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A Rare Case Report: Hemodynamic Responses and Exercise Capacity Before and After Becoming a Non-Biological Live Liver Donor

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ABSTRACT

Background: According to the United States Department of Health and Human services 8,497 liver transplants were accomplished in the United States in 2016. Of those transplants, only 345 (4.1%) of the transplants came from a live donor and only 9 (0.03%) of the live donor transplants came from a non-biological paired donor [1]. Very little published data exists regarding Living Donor Liver Transplant (LDLT) influences on the live donor's responses to exercise post-surgery.

Purpose: To study the acute and prolonged effects of exercise and LDLT on heart rate, blood pressure, Lactate, Glucose, estimated maximal aerobic capacity, muscular strength, and the responses during submaximal exercise testing (6MWT and/or submaximal Bruce protocol).

Methods: A single female subject, age 53 years, volunteered to participate in this study after already agreeing to become a live liver donor. Data was obtained once prior to the procedure and every month thereafter, for a total of eight months post-surgery.

Conclusions: There was minimal changes in aerobic capacity and strength due to lack of consistency with an exercise program. Findings of this case report cannot be generalized to all LDLT donors. However, the information on the recovery of an LDLT donor in respect to exercise testing may be beneficial to clinicians and professionals in prescribing an exercise program for similar patients in similar circumstances.

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Introduction

Liver transplantation is a surgical technique to replace a diseased liver with a healthy functioning liver in some patients with end stage liver disease. The recipient of the liver may have only part, or the entire liver removed, which is then replaced by the portion of the donor's liver. The liver donor may either be living or deceased. Although a living donor is most commonly a biological relative, a non-related individual can also be matched as a donor. During the living-donor liver transplant (LDLT) procedure, the recipient and donor are placed side by side in the operating room. Once a portion of the liver is removed from the donor, it is immediately placed into the recipient. The donor then has only a portion of their liver, which will regenerate to about 90% of its original full size within six months [2].

According to the United States Department of Health and Human Services, 8,497 liver transplants were accomplished in the United States in 2016 [1]. Of those transplants, only 345 (4.1%) came from a live donor and only 9 (0.03%) came from a non-biological paired donor [1]. In this case report, the donor was a non-biological paired live donor. In reviewing the literature, limited data exist on the impact of LDLT on the live donor. This case report was designed to discover relationships between the hemodynamic responses, aerobic capacity, and muscular strength before and after an LDLT, following an exercise regimen in an advanced age woman.

The recovery of recipients has been studied thoroughly, yet the recovery of the live donor is less known. The purpose of this case report was to observe the aerobic capacity and hemodynamic responses in response to an exercise program after a LDLT in a live donor. The design of this report was chosen in order to contribute new information to the current literature and provide insight as to the exercising of an individual during her recovery from a live liver donation.

Background of LDLT

Organ transplantations began as early as 1954, with the first successful kidney transplantation [3]. Other organs, such as livers, hearts, and pancreas transplants followed in the 1970s [3]. The United Network for Organ Sharing (UNOS) began in 1984, with the intent of supporting organ donation and transplantation professionals [3]. In the same year, the Organ Procurement and Transplantation Network (OPTN) was created to maximize organ sharing efficiency by establishing a system of data and provide information on human organ transplantation [3]. With these established organizations, the demand for organ transplantation and the occurrence of successful treatment due to transplantation have both increased [3]. Worldwide, there have been over 12,000 LDLTs performed since 1989 averaging 428 per year [4].

In 2016, UNOS and OPTN reported 8,497 liver transplants in the United States, which accounted for 25.3% of all transplants in the United States [3]. Of these liver transplants, only 345 were from a live donor, which is approximately 4.1% of all liver transplants in the United States [1]. The subject of this case report was a resident of the state of North Dakota. In the year 2016, there were only 2 live liver donors that resided in the state of North Dakota, which is 0.024% of the total liver transplants that took place in the United States during that year [1]. Regarding the age and gender of living donors for liver transplants, the Organ Procurement and Transplant Network reported that out of 345 live donors, 44 (12.8%) were within the ages of fifty to sixty-four, 206 (59.7%) donors were female, and 27 (7.8%) were female and within the ages of fifty to sixty-four [1].

Liver Donation

Trends in live liver donations from 2000-2007 were reported by Nadalin et al [4]. A potential donor must fit several criteria before undergoing an evaluation for the procedure to be approved [4]. Criteria include biological age between eighteen and fifty-five years old, ABO (blood type) compatibility, Body Mass Index (BMI) of less than 30 kg·m-2, and free of any medical disorder that could complicate the procedure for either the donor or recipient [4]. The decision to donate must be completely voluntary, and is assessed through psychological evaluations [4]. Some countries only allow the donor to be a relative or spouse of the recipient - this is not the case in The United States [4]. The evaluation process includes blood tests, imaging, psychological evaluation for altruism and possible coercion, and possibly a liver biopsy [4]. After the evaluations, the benefits of the procedure must outweigh the risk for both the donor and the recipient before the procedure is scheduled [4]. Both left lateral segment donor hepatectomy and right hemi-hepatectomy are standard procedures for LDLT [4]. Nadalin et al found donor mortality rate and morbidity rate at 0.2%-2% and 20%-60% respectively [4].

In 2013, Soubrane et al. reported on a pure laparoscopic right hepatectomy in a living donor [5]. This donor was a fifty-year-old female, whom donated 56% of her liver to her sister [5]. The recipient suffered from primary biliary cirrhosis which was complicated by portal hypertension and became a candidate for liver transplantation [5]. Both the donor and recipient had an uneventful postoperative hospital stay with normal liver function [5].

Liver Resection/Regeneration

Liver resection occurs for medical indications, such as liver tumors or liver donation, as well as other indications. Regardless of the indication for resection, liver regeneration and related factors have been observed in several cases. Kele et al. observed liver regeneration after liver resection in ninety-one patients [6]. Liver volume was observed before the resection, one week post-operation, and six months post-operation [6]. Of the ninety-one patients, there were fifty men and forty-one women, with a median age of 62 with 82% being over the age of 50 [6]. Patients were then classified in groups according to the percentage of their liver resected [6]. The results showed that those patients with large resection volumes (>40%) had slower regeneration within the first week of the operation and did not have full regeneration at six months post-operation [6]. Kele et al. attributed this delay in regeneration to the fact that cells in mitosis are not participating in liver function, and the metabolic processes are the primary concern of the liver after resection [6]. The results also showed that only 45% of liver resection patients had full liver regeneration at six months post-operation, and none with ≥70% resection achieved full regeneration [6].

Over the course of three years, Ibrahim et al. studied 108 LDLT donors [2].The demographics of those included were sixty-three females and fourty-six males, a mean age of 32.32±8.48 years, and the donor's mean weight of 62.92±12.33 kg [2]. Prior to the liver donation, the mean liver size was 1207.72±219.95 cm^3.2 At the six-month follow up, the mean liver size was 1087.18±202.41 cm3.2 The researchers reported that within 6 months, the donor's liver after a LDLT was 90.70±12.47% of its size prior to the procedure, and found only twenty-six donors achieved complete liver regeneration in this time frame [2]. Garcea et al published a review with conflicting results to the above mentioned studies on liver regeneration [7]. The purpose of the article was to review factors during major hepatic resection that effect liver regeneration and function [7]. They suggested that liver regeneration is evident within two weeks after the resection and complete regeneration was possible at only three months post-operation [7]. Although the liver is one of the fastest regenerating organs, the immediate loss of cells and function due to a resection is detrimental to the health of the patient [7]. Garcea et al. concluded that there are "a small but significant number of individuals that will succumb to liver failure in the immediate post-operative period" yet can be prevented with careful patient inclusion criteria and post-operative preservation of the remaining liver [7].

Pre-habilitation Prior to Liver Resection

Dunne et al examined thirty-five subjects (twenty-five men and ten women with age range of 54–69 years) that have participated in a pre-habilitation program before a planned liver resection [8]. The group was divided into those who would receive standard care (n=16) and those that would participate in a pre-habilitation exercise program (n=19) [8]. The pre-habilitation program included twelve 30-minute interval exercise sessions over the course of four weeks [8]. Those that participated in the pre-habilitation exercise program increased their VO_2 at anaerobic threshold (AT) by 1.5 $ml·kg^{-1}·min^{-1}$, VO_2 peak by 2 $ml·kg^{-1}·min^{-1}$, and had a significantly ($p<0.05$) higher peak work rate (compared to standard care), as well as improvements in heart rate reserve ($p=0.074$) and pulse oxygen saturation at AT ($p=0.062$).8 These increased values were associated with lower morbidity, mortality, and hospital stay after major abdominal surgery [8].

Blood Lactate, Glucose, Insulin, Glucagon, and Fatty Acids after Major Surgery

In 2011, Shin et al. reported on lactate, acid-base status, electrolyte, and hemoglobin concentrations before and after LDLT of 104 donors (eighty-one males, twenty-three females; age ranges from nineteen to thrity-two years of age) [9]. They found that lactate concentration increased significantly one-hour post operation (p=0.005) [9]. These measures declined rapidly over the first two days post operation and were resolved to normal by the second day post operation [9]. It was stated that "lactate clearance is likely to be preserved in healthy donors with normal liver parenchyma" [9].

Pietsch et al observed blood lactate and pyruvate after liver resection in twenty-five patients (thirteen males, twelve females) [10]. The purpose was to compare the Pringle maneuver (n=14; mean age of 53±2.6 years) and a hemi- hepatectomy without vascular occlusion (n=11; mean age of 59.4±4.8 years) [10]. The researchers reported an increase in lactate levels as well as a significant increase in hepatic venous lactate levels at time of liver resection in patients that had Pringle maneuver than with the control procedure [arterial samples: 1.9±0.2mmol·L^{-1} (Pringle group), 2.3±0.5 mmol·L^{-1} (Controls); hepatic vein: 1.3±0.2 mmol·L^{-1} (Pringle group), 1.5±0.3 mmol·L^{-1} (Controls); p<0.05)] [10]. The results were contributed to the fact that the "Pringle maneuver leads to tissue hypoxia by clamping of the hepatic artery and the portal vein" and the conversion of lactate to glucose during the Cori-cycle, which takes place in the liver, is not possible without a supply of oxygen [10].

A comparative study between fasted, healthy individuals and those undergoing a major hepatectomy was completed before the turn of the century, which observed changes in glucose and lactate metabolism.11 Chiolero et al. monitored plasma glucose, plasma lactate, insulin, cortisol, IGF-1, and glucagon before and after an experimental procedure [11]. Seven healthy control subjects (age range nineteen to forty-two years old) and six patients (one male, five female; age range forty-nine to sixty-eight years old) whom had undergone a major liver resection in various conditions, were given an infusion of lactate and glucose [11]. Chiolero et al reported a continuous lactate production with high metabolic rate, as well as a lactate delay described as lactate oxidation and lactate transforming into glucose [11]. It was concluded that "patients who have undergone major hepatectomy have normal glucose and lactate metabolism after a short fast. This clearly demonstrate the absence of major alterations of fuel metabolism due to a large metabolic reserve of the liver parenchyma" [11].

Margonis et al. observed phosphorus and glucose levels in ninety-five liver resection patients (median age=58.4 years; n=50:45 males to females) at John Hopkins Hospital during liver regeneration [12]. "Most common indications for a hepatic resection were colorectal liver metastasis (n = 39, 41.5 %), cholangiocarcinoma (n= 30, 31.9 %), and hepatocellular carcinoma (n= 12, 12.8 %)" [12]. The researchers observed that those patients with high pre-operative glucose levels (fasting blood sugar ≥ 126 mg·dl-1) had higher volumetric gains (32.72%; p<0.05) two months after resection.12 This was not seen again at seven months post-operation, and is not associated with long-term outcomes such as decreased liver function or possible liver failure [12]. Dyrczynski et al. investigated insulin resistance in response to a major liver resection [13]. In thirty hemi-hepatectomy patients (mean age 58.0 ± 12.2 years), an oral glucose tolerance test (OGTT) was administered before the procedure, as well as one week and one month post operation [13]. Fasting glucose increased by 15.5% (from 89.6 to 103.5 mg/dL), showing an exacerbated insulin resistance post liver resection [13]. These post-operative changes in glucose metabolism are similar to the changes observed in those that develop Type 2 Diabetes Mellitus [13]. Dyrczynski et al concluded that these results are not relevant to the majority of patients; although, those patients that are already at an increased risk for developing diabetes should be monitored more closely [13]. It was also stated that long-term survival might lead to an increased risk of developing diabetes [13].

Furthermore, Thorell et al investigasted insulin resistance as a marker of surgical stress [12]. Post trauma (such as surgery), catabolism changes to anabolism in favor of recovery, and a decrease in the anti-lipolytic effect of insulin, which is an anabolic hormone [14]. The degree of insulin sensitivity after abdominal surgery is significantly correlated with the hospital stay duration after the procedure [14]. Two factors that the authors contributed to this peripheral tissue insulin resistance are the combination of hypocaloric nutrition and bed rest.14 The authors concluded that insulin resistance is a metabolic variable related to uncomplicated elective surgery, that it may be advantageous to control glycaemia and minimize metabolic stress and would encourage proper nutrition after this type of procedure [14].

Major Surgery Associated with Aerobic Capacity and Muscular Strength

In Japan, researchers investigated the changes in muscular strength and the Six Minute Walk Test (6MWT) distance achieved in LDLT recipients.15 Twelve transplant recipients (age: 50.8 ± 14.5 years; six males and six females) were included in this study.15 At approximately one month post LDLT, there was a 27% decline in isometric knee strength (kgf), a 17% decrease in hand grip strength (kgf), and non-significant changes in the 6MWT distances (preoperative: 365.9± 141.3 m, postoperative: 341.1±139.7 m; p=0.182).15 The authors concluded that the patients were not fully recovered at four weeks post LDLT, and further research was necessary [15].

In 2012, Junejo et al. observed the prognostic value of preoperative cardiopulmonary exercise testing for patients undergoing a hepatic resection [16]. The subjects (males n=107, females n=83) were either patients over the age of sixty-five, younger patients with comorbidities, or those undergoing a complex resection (n=204).16 With regard to the post-operation outcomes, VO_2 at the anaerobic threshold (AT) was the only preoperative marker associated with in-hospital mortality (p= 0.032), at values less than 9.9 mL·kg^{-1}·min^{-1}.16 This value had a significant and negative correlation (r = −0.26, p=0.012) between AT and Intensive Care Unit (ICU) stay duration [16].

Methods

Sampling Procedures

The present study included one subject (n= 1) as it was planned as a case report. The subject was a female aged 53, with no known physical or mental diseases, and/or skeletomuscular injuries, which volunteered to participate in this study. The subject had begun meeting with a personal trainer at her place of work after finding out she could be a live donor for a friend in need of a liver transplant. For the four months prior to the procedure, the subject was completing approximately 5 hours of moderate aerobic activity and 2-3 resistance training sessions per week. The subject reported walking at a moderate intensity for approximately an hour at least 5 days per week. As for resistance training, the subject's routine included body weight lower body strengthening exercises, dumbbell upper body strengthening exercises, and core exercises. These resistance training sessions lasted approximately 30 minutes, 2 to 3 times per week. Throughout the duration of this study, the subject did not experience any adverse reactions to the LDLT procedure or the data collection protocols.

Selection of Instrument(s)

The following procedures and equipment were chosen to achieve the goals of this study. Equipment utilized in this study was available at the exercise physiology lab, Department of Exercise Physiology, School of Health Sciences, University of Mary, Bismarck, ND. Height (cm) was obtained in the first visit using a stadiometer. Weight (kg) was obtained using an electronic floor scale. Blood pressure (mmHg) was manually measured with an Omron sphygmomanometer and a Littmann stethoscope. Plasma oxygen saturation (%) was measured via a pocket pulse oximeter, which has been shown to have similar values, of insignificant differences (.01%), according to a study by Da Costa et al [17]. A Polar FS1 heart rate monitor was used to measure heart rate (bpm). In the Polar FS1 manual, Polar reports the heart rate accuracy of "±1% or ±1 bpm, whichever is larger"[18]. Lactate (mmol/L) and glucose (mg/dL) were obtained via Point-of-Care Testing using a Nova Biomedical Lactate Plus meter and a HealthMart True Metrix meter respectively. Tanner et al. evaluated three blood lactate analyzers, including the Nova Biomedical Lactate Plus, and found the Lactate Plus was most favorable in reliability and accuracy [19]. Trividia Health, the makers of True Metrix Self-Monitoring Blood Glucose system, investigated the accuracy of the device for diabetic patients and concluded the device meets the ISO (International Organization for Standardization) standard for accuracy [20]. Body composition was assessed using a seven site skinfold assessment via a Lange skinfold caliper, which are noted to be a high-quality instrument of excellent scale precision of 1.0 mm [21]. All seven sites were assessed on the right side of the body, which included the subscapular, triceps, chest, mid-axillary, supra-ilium, abdominal, and thigh sites. Heyward et al noted it is standard to measure on the right side of the body [21]. Body density ($kg \cdot L^{-1}$) and estimated body fat percentage (%) were calculated, using the Jackson Pollock seven-site formula for women and Siri equations, respectively. To test aerobic capacity, one of two assessments were utilized dependent on the subject's activity limitations post-procedure. The first and primary assessment chosen was the submaximal Bruce protocol, due to the researcher's familiarity with the protocol and no need for a maximal exertion assessment. This protocol is a commonly used treadmill protocol as recommended by the American College of Sports Medicine (ACSM) [22]. The treadmill used in this study was a Sports Art Fitness 6320. The Six Minute Walk Test (6MWT) was also used to assess the subject's aerobic capacity post-procedure, while the subject was only cleared for walking, but the physician restricted moderate to high intensity exertion. The 6MWT is recommended by multiple organizations, such as the ACSM and AACVPR, as an aerobic assessment for clinical populations [23]. The Rating of Perceived Exertion (RPE) scale (6-20) was used during the aerobic assessments, which has a positive, strong, and significant correlation ($r=0.74$, $p=0.02$) to percentage of maximal aerobic capacity in active men according to Satonaka et al. [24] It is also reported that RPE generally underestimates the percentage of maximal aerobic capacity in those with good fitness, while the reverse is true for those with poor fitness [24]. For this reason, it is important to use RPE alongside objective physiological measures, such as heart rate [24]. Muscular strength assessments were conducted on a Cybex chest press machine and leg press machine.

Data Collection Procedures

The subject approached the researcher for assistance with an exercise program, to prepare to potentially donate her liver to a close friend. The subject had already begun the process to be cleared for this procedure. The researcher did not coerce the subject to undergo this procedure or to be the subject of this research.

The subject was cleared to be a live liver donor by the Mayo Clinic, MN, and underwent the LDLT procedure as the donor in mid-December of 2016.

Upon approval from the IRB committee at the University of Mary, Bismarck, ND, the subject was enrolled into the study and has presented at that point of time the clearance received by her physician to participate and exercise as part of this study. An informed consent form was read and signed by the subject in the first visit to the lab followed by a Health History Questionnaire completed by the subject, which the researchers used to risk-stratify the subject according to the ACSM [22].

Exercise testing was completed nine times throughout the study; once prior to the procedure, and every month thereafter for the duration of eight months post-surgery. The first data collection took place approximately one month prior to the live donor liver transplantation. At approximately one-month post-operation, the subject was cleared for walking, but still had push/pull/lift restrictions of no more than 4.45 kg (10 lbs). After 10 weeks post-operation, the subject was cleared for jogging and the push/pull/lift restrictions changed to 6.81 kg (15 lbs). The subject was instructed to advance in exercise as tolerated.

Height (cm), weight (kg), heart rate (bpm), blood pressure (mmHg), muscular strength (1 Repetition Maximum), lactate ($mmol \cdot L^{-1}$) and glucose ($mg \cdot dL^{-1}$) were measured, while body fat percentage (%) and VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) were estimated according to the results of the skinfold measurement or the aerobic assessment respectively.

VO_2 was estimated for the last two stages that were completed, using the following equation: $VO_2 = 3.5 + (0.1 \times speed\ (m \cdot min^{-1})) + (1.8 \times speed\ (m \cdot min^{-1}) \times grade\ (\%))$. Then, the slope of the graph was calculated using the following equation: $b = (VO_{2higher} - VO_{2lower})/(HR_{higher} - HR_{lower})$. The calculated outcome values were then included in the following equation to predict VO_{2max}: $VO_{2max} = VO_{2higher} + b\ (HR_{max} - HR_{higher})$.

In the first data collection, which was performed prior to the procedure, a 1 Repetition Maximal (1RM) assessment was conducted for both upper body and lower body strength. This protocol consisted of a warm up of ten repetitions at a weight that was rated as a 3 or 4 on a 1-10 scale of exertion, followed by a three-minute rest period. The next weight was set at a heavier weight in order to achieve a higher rating on the 1-10 exertion scale with one repetition, which was followed by a three-minute rest period. The weight was repeatedly increased until the subject reaches a 10 on the 1-10 exertion scale, with a maximum of four trials.

Visit 1

The first visit to the lab occurred approximately one month before the LDLT procedure. The subject reported to the lab in the afternoon and was seated immediately upon entering the lab. The subject was then introduced to the research team, had the research design explained, and had any possible questions addressed. An informed consent was completed and signed by the subject, followed by a health history questionnaire used for risk stratification according to the ACSM guidelines [22]. Baseline measurements including height and weight were obtained. After being seated in a chair for five minutes, resting measurements were obtained. Resting measures included heart rate (HR), blood pressure (BP), blood glucose, and blood lactate.

The subject then had her body composition assessed using a skinfold caliper for a seven-site skinfold assessment on the right side of the body. Sites that were utilized included the subscapular, triceps, chest, mid-axillary, supra iliac, abdominal, and thigh sites. Body density was calculated using the Jackson Pollock seven-site formula for women. Body density was then converted to an estimation of body fat percentage (%) using the Siri equation.

As for the primary aerobic assessment, the submaximal Bruce protocol was conducted on the treadmill. A standing blood pressure was assessed while the subject was standing on the treadmill. HR was assessed every minute throughout the exercise test, while BP and rate of perceived exertion (RPE) were assessed during the last minute of every stage (every three minutes). The test was terminated if the subject's heart rate reached 85% of her age-predicted heart rate maximum (142 bpm), if the subject reached two stages of steady-state (HR above 110 bpm), if the subject reported an RPE of 17 or greater, if the subject reported any abnormal signs or symptoms, or if the subject requested to stop. Post-procedure, during the time that the subject was under activity limitations, the 6MWT was administered as the aerobic assessment instead of the Bruce submaximal protocol. Before beginning, the subject was instructed to walk the length of a 100-foot (30.48 m) hallway, as quickly as possible for six minutes, resting as needed. The researcher walked behind the subject during the test while monitoring the subject's HR every minute. At exactly six minutes, the test was terminated, and the subject sat in order to obtain BP immediately. If the subject felt symptomatic before the six minutes were completed, the test was terminated at the onset of symptoms.

During recovery, HR, BP, glucose, and lactate were measured at five, ten, and fifteen minutes after completing the aerobic assessment. Once these measures were completed and the subject's HR was below 100 bpm, the subject completed the muscular strength assessments on the chest press machine and leg press machine. The 1RM assessment consisted of a warm up of ten repetitions at a weight that was rated as a 3 or 4 on a 1-10 scale of exertion, followed by a three-minute rest period. The next weight was set at a heavier weight, with the goal of achieving a higher rating on the 1-10 exertion scale with one repetition, which is followed by a three-minute rest period. The weight is repeatedly increased until the subject reaches a 10 on the 1-10 exertion scale, with a maximum of 4 trials.

When the assessments were completed, the subject's HR was below 100 bpm and BP was within 20 mmHg of resting, and the subject felt symptom-free, the subject was then allowed to leave the lab.

In-Between Visits

The subject followed all exercise restrictions indicated by the subject's medical team. The subject continued to exercise in accordance to the exercise plan given to the subject at the subject's place of work. Exercise was prescribed by a certified professional and was in accordance to the physician's activity restrictions. The exercise program included total body resistance training, flexibility, and aerobic training. The subject completed a weekly self-report log including information on the subject's sleep, nutrition, hydration, exercise, and medications.

Precautions during Data Collection

The following criteria were followed for each lab visit:

- If the subject was symptomatic (light-headed, nauseous, unusual fatigue, unusual soreness, etc.) the day of testing, to the point that leaving the house is difficult: testing was postponed, and the subject was be encouraged to contact her physician.
- If the subject was symptomatic (light-headed, nauseous, unusual fatigue, unusual soreness, etc.) the day of testing, but symptoms did not worsen when active: resting measures (HR, BP, blood glucose, and blood lactate) were taken while proceeding cautiously with exercise testing or omit exercise testing for that session. The subject was encouraged to contact her physician if symptoms persisted.
- If the subject became symptomatic during exercise testing: testing was terminated immediately, and the subject was encouraged to contact her physician.
- The ability to exercise test the subject was re-evaluated on a visit by visit basis according to exercise restriction in place. The 6MWT was utilized while restrictions did not allow for the submaximal Bruce protocol to be utilized.

Visit 2

The subject reported to the lab in the afternoon, where she was weighed immediately. She was then seated for five minutes, before obtaining resting values. When HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained, her body composition was assessed. The 6MWT was administered with the researcher walking behind the subject, at the subject's own pace, monitoring HR every minute and BP at the end of the test. Verbal and visual assessments were utilized, and an AED was located nearby, for safety precautions. The test was terminated at 6 minutes exactly, and the subject was seated. HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained at five, ten, and fifteen minutes after the completion of the 6MWT. Due to push/pull/lift restrictions from her medical team, strength assessments were not completed. The subject was dismissed from the lab symptom-free.

Visit 3

The subject reported to the lab in the afternoon and her body weight was assessed immediately. She was then seated for five minutes, before obtaining resting values. When HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained, her body composition was assessed. The 6MWT was administered with the researcher walking behind the subject, at the subject's own pace, monitoring heart rate every minute and blood pressure at the end of the test. Verbal and visual assessments were utilized, and an AED was located nearby, for safety precautions. The test was terminated at 6 minutes exactly, and the subject was seated. HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained at five, ten, and fifteen minutes after the completion of the 6MWT. Due to push/pull/lift restrictions from her medical team, strength assessments were not completed. The subject was dismissed from the lab symptom-free.

Visit 4

The subject reported to the lab in the afternoon, where she was weighed immediately. She was then seated for five minutes, before obtaining resting values. When HR, BP, pulse oxygen saturation, glucose, and lactate measurements were obtained, her body composition was assessed. Activity restrictions were lifted by the subject's medical team prior to this lab visit. The subject completed a submaximal Bruce protocol on the treadmill. Verbal and visual assessments were utilized, and an AED was located nearby, for safety precautions. The test was terminated when the subject's heart rate reached 85% of her age-predicted maximal heart rate. HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained at five, ten, and fifteen minutes after the completion of the submaximal Bruce protocol.

Due to push/pull/lift restrictions from her medical team, strength assessments were not completed. The subject was dismissed from the lab symptom-free.

Visit 5
The subject reported to the lab in the afternoon and her body weight was assessed immediately. She was then seated for five minutes, before obtaining resting values. When HR, BP, pulse oxygen saturation, glucose, and lactate measurements were obtained, her body composition was assessed. The subject completed a submaximal Bruce protocol on the treadmill. Verbal and visual assessments were utilized, and an AED was located nearby, for safety precautions. The test was terminated when the subject's heart rate reached 85% of her age-predicted maximal heart rate. HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained at five, ten, and fifteen minutes after the completion of the submaximal Bruce protocol. Due to push/pull/lift restrictions from her medical team, strength assessments were not completed. The subject was dismissed from the lab symptom-free.

Visit 6
The subject reported to the lab in the afternoon, where she was weighed immediately. She was then seated for five minutes, before obtaining resting values. When HR, BP, pulse oxygen saturation, glucose, and lactate measurements were obtained, her body composition was assessed. The subject completed a submaximal Bruce protocol on the treadmill. Verbal and visual assessments were utilized, and an AED was located nearby, for safety precautions. The test was terminated when the subject's heart rate reached 85% of her age-predicted maximal heart rate. HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained at five, ten, and fifteen minutes after the completion of the submaximal Bruce protocol. Due to push/pull/lift restrictions from her medical team, strength assessments were not completed. The subject was dismissed from the lab symptom-free.

Visit 7
The subject's medical team lifted all activity restrictions prior to the seventh lab visit. The subject reported to the lab in the afternoon and her body weight was assessed immediately. She was then seated for five minutes, before obtaining resting values. When HR, BP, pulse oxygen saturation, glucose, and lactate measurements were obtained, her body composition was assessed. The subject completed a submaximal Bruce protocol on the treadmill. Verbal and visual assessments were utilized, and an AED was located nearby, for safety precautions. The test was terminated when the subject's heart rate reached 85% of her age-predicted maximal heart rate. HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained at five, ten, and fifteen minutes after the completion of the submaximal Bruce protocol. Following the above measurements, upper and lower body strength assessments were completed. The subject was dismissed from the lab symptom-free.

Visit 8
The subject reported to the lab in the afternoon, where she was weighed immediately. She was then seated for five minutes, before obtaining resting values. When HR, BP, pulse oxygen saturation, glucose, and lactate measurements were obtained, her body composition was assessed. The subject completed a submaximal Bruce protocol on the treadmill. Verbal and visual assessments were utilized, and an AED was located nearby, for safety precautions. The test was terminated when the subject's heart rate reached 85% of her age-predicted maximal heart rate. HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained at five, ten, and fifteen minutes after the completion of the submaximal Bruce protocol. Following the above measurements, upper and lower body strength assessments were completed. The subject was dismissed from the lab symptom-free.

Visit 9
The subject reported to the lab in the afternoon and her body weight was assessed immediately. She was then seated for five minutes, before obtaining resting values. When HR, BP, pulse oxygen saturation, glucose, and lactate measurements were obtained, her body composition was assessed. The subject completed a submaximal Bruce protocol on the treadmill. Verbal and visual assessments were utilized, and an AED was located nearby, for safety precautions. The test was terminated when the subject's heart rate reached 85% of her age-predicted maximal heart rate. HR, BP, pulse oxygen saturation, blood glucose, and blood lactate measurements were obtained at five, ten, and fifteen minutes after the completion of the submaximal Bruce protocol. Following the above measurements, upper and lower body strength assessments were completed. The subject was dismissed from the lab symptom-free.

Statistical Analysis Procedures
The researcher followed the commonly utilized instructions for the writing of a case report, in the absence of appropriate parametric analysis procedures [25- 27].

Results
Visit 1
During the first visit, the subject's resting vitals were as follows: HR of 58 bpm, BP of 116/72 mmHg , oxygen saturation of 94%, blood glucose of 90 mg·dL-1, and blood lactate of 0.9 mmol·L^{-1}, with a body weight of 84 kg, BMI of 29.76 kg·m^{-2}, and height of 1.68 m. From the seven-site skinfold assessment, the subject's body fat percentage was estimated as 34.75%. The aerobic exercise assessment was terminated during the second stage of the submaximal Bruce protocol, at a speed of 2.5 mph and grade of 12%, due to the subject's heart rate reaching 85% of her age-predicted maximum heart rate, which was 142 bpm. Estimated VO2max was 31.05 ml·kg·min^{-1}. Five minutes after terminating the test, her HR was 83 bpm, as well as BP of 118/76 mmHg, blood glucose of 76 mg·dL^{-1}, and blood lactate of 1.3 mmol·L^{-1}. At ten minutes post-exercise, the subject's HR was 70 bpm, as well as a BP of 114/76 mmHg, blood glucose of 76 mg·dL^{-1}, and blood lactate of 1.1 mmol·L^{-1}. After an additional five minutes, at a total of fifteen minutes post-exercise, the subject had a HR of 72 bpm, BP of 112/74 mmHg, blood glucose of 74 mg·dL^{-1}, and blood lactate of 1.0 mmol·L^{-1}. The subject then completed the upper body chest press and lower body leg press 1RM assessments, and lifted weights of 45 pounds and 140 pounds respectively. During this initial visit, the subject did not report any symptoms and left the lab in good spirits and health.

Visit 2
The second visit to the lab was approximately one month after the LDLT procedure. The subject weighed in at 81 kg (BMI = 28.7 kg·m^{-2}), with an estimated 33.27% body fat, as well as a resting HR of 66 bpm, resting BP of 134/76, resting oxygen saturation of 98%, casual blood glucose of 89 mg·dL^{-1}, and blood lactate of 1.1 mmol·L^{-1}. Due to physician activity limitations, a 6MWT was completed instead of the submaximal Bruce protocol. The subject walked 554.7 m, with a maximal HR of 123 and BP of 162/70

mmHg. At five minutes post-exercise, her HR was 78 bpm, BP was 128/78 mmHg, blood glucose was 69 mg·dL^{-1}, and blood lactate was 1.4 mmol·L^{-1}. After ten minutes post-exercise, the subject had a HR of 68 bpm, BP of 124/76 mmHg, blood glucose of 75 mg·dL^{-1}, and blood lactate of 1.3 mmol·L^{-1}L. A total of fifteen minutes after the end of exercise, the subject's HR was 67 bpm, BP was 122/70 mmHg, blood glucose was 67 mg·dL^{-1}, and blood lactate was 0.8 mmol·L^{-1}. No strength assessments were completed due to the subject's push, pull, and lift restrictions. During this visit, the subject did not report any symptoms and left the lab in good spirits and health.

Visit 3

The next lab visit was about two months after the LDLT procedure, when the subject's body weight was 80.5 kg (BMI = 28.52 kg·m^{-2}) and body fat estimation of 33.10%. Her resting HR was 66 bpm, resting BP was 122/74, resting oxygen saturation was 98%, casual blood glucose was 103 mg·dL^{-1}, and blood lactate was 1.9 mmol·L^{-1}. A 6MWT was completed, in line with the physician's activity restrictions. The subject walked a total distance of 533.4 m, with a maximal HR of 125 bpm and BP of 146/58 mmHg. After five minutes, the subject had a HR of 68 bpm, BP of 128/78 mmHg, blood glucose of 68 mg·dL^{-1}, and blood lactate of 1.6 mmol·L^{-1}. An additional five minutes, her HR was 76 bpm, BP was 126/70 mmHg, blood glucose was 66 mg·dL^{-1}, and blood lactate was 1.5 mmol·L^{-1}. At fifteen minutes post-exercise, the subject's HR was 72 bpm, BP was 118/70 mmHg, blood glucose was 72 mg·dL^{-1}, and blood lactate was 1.5 mmol·L^{-1}. Once more, no strength assessments were completed due to physician's activity restrictions. During this visit, the subject did not report any symptoms and left the lab in good spirits and health.

Visit 4

Three months after the LDLT procedure, the subject reported to the lab for a fourth time. The subject weighed in at 83.1 kg (BMI = 29.44 kg·m^{-2}), with an estimated 32.47% body fat. The subject's resting vitals were as follows: HR of 80 bpm, BP of 122/76 mmHg, oxygen saturation of 96%, blood glucose of 85 mg·dL^{-1}, and blood lactate of 0.9 mmol·L^{-1}. The subject's physician lifted some of the activity restrictions, but not the push/pull/lift restrictions. With these changes, the submaximal Bruce protocol was used as the aerobic assessment, which was terminated during the second stage at a speed of 2.5 mph and grade of 12%, due to the subject's heart rate reaching 85% of her age-predicted maximum heart rate, at 142 bpm. Estimated VO_2max was 33.09 ml·kg·min^{-1}. At five minutes post-exercise, the subject's HR was 96 bpm, BP was 118/68 mmHg, blood glucose was 71 mg·dL^{-1}, and blood lactate was 2.5 mmol·L^{-1}. Ten minutes after exercise, the subject's HR was 82 bpm, BP was 118/68 mmHg, blood glucose was 81 mg·dL^{-1}, and blood lactate was 2.5 mmol·L^{-1}. At the fifteen minutes post-exercise, her HR was 82 bpm, BP was 112/68 mmHg, blood glucose was 88 mg·dL^{-1}, and blood lactate was 2.1 mmol·L^{-1}. Push/pull/lift restrictions were still in place, thus no strength assessments were completed. During this visit, the subject did not report any symptoms and left the lab in good spirits and health.

Visit 5

During the fifth lab visit, which took place four months post-procedure, the subject's body weight was 83.4 kg (BMI = 29.54 kg·m^{-2}) and had an estimated 34.10% body fat percentage. At rest, her HR was 67 bpm, BP was 118/68 mmHg, oxygen saturation was 98%, blood glucose was 98 mg·dL^{-1}, and blood lactate was 1.2 mmol·L^{-1}. The aerobic assessment was terminated during the second stage of the submaximal Bruce protocol, at a speed of 2.5 mph and grade of 12%, due to the subject's heart rate reaching 85% of her age-predicted maximum heart rate, which was 142 bpm. Estimated VO_2max was 30.68 ml·kg·min^{-1}. Five minutes after test termination, her HR was 91 bpm, BP was 120/68 mmHg, blood glucose was 83 mg·dL^{-1}dL, and blood lactate was 3.1 mmol·L^{-1}. At ten minutes post-exercise, the subject's HR was 82 bpm, BP was 112/66 mmHg, blood glucose was 86 mg·dL^{-1}, and blood lactate was 2.3 mmol·L^{-1}. The last measures were taken fifteen minutes after exercise, with a HR of 67 bpm, BP of 112/66 mmHg, blood glucose of 91 mg·dL^{-1}, and blood lactate of 2.1 mmol·L^{-1}. Strength assessments were not completed due to push/pull/lift restrictions from her physician. During this visit, the subject did not report any symptoms and left the lab in good spirits and health.

Visit 6

Five months after the LDLT, the subject weighed in at 84.4 kg (BMI = 29.9 kg·m^{-2}), with an estimated 32.87% body fat percentage, as well as a resting HR of 70 bpm, resting BP of 110/72, casual blood glucose of 94 mg·dL^{-1}, and blood lactate of 0.5 mmol·L^{-1}. The aerobic exercise assessment was terminated during the second stage of the submaximal Bruce protocol, at a speed of 2.5 mph and grade of 12%, due to the subject's heart rate reaching 85% of her age-predicted maximum heart rate, at 142 bpm. Estimated VO_2max was 33.82 ml·kg·min^{-1}. At five minutes post-exercise, her HR was 89 bpm, BP was 116/76 mmHg, blood glucose was 84 mg·dL^{-1}, and blood lactate was 2.0 mmol·L^{-1}. After ten minutes post-exercise, the subject had a HR of 88 bpm, BP of 114/76 mmHg, blood glucose of 88 mg·dL-1, and blood lactate of 1.3 mmol·L^{-1}. A total of fifteen minutes after the end of exercise, the subject's HR was 75 bpm, BP was 110/72 mmHg, blood glucose was 95 mg·dL^{-1}, and blood lactate was 1.3 mmol·L^{-1}. No strength assessments were completed due to the subject's push/pull/lift restrictions from the physician. During this visit, the subject did not report any symptoms and left the lab in good spirits and health.

Visit 7

The next lab visit was about six months after the LDLT procedure, when the subject's body weight was 86.4 kg (BMI = 30.61 kg·m^{-2}) and body fat estimation of 35.33%. Her resting HR was 90 bpm, resting BP of 106/78, casual blood glucose of 118 mg·dL^{-1}, and blood lactate of 1.3 mmol·L^{-1}. The submaximal Bruce protocol was terminated during the second stage, with a speed of 2.5 mph and grade of 12%, due to the subject's heart rate reaching 85% of her age-predicted maximum heart rate of 142 bpm. Estimated VO2max was 33.44 ml·kg·min^{-1}. After five minutes, the subject had a HR of 97 bpm, BP of 112/74 mmHg, blood glucose of 104 mg·dL^{-1}, and blood lactate of 2.7 mmol·L^{-1}. After an additional five minutes, her HR was 95 bpm, BP was 104/74 mmHg, blood glucose was 110 mg·dL^{-1}, and blood lactate was 2.7 mmol·L^{-1}. At fifteen minutes post-exercise, the subject's HR was 79 bpm, BP was 104/76 mmHg, blood glucose was 107 mg·dL^{-1}, and blood lactate was 2.0 mmol·L^{-1}. At this time, the push/pull/lift restrictions were cancelled, and the strength assessments were completed. Upper body chest press and lower body leg press 1RM assessments were completed, which the subject lifted 50 pounds and 180 pounds respectively. During this visit, the subject did not report any symptoms and left the lab in good spirits and health.

Visit 8

During the eighth lab visit, which took place seven months post-procedure, the subject's body weight was 89.2 kg (BMI = 31.6 kg·m^{-2}) and had an estimated 36.10% body fat percentage. At rest, her HR was 73 bpm, BP was 118/74 mmHg, oxygen saturation was 97%, blood glucose was 84 mg·dL^{-1}, and blood lactate was 0.8 mmol·L^{-1}. The aerobic assessment was terminated during the second stage of the submaximal Bruce protocol, at a speed of 2.5 mph and grade of 12%, due to the subject's heart rate reaching 85% of her age-predicted maximum heart rate, at 142 bpm. Estimated VO_2max was 32.77 ml·kg·min^{-1}. Five minutes after test termination, her HR was 90 bpm, BP was 128/74 mmHg, blood glucose was 90 mg·dL^{-1}, and blood lactate was 3.1 mmol·L^{-1}. At ten minutes post-exercise, the subject's HR was 86 bpm, BP was 126/76 mmHg, blood glucose was 82 mg·dL^{-1}, and blood lactate was 2.5 mmol·L^{-1}. The last measures were taken fifteen minutes after exercise, with HR of 86 bpm, BP of 124/78 mmHg, blood glucose of 82 mg·dL^{-1}, and blood lactate of 2.1 mmol·L^{-1}. The 1RM assessments were completed, and the subject was able to lift 50 pounds during the upper body chest press and 220 pounds during the lower body leg press. During this visit, the subject did not report any symptoms and left the lab in good spirits and health.

Visit 9

The last visit to the lab was approximately nine months after the LDLT procedure. The subject weighed in at 90 kg (BMI = 31.88 kg·m^{-2}), with an estimated 35.85% body fat, as well as a resting HR of 66 bpm, resting BP of 120/76, and a casual blood glucose of 121 mg·dL^{-1}. Blood lactate was not assessed during this visit, due to equipment malfunction. The submaximal Bruce protocol was terminated during the second stage with a speed of 2.5 mph and grade of 12%, due to the subject's heart rate reaching 85% of her age-predicted maximum heart rate, which was 142 bpm. Estimated VO_2max was 34.69 ml·kg·min^{-1}. At five minutes post-exercise, her HR was 90 bpm, BP was 118/90 mmHg, and blood glucose was 93 mg·dL^{-1}, After ten minutes post-exercise, the subject had a HR of 90 bpm, BP of 116/88 mmHg, and a blood glucose of 94 mg·dL^{-1}. A total of fifteen minutes after the end of exercise, the subject's HR was 85 bpm, BP was 112/86 mmHg, and blood glucose was 89 mg·dL^{-1}L. Upper body chest press and lower body leg press 1RM assessments were completed, and the subject lifted 50 pounds and 220 pounds respectively. During this visit, the subject did not report any symptoms and left the lab in good spirits and health.

Table 1: Heart rate and blood pressure at various intervals according to lab visit

Variable	Lab Visit Number								
	Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Visit 5	Visit 7	Visit 8	Visit 9
HR (bpm)									
Resting	58	66	66	80	67	70	90	73	66
submax Bruce Stage 1	109	α	α	117	107	119	118	116	121
Post 5 Minutes	83	78	77	96	91	89	97	90	90
Post 10 Minutes	70	68	76	82	82	88	95	86	90
Post 15 Minutes	72	67	75	82	67	75	79	86	85
SBP (mmHg)									
Resting	116	134	122	122	118	110	106	118	120
submax Bruce Stage 1	154	α	α	132	138	148	122	128	132
Post 5 Minutes Minute	118	128	128	118	120	116	112	128	118
Post 10 Minutes	114	124	126	118	112	114	104	126	116
Post 15 Minutes	112	122	118	112	112	110	104	124	112
DBP (mmHg)									
Resting	72	76	74	76	68	72	78	74	76
submax Bruce Stage 1	76	α	α	78	70	76	70	70	68
Post 5 Minutes	76	78	78	68	68	76	74	74	90
Post 10 Minutes	76	70	70	68	66	76	74	76	88
Post 15 Minutes	74	70	70	68	66	72	76	78	86

α = missing value due to not utilizing the sub-maximal Bruce protocol; HR= heart rate; bpm = beats per minute; SBP= systolic blood pressure; DBP= diastolic blood pressure; mmHg = millimeter of Mercury; Sub-maximal Bruce Stage 1= measurement taken during the first stage of the submax Bruce protocol

Table 2: Blood glucose and blood lactate at various intervals according to lab visit

Variable	Lab Visit Number								
	Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Visit 6	Visit 7	Visit 8	Visit 9
Blood Glucose ($mg \cdot dL^{-1}$)									
Resting Casual	90	89	103	85	98	94	118	84	121
Post 5 Minutes	76	69	68	71	83	84	104	90	93
Post 10 Minutes	76	75	66	81	86	88	110	82	94
Post 15 Minutes	74	67	72	88	91	95	107	82	89
Blood Lactate ($mmol \cdot L^{-1}$)									
Resting	0.9	1.1	1.9	0.9	1.2	0.5	1.3	0.8	α
Post 5 Minutes	1.3	1.4	1.6	2.5	3.1	2.0	2.7	3.1	α
Post 10 Minutes	1.1	1.3	1.5	2.1	2.3	1.3	2.7	2.5	α
Post 15 Minutes	1.0	0.8	1.5	1.6	2.1	1.3	2.0	2.1	α

α = missing value due to equipment malfunction; $mg \cdot dL^{-1}$ = milligram per deciliter; $mmol \cdot L^{-1}$ = millimole per liter

Table 3: Subject's weight (kg), BMI ($kg \cdot m^{-2}$) and estimated body fat (%) according to lab visit

Variable	Lab Visit Number								
	Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Visit 6	Visit 7	Visit 8	Visit 9
Weight (kg)	84.0	81.1	80.5	83.1	83.4	84.4	86.2	89.2	90.0
BMI (kg·m-2)	29.76	28.7	28.52	29.44	29.54	29.9	30.61	31.6	31.88
Estimated Body Fat (%)	34.75	33.27	33.1	32.4	34.1	32.87	35.33	36.1	35.85

kg = kilogram; % = percentage

Table 4: 6MWT distance (m), systolic and diastolic blood pressures (mmHg) in lab visits 2 and 3

Variable	Visit 2	Visit 3
6MWT Distance (m)	554.7†	533.4†
6MWT SBP (mmHg)	162	146
6MWT DBP (mmHg)	70	58

6MWT = Six Minute Walk Test; m = meters; mmHg = millimeters of mercury; † = positive prognosis (≥332 est vo_2)

Table 5: Estimated VO_2 max (ml•kg•min-1) according to lab visit

Variable	Lab Visit Number						
	Visit 1	Visit 4	Visit 5	Visit 6	Visit 7	Visit 8	Visit 9
Estimated VO_2max ($ml \cdot kg \cdot min^{-1}$)	31.05	33.09	30.68	33.82	33.44	32.77	34.69

*Visits 2 and 3 were omitted due to not completing sub-maximal Bruce protocol; ml·kg·min-1= milliliter of oxygen consumed per kilogram of body weight per minute

Table 6: 1RM absolute (lbs) and ratio (lbs/lbs) results according to lab visit

Variable	Lab Visit Number			
	Visit 1	Visit 7	Visit 8	Visit 9
Lower Body 1RM (lbs)	140	180	220	220
LB Strength Ratio (lbs/lbs)	1.667	2.087	2.466	2.444
Upper Body 1RM (lbs)	45	50	50	50
UB Strength Ratio (lbs/lbs)	0.536	0.580	0.560	0.556

1RM = One Repetition Maximal; LB = lower body; UB = upper body; lbs = pounds; lbs/lbs = pounds lifted per pounds of body weight

Table 7: Heart rate at various intervals according to lab visit depicted in Figure 5

HR (bpm)	Lab Visit Number								
	Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Visit 6	Visit 7	Visit 8	Visit 9
Resting	58	66	66	80	67	70	90	73	66
Submax Bruce Stage 1	109	α	α	117	107	119	118	116	121
Post 5 Minutes	83	78	77	96	91	89	97	90	90
Post 10 Minutes	70	68	76	82	82	88	95	86	90
Post 15 Minutes	72	67	75	82	67	75	79	86	85

α=missing values due to not utilizing the sub-maximal Bruce protocol; HR = heart rate; bpm= beats per minute

Table 8: Blood glucose at various intervals according to lab visit depicted in Figure 6

Blood Glucose (mg·dL-1)	Lab Visit Number								
	Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Visit 6	Visit 7	Visit 8	Visit 9
Resting Casual	90	89	103	85	98	94	118	84	121
Post 5 Minutes	76	69	68	71	83	84	104	90	93
Post 10 Minutes	76	75	66	81	86	88	110	82	94
Post 15 Minutes	74	67	72	88	91	95	107	82	89

$mg \cdot dL^{-1}$ = milligram per deciliter

Table 9: Blood lactate at various intervals according to lab visit depicted in Figure 7

Blood Lactate (mmol·L-1)	Lab Visit Number								
	Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Visit 6	Visit 7	Visit 8	Visit 9
Resting	0.9	1.1	1.9	0.9	1.2	0.5	1.3	0.8	α
Post 5 Minutes	1.3	1.4	1.6	2.5	3.1	2.0	2.7	3.1	α
Post 10 Minutes	1.1	1.3	1.5	2.1	2.3	1.3	2.7	2.5	α
Post 15 Minutes	1.0	0.8	1.5	1.6	2.1	1.3	2.0	2.1	α

α = missing value due to equipment malfunction; $mmol \cdot L^{-1}$ = millimole per liter

Discussion

Weight and BMI

The results of this case report show a clear trend of weight gain and BMI increase, starting at the third visit (Table 3, Figure 1). The gain of weight and increase in BMI has been previously reported in women [28, 29]. Several causes are associated with weight gain post-surgery, and hence an increase in BMI. One of the causes suspected as a weight gain inducer is fluid retention. Although well documented in organ recipients, the scientific community lacks information pertaining to the mechanisms that cause total fluid retention post operation. Increased ADH secretion has been suggested as one cause, and edema as another31. Moreover, changes to BNP were also indicated as a possible cause of fluid retention and weight gain [30,31]. Over compensation, leading to hormonal imbalance may act as an additional mechanism [32]. Surgery may be traumatic for the body and often will induce inflammation, which in turn may be within itself a promotor of weight gain [33,34]. Both stress and changes to nutrition related behavior (increase in comfort food intake) are strongly correlated to weight gain in general and post-procedure in particular (induced hormonal imbalance, stagnation, and changes to nutrition related behavior (increase in comfort food intake) [35]. As the relationship between surgery and emotional eating is established, therefore an increase in fatty tissue to weight, BMI, and changes to body composition are obvious [35].

Resting Heart Rate

Subject's resting heart rate (Table 1, Table 7, Figure 5) was generally within a range of seven beats per minute and was lower than the resting heart rate previously reported for matching age and sex subjects for the majority of data collecting sessions [36]. Higher than average for sex and age matching resting heart rate values were observed during visits 4 and 7. The researcher suspects that the physical challenge of reaching the lab, unusually, caused heart rate to be high though measured after sitting for five minutes. The actual reasons have not been investigated. Other possible reasons could include nervousness, unusual accumulated fatigue for the specific day and time, hormonal changes (pre or post the monthly cycle), and unusual psychological stress [37].

Resting Blood Pressure

Post-procedure, subject's resting blood pressure (Table 2, Figure 2) was within a range of four mmHg. These values are similar to previously reported data for matching age and sex. Lin et al reported resting BP to be 115.6±18.3 mmHg for SBP and 72.1±10.8 mmHg for DBP respectively.38 Although BP during the sixth and seventh sessions were lower, values were within the previous indicated ranges [38]. Values during the second session were unusually high compared to other values for the same variable during other visit. Several explanations may exist. Nelesen et al reported a subtle increase in resting systolic BP when low fatigue was compared to high fatigue (124±1.83 mmHg 128±2.47 mmHg) [39]. While the design of this study does not investigate the actual mechanisms influencing resting BP, it is the researchers' suggestion that fatigue was the leading cause for this report.

Casual Blood Glucose

On most visits, the subject's casual blood glucose (Table 2, Table 8, Figure 6) was within a range of twenty mg/dL with two exceptions. All the values are similar to those reported previously [40]. Ohwovoriole et al reported casual blood glucose in females to be 82.8±19.1 [40]. In visits seven and nine, the subject's casual blood glucose values were higher than the rest of the values. Per the design of this report, the subject's diet was not tightly controlled. Freckmann et al reported higher casual blood glucose values following a meal a higher percentage of fast-absorbing carbohydrates [41]. Even though the values in visit seven and nine were higher than the rest of the measures, the casual blood glucose values are still within the previously reported values for peak concentrations after lunch, of 118.2±13.4 mg/dl [41].

Resting Blood Lactate

The subject's resting blood lactate values (Table 2, Table 9, Figure 7) were all similar to those previously reported. Kruse et al reported normal blood lactate concentrations to be between 0.5-1.8 mmmol/L, and Khosravani et al defined normal values to be less than 2 mmol/L [42,43]. Although all values were within the reported normal range, the value in visit three was higher than the rest. A possible reason for an elevation in resting blood lactate may include delayed response in the liver due to the hepatic procedure [44].

Six-Minute Walk Test

In the two months following the LDLT procedure, the subject completed a 6MWT in place of the sub-maximal Bruce protocol due to the physician's activity restrictions. Rasekaba et al reported a distance of less than 350 m is associated with increased mortality in those with cardiopulmonary conditions [45]. A study of 117 males and 173 females, age 40- 80 years old, completed the 6MWT to establish reference equations for prediction distances [46]. Enright and Sherrill (1998) found the median distance for women was 494 m [46]. A similar study was conducted by Troosters et al that observed 6MWT distance in healthy elderly subjects [47]. Healthy subjects aged 50-85 (23 females, 30 males) walked an average of 631±93 meters in six minutes [47]. In the present study, the subject's 6MWT distances (Table 4) were between the values mentioned above, and are considered normal for a healthy female adult.

Sub-Maximal Bruce protocol

Prior to the LDLT and in visits four through nine, the sub-maximal Bruce protocol was utilized for the aerobic assessment. In each trial, the test was terminated during the same stage, due to the subject reaching 85% of her estimated age-predicted maximal heart rate. Data that was analyzed were BP (Table 1, Figure 4) and HR (Table 1, Table 7, Figure 5) during the assessment. With increasing workload, it is expected for both heart rate and blood pressure to increase by 10 bpm or 5-10 mmHg per every MET increase [48, 49]. As the first stage in the sub-maximal Bruce protocol is between 4-5 METs, one would anticipate approximately a 40-50 bpm increase. From rest to the heart rate at the end of the first stage, the subject's heart rate increased within a range of 37-55 bpm. In the same period, the subject's blood pressure increased within a range of 10-20 mmHg with the exception of the first and sixth visit. On both of these occasions, the systolic BP increased by 38 mmHg from rest to the end of the first stage. This elevated rise in systolic BP may be contributed to discomfort with the treadmill grade on the first visit or inconsistency with an exercise routine in the later visit. VO_2max (Table 5, Figure 3) was estimated using the data from the sub-maximal Bruce protocol, which was terminated at the same workload and heart rate in each visit. The variable that effected the estimation was the heart rate in the first stage; therefore, the same trend in heart rate was mirrored in estimated VO_2max. The window of change for estimated VO_2max was narrow within 5 ml•kg•min^{-1}. Kaminsky et al reported data from the Fitness Registry and the Importance of Exercise National Database (FRIEND) and by the Cooper Clinic on the sex-specific percentiles [50]. According to FRIEND, our subject's estimated VO_2max is between the 75th (27.6 ml•kg•min^{-1}) and 95th (35.9 ml•kg•min^{-1}) percentile, while according to the Cooper clinic our subject's estimated VO_2max is between the 50th (31.4 ml•kg•min^{-1}) and 75th (35.2 ml•kg•min^{-1}) percentile for her age and sex [50].

Heart Rate- Post Aerobic Assessment

Cole et al defined heart rate recovery as the decrease in heart rate from peak exercise to one minute after the cessation of exercise, which a normal response would be greater than 12 bpm [51]. Antelmi et al observed heart rate recovery after a treadmill exercise test [52]. They reported the change from peak heart rate to five minutes post exercise was 68±12.7 bpm [52]. To note, the exercise test conducted by Antelmi et al was a maximal effort protocol, whereas the present study was sub-maximal. The sub-maximal Bruce protocol was terminated at 142 bpm in each visit in the present case report. Five minutes after the termination of the treadmill protocol, the values (Table 1, Table 7, Figure 5) were 42-59 bpm lower than the peak, which is a similar decrease when compared to values previously reported.

Blood Pressure - Post Aerobic Assessment

After the sub-maximal Bruce protocol, the subject's systolic BP decreased from the exercising value and continued to decrease or level off over time (Table 1). Karavelioglu et al. (2013) reported a decrease from peak blood pressure to three minutes post exercise of 165.9±18.9 mmHg to 127.6±13.1 mmHg for systolic BP and 86.2±8.7 mmHg to 76.6±7.4 mmHg in healthy control subjects [53]. A similar decrease was found in the present case report. With the exception of visit 8, the subject's systolic BP after fifteen minutes was below the resting value of that visit. Similarly, Pescatello and Kulikowich found a decrease of 3.2±1.0 mmHg and 1.6±0.6 mmHg in systolic and diastolic BP (respectively) after exercise [54]. Exercise is known to vasodilate the blood vessels to allow greater blood flow during exercise, which in turn decreases blood pressure when blood flow returns to normal [55].

Blood Glucose- Post Aerobic Assessment

In all visits, the subject's blood glucose decreased from rest to after exercise, with the exception of visit 8 (Table 2, Table 7, Figure 6). Goodwin ML reported that under normal conditions, the liver increases its output of glucose to maintain glucoregulation during exercise, as the skeletal muscles increase glucose uptake [56]. For this reason, he reports a normal response is not greater than a 10-15% decrease in blood glucose [56]. Visit 8 was the only visit in which the blood glucose increase at five minutes post exercise. To note, it did decrease again at ten and fifteen minutes post exercise and returned to baseline. Some possible explanations may be diet or changes in hepatic glycogenolysis or gluconeogenesis [57].

Blood Lactate- Post Aerobic Assessment

In visits one through three, there was a smaller lactate increase from rest to after exercise than in visits four though nine (Table 2, Table 9, Figure 7). To the best knowledge of the author, there is no information published on blood lactate after submaximal exercise in middle-aged women. Therefore, we suggest the smaller blood lactate increase after the 6MWT is due to a lower intensity when compared to the sub-maximal Bruce protocol. It is well established that blood lactate has a half-life of thirty minutes [58]. Thus, it is reasonable that the subject's blood lactate did not return to baseline by fifteen minutes post aerobic assessment.

Strength Assessments
A small increase in strength was seen over time (Table 6). Knowing that the subject was not faithful to a resistance training program in the months following the LDLT procedure, it is not reasonable to conclude that the increase in 1RM is due to an increase in strength. We suggest that the increase in absolute weight lifted is due to improvements in technique along with familiarization with the 1RM protocol and machines used for the assessments. Soares-Caluderia LF et al observed familiarization of 1RM in 27 healthy women (21.6±2.5 years old), that had a history of strength training but had not been strength training for the previous six months.58 Throughout the five familiarization sessions for bench press, squat, and arm curl, the results confirmed the importance of familiarization; that some strength increase that is typically contributed to training adaptations is actually from a lack of familiarization in previous 1RM assessments [58].

Conclusions
With very minimal information published on an LDLT donor, this case report provides insight on the recovery of the procedure as well as the changes in aerobic capacity and hemodynamics. The fifty-three-year-old female subject responded to sub-maximal exercise comparable to healthy subjects of similar age and sex. Overtime, there was minimal changes in aerobic capacity and strength due to lack of consistency with an exercise program. Findings of this case report cannot be generalized to all LDLT donors. However, the information on the recovery of an LDLT donor in respect to exercise testing may be beneficial to clinicians and professionals in prescribing an exercise program for similar patients in similar circumstances.

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