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The Effect of Yoga on Growth Hormone Secretion in Young Men and Women

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THE EFFECT OF YOGA ON GROWTH HORMONE SECRETION IN YOUNG MEN AND WOMEN

By

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The Effect of Yoga on Growth Hormone Secretion in Young Men and Women

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ABSTRACT

By

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PURPOSE The purpose of this study was to examine the effects of an acute bout of yoga exercise on the secretion of growth hormone (GH) in healthy, young males and females. **METHODS** Seventeen participants (mean age 23.9 ± 3.9) were volunteered and completed the university IRB approved study. Participants completed a 60-min, certified instructor led yoga session. Blood (5ml) was collected at rest, 10-min prior (PRE), at the 35-min point during (MID), and immediately post (POST) the yoga session. Serum GH was measured using immunochemiluminometric assay. Resting GH levels were statistically compared to mid- and post-yoga GH levels using a repeated measure ANOVA. **RESULTS** Significant increases in GH were seen 35-min into the yoga session ($P < 0.05$) and immediately after the yoga ($P < 0.05$) when compared to the resting GH levels. **CONCULSION** The release of GH into the blood during yoga may partially explain the physiological mechanisms underlying the health benefits of this low impact activity.

Key Words adults; low intensity; exercise

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The researcher wants to give thanks to everyone who made the study possible.

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This thesis follows the format prescribed by the Journal of Strength and Conditioning Research and the School of Health and Human Performance of Northern Michigan University.

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INTRODUCTION

Yoga is an increasingly popular mode of exercise that has been shown to elicit many favorable health benefits, including increasing muscular strength and reducing body fat (5), but the mechanisms responsible remain unclear in the literature. Growth hormone (GH), which can be stimulated through exercise (4) has been shown to facilitate increases in muscular strength (27) and reductions in abdominal fat and overall adipose tissue (29).

Growth hormone occurs naturally in the body and elicits many favorable health benefits, such as tissue growth and repair and leads to stronger muscles, bones, and ligaments(15). GH also increases the mobilization of stored fat to be used as fuel, which can help to reduce adipose tissue and maintain a healthy body composition (6). The release of GH from the anterior pituitary gland happens in several bursts throughout a 24-hour time period, and can also be stimulated by a number of physiological and metabolic factors.

Exercise is a powerful stimulant for GH secretion (7). Many studies have explored the relationship between mode, frequency, duration and intensity as stimulants for GH secretion, mostly manipulating resistance exercise and/or aerobic exercise. Resistance exercise may be the greatest exercise stimulant for GH secretion. Moderate intensity resistance exercise has been shown to significantly stimulate growth hormone in young men (8) and women (7). Increasing intensity of resistance training by reducing rest periods seems to further increase GH stimulation. Resistance training protocols that emphasis low resting periods (less than 90 seconds) have been shown to significantly stimulate circulating GH (8) greater than longer rest periods.

Aerobic exercise has been shown to stimulate an increased secretion of GH as well (37). Time to peak GH secretion varies with aerobic intensity; with significant findings at 60-minutes at 50% VO2max (8), 45-minutes at 70% peak aerobic capacity (7) and 30-minutes at lactate threshold (37).

Yoga is an alternate form of exercise that combines focused breathing, stretching, moving and holding various sitting, standing and lying poses. It utilizes body weight resistance to increase muscular strength and endurance while either statically holding a position or moving from one pose to another. The overall duration of a typical yoga session can last for 60 – 120 minutes with very little rest throughout the session and utilizes large muscle groups working in conjunction with each other. Due to the nature of yoga, it can be argued that it can be considered a muscular strength, muscular endurance, and/or aerobic endurance exercise, which can be performed at light, moderate and higher intensities.

There is a wealth of information regarding yoga and its psychological benefits, but the explanation for yoga's physiological effects on physical fitness remains unclear. Yoga has been shown to increase muscular strength (2)(18)(31) and cardiovascular fitness (23)(31). Although there is significant evidence showing the fitness benefits of yoga, the physiological mechanisms behind these improvements are not fully understood. Growth Hormone has been shown to have a positive effect during resistance and aerobic training and may be partially responsible for the adaptations seen for these modes of exercise. Since yoga is different from traditional resistance training and aerobic exercise, but embodies qualities of both, it is unclear what effect it will have on GH stimulation.

We hypothesize that a partial explanation for fitness improvements seen in yoga practitioners are due to increases in GH secretion, but there has not been a study to date that has measured growth hormone during yoga.

METHODS

Experimental Approach to the Problem. Resting GH levels were analyzed from blood samples taken from all participants prior (PRE) to a 1-hour yoga exercise session. The seventeen young men and women completed a 1-hour yoga sessions that consisted of a 5-min low intensity yoga warm up, followed by 30-minutes of standing poses. Blood was sampled again (MID) from each participant followed by 20-minutes of sitting poses and a 5-minute low intensity cool-down. The third POST yoga blood sample was immediately taken. The blood samples were analyzed for GH levels via immunochemiluminometric assay (14) and the GH levels MID, and POST yoga were compared against resting conditions.

Subjects. Seventeen young, healthy men and women volunteered to participate in this study (see table 1 for descriptive data). Subjects were screened prior to participating in the study to ensure they were healthy enough to participate in moderately intensity exercise (as described by the ACSM risk stratification), free of joint and musculoskeletal injury or pain that would inhibit a free range of motion and the completion of all yoga poses, and had no contraindications to having blood drawn and had a BMI between 18.5 to 29 were used in this study. All subjects were required to have a low level of yoga experience, indicated by participating in yoga no more than twice a month for the previous four months. Informed consent was obtained stating each subject understood the study design and potential risks. The university's Institutional Review

Board approved the experimental protocol. Signed informed consent was obtained from all participants following both written and verbal explanation of the procedures.

Procedures. All subjects completed a 24-hr dietary intake log prior to their scheduled yoga session. To ensure accurate GH measurements, prior to the yoga sessions participants were asked to: refrain from exercise for 24-hrs, get a full 7-8 hours of sleep the previous night, ingest no alcohol for the previous 24-hrs, and avoid tobacco use and caffeine consumption for at least 4-hrs.

All subjects underwent the same procedures. There were a total of five identical yoga sessions, in which the participants attended only one for the data collection. Upon arrival at the yoga site, participants were seated quietly for 10-min. During this time Rate of Perceived Exertion (RPE) to measure individual intensity was explained to them using a 10-point scale(22). After this initial rest period, the PRE blood sample (5mL) was taken from the antecubital vein by certified laboratory technicians. Serum separator tubes were used to collect the blood samples, and were labeled with the participants name and exact time of blood draw.

Immediately after the PRE blood sample was taken, the participants began the yoga session. The yoga was done on standard yoga mats and was led by a certified yoga instructor (see table 2 for yoga class description). The yoga was classified as a Vinyasa Flow type yoga in which continuous movement was emphasized. Music was quietly played during the yoga session, and the yoga instructor gave visual demonstrations and verbal instructions for the entire session. The MID yoga blood draw (5mL) was collected at the 35-min point after onset of yoga exercise and the POST blood draw (5mL) was collected at 60-min, immediately after cessation of exercise. To monitor intensity, RPE was recorded for all subjects at the 5-min, 20-min, and 40-min time points after the start of the yoga.

The blood samples were cooled and transported to a local hospital to be sent to a lab (Labcorps America Inc.) for analysis. An immunochemiluminometric assay (ICMA) was used to measure the GH in each sample (14). The GH results of each sample were sent to the researcher as they became available.

Statistical Analyses. The statistical analysis was conducted using SPSS version 22 (SPSS Inc., Chicago, IL). A repeated measures ANOVA was used to determine if any differences are observed between the mid-yoga and post-yoga GH levels and compared to the resting values. Follow-up pairwise comparisons were performed with Bonferroni's correction when significant differences were found. An independent t-tests was used to determine any differences in GH between genders during the MID yoga blood draw. An alpha of 0.05 will be used to determine is differences observed are significant.

RESULTS

One hour of yoga was a sufficient exercise stimulus to increase GH from rest. Subject's serum GH data for the yoga session (PRE, MID, and POST) is presented in Table 3. Serum GH significantly increased from PRE compared to MID yoga session (7.4 fold, 95% CI, P = 0.001), and from PRE compared to POST yoga (4.5 fold, 95% CI, P = 0.050) (figure 1). Women had higher mean GH levels during exercise at the 35-minute time point in the yoga session than the men (11.1ug/L and 4.21ug/L respectively, p = 0.035).

DISCUSSION

The purpose of the current study was to determine the effect that yoga exercise has on GH secretion in young men and women. This was the first study to analyze GH as a possible mechanism responsible for the physiological adaptations, specifically the increases in muscular strength and fat loss, seen in other studies. The researchers' hypothesis was correct, as yoga did significantly increase GH secretion. These findings may help to explain the fitness benefits seen from practicing yoga.

Yoga and Growth Hormone. Growth hormone was significantly stimulated in all participants during and immediately after the yoga session when compared to resting values. Mean serum GH levels during yoga were 8.45ug/L and 5.0ug/L immediately after the cessation of yoga. When compared to studies that measured GH stimulation from resistance training, GH stimulated by yoga was considerably lower. West et al. (36) found peak GH levels reached of 20ug/L during heavy resistance training. Nindl et al. (19) reported peak values of 22ug/L during similar high volume training. In the previous studies GH was sampled more frequently than in the current yoga study, which allowed for more accurate GH recordings. It is possible, in the current study, that peak GH secretion may have been missed due to the lack of sampling time points.

When factoring out gender by looking at the female participants only, GH during yoga was lower than those reported by other studies. Gordon et al. (7) investigated the GH response for similar aged women during one hour of steady-state aerobic and heavy resistance exercise; and found mean GH values of 16ug/L and 22ug/L at the 35-minute point during the resistance and aerobic exercise respectively. In the current study, the mean GH level at the 35-minute time point was 11.1ug/L. The mean GH immediately levels after the resistance and aerobic exercise were 14ug/L and 16ug/L respectively but only reached and 6.6ug/L after yoga. The lower GH response may be due to the lower intensity of our yoga program in comparison to other modes of exercise seen in other studies with that were performed at a higher intensity. During our study perceived intensity varied between participants based on individual differences, possibly fitness levels and flexibility. Average RPE during the yoga was of 3.1 on a 10-point scale, indicating a perceived moderate intensity of activity (22), which was most likely a lower intensity than the previous studies.

Gender Differences. The differences seen between men and women's resting and exercise induced GH was consistent with the literature. Wideman et al. (37) looked at the differences between genders at rest and during exercise. At rest Wideman and colleagues reported women averaged a 3.3 times greater release of GH over a 6-hour period than men. In our study, women secreted 4.9 times greater GH at rest than men. Since GH is secreted in a pulsatile manner, the degree of difference seen between the men and women participants may have been caused by fluctuations in the GH pulse cycle for each participant. During a bout of aerobic exercise at a power output near LT, women had a 1.7 times greater peak GH secretion than men. The peak for women occurred at 24-minutes into exercise, and the men's peak occurred 2-minutes after the bout of exercise ended. Without continuous GH sampling it is difficult to determine when the peak occurred in our study. However, the highest collected amount of GH during our yoga program occurred at MID and the women's GH levels were 2.6 fold greater than the men's, which is expected based on previous literature (37).

Conflict of Interest. The authors associated with this study certify that they have no affiliations with or involvement in any organization with financial interest or non-financial interest in the subject matter discussed in this manuscript.

PRACTICAL APPLICATION

Increasing GH can have positive fitness benefits for athletes as well as recreational exercisers. Growth hormone aids in repair and growth of muscle tissue and by increasing GH during low-moderate intensity exercise in which little fatigue is accumulated recovery from exercise may be theoretically enhanced. However, further research needs to be completed to fully support yoga's effect on recovery from pervious exercise due to GH secretion.

For young adults exercising to improving physical fitness, yoga may enhance the secretion of GH, which in turn may increase muscular strength and improve body composition. The current study can also be used to show the limitations of yoga on GH secretion. Yoga may not be as appropriate as some other form of exercise that are performance at higher intensity's, if the goal is to maximize the GH response.

Table 1. Mean age, height, weight, and BMI data and standard deviation of subjects.

	Total (n = 17)	Women (n = 10)	Men (n = 7)
Age (yr)	23.9 ± 3.9	22.8 ± 3.9	25.6 ± 3.4
Height (cm)	171.4 ± 7.5	166.3 ± 4.4	178.6 ± 4.4
Weight (kg)	71.4 ± 13.1	62.8 ± 6.1	83.7 ± 10.1
BMI (kg/m^2)	24.1 ± 3.3	22.7 ± 2.5	26.1 ± 3.3

Table 2. Description of yoga sequence.

*Blood Draw 1 (-5min)
Warm Up
Sun Salutation x6
Standing Postures
Extended Triangle Pose
Revolved Triangle Pose
Extended Side Angle Pose
Feet Spread - Forward Fold
Pyramid Pose
One Leg Balance
*Blood Draw 2 (35min)
Seated Postures
Staff Pose
Seated Forward Fold
Head to Knee Pose
Seated Twist
Cool Down
Final Relaxation Sequence
*Blood Draw 3 (60min)

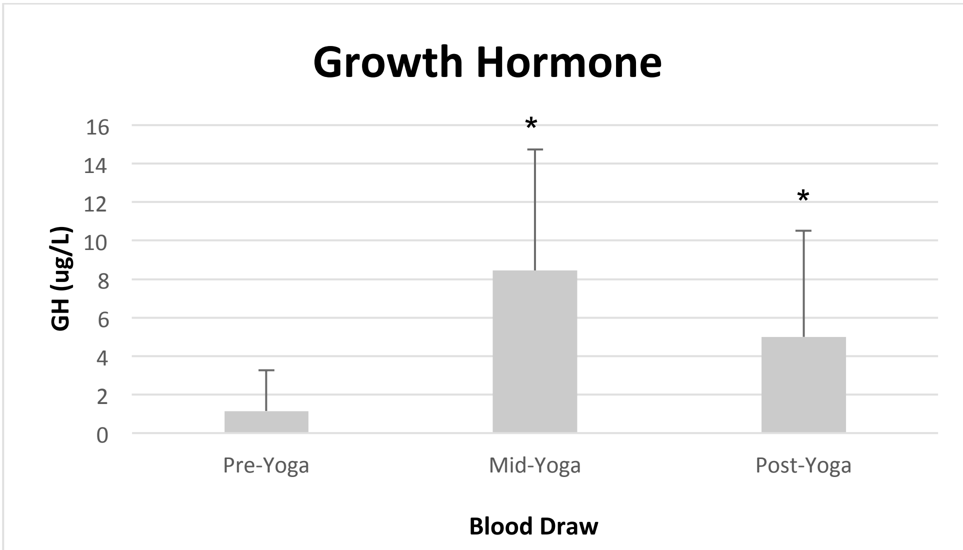

Figure 1 – Reported subjects (n=17). Growth hormone levels pre- (SD ± 2.1), mid- (SD ± 6.3), and post- (SD ± 5.5) yoga exercise. * Significantly different compared to pre- GH levels (p<0.05)

II. LITERATURE REVIEW

I. Growth Hormone

In healthy individuals growth hormone (GH) is naturally synthesized in the body and acts to stimulate tissue growth and repair, which can lead to stronger muscles, bones, and ligaments. It has also been shown to increase the mobilization of fats to be used as fuel, which can help maintain a healthy body composition (6).

Growth hormone naturally is released from the anterior pituitary gland in 6-12 bursts throughout the day (6). Once released, GH binds to the carrier protein GH-binding protein in the blood plasma and is delivered to GH receptors throughout the body. When GH binds to receptors on adipose tissue it stimulates lipolysis and the resulting free fatty acids (FFA) are available to be used as fuel (17)(29). Growth hormone has an anabolic effect on bone, cartilage, and muscle tissue. When GH binds to GH receptors in skeletal muscle (3) there is a direct effect for tissue synthesis. When GH binds to receptors in liver, insulin-like growth factor-I (IGF-I) and insulin-like growth factor-II (IGF-II) are released (15), resulting in an indirect stimulation for increases in cartilage formation, bone growth, and increased protein synthesis and cell growth within muscle tissue (6).

Gender Differences. Men and women exhibit differences in GH secretion both at rest and when stimulated by exercise. Women secrete larger amounts of GH per burst at rest (35), and exercise(37) compared to aged matched men. Despite these differences, the increase from resting secretion to peak secretion during exercise is similar between men and women (37). This means that the growth hormone response to exercise is the same across genders of similar ages.

Women also seem to reach peak blood GH concentrations quicker than men during exercise. A study by Wideman et al. (37) compared men and women cycling at a constant load based on their lactate thresholds and measured GH responses. Women reached maximum GH concentrations in 24 minutes, and men reached maximum GH concentrations in 32 minutes. The GH differences across genders are thought to be caused by the sex-hormone estrogen (33), but it is unclear whether estrogen causes increased GH to be secreted at the pituitary gland, or if it interrupts the negative feedback loop and interferes with the signals to stop production of GH, resulting in the larger, more un-orderly bursts.

Although there are no differences between men and women with respect to exercise induced GH secretion, the use of oral contraceptives may increase GH response to exercise. A study by Sunderland et al. (10) found that serum GH levels were higher in women taking oral contraceptives in repeated treadmill sprint bouts than in those not taking oral contraceptives.

Age. As humans age they experience a natural progressive decline in GH secretion (7)(12)(26), and low levels of GH in middle aged individuals has been linked to premature aging (1). Along with decreased GH, decreased bone mineral density, atrophy of skeletal muscle and increases in visceral fat are associated with aging. Since GH is linked to increased bone formation, muscular growth and repair, and fat metabolism, some researchers speculate that the age related decline in GH might be responsible for the other physical symptoms of aging (1). Others believe that reductions in physiological capacity and accumulation of fat mass may be the cause of the reductions seen in GH later in life. This is supported by reductions in GH in midlife are more strongly associated with visceral fat than chronological age (32).

As people age, their GH response to exercise is also diminished. Gordon et al. (7) looked at the GH response in elderly women (61.6 ± 1.3 years) during exercise and found that there was no significant GH response during aerobic or resistant training protocols, however these same relative protocols did elicit a significant GH response in younger individuals (7).

Body Composition. Body composition can also have an effect on GH secretion. Those classified as obese (>29 BMI) have lower resting growth hormone levels than someone classified as having a normal BMI (18.5 – 25) (29). This appears to be caused by lower overall GH production and faster clearing rates after secretion (11).The blunted secretion of GH due to an increased fat to fat-free mass ratio puts individuals in this category at increased risk of fat gain due to GH's role in fat metabolism. This can also make it more difficult for obese individuals to reduce body fat.

Diet. Diet can affect circulating GH. A high concentration of free fatty acids and glucose in the blood can diminish the GH response (17), while reduced circulating free fatty acids increase GH response in healthy individuals during resting conditions (8)(29). This is due to the negative feedback mechanism, in which circulating FFA signal the pituitary to stop secreting GH. During times of fasting or very low-calorie diet, GH secretion increases (17)(29). This is most likely caused by the stomach hormone ghrelin, which is secreted from the empty stomach and signals the pituitary to secret GH as well as promoting the feeling of hunger.

Due to the increased popularity of pre-exercise supplements containing caffeine, it is important to understand caffeine's effect on GH secretion. Wu & Lin, (39) examined the effects caffeine had on GH response to resistance training. Ten trained men participated in a bout of resistance exercise consisting of 8 exercises, of 3 sets of 10 repetitions at 75% 1RM, with and without caffeine supplementation in a counter balanced study design. The caffeine dose was 6 $mg \cdot kg^{-1}$ of caffeine taken 60-minutes prior to resistance training. Growth hormone secretion was significantly lower during the with-caffeine trials immediately after, 15-minutes post, and 30 minutes post resistance training than during the no-caffeine trials. Free fatty acid concentrations were significantly higher during the caffeine trials than in the non-caffeine trials at the pre-exercise, immediate post, 15-minute post, and 30-minute post time points. The increases in FFAs seen prior to the onset of resistance training may influence the negative feedback response to the hypothalamus resulting in a decreased rate of GH release.

Sleep. Sleep patterns have an effect on GH response to exercise. During sleep, up to 60% of 24-hour total GH is secreted (25). This is seen mostly in the early stages of sleep and increases in GH are due to larger secretion bursts. During a time of sleep deprivation, serum 24-hour total GH is much less than compared to a rested individual. This is also seen during exercise stimulation where rises in GH are much less during exercise then when fully rested (25).

Exercise and Growth Hormone

Exercise is a powerful stimulant for GH secretion (7)(28). Many studies have explored the relationship between mode, frequency, duration and intensity as stimulants for GH secretion. Even in obese individuals who have lower GH responses, exercise still stimulates an acute increase in GH release (29). The most common forms of exercise examined with regards to GH secretion are resistance and aerobic exercise, although varying protocols quite possibly contribute to variable results

Resistance Exercise. Resistance exercise has been shown to be a powerful stimulant for GH secretion. The amount of GH secreted is mainly determined by the amount of muscle mass recruited and the total amount of work performed. Other factors that may influence GH secretion during resistance exercise are exercise volume, intensity and rest intervals (29). Similar GH responses are seen in both men and women (7)(8).

When completing resistance exercise it is generally emphasized to begin with larger muscle groups and end with smaller, assisting muscle groups. Some bodybuilding protocols, however, begin with smaller assisting muscle groups, before completing large muscle, compound exercises, in hopes of fatiguing the assisting muscle groups to isolate the larger ones. From a GH standpoint exercise order does not seem to make a difference. A study by West et al. (36) demonstrates this by looking at the effect of exercise order of arm exercises and leg exercises. Ten healthy, lean, young men performed two-resistance training protocols which consisted of arm exercises followed by leg exercises, or leg exercises followed by arm exercises, on separate weeks in a randomized crossover fashion. The arm exercises consisted of 4 sets of elbow flexion at 75% 1RM to failure, followed by 2-minutes rest. The leg exercises consisted of 5 sets of 10 repetitions of 95% 10RM with 1-minute rest between sets. Both exercise protocols produced the same maximal GH peak levels which occurred 15-minutes after the onset of the leg exercises. Since total GH concentration did not significantly differ, exercise order does not seem to have an effect on overall GH secretion. Furthermore, it seems that larger muscles may have a greater effect on GH than smaller ones. It is worth mentioning that since the arm and leg exercises had different resting intervals between sets, it is hard to make a conclusion based on the results of this study regarding GH stimulation. Resistance training protocols that emphasis low resting periods, generally less than 90-seconds, have a greater effect on circulating GH than longer rest periods (8). This may confound the results as to if the shorter rest periods had an influence in the GH secretion during the leg exercise.

Increasing volume of training appears to increase GH stimulation. A study by Nindl et al. (19) looked at the effects of a 50 set, high intensity resistance training protocol on 10 young, lean, men. The protocol consisted of large muscle group, compound exercises that were a combination of either 10 repetitions of 70% 1 RM, or 5 repetitions of 85% 1 RM. The results showed a 20 ug/L increase in GH immediately after exercise than during the control trial in which no exercise was done. This increase was larger than other protocols that consisted of 12 or 21 sets of exercises (5)(26).

Eccentric resistance exercise and GH secretion has also been studied. Ojasto and Hakkinen (21) compared the GH secretion changes in different eccentric resistance training loads. The study compared training using 10-repetition eccentric/concentric training loads of 70%/70%, 80%/70%, 90%/70%, and 100%/70% 1-repetition maximum. Each training load was done for four sets, with 2-minutes rest between sets. Although each load stimulated a rise in serum GH, none of the loads were significantly greater than baseline. Also, the 90%/70% load stimulated the greatest rise in GH, but it was not significantly different than the 70%/70% load. A previous study by Kraemer et al. (13) supports the findings of Ojasto and Hakkinen. Kraemer et al. investigated the difference in relative loaded eccentric and concentric training protocols. Each protocol consisted of four sets of six compound exercises; each completed at 65% 1-repetition maximum eccentrically or concentrically, with 90 seconds of rest between each set. Unlike the previous study, a significant rise in GH was seen after completion of each exercise protocol compared to baseline measures. This difference may be caused by the decreased rest periods between sets, which increase the muscle's time under tension, or the mere four sets in the previous study (21) were not enough of a stimulus to see the rise in serum GH as in the 24 total sets of Kraemer's study (13).

Aerobic Exercise. Aerobic activity has been shown to acutely stimulate GH in short bouts of aerobic activity. In one study by Wideman et al. (27), 30 minutes of cycling at a constant load at lactate threshold was enough to stimulate significant GH secretion above resting conditions (37). Average maximal serum GH was 21.45 $ug \cdot L^{-1}$ and occurred at 28minutes. Another study by Nooitgedagt et al. (14) with a similar design found that when cycling for 20-minutes at an intensity near lactate threshold, average maximal serum GH levels reached 27.7 $ug \cdot L^{-1}$ 10-minutes after the completion of the exercise protocol(20). In the study by Wideman et al. blood samples were collected every 5-minutes, where as in the study by Nooitgedagt et al. collected blood every 15 minutes. The longer intervals between blood samples in the Nooitgedagt study may have missed the true maximal GH peak, which may have accounted for the differences in the two studies.

Intensity may also be an important factor for GH stimulation during aerobic activity. Weltman et al. (34) looked at the long term effects of different running intensities on untrained women. Twenty-one female subjects (29 ± 11 years old) completed a 52-week running program that gradually increased from 5-miles/week to 35-40 miles/week. The subjects were split into an above lactate threshold group (>LT) which trained six days a week, with 50% of training done over LT, with the rest of training completed at LT, and an at lactate threshold group (@LT) which trained six days a week at lactate threshold. Twenty-four hour, intermittent blood samples were taken at baseline, and once a month on rest days for the duration of the training and analyzed for GH pulse peaks and circulating GH levels. Although there was no significant difference in the number of peaks after one year of training compared to baseline in any of the groups, there was a significant difference in the amount of GH released per pulse. While the @LT group showed no significant increases in GH levels after 1-year of training, the >LT showed a significant increase in total 24-hour GH volume by increasing maximum peak levels and average GH volume per pulse. Furthermore, the >LT threshold group showed greater body fat reduction than the @LT group. Although the mechanism behind the differences in body fat reduction between the two groups cannot be determined, it makes sense to see a greater reduction in body fat in the training group who had a greater GH response because of GH's role in fat metabolism.

Comparing exercise types. Aerobic and resistance exercise both have been shown to elicit significant acute increases in GH volume, but with unlimited protocols for each type of exercise it is difficult to make a conclusion on which exercise type stimulates GH release more. Some studies have compared aerobic exercise to resistance training using common protocols to determine the differences in GH secretion. Gordon et al. (7) used a crossover designed to examine the differences between 45-minute sessions of heavy resistance training and steady-state aerobic exercise. The heavy resistance training consisted of 10 repetitions of 75% each subject's 1 repetition maximum for each exercise, completed in circuit style, alternating between six total pushing, pulling, and lower body movements with little rest between sets. The aerobic exercise was completed on a cycle ergometer at an intensity of 70% each subject's peak aerobic capacity. The findings of this study showed that both aerobic and resistance training protocols significantly increased serum GH concentrations compared to resting conditions. The aerobic exercise protocol had greater increases of GH, with the highest value of 28 $ug \cdot L^{-1}$ seen after 15-minutes of onset of exercise, with an almost linear drop seen thereafter. The highest value for the resistance protocol was seen around the 45-minute mark at the end of training, with a value of 16 $ug \cdot L^{-1}$. The GH levels increased in a linear fashion until the termination of exercise where they began to decrease.

There also seem to be some differences in GH stimulation based the order resistance and aerobic training are completed in during a single exercise session. Goto et al. (8) examined GH response when aerobic exercise is completed before resistance training. The cross-over study compared GH secretion during a resistance exercise with and without 60-minutes of cycling at 50% maximum oxygen consumption (VO_{2max}). The resistance exercise protocol consisted of 4 sets of bench press and leg press, for 10 repetitions of 75% 1RM, and 90-second rest periods between sets. In this study GH and free-fatty acids significantly increased after the aerobic cycling. During the resistance exercise, GH secretion was significantly lower in the trial that followed the aerobic cycling compared to the group that performed resistance exercise only. It is interesting to note that free fatty acids were elevated after the aerobic exercise, but there was no response during the resistance training alone. The researchers in this study suggest that the increase in free fatty acids during the aerobic exercise may have blunted GH secretion during subsequent resistance exercise. Since blood was not sampled during the aerobic exercise it is unclear whether increases in GH during the cycling contributed to the rise in free fatty acids.

Yardley et al. (40) examined the relationship between aerobic exercise and resistance training sequences further. The study was a cross over design in which participants completed two training sessions on two separate days. During one training session the participants completed a resistance training protocol first, followed by a bout of aerobic exercise, and during the other training session the participants completed the aerobic exercise first, followed by the resistance training. The resistance training protocol consisted of seven exercises with three sets of eight repetitions at 8RM and the aerobic exercise protocol was 45-minutes of treadmill running at 60% peak oxygen consumption. The results were in agreement with the previous study by Goto et al. (8) that found prior aerobic exercise reduces GH secretion during subsequent resistance training. Although after 30-minutes of the onset of exercise, despite the mode, there was a significant rise in GH from baseline, but there was no significant difference between modes during the first mode of exercises. During the second mode of exercise, the group that performed aerobic exercise first, had significantly lower GH levels during the subsequent resistance training compared to the group who performed resistance training first; who's GH continued to rise during the following aerobic exercise.

Obesity, Exercise, and Growth Hormone. Several studies have examined the GH blunting effect that is seen with obesity during exercise. Weltman et al. (35) examined the differences in 24-hour GH secretion during exercise between obese and non-obese individuals for two different aerobic treadmill protocols: a single 30 minute treadmill bout, and three 10 minute treadmill bouts done throughout the day. The total work completed in the three treadmill bouts equaled the work completed during the single 30-minute bout. The results showed a significantly reduced 24-hour serum GH stimulation for the obese group compared to the non-obese group regardless of exercise protocol. Wong and Harber, (38) compared cycling at the same relative power outputs for 30-minutes between obese and non-obese men. The results of this study showed that while there were no significant differences in VO_2, heart rate, blood lactate, or respiratory exchange ratio, there was a significant difference in GH secretion. The lean group had a peak GH measure of 44.0 ± 22.2 ug/mL compared to the obese group which had a peak of only 13.4 ± 12.2 ug/mL.

Growth hormone secretion rates seem to be similarly blunted during resistance exercise for obese individuals. Thomas et al. (30) investigated the differences in serum GH concentrations after acute resistance exercise between obese and lean men. The resistance exercise protocol consisted of 3 lower body compound exercises, and 3 upper body compound exercises completed in alternating fashion, for 3 sets, or 10 repetitions of 85-95% 10 repetition maximum. Although both groups had a significant GH response to the resistance exercise, the lean participants had a significantly higher response than the obese participants.

Yoga

Yoga is a form of physical activity that originated in ancient India(18) that combines focused breathing, stretching, and moving and holding various sitting, standing and lying poses. It utilizes body weight resistance to increase muscular strength while either statically holding a pose or moving from one pose to another. The overall duration of a yoga session typically lasts for 60 – 120 minutes with little rest throughout the session and utilizes large and compound muscle groups. Due to the nature of yoga, it can be argued that yoga can be considered a muscular strength, muscular endurance, and aerobic endurance exercise.

Yoga's Effect on Fitness Levels. Yoga has been studied a great deal on its psychological benefits associated with mood, depression, and other psychological disorders, but the research is lacking on yoga's effect on physical health and fitness. Yoga has been shown to have a positive effect on muscular strength. When looking at upper and lower body strength studies indicate that practicing yoga for 8 weeks may increase lower body strength by 10% (2), and other muscle actions such as knee extension by 28%, elbow extension by 31%, and elbow flexion by 19% (31). Core muscles (rectus abdominis, longissimus thoracis, external obliques, and gluteal maximus) have been shown, through electromyography, to display firing activity significant enough to increase muscular strength and endurance when practicing a series of common yoga poses (halfway lift, downward facing dog, upward facing dog, high plank, low plank, chair, mountain, and warrior) (18).

Practicing yoga has also been shown to evoke improvements in cardiovascular fitness. A review by Raub, JA (23) analyzed several articles that confirmed yoga's benefits on cardiovascular function and performance. Improvements from yoga included decreased submaximal work rates, increased maximal oxygen consumption, and increased lactate thresholds. Tran et al. (31) showed a 7% increase in maximal oxygen consumption after 8-weeks of yoga. This confirms the notion that Yoga can be classified as an aerobic exercise.

Intensity. Few studies have examined intensity of yoga using objective measures. One of these studies compared yoga to treadmill walking found that certain sequences of poses were similar in energy cost, oxygen consumption, and percent of predicted maximal heart rate when compared with level walking at 3mph (9). These measurements indicate that yoga meets the American College of Sports Medicine's criteria for moderate intensity exercise (16).

Some studies have reported that exercise intensity for certain types of yoga are too low to elicit the stimulus needed for improvements in fitness. Ray et al. (24) observed a very low intensity (9.9 to 26.5% maximal oxygen consumption) during an hour of yoga. Even at 26.5% maximum oxygen consumption, this would be considered very light exercise intensity (15) that would not meet the American College of Sports Medicine's criteria for moderate exercise (16). These findings were not surprising as the study was conducted on a very low intensity form of yoga that focused on breathing and less difficult poses. These findings indicate that yoga can be done at varying intensity levels, and perhaps not all types of yoga are sufficient to induce fitness benefits.

Since yoga can be modified to meet each individual's fitness level, it is well suited for a wide array of age groups and experience levels. Obese as well as healthy elderly individuals may benefit from this form of exercise, as it is low-impact, adaptable, and offers adjustments to meet the needs of the participant, and the individual primarily drives the intensity and is capable of inducing many fitness and health benefits.

Yoga's Effect on Growth Hormone? There is sufficient evidence that indicates moderate intensity exercise (aerobic and resistance) stimulates GH secretion. Since yoga is neither traditional resistance training, as previous research has focused on, nor can be classified as aerobic exercise, it is unclear what effect it will have on GH stimulation. It embodies qualities of resistance exercise, in which muscle groups are worked to hold and move the body to difference positions, as well as aerobic attributes as it involves constant muscle activation with little to no rest for a long duration. A moderate intensity yoga session lasting for 1-hour seems plausible to increase GH secretion as other fitness benefits have clearly been demonstrated.

The aim of this study is to determine if a 60-minute acute bout of moderate intensity yoga is a sufficient stimulus to cause significant increases in GH secretion as seen in other modes of exercise.

III. CONCLUSIONS AND RECOMMENDATIONS

Summary and Conclusions. The current study indicates that GH significantly increases during a single 60-minute bout of yoga exercise. The rise in GH is less than other studies focusing on heavy resistance training and aerobic exercise, which is likely due to yoga being a lower intensity form of exercise. The current findings may partially help explain the increased strength and fat loss benefits seen in yoga participants.

Recommendations. Future research studies should focus on monitoring intensity through heart rate or portable gas-exchange analyzers while simultaneously monitoring GH responses. This may help determine at what intensity yoga best stimulates GH. Other studies should focus on fitness benefits from a long-term yoga regimen, while monitoring the yoga-GH response during each session. This may further link the muscular adaptations and fat-loss seen from practicing yoga to GH secretion. Furthermore, controlling for different populations may help determine if some people have a greater GH response to yoga than others.

Another focus should be given to the possibility of GH induced health benefits during yoga on overweight and obese individuals. Determining if yoga can significantly increase GH in these populations may have potential benefits of validating yoga as a weight loss intervention. Yoga is a low impact exercise that can be adapted to any fitness level, but do to its perceived lack of intensity and metabolic stimulation, it is often overshadowed by other forms of exercise, in which adherence can be very low.

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Appendices

Appendix A

Informed Consent -Yoga's Effect on Growth Hormone Secretion

I am an Exercise Science graduate student at Northern Michigan University and am conducting a study to understand the effect yoga has on natural growth hormone secretion. Previous research has shown that weight training as well as some aerobic activities have been shown to increase growth hormone release, which is linked to muscle and bone tissue growth as well as fat loss. Research has shown practicing yoga has these beneficial effects, but it is not clear if growth hormone is partially responsible for these benefits. The current study aims to learn if growth hormone contributes to the fitness benefits of practicing yoga. I would appreciate your participation in this study, which will help to explain the physical benefits of practicing yoga.

All personal information will be kept confidential. There will be no link to your identity and the data collected, nor any identifying markers that could link you with the results of this study. The requirements to participant in this study are:

- You must be between the ages of 18 and 31.
- Be free of injury and able to perform moderate to intense yoga poses without pain.
- Be available for the required yoga session and blood draws.

Please read the entire informed consent carefully. If you have any further questions please ask and I will be glad to answer them. If you wish to be a participant in this study please sign and date the informed consent, stating that you have completely read and understand the expectations of your involvement in this study.

Participants: Prior to the testing date you will be required to fill out a Health History Questionnaire and PAR-Q, which are used to screen for health conditions to ensure your safety during the yoga sessions. The total time required to complete this paperwork is approximately 10 minutes.

Procedures: You will be required to complete a food log during the 24 hours leading up to the yoga session. A food log form and instructions will be provided. During the 24-hour period before the yoga session you are required to refrain from exercise, tobacco products and alcohol. You will also be required not to consume any caffeine during the 4-hour period prior to the yoga session. Your entire involvement is as follows:

- Arrive at the yoga studio with completed food log leading up to the yoga session.
- Sit and rest quietly for 5 minutes.
- A small sample of blood will be drawn (about a teaspoon).
- You will complete a 1-hour, instructor led yoga session, which includes a warm up and cool down portion. During the yoga session a second sample of blood will be drawn after 30 minutes of yoga.
- Immediately after completion of the yoga session, a third sample of blood will be drawn.

The total time needed from you to participate in this study is approximately 1.25 hours.

<u>Risks and Benefits:</u> As with any exercise, the risk of discomfort or injury is always present. A certified yoga instructor will help to ensure proper form and technique, which will help reduce these risks.

As with any blood draw the risk of pain, bleeding or infection may be present. The blood draw will be conducted by a certified phlebotomist and will adhere to proper blood draw procedures, which include cleaning the blood draw site, disposing of used needles immediately after use, and bandaging the site afterward.

The benefits of this research are that you will be able to learn your resting growth hormone levels, as well as your growth hormone response to yoga and help to contribute to the knowledge regarding yoga and fitness. You will also be able to participate in all yoga sessions during this study, free of charge. You may request your growth hormone results to be e-mailed to you upon completion of this study.

<u>Safeguards:</u> All personal information gathered will be kept confidential and there will be no link between your identification and data collected in any published information. Upon completion of the data collection the results of your blood samples and other collected data will be destroyed.

<u>Results:</u> If you are interested in the results of your growth hormone blood analysis, they are available to you upon your request. It is recommended to discuses these results with your physician if you have any concerns or questions.

<u>Freedom to Withdraw from Study:</u> All participation in this study is completely voluntary. You have the right to withdraw from this study at any time with no consequence. If you choose to withdraw, all of your personal information gathered and data gathered from you will not be used and be immediately destroyed. The researcher may end your participation in this study at any time if any circumstances arise that may compromise your health or effect the testing results (i.g. illness or injury). Also, the researcher may end your participation if you fail to show up for your testing appointment.

Once this study is completed, the researcher will share the results with you. If you have any questions concerning this study, or your involvement in it, please contact:

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By signing below, you state that you have read and understand the risks and benefits of this study and are volunteering to participate.

Name (print) ____ Date: ___________________

Name (signature) _______________________________________ Date: ___________________

Student Researcher ______________________________________ Date: ___________________