges). You will complete six sets of ten repetitions of the squat or leg press with 2 minutes of rest between sets. The intensity will be 80% of your 1-RM. Immediately after the 6^{th} set, a blood samples will be obtained. You will then rest in a comfortable chair (resting, reading, or watching material that will not evoke heavy emotions). Blood will be drawn 15 and 30 min into recovery from exercise. Heart rate and rating of perceived exertion (RPE) will be assessed at rest, immediately after each set of squat, and at 15 and 30 min following exercise.

Specific Procedures:

Heart rate and Rating of perceived exertion:

You will be asked to wear a standard heart rate monitor during the 2 protocol visits. You will be asked to rate how hard you were working (what your exertion was) on a scale from 0 to 10.

Body composition testing: You will receive a scan using the dual-energy X-ray absorptiometry (DXA) machine. This test will determine your percent body fatness and also your bone mineral density. For this test, you will remove your shoes and any metal objects (like belt buckles, zippers, and jewelry). You will lie still on a table for about 15 minutes. A mechanical “arm” will move slowly from over your head to over your toes.

Blood draws: For each blood draw, ~20 ml of blood will be collected (about 1 table spoon). For each of the 2 protocol visits a total of about 80 ml of blood will be collected. Although this blood volume is replenished almost immediately we ask that as a safety precaution, you refrain from donating blood within the time period two weeks before the start of the study through four weeks after the end of the study. The blood samples will be analyzed for testosterone, growth hormone, cortisol, lactate, and hemoglobin concentration as well as hematocrit.

Diet: You will be provided diet logs to record everything that you eat and drink during the 3 days preceding the first of the 2 experimental protocol visit (including the day of the visit). You will then be provided a copy of this log and asked to replicate it for the remaining protocol visit. Additionally, you must drink at least 0.5 liter of water the night before and the morning of the experimental trials to ensure adequate hydration. Hydration state will be determined from a small urine sample you will provide. If you are not hydrated you will be asked to drink additional water.

Other instructions and restrictions: All experimental trials will be performed at the same time of day. From 3 days before each visit you must refrain from resistance or exhaustive exercise, alcohol, and high doses of caffeine (more than 1 cup of coffee per day). You must refrain from engaging in sexual activities for 24 hours before each protocol (visits 3-4) as this can affect the variables measured in this study.

Your total time commitment is approximately 4 hours: Four 1-hour visits.

Foreseeable Risks: The potential risks involved in this study are as follows:

Resistance Exercise: The performance of muscular exercise and physical effort can entail the potential hazards of injury from over-exertion and/or accident. This study will be planned to avoid injury to the musculoskeletal system. The possibility of cardiopulmonary overexertion is slight and will be minimized by screening, selection and monitoring procedures that are designed to anticipate and exclude the rare individual for whom exercise might be harmful. It is questionable whether it is possible to overexert the heart by voluntary exercise unless there is some underlying disease. Nevertheless, there are a number of disorders, some of which can readily escape clinical detection, where strenuous exercise may be potentially hazardous or may precipitate disability. Some of these, such as intracranial aneurysms or solitary pulmonary cysts or alveolar blebs, are rare and not readily diagnosed in the absence of symptoms; for these a history of tolerance to prior strenuous exercise must suffice. For other conditions, which might be more common, such as ischemic heart disease, the striking age-related incidence and the association of several identifiable risk factors with latent disease provides a rationale for a directed screening of certain participant candidates.

Performing lower-body resistance exercises such as the squat may cause back pain and, in rare instances, back injury. During this type of testing, transient episodes of lightheadedness, chest discomfort, irregular heartbeats, abnormal blood pressure responses, and/or leg cramping may occur. The risk of heart attack, although small, (approximately 1 occurrence in 15,000 tests) does exist. The chance of any of these events occurring will be minimized by our screening, selection and monitoring procedures, and by the use of properly conducted research procedures. Laboratory personnel involved in the testing are currently certified in CPR and we have emergency procedures in place for the rare event of an injury or heart attack. Additional risks associated with resistance exercise and with the strength and power tests and training involve the possibility of muscle strains or pulls of the involved musculature, delayed muscle soreness 24 to 48 hours after exercise, muscle spasm, and in extremely rare instances, muscle tears. Such risks are very low. Every effort will be made to make this investigation safe for the participant through familiarization, experienced personnel, warm-up and cool-down (i.e., stretching and low intensity activity-specific exercise), technique instruction and practice, supervision, screening, monitoring and individualized exercise testing. All of these factors, including those previously outlined, should dramatically contribute to a reduction, if not an elimination, of any potential risks associated with this study.

The Principal Investigator (Dr. Jakob Vingren) is a National Strength and Conditioning Association (NSCA) Certified Strength and Conditioning Specialist recertified with Distinction.

Blood Draws: We will take blood samples from a small needle which will be inserted in a vein in your arm. There will be discomfort when the needle initially punctures your skin. While blood draws are normally a safe procedure, it is possible that short-term side effects can occur, such as dizziness, bruising, or fainting. Although the chances are remote, it is also possible that bruising around the vein, an infection, or nerve damage can develop. All possible precautions to avoid infection will be taken including use of sterile disposable needles, drapes and gauze and the practice of sterile techniques during blood sampling. All blood samples will be obtained by a person trained in drawing blood who will use standard laboratory operating procedures. In case of emergency, we will call 911.

Body Composition: You will be exposed to a very small amount of radiation by the scanner used to measure your body composition. Exposure to any amount of radiation, no matter how low, may cause abnormal changes in cells. However, the body continuously repairs these changes and the amount of radiation is very low in this study. The total exposure for a whole body scan is approximately 125 times less than the average radiation from a standard chest x-ray or 150 times less than a round trip transcontinental flight. Thus, the radiation levels are extremely low and the health risk minimal. The scan will be performed by a technician who has received training required by the State of Texas for operating the scanner. You will complete a separate "Acknowledgement of risk" from for the scan as well as a safety questionnaire prior to any scan to ensure you are not at increased risk during the scan.

Benefits to the Participants or Others: There is limited direct benefit to you for participating in this study; however, all your data will be explained to you and interpreted for you so that a maximum amount of educational understanding and use of the data will be achieved. Participation in this study will also afford you instruction in correct weight-lifting techniques and you will learn your endocrine and physical response to resistance exercise. You will also learn your body composition and bone density values.

The results could help researchers better understand the hormonal response to resistance exercise and help in the prescription of resistance exercise.

Compensation for Participants: There will be no compensation for this study.

Procedures for Maintaining Confidentiality of Research Records: All data will be kept in coded participant files in the primary investigator's locked files. Participant codes will be used when statistical analyses are performed or when experimental feedback sheets are provided to you. All investigators, professional staff, and technicians are aware of the confidentiality involved with this study and have completed the confidentiality training required by the University. Your data will not be available or divulged to anyone outside of the experimental research team. The data files will be kept for 3 years after the study is terminated. The confidentiality of your individual information will be maintained in any publications or presentations regarding this study.

Questions about the Study: If you have any questions about the study, you may contact *Dr. Jakob Vingren* at telephone number (940) 565 3899.

Review for the Protection of Participants: This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). The UNT IRB can be contacted at (940) 565-3940 with any questions regarding the rights of research participants.

Research Participants' Rights: Your signature below indicates that you have read or have had read to you all of the above and that you confirm all of the following:

- *Dr. Jakob Vingren* or another researcher has explained the study to you and answered all of your questions. You have been told the possible benefits and the potential risks and/or discomforts of the study.
- You understand that you do not have to take part in this study, and your refusal to participate or your decision to withdraw will involve no penalty or loss of rights or benefits. The study personnel may choose to stop your participation at any time.
- You understand why the study is being conducted and how it will be performed.
- You understand your rights as a research participant and you voluntarily consent to participate in this study.
- You have been told you will receive a copy of this form.

____
Printed Name of Participant

________________________________ ____________
Signature of Participant Date

For the Principal Investigator or Designee:

I certify that I have reviewed the contents of this form with the participant signing above. I have explained the possible benefits and the potential risks and/or discomforts of the study. It is my opinion that the participant understood the explanation.

______________________________________ ____________

Signature of Principal Investigator or Designee Date

APPENDIX B

1 RM DETERMINATION SHEET

Visit 1 & 2

Subject: ____________ Height: ___________

1 RM Tests

Visit 1:___________ Visit 2:_______________

Squat *Visit*_____ **Date:_________** **Body mass:_______kg**

Bar weight:_______kg ______lb

Dynamic Warm-up (*10 lunges, 20 heel kicks, 20 high knees, 10 moving squats, shoulder circles*)? Yes__

Upper Rack Height:_______________

Lower Rack Height:______________

Displacement of the bar:_____________

Record weight added to bar

Squat Warm-ups: ______________

Lift 1:____________

Lift 2:____________

Lift 3: ____________

Lift 4: ____________

Lift 5: ____________

Leg Press *Visit*_____ **Date:_________** **Body mass:_______kg**

Loading bar weight:__________kg __________lb

Dynamic Warm-up (*10 lunges, 20 heel kicks, 20 high knees, 10 moving squats, shoulder circles*)? Yes__

Displacement of the loading bar:____________

Width between feet:______________

Leg Press Warm-ups___________

Lift 1:______________

Lift 2:______________

Lift 3:______________

Lift 4:______________

Lift 5:______________

APPENDIX C

EXERCISE PROTOCOL SHEET

6 x 10 Day Exercise Testing and Data Collection

Date: ____ **Subject: ________** **Visit#:______**

Exercise:__________

Body mass: _____ kg **HR monitor #:**___________
Sleep ________hours
Overnight Fast? _______
Urine specific gravity:_____
Provided water? Yes(__) No(__)
Dynamic Warm-up(*10 lunges, 20 heel kicks, 20 high knees, 10 moving squats, shoulder circles*)? Yes_

Squat (lbs to be added to bar):
50% of 1 RM:_______lbs
80% of 1 RM:__ _____ lbs

Leg Press (lbs to be added to bar):
Width between feet:______________
50% of 1 RM:_______lbs
80% of 1 RM:_______lbs

Pre blood (time_____)

(start time:____; end time:____)

	Initial	Time	HR	RPE	Reps	Weight
Pre						
Set 1						
Set 2						
Set3						
Set 4						
Set 5						
Set 6 (IP)						
IP BD						
+15						
+30						
Release						

APPENDIX D

BLOOD SAMPLE HB, LACTATE, AND HCT

6 x 10 Day Blood Draws and Processing

Date: ______ Subject: ________
Visit#:___________

Cannulla insertion time: _______________________ Location: __________
______

	Time	Inital	Hb1	Hb2	Lac1	Lac 2	Hct1	Hct2	Hct3
Pre									
IP									
+15									
+30									

Samples aliquated into time periods?: Yes: _______

Samples transferred to -80° Freezer? Yes: _______

APPENDIX E

HORMONE ANALYSIS SHEET

Analyte:__________ Study:______________________________________ Date:_____________ Technician _________________________

	1	2	3	4	5	6	7	8	9	10	11	12
A												
B												
C												
D												
E												
F												
G												
H												

Incubation 1 start time:___________ Incubation 2 start time:___________ Incubation 3 start time:_______________

Comments:

APPENDIX F

FOOD LOG

Time:	**FOOD/BEVERAGE DESCRIPTION**	**AMOUNT**	**Total Kcal**

Comments:

APPENDIX G

MEDICAL HISTORY QUESTIONNAIRE

UNT EXERCISE PHYSIOLOGY LABORATORY MEDICAL HISTORY QUESTIONNAIRE

Study ____________________ Subject # ____________

Name ____________________ Sex ______ Age ______ DOB ______

Street ____________________

City ____________ State ______ Zip ______ Phone ______

Email ____________________

PLEASE ANSWER ALL OF THE FOLLOWING QUESTIONS AND PROVIDE DETAILS FOR <u>ALL</u> "YES" ANSWERS IN THE SPACES AT THE BOTTOM OF THE FORM.

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2.	Has your doctor ever denied or restricted your participation in sports or exercise for any reason?
☐	☐	3.	Do you ever feel discomfort, pressure, or pain in your chest w hen you do physical activity?
☐	☐	4.	In the past month, have you had chest pain w hen you w ere not doing physical activity?
☐	☐	5.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	6.	Does your heart race or skip beats during exercise?
☐	☐	7.	Has a doctor ever ordered a test for you heart? (i.e. EKG, echocardiogram)
☐	☐	8.	Has anyone in your family died for no apparent reason or died from heart problems or sudden death before the age of 50?
☐	☐	9.	Have you ever had to spend the night in a hospital?
☐	☐	10.	Have you ever had surgery?
		11.	Please check the box next to any of the follow ing illnesses w ith w hich you have ever been diagnosed or for w hich you have been treated

☐ High blood pressure	☐ Elevated cholesterol	☐ Diabetes
☐ Asthma	☐ Epilepsy (seizures)	☐ Kidney problems
☐ Bladder Problems	☐ Anemia	☐ Heart problems
☐ Coronary artery disease	☐ Lung problems	☐ Chronic headaches

YES	NO		
☐	☐	12.	Have you ever gotten sick because of exercising in the heat? (i.e. cramps, heat exhaustion, heat stroke)
☐	☐	13.	Have you had any other significant illnesses not listed above?
☐	☐	14.	Do you currently have any illness?
☐	☐	15.	Do you know of <u>any other reason</u> w hy you should not do physical activity?
		16.	Please list all medications you are currently taking. Make sure to include over-the-counter medications and birth control pills.

Drugs/Supplements/Vitamins	Dose	Frequency (i.e. daily, 2x/day, etc.)

DETAILS:

____

____

____

____

____

____

____

____

17. Please list all allergies you have.

Substance	Reaction

		18. Have you smoked?	If yes, #/day	Age Started	If you've quit, w hat age?
☐	☐	Cigarettes			
☐	☐	Cigars			

Pipes ______ ______ ______

19. Do you drink alcoholic beverages? If yes, how much? ______ How often? ______

20. Do you have a family history of any of the following problems? If yes, note who in the space provided.

- [ ] High blood pressure ______
- [ ] High cholesterol ______
- [ ] Diabetes ______
- [ ] Heart disease ______
- [ ] Kidney disease ______
- [ ] Thyroid disease ______

21. Please check the box next to any of the following body parts you have injured in the past and provide details.

- [ ] Head ______
- [ ] Neck ______
- [ ] Upper back ______
- [ ] Lower back ______
- [ ] Chest ______
- [ ] Hip ______
- [ ] Thigh ______
- [ ] Knee ______
- [ ] Ankle ______
- [ ] Foot ______
- [ ] Calf/shin ______
- [ ] Shoulder ______
- [ ] Upper arm ______
- [ ] Elbow ______
- [ ] Hand/fingers ______

22. Have you ever had a stress fracture?

23. Have you ever had a disc injury in your back?

24. Has a doctor ever restricted your exercise because of an injury?

25. Do you currently have any injuries that are bothering you?

26. Do you consider your occupation as?

- [ ] Sedentary (no exercise)
- [ ] Inactive-occasional light activity (walking)
- [ ] Active-regular light activity and/or occasional vigorous activity (heavy lifting, running, etc.)
- [ ] Heavy Work-regular vigorous activity

27. List your regular physical activities

Activity	How often do you do it?	How long do you do it?	How long ago did you start?

ADDITIONAL DETAILS:

______

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