

**EFFECTS OF A 12-WEEK HOME-BASED RESISTANCE TRAINING INTERVENTION
ON PERIPHERAL MUSCLE OXYGENATION AND EXERCISE TOLERANCE IN
CHILDREN WITH CONGENITAL HEART DISEASE**

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ABSTRACT

Congenital heart disease (CHD) is the most common birth defect occurring in approximately 1 in 100 live births. A hallmark feature of children with CHD is exercise intolerance, despite successful surgical intervention and medical management. Although central mechanisms have been shown to play a role in reduced exercise tolerance in children with CHD, information regarding the influence of peripheral mechanisms is lacking. Exercise rehabilitation programs have been shown to improve exercise tolerance in children with CHD; however, exercise tolerance is still limited compared to healthy matched controls. Whether a home-based exercise intervention including primarily strength activities improves muscle oxygenation (as measured by tissue oxygenation index, TOI) in children with CHD compared to healthy children is unknown. **PURPOSE:** To determine whether a 12-week home-based exercise intervention can improve TOI, $\dot{V}O_2$ and heart rate (HR) during submaximal and maximal exercise in children with CHD compared to healthy children. **METHODS:** 14 children with simple and complex lesions (f/m: 5/9; mean \pm SD age: 12 \pm 2 yrs) and nine healthy controls (f/m: 5/4; mean \pm SD age: 12 \pm 3 yrs) were studied. Children with CHD completed a home-based exercise program 3 times/week for 12 weeks, in addition to 6 biweekly in-person sessions. Exercise tolerance was assessed with peak $\dot{V}O_2$ testing to volitional fatigue on a cycle ergometer. Vastus lateralis TOI was continuously sampled during the peak $\dot{V}O_2$ test via near-infrared spectroscopy (NIRS). Peak TOI, $\dot{V}O_2$ and HR were analyzed as the average value over 30-s within the last 1-minute of exercise. Submaximal TOI, $\dot{V}O_2$ and HR were analyzed as the average of the last 30-s of stage 1 (25W) and stage 2 (50W). TOI was expressed as a percentage scaled to the total liable signal (TLS). Pre- vs post- training changes in children with CHD were analyzed using paired *t*-tests. Pre- and post- training CHD data compared to healthy control data were analyzed using one-way ANOVAs with Holm-Sidak post-hoc testing. Significance was accepted when $p < 0.05$. **RESULTS:** TOI at peak $\dot{V}O_2$ was significantly lower post-training compared to control (20 \pm 13% vs 41 \pm 11%; $p = 0.02$). Peak $\dot{V}O_2$ was significantly lower pre-training (35 \pm 7 mL/kg/min vs 48 \pm 7 mL/kg/min; $p = 0.006$) and post-training (36 \pm 9 mL/kg/min vs 48 \pm 7 mL/kg/min; $p = 0.005$) in children with CHD compared to control. Although not significant, HR at peak $\dot{V}O_2$ was lower pre- training (175 \pm 23 bpm vs 189 \pm 12 bpm; $p = 0.06$) and post-training (169 \pm 21 bpm vs 189 \pm 12 bpm; $p = 0.06$) in children with CHD compared to control. **CONCLUSION:** Despite no change in $\dot{V}O_2$ and HR, TOI is lower during submaximal and

maximal exercise after home-based exercise in children with CHD compared to healthy children. Our findings suggest that peripheral mechanisms (such as oxygen uptake and utilization) can be improved using a strength-based exercise intervention, and may influence exercise intolerance in children with CHD.

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DEDICATION

This thesis is dedicated to my mom. It is because of her that I developed an interest in research, and ultimately found my passion for clinical exercise therapy. She has given me strength and courage through some of the hardest times in my life, and I would not be at this point without it. This thesis is also dedicated to all of the children and their families who are involved in CHAMPS, who have brought so much happiness to my life for the past 5 years. This project would not have been possible without their support and willingness to participate.

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CHAPTER ONE: LITERATURE REVIEW

1.1 Introduction

Congenital heart disease (CHD) is the most common birth defect occurring in approximately 1 in 100 live births (62), with as many as 1 in 45 children and 1 in 170 adults currently living with CHD in North America (33, 48). CHD lesion types range in severity based on size and location, and may predispose individuals to various chronic risk factors such as obesity and vascular disease later in life (27). Improvements in detection, management and treatment of CHD has resulted in an increasing number of children with CHD reaching adulthood (3, 31). Approximately 90% of children with CHD have the prospect of surviving to adulthood, compared to a survival rate of 20% 60 years ago, resulting in a growing population of adults that require life-long cardiac care (40). Individuals with CHD account for the largest percentage of birth-defect associated hospitalizations (14%), and the highest total healthcare cost (\$6.1 billion) (2), representing significant resource utilization in the health care system. Unfortunately, far fewer resources are allocated for adult CHD care compared to other cardiac patients, contributing to approximately 77% of these individuals considered lost to follow up (4). Lack of appropriate resources and support for adults with CHD may increase the risk of premature death (34). With a large disparity between adult and pediatric CHD care, it is important to address modifiable risk factors while in pediatric care. Children with both simple and complex CHD lesions present with reduced exercise tolerance when compared to healthy peers (19, 30), despite successful surgical intervention and appropriate medical management. Reduced exercise tolerance may predispose these children to cardiovascular disease later in life (1, 19, 30, 51, 58). Mechanisms that may contribute to persistent exercise intolerance in children with CHD are not fully understood, resulting in a lack of practical, evidence-based chronic disease management for these children. As exercise intolerance is a major predictor for all-cause and cardiovascular mortality (13, 41), further research in this area should be prioritized.

1.2 Central mechanisms of exercise intolerance in CHD

Exercise intolerance is the single best independent predictor of mortality (13, 41). Individuals with CHD have been shown to have an exercise tolerance up to 60% lower than that of a healthy individual (30), highlighting the importance of determining mechanisms of exercise intolerance to improve quality of life and mitigate disease risk later in life. Central (cardiac) mechanisms of exercise tolerance in both adults and children with CHD have been examined extensively (1, 7, 49, 50, 56, 20, 22, 29, 35, 37, 38, 46, 47). CHD lesion type and severity determine structural and physiological abnormalities that may impair central factors such as cardiac output, stroke volume and left ventricular function (3), preventing the appropriate increase of oxygen (O_2) delivery to the working muscle to match increasing metabolic demand. Chronotropic incompetence, or an abnormal heart rate (HR) response to exercise, is a common complication after surgical intervention for CHD (45), as well as a side effect from some cardiac medications. It is an additional central mechanism that may contribute to exercise intolerance in CHD. Chronotropic incompetence has been shown to be correlated with exercise tolerance and is a predictor of cardiac death and all-cause mortality in patients with heart failure (64). Central mechanisms contributing to exercise intolerance are commonly assessed objectively using a peak oxygen uptake ($\dot{\text{V}}\text{O}_2$) test. In children with CHD, previous studies have used peak $\dot{\text{V}}\text{O}_2$ to evaluate the effectiveness of structured exercise interventions in mitigating cardiac-related limitations to exercise. Rhodes et al. (49) demonstrated that a 12-week rehabilitation program augmented diastolic blood pressure and stroke volume, subsequently increasing cardiac output in children with CHD. As a result, a significant increase in peak $\dot{\text{V}}\text{O}_2$ of 4 mL/kg/min was observed post-training (49). Others have shown similar central adaptations to various exercise interventions, improving peak $\dot{\text{V}}\text{O}_2$ by 3-4 mL/kg/min in children with CHD (1, 20, 35, 39, 46, 49). Despite improvements in peak $\dot{\text{V}}\text{O}_2$ with exercise training, exercise tolerance in children with CHD is still reduced compared to healthy age- and sex-matched controls, leaving them at a higher risk for cardiovascular and all-cause mortality (13, 41).

1.3 Peripheral mechanisms of exercise intolerance in CHD

Peripheral (muscular and vascular) mechanisms may play a more significant role in reduced exercise tolerance in CHD than central mechanisms (3, 9, 10). Patients with heart failure present with impaired O_2 delivery and utilization at the working muscle, which is a possible rate limiting step in reduced exercise tolerance in these individuals (5, 63). After a structured exercise training

intervention, adaptations at the muscle such as improved endothelial function, larger muscle fiber size, and increased muscle capillary and mitochondrial density have been shown (42, 63). These peripheral adaptations improve peak $\dot{V}O_2$ in patients with heart failure by increasing the amount of O_2 that is available at the muscle and improving the efficiency of the muscle to utilize O_2 for metabolic demands (42, 63). Individuals with heart failure may share common anatomical and/or physiological features with individuals with CHD that contribute to reduced exercise tolerance. However, few studies have provided evidence for similar peripheral limitations to exercise in adults and children with CHD. Many, such as Sandberg et al. (54) and Rhodes et al. (49) focus on central mechanisms (such as impaired cardiac output) as the primary contributor to reduced peak $\dot{V}O_2$, and only account for indirect measures of peripheral adaptations. O_2 pulse is frequently used as a surrogate for stroke volume and O_2 extraction. An increase in O_2 pulse may be attributed to an increase in O_2 extraction, leading to increased exercise tolerance in adults and children with CHD after an exercise intervention (7, 35, 49). Muscle strength and mass have also been used as an indicator of peripheral adaptation to exercise (49, 55). Augmented muscle metabolism and oxidative capacity are suggested to occur with increased muscle strength and mass, thereby enhancing O_2 utilization at the muscle during exercise (49, 55). Endurance capacity may also reflect increased oxidative capacity and muscle capillarization in individuals with CHD (20, 54). Similarly, the efficiency of the muscle to pump blood back to the heart to maintain ventricular preload is influenced by muscle strength and mass (49, 61). Increased blood flow returning to the heart maintains normal increases in cardiac output during exercise; therefore, ensuring there is adequate O_2 delivered to the muscle (49). Thus, highlighting the interplay between the central and peripheral mechanisms their important role in exercise tolerance. Few studies have addressed direct measures of peripheral mechanisms of exercise tolerance in CHD. Whether these mechanisms play a significant role in limiting exercise tolerance in children with CHD has yet to be determined.

1.3.1 Near-infrared spectroscopy

Microvascular function may play an important role in impaired exercise tolerance in CHD; however, a typical exercise tolerance test (objectively measured by peak $\dot{V}O_2$) cannot directly assess the impact of these mechanisms (17, 26, 38). Near-infrared spectroscopy (NIRS) is a noninvasive, reliable and valid measurement of peripheral limitations associated with exercise tolerance (17, 23, 44). NIR light measures changes in oxygenated and deoxygenated hemoglobin

in the arterioles, capillaries and venules of the contracting muscle (6). As such, O₂ delivery, availability and utilization in the microvasculature can be quantified using NIRS (8). Tissue oxygenation index (TOI) is a specific measure outputted by NIRS to assess muscle oxygenation. This measure has been used to evaluate microvascular dysfunction in patients with heart failure. Specifically, endothelial dysfunction preventing proper vasodilation during exercise, reduced proportion of capillaries supporting O₂ delivery, as well as an impaired rate of O₂ offloading from the blood to the working muscle (O₂ flux), have been shown to contribute to exercise intolerance in patients with heart failure (24, 25). Following an exercise intervention, TOI is improved in heart failure patients as a result of augmented microvascular blood flow due to improved endothelial and capillary function, and muscular oxidative capacity due to an increased number of type I muscle fibers (21, 60). These peripheral adaptations improve the matching of O₂ delivery and utilization at the working muscle (18, 25, 63). To our knowledge, there are select few studies that have used NIRS to assess peripheral dysfunction related to exercise intolerance in CHD. In 2007, Moalla et al. (37) conducted a study to determine respiratory muscle function using NIRS during aerobic exercise in children with CHD. At exercise onset, deoxygenation (or a decrease in TOI) of the respiratory muscles was more pronounced in children with CHD compared to matched healthy controls. In addition, TOI and $\dot{V}O_2$ were significantly lower in children with CHD at submaximal and peak exercise compared to controls (37). With exercise training, improved exercise tolerance in children with CHD was associated with higher muscle oxygenation (increase in TOI) of the respiratory muscles during aerobic exercise (39). Further, similar results were found measuring muscle oxygenation at the vastus lateralis during isometric knee extensor exercise in children with CHD (36). In a subsequent study, a home-based aerobic interval training program was implemented (38). Post-training, enhanced muscular strength and endurance performance of the vastus lateralis was related to an improvement of muscle oxygenation during isometric knee extensor exercise (38). More recently, Sandberg et al. (53) revealed similar impaired muscle oxygenation during shoulder flexion exercise in adults with CHD compared to controls. They determined altered skeletal muscle metabolism as a contributor to reduced endurance capacity and exercise tolerance in adults with CHD (53). The importance of implementing rehabilitation targeting muscle function was also indicated to prevent further peripheral dysfunction (53). Muscle oxygenation has also been examined in the forearm and calf during rest (52). Adaptive responses in children with CHD were found to be inadequate to provide for normal muscle oxygenation at rest compared to healthy

peers (52). This response was attributed to reduced skeletal muscle blood flow despite maintained oxygen consumption, resulting in decreased O_2 saturation and increased arterial-venous difference (52). In a focused study of children with Fontan circulation (CHD lesion type), muscle oxygenation was measured using NIRS at the vastus lateralis (61). Muscle oxygenation and $\dot{V}O_2$ were lower at rest and unloaded cycling compared to healthy controls, which may be related to an abnormal balance between O_2 supply and demand in these patients, or a reduced cardiac output inherent to the disease (61). With varying methodology measuring muscle oxygenation in children with CHD, further research is needed to reduce inconsistencies and validate results. The measurement of the total liable signal (the difference between the baseline and nadir in TOI) should be included, to allow for proper calibration of the physiologic TOI range and to increase precision when comparing TOI values across multiple participants (43). Protocols that include measurement of muscle oxygenation during aerobic exercise and exercise training should be prioritized, to provide results that can be applied to activities of daily life and chronic disease management programming for children with CHD.

1.4 Exercise Training in CHD

1.4.1 Benefits of exercise training

Structured cardiac rehabilitation programs and home-based exercise training are well established nonpharmacological treatments for individuals with various cardiac conditions (11). The positive benefits gained through regular physical activity and exercise training are extensive. As previously mentioned, exercise interventions have been shown to increase cardiac output, a central mechanism of exercise tolerance in CHD (49, 59). In addition to increases in muscle oxygenation, oxidative metabolism and mitochondrial and capillary density, these adaptations contribute to increased peak $\dot{V}O_2$ and exercise tolerance post-training in CHD (38, 42, 49, 55, 63). Peak $\dot{V}O_2$ is the gold standard indicator for cardiovascular and all-cause mortality risk (41). After an exercise intervention, peak $\dot{V}O_2$ has been shown to increase approximately 3-4 mL/kg/min in children with CHD (1, 20, 35, 39, 46, 49). This is significant as every 1 mL/kg/min gain in $\dot{V}O_2$ has been shown to reduce cardiac mortality by 10% (28). Central and peripheral adaptations to exercise training have also been shown to reduce the risk of various other adverse long term health conditions such as obesity, vascular disease and high blood pressure (51).

Non-physiological benefits of exercise rehabilitation are also important to note. Improvement in health-related and general quality of life (14), as well as psychosocial aspects such as improved cognitive and social functioning, improved concentration and decreased anxiety, are present after exercise training in individuals with CHD (15, 16, 20). Together, physical and mental benefits from chronic exercise ensure well-rounded life-long care for adults and children with CHD.

1.4.2 Exercise training modalities and prescription

Previous studies have implemented various exercise interventions to improve peak $\dot{V}O_2$ and exercise tolerance in children with CHD (1, 7, 20, 22, 35, 38, 39, 46, 49). The most common exercise modality that is utilized in these studies is interval training on a cycle ergometer (1, 22, 38). Participants complete prescribed exercise at a health care facility or are given a cycle ergometer to use at home (1, 22, 38). Cordina et al. (12) are among few to prescribe primarily resistance training exercise to participants. Supervised high-intensity total body resistance training exercises were completed using machines and dumbbells, with a focus on calf muscles (12). Brassard et al. (10) prescribed a combined aerobic and resistance training regime, utilizing interval training on a cycle ergometer and upper and lower body strength exercises using machines and dumbbells. Both Fredriksen et al. (20) and Longmuir et al. (32) implemented a different approach, focusing on play-based functional activities as well as educational activities intended to encourage behaviour change. Participants completed activities including mainstream sports such as swimming, volleyball, skiing and hiking (20), or motor skill activities such as frisbee throw, jumping up the stairs and sit to stand (32). The interventions were designed to be completed at home and/or in the community to increase compliance.

Review of exercise rehabilitation studies in children with CHD shows programming typically is implemented 3 times per week for 30-45 minutes (1, 10, 12, 15, 38). However, length of programming varies greatly, ranging from 8 weeks up to 5 months. Prescribed intensity for exercise sessions is typically assessed using a HR monitor, with researchers providing participants with a specific HR range (e.g. 50-80% peak HR) to target during exercise (1, 14, 20, 38). Goldberg et al. (22) instructed parents or guardians of the participants to measure manual pulse rate during exercise. Peak $\dot{V}O_2$ score has also been used to determine work rate and intensity of exercise sessions (10, 22). Despite available evidence-based research, nationally and internationally

accepted exercise recommendations and guidelines for children with CHD have not been updated since 2011 (57). Future research is required to determine optimal exercise modalities, training duration, length and intensity for children with CHD. Keeping exercise guidelines and recommendations current and specific to CHD lesion type should also be prioritized.

1.4.3 Limitations of prior work

Adults and children with CHD are typically grouped with various other cardiac conditions when referred for exercise therapy. Although individuals with CHD may share anatomical and/or physiological similarities with other cardiovascular diseases, specific guidelines and individualized rehabilitation is needed to properly meet the needs of this population. Only 10% of all potential adult candidates for exercise rehabilitation programs actually receive therapy, and among children that percentage is even lower (58), highlighting the need for improvements to clinical exercise rehabilitation care.

Previous studies have provided a basis for exercise prescription for children with CHD (32, 38, 49, 57); however, future work must focus on practical programming for these children to benefit short and long term. For example, providing a cycle ergometer for every child with CHD is not viable in most communities, where the economic burden of the health care system is already heightened. Similarly, HR monitors, although more accurate and precise, are unlikely to be feasible measures of exercise intensity in real-world situations. For younger children, HR monitors may also require assistance from an adult, potentially increasing barriers to exercise. Compliance may also be an issue when using repeated cycle ergometer exercise, as constant stimulation and new challenges are important for children to remain engaged and motivated. Prescription guidelines are also lacking applicability to activities of daily living. Children rarely utilize a single exercise modality at one time. More often, they utilize aerobic, strength and play-based activities within the same day, and even to complete a single task. Future studies should prioritize exercise interventions that could be used in a real-world setting to properly assess the impact on exercise tolerance in children with CHD.

1.5 Purpose, Outcomes, and Hypotheses

The majority of research involving exercise intolerance in children with CHD has focused on central limitations such as cardiac output and stroke volume, and indirect measures of peripheral

limitations such as O_2 pulse. Previous exercise interventions for children with CHD have focused on primarily aerobic exercise, but have not also incorporated strength training and/or play-based activities suitable for children to complete on a regular basis outside of a research-based environment. To our knowledge, there are no studies that incorporate a direct measurement of peripheral mechanisms of exercise intolerance using NIRS during aerobic exercise, that also include a well-rounded exercise intervention. Therefore, no evidence-based age-appropriate exercise rehabilitation program exists in Canada for children with CHD, despite widespread exercise rehabilitation programs available for adults with various cardiovascular issues. This knowledge gap should be prioritized, as exercise tolerance is the single best independent predictor for cardiovascular and all-cause mortality (13, 41).

1.5.1 Purpose

The purpose of this study was to determine if a 12-week home-based exercise intervention including strength training, aerobic exercise and play activities can improve muscle oxygenation (TOI) and exercise tolerance ($\dot{V}O_2$ and HR) during submaximal and maximal aerobic exercise in children with CHD compared to healthy age- and sex-matched controls (CTL).

1.5.2 Primary Outcome

The primary outcome was muscle oxygenation as measured by TOI during submaximal and maximal aerobic exercise.

1.5.3 Secondary Outcomes

The secondary outcomes were exercise tolerance as measured by $\dot{V}O_2$ and HR during submaximal and maximal aerobic exercise.

1.5.4 Primary Hypothesis

We hypothesized that TOI would improve post-training compared to pre-training in children with CHD during submaximal and maximal exercise.

1.5.5 Secondary Hypotheses

We hypothesized that with training, $\dot{V}O_2$ and HR would improve when compared to pre-training in children with CHD during submaximal and maximal exercise. We hypothesized that TOI, $\dot{V}O_2$ and HR would improve after training in children with CHD compared to healthy age- and sex- matched children.

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CHAPTER TWO: MANUSCRIPT

2.1 Introduction

Despite medical advances, children with congenital heart disease (CHD) continue to exhibit reduced exercise tolerance compared to healthy peers, which may predispose them to cardiovascular disease later in life (1, 15, 20, 25, 40, 44). Mechanisms that contribute to exercise intolerance in children with CHD are not fully understood, resulting in a lack of practical, evidence-based exercise programming for these children to participate in. As exercise intolerance is a major predictor for all-cause and cardiovascular mortality, it is vital that this knowledge gap be explored (15, 32).

Both central (cardiac) and peripheral (vascular and muscle) mechanisms are known to play a role in reduced exercise tolerance in CHD (4, 16). Impaired central mechanisms such as cardiac output, stroke volume and heart rate have been attributed to reduced $\dot{V}O_2$, a measure of exercise tolerance in both children and adults with CHD (38, 45, 47). Structured aerobic exercise training interventions have improved these cardiac-related factors and subsequently increased peak $\dot{V}O_2$ (1, 9, 21, 27, 31, 35, 39). However, exercise tolerance was still reduced when compared to healthy age- and sex-matched controls (9). Therefore, impaired oxygen (O_2) delivery as a result of impaired blood flow and microvascular dysfunction, as well as reduced O_2 utilization at the working muscle may be major peripheral determinants of reduced exercise tolerance rather than central adaptations (47).

In children with CHD, few studies have examined peripheral adaptations to exercise training using direct measurements. Near-infrared spectroscopy (NIRS) is a commonly used technique to assess microvascular dysfunction in the muscle as it is a direct, reliable and valid non-invasive measure (18, 26). NIR light monitors continuous changes in oxygenated and deoxygenated hemoglobin and myoglobin in the microvasculature (small arterioles, capillaries and venules) (6, 8, 18, 22, 25). As such, O_2 delivery, availability and utilization at the muscle can be measured using NIRS. Tissue oxygenation index (TOI) quantifies the NIRS signal and may give an indication of peripheral mechanisms contributing to exercise intolerance. Few studies have

determined TOI in children with CHD, and thus our understanding of skeletal microvascular function in this patient group is limited. Moalla et al. (28) found reduced TOI, a measure of muscle oxygenation, in the vastus lateralis in children with CHD compared to healthy peers. After a 12-week aerobic interval training intervention, TOI and muscle strength were shown to improve during isometric knee extensor exercise despite no change in $\dot{V}O_2$ (30). In a focused study of children with Fontan circulation (CHD lesion type), TOI was lower at rest and during unloaded cycling compared to healthy controls (46). $\dot{V}O_2$ was also reduced at rest and unloaded cycling, leading Vandekerckhove et al. (46) to speculate that both impaired O_2 delivery, and the rate of O_2 uptake contribute to reduced exercise tolerance in children with Fontan circulation (46). Further investigation is required to evaluate TOI during submaximal and maximal aerobic exercise with the addition of an exercise intervention, to determine if impaired TOI in children with CHD can be mitigated. By examining the relationship between TOI and $\dot{V}O_2$, further determinations of the interplay of central and peripheral factors contributing to exercise intolerance in children with CHD can be made.

Structured cardiac rehabilitation programs and home-based exercise training are well established nonpharmacological treatments for adults and children with CHD (7, 12, 27, 30, 38, 45). Numerous studies have shown the effectiveness of aerobic exercise training on reducing the effect of peripheral and central limitations contributing to exercise intolerance in children with CHD (1, 10, 21, 22, 27, 30, 31, 35, 38, 39). However, these interventions have not also incorporated both strength training and play-based activities in addition to aerobic exercise that is suitable for children with CHD to participate in on a regular basis outside of a research-based environment.

The aim of this study was to determine if a 12-week home-based exercise intervention including strength training, aerobic exercise and play activities influenced muscle oxygenation (TOI) and exercise tolerance ($\dot{V}O_2$ and HR) during submaximal and maximal aerobic exercise in children with CHD. The primary hypothesis was that the 12-week home-based exercise intervention would improve TOI during submaximal and maximal aerobic exercise in children with CHD. The secondary hypothesis was that the exercise intervention would improve $\dot{V}O_2$ and HR during submaximal and maximal aerobic exercise in children with CHD, and would improve TOI, $\dot{V}O_2$ and HR compared to healthy age- and sex-matched children.

2.2 Methods

2.2.1 Participants

Participants included 21 children with CHD between the ages of 9-16 recruited from the Division of Pediatric Cardiology at the Jim Pattison Children's Hospital in Saskatoon, Saskatchewan. A pediatric cardiologist pre-screened patients for study eligibility and reviewed the home-based exercise program to ensure it was safe for all participants to complete before it was administered. Exclusion criteria for children with CHD included cardiac surgery within the last six months, inability to perform moderate to vigorous activity and inability to follow verbal commands related to the experimental procedures. 14 children with CHD completed both pre- and post-program measures, and seven children with CHD completed only pre-program measures. Reasons for withdrawal from the study included health status, voluntary withdrawal, and proximity to study location. For detailed study enrolment, please refer to Figure 2.1. Nine typically developing children (CTL) between the ages of 9-16 were recruited through word of mouth and posters. The CTL group completed a one-time assessment of all measures. The CTL group did not participate in the exercise intervention or post-testing session, as we were interested in the CTL data only as a reference. Inclusion criteria for the CTL group included the absence of cardiovascular and respiratory disease, ability to perform moderate-vigorous activity and ability to follow verbal commands related to the experimental procedures. For detailed study enrolment, please refer to Figure 2.2. Consent was obtained from all parents and/or legal guardians (Appendix A & B) and assent was obtained from all children (Appendix C & D). Ethical approval was obtained from the University of Saskatchewan Biomedical Research Ethics Board Bio #15-148 (Appendix E).

2.2.2. Anthropometric Measurements

Anthropometric measurements for children with CHD and healthy CTL children included chronological age, sex, standing height, weight, and right thigh skinfold and girth. Relevant medical history (i.e. diagnosis, current medications, time since last cardiac-related surgical intervention) was obtained from medical records from the Division of Pediatric Cardiology at the Jim Pattison Children's Hospital for participants with CHD.

2.2.3 Pre- and Post- Program Measurements

Participants completed a peak $\dot{V}O_2$ test to volitional fatigue on an electromagnetically braked cycle ergometer (Ergoline 800S, SensorMedics Corp, Yorba Linda, CA). Before each test,

flow and volume were calibrated using a 3-L capacity syringe. Gas analyzers were calibrated using known gas concentrations of O₂ (16%) and carbon dioxide (4%). Participants were instructed to refrain from heavy exercise, caffeine and large meals before the test. Participants sat quietly on the cycle ergometer for three minutes to obtain resting baseline data. A modified Oslo protocol, designed for maximal exercise testing children (11, 19), was used to ensure participants could complete the exercise test properly by achieving at least the first two stages of the test. The reproducibility of this test has been validated previously (19). The test began at 25 watts for 2 minutes, followed by 25 watts per 2-minute increments to volitional fatigue. Submaximal $\dot{V}O_2$ data was collected at 25 and 50 watts, in addition to peak $\dot{V}O_2$ data. Participants were provided with standard verbal checkups at regular intervals by the investigator. Exercise was terminated when participants indicated they wished to stop or if they failed to sustain a pedal rate of 65-70 revolutions/minute. Results of the test were accepted if the respiratory exchange ratio (RER) was greater than 0.95. Once the test was terminated, participants continued to pedal on the ergometer for four minutes at 20 watts to obtain recovery data. Breath-by-breath gas exchange, HR and ventilation parameters were measured as the highest 30-s values within the last 1-minute of exercise, and submaximal parameters were measured as the average value within the last 30-s of stage 1 (25W) and stage 2 (50W) (SensorMedics® Vmax 229; VIASYS™ Healthcare Respiratory Technologies, Yorba Linda, CA, US). Beat-by-beat HR was monitored with a three-lead electrocardiogram (ECG), in a lead II configuration (SensorMedics® Vmax 229; VIASYS™ Healthcare Respiratory Technologies, Yorba Linda, CA, US).

Muscle oxygenation (as measured by tissue oxygenation index; TOI) was measured using continuous-wave near-infrared spectroscopy (NIRS), with two non-stick diodes placed on the skin surface on the right vastus lateralis (NIRO-200NX, Hamamatsu Photonics K.K., Hamamatsu City, Shizuoka Pref., Japan). Placement was determined as mid-way between the femoral head and the lateral epicondyle. The proximal diode emits light into the tissue at three wavelengths (735, 810, and 850 nm), and the distal diode measures the returning wavelengths not absorbed by hemoglobin. Light emitted from the diode penetrates the skin, subcutaneous fat and underlying muscle and is either absorbed by hemoglobin or myoglobin or scattered within the tissue (17). Adipose tissue thickness does not alter the NIRS signal (37). The inter-diode surface distance was 3cm for all participants, and the depth of penetration of the near-infrared light was approximately equal to half the distance between the light source and the diode (17, 23). Right thigh skinfold and girth were

used to validate the depth of near-infrared light penetration. A thick black cloth was placed over the diodes to block ambient light that may interfere with the NIRS signal. A tensor bandage was secured over the diodes and the cloth to hold them in place during exercise. To ensure NIRS diodes were placed in the same location pre- and post-testing, the investigator referred to anatomical landmarks and anthropometric measurements taken at the diode site during preliminary testing to reduce pre- vs post-measurement variability. Once the peak $\dot{V}O_2$ test recovery period was complete, a blood pressure cuff was inflated on the thigh above the NIRS diodes to suprasystolic pressure (220 mmHg) for 3 minutes to establish the total liable signal (TLS; the difference between the baseline and nadir TOI). Determining the TLS allowed calibration of the physiologic TOI range, and changes in TOI pre- and post-training were expressed as a percentage of the TLS (Figure 2.4). Peak TOI (%TLS) was measured as the highest 30-s value within the last 1-minute of exercise, and submaximal TOI (%TLS) was measured as the average value within the last 30-s of stage 1 (25W) and stage 2 (50W).

2.2.4 Home-Based Exercise Program

Children with CHD completed a home-based exercise program following completion of preliminary measures. The program was 12 weeks long, with 30-45 minute sessions completed 3 times per week. The primary focus of the exercise sessions was to improve strength and aerobic capacity. Each exercise session included a strength component (exercises targeting the lower body), aerobic component (brisk walking, running, stair climbing) and a flexibility component (warm-up stretches). Strength exercises comprised of activities that utilized the participant's own body weight (no equipment was required). The 12-week exercise program was divided into 3 different phases of 4 weeks. In each phase, the intensity of the strength and aerobic exercises was increased for number and/or duration completed, and new exercises were added. Participants were provided detailed instructions for completing each session, including pictures and informative videos of specific movements (Appendix F). Participants were instructed to complete each session at or above a rating of perceived exertion (RPE) of 4-6 (moderate-intensity exercise). The RPE scale was explained in detail, and take-home information was given to participants to ensure they understood the RPE scale properly while exercising (Appendix F). Logbooks were given to each participant to record the completion of each session, the RPE level attained during the session, as well as any other physical activity they participated in each week (Appendix G). Participants were

also asked to record if they missed any sessions along with the reason they were not able to complete it (sickness, injury, etc.). Weekly follow-ups were conducted by phone, email and/or in-person to aid in adherence and to facilitate questions regarding the program. Each participant was given the opportunity to have the researcher come to their home and complete an exercise session alongside them at least 1-2 times per phase, to ensure proper technique and completion of the exercise sessions. Participants who resided further than 100km away from the testing site did not receive an in-person exercise session.

2.2.5 Biweekly Sessions

In addition to the home-based exercise program, participants attended six biweekly in-person sessions as part of a larger intervention program, CHAMPS camp, at the University of Saskatchewan Physical Activity Complex in Saskatoon, Saskatchewan, and the YMCA in Regina, Saskatchewan. These sessions were 3-4 hours in length and supplemented the 12-week exercise program. The program had a multidisciplinary approach, including mental wellness and physical literacy sessions along with physical activity promotion in the form of play activities. For the purposes of this study, only the physical activity portion of these sessions is considered when interpreting results. Play activities included swimming, rock climbing, yoga, gymnastics, and sports such as basketball and volleyball. In addition, each participant completed 20 minutes of aerobic exercise on a cycle ergometer, and were asked to exercise at an RPE intensity of 4-6 (scale was visually presented to them). The participants then completed 15-minutes of resistance training led by the investigator, including similar and/or different exercises than the home-based exercise program. Similar to the home-based program, exercise was primarily lower-body resistance exercise. The upcoming two weeks of the home-based program was reviewed with the participants, and any new exercises or progressions were demonstrated.

2.2.6 Data Analysis

The primary outcome was TOI measured by NIRS on the right vastus lateralis. The secondary outcomes were exercise tolerance measured by peak $\dot{V}O_2$ and HR. Based on previously reported muscle oxygenation values in children with CHD (46), sample size calculation using G*Power 3.1.9.1 (Franz Faul, Kiel University, Germany) yielded a sample size of 15 participants ($1-\beta = 0.8$, $\alpha = 0.05$, $ES = 0.8$). TOI was expressed as a percentage scaled to the TLS based on the

highest 5-s average at baseline (100%) and the lowest 5-s value at the nadir during circulatory occlusion of the right thigh (0%). Peak TOI, $\dot{V}O_2$ and HR were analyzed as the average value over 30-s over the last 1-minute of exercise. Submaximal TOI, $\dot{V}O_2$ and HR were analyzed as the average of the last 30-s of stage 1 (25W) and stage 2 (50W). Pre- versus post-training changes in TOI, $\dot{V}O_2$ and HR were analyzed using paired *t*-tests (SigmaPlot v13.0, Systat Software Inc. San Jose, CA, USA). If the assumption of homogeneity was violated, nonparametric Wilcoxon signed-rank test was used. Between-group differences were assessed using one-way ANOVAs with Holm Sidak post-hoc tests (SigmaPlot v13.0, Systat Software Inc. San Jose, CA, USA). Kruskal-Wallis one-way ANOVA nonparametric testing was used where the assumption of homogeneity of variances was violated. Cohen's *d* value for effect size was reported to describe the meaningfulness of the data. Data are reported as mean \pm standard deviation, and $p < 0.05$ was considered statistically significant.

2.3 Results

2.3.1 Demographics

Age was not significantly different between CHD and CTL groups (Table 2.1). Although not significant, standing height, weight and BMI tended to be higher pre- and post-training in children with CHD compared to CTL (Table 2.1). CHD type, severity, time since last cardiac-related surgical intervention and cardiac-related medications are listed in Table 2.2. HR was significantly lower at baseline in CHD pre- and post-training compared to CTL (84 ± 12 bpm vs 95 ± 13 bpm; 81 ± 11 bpm vs 97 ± 11 bpm; $p = 0.02$; Table 2.3). There were no significant differences in baseline relative or absolute $\dot{V}O_2$, TOI or VE (Table 2.3). Figure 2.3 shows representative data for TOI, $\dot{V}O_2$, HR and work rate.

2.3.2 Adherence

Adherence to the home exercise program and biweekly sessions were expressed as a percentage of sessions completed. Average adherence to the home-based exercise program was $68 \pm 32\%$. Nine participants completed $>80\%$ of the exercise sessions, and four participants completed $<50\%$ of the exercise sessions. Average attendance to the biweekly sessions was $77 \pm 28\%$. Ten participants attended $>80\%$ of the biweekly sessions, and two participants attended $<50\%$ of the biweekly sessions.

2.3.3 Effect of exercise training on TOI at peak $\dot{V}O_2$

Although not significant, TOI average at $\dot{V}O_2$ peak was lower post-training compared to pre-training in children with CHD ($20 \pm 13\%$ vs $30 \pm 16\%$; $p = 0.09$, $d = 0.66$; Figure 2.5). TOI average at $\dot{V}O_2$ peak was not significantly different in children with CHD pre-training compared to healthy CTLs ($30 \pm 16\%$ vs $41 \pm 11\%$; $p = 0.11$, $d = 0.82$; Figure 2.5). Post-training, children with CHD had significantly lower TOI at peak $\dot{V}O_2$ compared to CTLs ($20 \pm 13\%$ vs $41 \pm 11\%$; $p = 0.02$, $d = 1.33$; Figure 2.5).

2.3.4 Effect of exercise training on submaximal TOI

There was no significant difference pre- vs post-training TOI during stage 1 of exercise (25W) ($76 \pm 20\%$ vs $73 \pm 19\%$; $p = 0.60$, $d = 0.13$; Figure 2.6). Although not significant, TOI at stage 2 of exercise (50W) was lower post-training compared to pre-training ($47 \pm 26\%$ vs $62 \pm 20\%$; $p = 0.06$, $d = 0.59$; Figure 2.7). TOI at stage 1 was not significantly different in children with CHD pre- or post-training ($76 \pm 20\%$ vs $83 \pm 11\%$, $d = 0.45$; $73 \pm 19\%$ vs $83 \pm 11\%$, $d = 0.62$; $p = 0.68$; Figure 2.6) compared to CTLs. TOI at stage 2 was not significantly different in children with CHD pre- or post-training ($62 \pm 20\%$ vs $70 \pm 16\%$, $d = 0.49$; $47 \pm 26\%$ vs $70 \pm 16\%$, $d = 0.95$; $p = 0.16$; Figure 2.7) compared to CTLs.

2.3.5 Effect of exercise training on peak $\dot{V}O_2$

There was no significant difference pre- vs post-training in relative peak $\dot{V}O_2$ (35 ± 7 mL/kg/min vs 36 ± 9 mL/kg/min; $p = 0.56$, $d = 0.10$; Figure 2.8) or absolute peak $\dot{V}O_2$ (1.85 ± 0.39 L/min vs 1.93 ± 0.43 L/min; $p = 0.33$, $d = 0.19$; data not shown) in children with CHD. Relative peak $\dot{V}O_2$ pre- and post- training in children with CHD was significantly lower compared to healthy CTLs (35 ± 7 mL/kg/min vs 48 ± 7 mL/kg/min; $p = 0.006$, $d = 1.28$; 36 ± 9 mL/kg/min vs 48 ± 7 mL/kg/min; $p = 0.005$, $d = 1.16$; Figure 2.8). There was no significant difference in absolute peak $\dot{V}O_2$ pre- or post- training (1.85 ± 0.39 L/min vs 1.81 ± 0.40 L/min, $d = 0.10$; 1.93 ± 0.43 L/min vs 1.81 ± 0.40 L/min, $d = 0.28$; $p = 0.83$; data not shown) in children with CHD compared to healthy CTLs.

2.3.6 Effect of exercise training on submaximal $\dot{V}O_2$

There was no significant difference in relative $\dot{V}O_2$ at stage 1 (16 ± 4 mL/kg/min vs 16 ± 3 mL/kg/min; $p = 0.87$, $d = 0.04$; Figure 2.9) or stage 2 (22 ± 4 mL/kg/min vs 23 ± 5 mL/kg/min; $p = 0.52$, $d = 0.11$; Figure 2.10) pre- vs post- training in children with CHD. There was no significant difference in absolute $\dot{V}O_2$ at stage 1 (0.84 ± 0.14 L/min vs 0.85 ± 0.10 L/min; $p = 0.43$, $d = 0.09$; data not shown) or stage 2 (1.15 ± 0.16 L/min vs 1.18 ± 0.10 L/min; $p = 0.46$, $d = 0.25$; data not shown) pre- vs post- training in children with CHD. In children with CHD, pre- and post- training relative $\dot{V}O_2$ was significantly different compared to CTLs at stage 1 (16 ± 4 mL/kg/min vs 21 ± 3 mL/kg/min, $d = 1.10$; 16 ± 3 mL/kg/min vs 21 ± 3 mL/kg/min, $d = 1.27$; $p = 0.01$; Figure 2.9). Absolute $\dot{V}O_2$ in children with CHD pre- and post-training compared to CTLs was not significantly different at stage 1 (0.84 ± 0.14 vs 0.79 ± 0.08 L/min, $d = 0.42$; 0.85 ± 0.10 vs 0.79 ± 0.08 L/min, $d = 0.62$; $p = 0.51$; data not shown). In children with CHD, relative $\dot{V}O_2$ at stage 2 was significantly lower pre- (22 ± 4 mL/kg/min vs 31 ± 8 mL/kg/min; $p = 0.006$, $d = 1.19$; Figure 2.10) and post-training (23 ± 5 mL/kg/min vs 31 ± 8 mL/kg/min; $p = 0.01$, $d = 1.13$; Figure 2.10) compared to CTL. Pre- and post- training absolute $\dot{V}O_2$ at stage 2 (1.15 ± 0.16 L/min vs 1.20 ± 0.16 L/min, $d = 0.31$; 1.18 ± 0.10 L/min vs 1.20 ± 0.16 L/min, $d = 0.12$; $p = 0.76$; data not shown) in children with CHD compared to CTLs was not significantly different.

2.3.7 Effect of exercise training on HR at peak $\dot{V}O_2$

HR at peak $\dot{V}O_2$ was not significantly different pre- vs post-training (175 ± 23 bpm vs 169 ± 21 bpm; $p = 0.18$, $d = 0.27$; Figure 2.11) in children with CHD. Although not significant, HR at peak $\dot{V}O_2$ was lower in children with CHD compared to CTLs pre- and post-training (175 ± 23 bpm vs 189 ± 12 bpm, $d = 0.74$; 169 ± 21 bpm vs 189 ± 12 bpm, $d = 1.03$; $p = 0.06$; Figure 2.11).

2.3.8 Effect of exercise training on submaximal HR

There were no significant differences pre- vs post- training HR at stage 1 (111 ± 16 bpm vs 108 ± 11 bpm; $p = 0.34$, $d = 0.22$; Figure 2.12) or stage 2 (130 ± 12 bpm vs 126 ± 16 bpm; $p = 0.20$, $d = 0.33$; Figure 2.13s) in children with CHD. At stage 1, pre- (111 ± 16 bpm vs 127 ± 18 bpm; $p = 0.04$, $d = 0.89$; Figure 2.12) and post- training HR (108 ± 11 bpm vs 127 ± 18 bpm; $p = 0.03$, $d = 1.11$; Figure 2.12) was significantly lower in children with CHD compared to CTL. Similarly, pre- (130 ± 12 bpm vs 147 ± 18 bpm; $p = 0.04$, $d = 0.96$; Figure 2.13) and post- training (126 ± 16 bpm vs

147±18 bpm; $p = 0.02$, $d = 1.07$; Figure 2.13) HR at stage 2 was significantly lower in children with CHD compared to CTL.

2.4 Discussion

The purpose of this study was to determine if a 12-week home-based exercise intervention improved TOI, $\dot{V}O_2$ and HR during submaximal and maximal aerobic exercise in children with CHD. The major novel finding of this study is that, contrary to previous research, TOI at maximal exercise (peak $\dot{V}O_2$) was lower after a resistance training intervention in children with CHD compared to pre-training values and healthy CTLs. This response was despite no significant changes in peak $\dot{V}O_2$ or HR, indicating a change in O_2 utilization without a change in O_2 delivery. To our knowledge, this is the first study to suggest peripheral mechanisms that contribute to exercise intolerance in children with CHD can be isolated and altered using a home-based strength training intervention.

2.4.1 TOI responses to exercise training in children with CHD

Our study demonstrated for the first time an exaggerated decrease in TOI at maximal and submaximal aerobic exercise after a strength-based exercise intervention in children with CHD. TOI reflects the balance between O_2 delivery and utilization (23). During exercise, TOI transiently decreases as O_2 is utilized at the muscle to meet increased metabolic demands in healthy individuals (5). In children with CHD, this response has been shown to be impaired compared to healthy age- and sex-matched peers due to various mechanisms contributing to reduced O_2 delivery and uptake at the working muscle, causing TOI to decrease to lower values during exercise (28, 29, 41, 46). Aerobic exercise interventions have been used to mitigate impaired exercise TOI contributing to exercise intolerance in these children, and reducing the disparity compared to healthy peers (30, 31). Moalla et al. (30) associated improvements in muscle oxygenation after an aerobic interval training program to both central (cardiac output) and peripheral (arteriovenous O_2 difference and capillary density) adaptations. Conversely, the present study demonstrated an augmented TOI decrease at maximal exercise, as well as stage 2 of submaximal exercise post-training. To our knowledge, this has not been demonstrated previously in children with CHD. Costes et al. (14) showed significant decreases in muscle oxygenation during submaximal exercise in young healthy males after an aerobic exercise intervention, with no change in $\dot{V}O_2$. Muscle biopsies obtained from

the vastus lateralis determined the decrease in TOI post-training was due to increased capillarization and oxidative enzyme capacity at the muscle, enhancing the matching of capillary flow to metabolic demand (14). Due to the enhancement of capillary flow, without a concurrent increase in O₂ delivery TOI was further decreased post-training (14). Similar results were demonstrated in a group of competitive cyclists during a submaximal endurance test after an interval training program (33). More recently, a study in COPD patients and healthy sedentary participants showed training-induced increases in skeletal muscle aerobic capacity without relevant changes in muscle blood volume, due to enhancement of the muscle capillary network and mitochondrial respiratory capacity (2). Although difficult to compare our findings due to differing participant group characteristics and exercise interventions, these mechanisms may prove as a starting point to explain our further impaired TOI response to exercise post-training in children with CHD. Indeed, as our exercise intervention focused on lower-body resistance training, one can infer that increases in muscle mass and strength occurred as a result. Coupled with significant changes in TOI observed post-training, we conclude that our intervention elicited adaptations in the periphery independent of changes in O₂ delivery, similar to those highlighted by Costes et al. (14). Thus, resulting in a greater disparity between oxygen delivery and utilization at the working muscle post-training in our CHD participants.

The use of the total liable signal (TLS) when analyzing muscle oxygenation data from NIRS provides an indication that changes in TOI pre- vs post-training in children with CHD are due to microvascular adaptations to training and not baseline TOI values. Previous studies that have used NIRS to evaluate TOI have not included TLS, which leads one to speculate whether the magnitude of change in TOI (either increase or decrease) is related to the relative baseline TOI level for each participant. In the present study, calibration of the physiologic TOI range via TLS allowed reliable comparisons and generalizations regarding peripheral responses to exercise training. This suggests our novel exercise intervention was successful in isolating and determining peripheral mechanisms associated with exercise intolerance in children with CHD.

2.4.2 $\dot{V}O_2$ responses to exercise training in children with CHD

There were no significant differences pre- vs post-training in submaximal or maximal $\dot{V}O_2$ in children with CHD. Previous work has not yet led to a consensus for the intervention required to elicit significant $\dot{V}O_2$ increases in children with CHD. Many have shown aerobic interval

training elicits increases in peak $\dot{V}O_2$ of 3-4 mL/kg/min (1, 22, 30). However, others have shown no change in peak $\dot{V}O_2$ after similar training (10). Cordina et al. (13) implemented a resistance training program that showed a significant increase of absolute peak $\dot{V}O_2$ of 0.5 L/min, and Rhodes et al. (38) showed an increase in peak $\dot{V}O_2$ of approximately 4.0 mL/kg/min after a combined aerobic and strength training intervention. Similarly, our study included primarily resistance-based exercise supplemented with aerobic training; however, it did not elicit significant changes in $\dot{V}O_2$. Our exercise intervention was designed to address our primary purpose of eliciting changes in the periphery that may contribute to exercise intolerance in children with CHD, rather than improving maximal performance. It is also possible that disproportional adaptations to exercise training in our study, characterized by significant changes in TOI without changes in $\dot{V}O_2$, may have masked central hemodynamic changes, if any.

Exercise intensity may be an important factor in our results. Intensity is widely regarded as the most important determinant of an exercise prescription's effectiveness for increasing $\dot{V}O_2$ (43). Unlike previous studies, our intervention only used an RPE scale to monitor intensity, as our program was designed to be feasible and easy for children to follow. Rhodes et al. (38) used HR at the ventilatory threshold as a target exercise intensity for participants. They were also able to more closely monitor their participants, with supervised exercise sessions two times per week for 12 weeks, compared to our intervention where supervised exercise only occurred every two weeks. Therefore, our method of self-reported intensity may not have had a strong enough stimulus to influence central hemodynamic factors, such as cardiac output, that contribute to $\dot{V}O_2$.

Our CHD participant characteristics may have also contributed to the absence of significant $\dot{V}O_2$ changes. Our group consisted of a heterogeneous sample of CHD lesion types, including both simple (Atrial Septal Defect, Bicuspid Aortic Valve, Coarctation of the Aorta, Pulmonary Stenosis, Ventricular Septal Defect), and complex lesions (Congenitally Corrected Transposition of the Great Arteries, Dextro-Transposition of the Great Arteries, Double Inlet Left Ventricle, Tetralogy of Fallot). Various central hemodynamic factors can be implicated as a result of lesion structure and morphology such as cardiac output, heart rate, left ventricular ejection fraction and atrial and ventricular pressure (3). As a result, lesion type and severity are a major determinant of $\dot{V}O_2$ for individuals with CHD (25), thus the effectiveness of an exercise intervention. Numerous studies involving homogeneous samples of children with complex CHD lesions consistently show improvements in both submaximal and maximal $\dot{V}O_2$ post-training, due to improved central

hemodynamic factors such as cardiac output, stroke volume and diastolic blood pressure (13, 27, 35, 38). In contrast, exercise interventions including a heterogeneous sample of both simple and complex lesions see little to no improvement in $\dot{V}O_2$ (21, 22). Exploratory analysis of our data revealed participants with complex lesions tended to have a lower exercise tolerance (peak $\dot{V}O_2$) both pre- and post-training compared to participants with simple lesions. This may have also contributed to the lack of change in $\dot{V}O_2$ after training, as our program was not specifically tailored to lesion type. However, due to an already low sample size, subgroup analyses are taken with caution. Future work should consider examining the effects of our exercise intervention on a homogenous group of CHD type or creating simple and complex lesion subgroups within a heterogeneous sample to determine altogether the effects of resistance training on $\dot{V}O_2$ during submaximal and maximal aerobic exercise in children with CHD.

2.4.3 Heart rate responses to exercise training in children with CHD

In children with CHD, HR was not significantly different during submaximal or maximal exercise pre- vs post-training. Children with CHD are unique in that lesion type and severity can play a major role in the ability to increase HR during exercise (34). Chronotropic incompetence, the inability to increase HR to normal levels during exercise, is common after surgery for various types of CHD (34). In addition, three CHD participants had a pacemaker device (Table 2.2) which may also prevent appropriate increases in HR in response to training. Previous work has shown in homogenous participant samples, heart rate responses can be improved as a result of training (42, 48). As our sample varies in the time since last cardiac surgical intervention, it is possible that our participants had differing levels of chronotropic incompetence impairing adaptation of HR to exercise training, therefore any improvements in HR may have been masked.

2.4.4 Role of O_2 flux on central and peripheral responses to exercise training

The role of O_2 flux may be an important factor to consider in TOI, $\dot{V}O_2$ and HR responses to exercise training in children with CHD. O_2 flux describes changes in arterial-venous O_2 content difference (A-V O_2) due to the rate of O_2 offloading from the blood to the working muscle. O_2 flux is influenced by many factors such as mitochondrial volume density, capillary density and function, red blood cell velocity, O_2 delivery and capillary to fibre ratio (24, 36). To our knowledge, none have characterized O_2 flux or A-V O_2 difference directly in children with CHD. In patients with

heart failure, O₂ flux has been shown to be impaired due to compromised microcirculatory function such as decreased capillary and mitochondrial density, decreasing the ability of O₂ to offload at the muscle (24, 36). Exercise training has been shown to improve blood-muscle O₂ transfer and increase A-V O₂ difference during exercise in patients with heart failure (24). Similarly, our exercise intervention may have elicited increases in capillary number and density, slowing blood flow at the working muscle and allowing for an increase in O₂ offloading from the blood to the muscle. With an increase in mitochondrial density, the muscle would be able to use the increased amount of O₂ available more efficiently to match metabolic demand, and A-V O₂ difference and subsequently TOI would increase. However, our results suggest that there was not a parallel increase in O₂ delivery with increased O₂ utilization (no change in $\dot{V}O_2$ or HR). The decreased TOI or O₂ content of the muscle post-training in children with CHD may be explained by an improved O₂ flux via increased O₂ extraction and utilization, without a subsequent increase in O₂ delivery to match. Further work is needed to determine the mechanisms behind this unique response, and to further investigate O₂ flux in children with CHD.

2.4.5 Effectiveness of the home-based exercise program

Our novel strength-based home-exercise intervention demonstrated for the first time that a program designed for research methodology as well as real-world application may be able to elicit positive peripheral adaptations related to exercise intolerance in children with CHD. Previous studies have primarily implemented aerobic-based exercise interventions (1, 22, 27, 30), likely due to ease of program implementation and the ability of these programs to produce significant improvements in exercise tolerance. Although both important, it is difficult to generalize these results and translate them into feasible clinical rehabilitation programs. By including primarily lower body strength exercises related to functional movement patterns, and supplementing it with aerobic and play components, our study addressed key aspects of daily activities for children with CHD. Our study successfully addressed a gap in the field of exercise rehabilitation for children with CHD. By developing our program so as to provide a feasible exercise intervention to ensure results were applicable to activities of daily living strengthened the impact our results may have on future studies.

2.4.6 Participant characteristics

As expected, children with CHD increased in height and weight over the 12-week training period, neither of which was significantly different compared to CTL. Although not significant, our CTL group was smaller in height and weight and had a BMI 2 kg/m² lower than the CHD group. There were no significant differences in right thigh girth between groups; however, right thigh skinfold thickness was significantly different pre- vs post-training in children with CHD. Skinfold thickness was approximately 3mm lower post-training compared to pre-training, which may indicate an increase of lean mass at the measurement site. Pre-training skinfold thickness in children with CHD was significantly higher compared to CTL. Coupled with fairly high peak $\dot{V}O_2$ scores, our reference CTL group may have represented a high fit healthy population. Future studies should ensure a more representative CTL group is used or consider utilizing low-fit and high-fit groups to allow more precise comparisons between CTL and CHD participants.

2.5 Conclusion

Our study demonstrated for the first time in a heterogeneous group of children with CHD that a home-based exercise intervention including strength, aerobic and play activities reduced submaximal and maximal TOI compared to pre-training values in children with CHD and healthy age- and sex-matched CTLs. The reduction in TOI, combined with a lack of change in $\dot{V}O_2$ and HR at submaximal and maximal exercise, points to a potential mismatch of central and peripheral adaptations in response to exercise training. These findings show that resistance training has the ability to mitigate peripheral mechanisms associated with exercise intolerance in children with CHD. These findings provide further evidence for the effectiveness of exercise rehabilitation to improve exercise tolerance and alleviate mortality risk in children with CHD.

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Table 2.1 Participant demographics.

	CHD Pre- Training	CHD Post- Training	CTL	<i>p</i> -value
Age (yrs)	12±2	12±2	12±3	0.80
Sex (f:m)	5:9	-	5:4	-
Height (cm)	154±13	156±13	149±13	0.43
Weight (kg)	48±14	49±14	41±12	0.27
BMI (kg/m ²)	20±4	20±4	18±3	0.44
Reside (U:R)	9:5	-	9:0	-
R Thigh Girth (cm)	46±7	46±7	43±7	0.62
R Thigh Skinfold Thickness (mm)	24±7	21±6	16±8	0.03*

Values are mean ± SD. CHD, Congenital Heart Disease; CTL, controls; BMI, body mass index; U, urban; R, rural. *Significantly lower in CTL compared to CHD pre-training.

Table 2.2 CHD participant characteristics.

	Diagnosis	Surgical Intervention (s)	Yrs since last intervention	NYHA Class	Cardiac- Related Medications
CHD02	PV Stenosis	Balloon valvuloplasty	12	I	-
CHD06	d-TGA	Balloon atrial septostomy, arterial switch, RVOT patch, balloon branch pass	10	I	-
CHD15	TOF	VSD patch, RVMB resection, pulmonary valvuloplasty	12	I	-
CHD16	DILV with normally related great arteries	Gortex shunt, bidirectional Glenn, Fontan	10	I	ASA
CHD25	CoA	End to end CoA repair, balloon reCoA	13	I	-
CHD27	PV stenosis, ASD	Balloon valvuloplasty, ASD closure, TV repair	8	I	-
CHD28	cc-TGA	ASD closure, pacemaker	1	I	ASA
CHD34	TOF	Right Blalock Taussig shunt, TOF repair	13	I	-
CHD38	TOF, right arch	TOF repair, PV replacement	14	I	ASA
CHD41	TOF	TOF repair, pacemaker	16	I	-
CHD59	VSD, heart block	VSD patch, pacemaker	4	I	-

CHD60	d-TGA, VSD	Arterial switch, VSD patch, CoA repair, ASD suture	16	I	-
CHD72	TGA, PV stenosis, VSD	Right & left Blalock-Taussig shunt, Nikaidoh procedure	12	I	-
CHD73	CoA, VSD, PDA, BAV, left SVC to dilated coronary sinus	End to end CoA repair, VSD closure, PA banding & debanding, RVMB resection	14	I	-
CHD76	Partial/transitional AVSD	AVSD repair	5	I	-
CHD78	CoA, BAV	End to end coarctation repair	10	I	-

PV, Pulmonary valve; d-TGA, Dextro-Transposition of the Great Arteries; RVOT, right ventricular outflow tract; TOF, Tetralogy of Fallot; VSD, Ventricular Septal Defect; RVMB, right ventricular muscle band; DILV, Double Inlet Left Ventricle; CoA, Coarctation of the Aorta; ASD, Atrial Septal Defect; TV, Tricuspid valve; cc-TGA, Congenitally Corrected Transposition of the Great Arteries; PDA, Patent Ductus Arteriosus; BAV, Bicuspid Aortic valve; SVC, Superior Vena Cava; AVSD, Atrioventricular Septal Defect.

Table 2.3 Baseline characteristics.

	CHD Pre- Training	CHD Post- Training	CTL	<i>p</i> -value
HR (beats/min)	84±12	81±11	97±11	0.02*
$\dot{V}O_2$ (mL/kg/min)	6.8±1.4	6.8±1.9	7.9±1.4	0.15
$\dot{V}O_2$ (L/min)	0.4±0.1	0.4±0.1	0.3±0.1	0.24
VE (L/min)	11.8±1.9	11.8±2.5	11.8±3.1	0.91
Relative TOI (%)	73±3	70±4	74±3	0.08
Absolute TOI (%TLS)	100±0.08	100±0.19	100±0.02	0.48

Values are mean \pm SD. CHD, Congenital Heart Disease; CTL, controls; HR, heart rate; $\dot{V}O_2$, oxygen consumption; VE, ventilation; TOI, tissue oxygenation index; TLS, total liable signal.

*Significantly lower in CHD pre- and post-training compared to CTL.

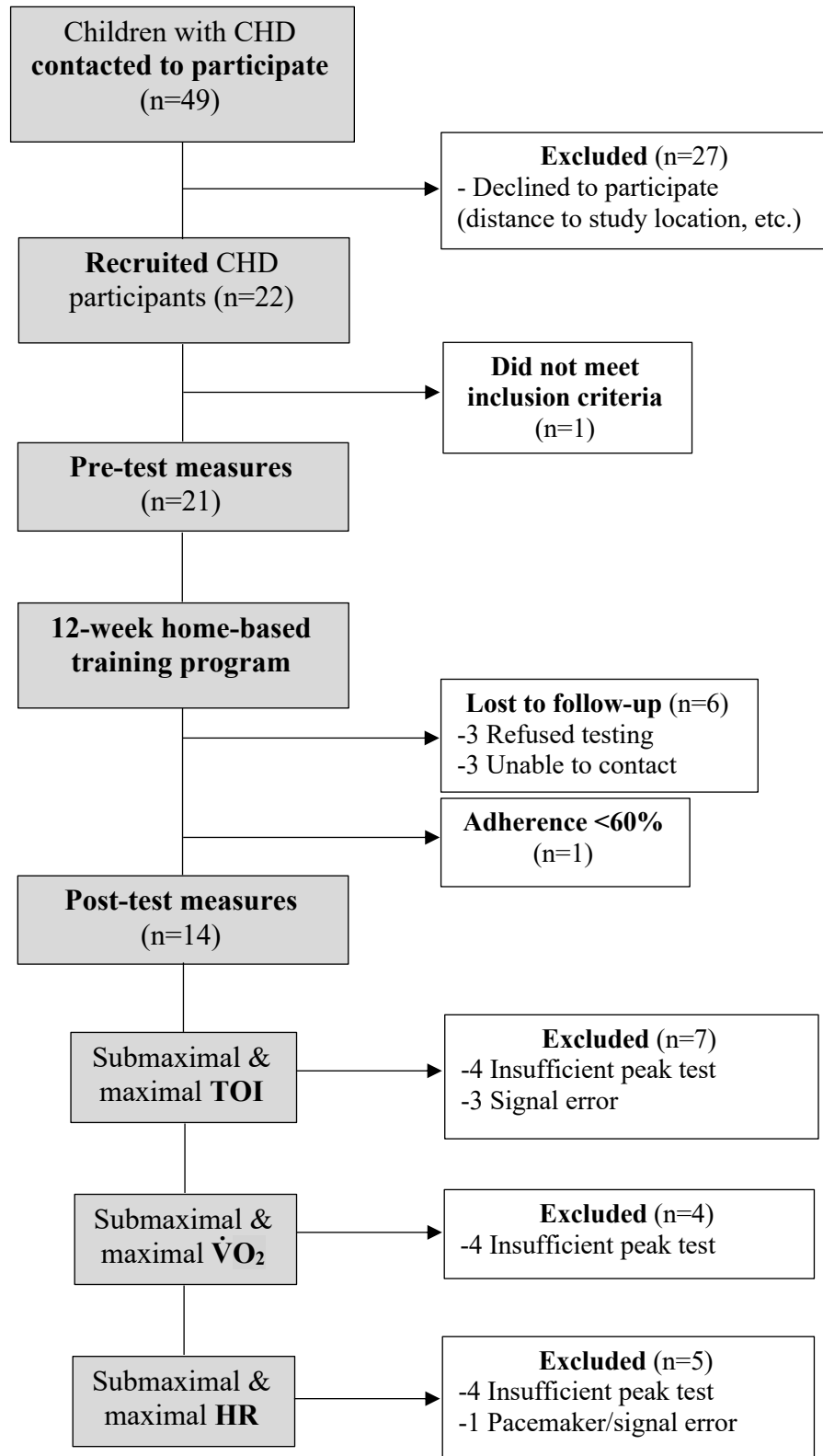


Figure 2.1: Study enrolment – children with CHD.

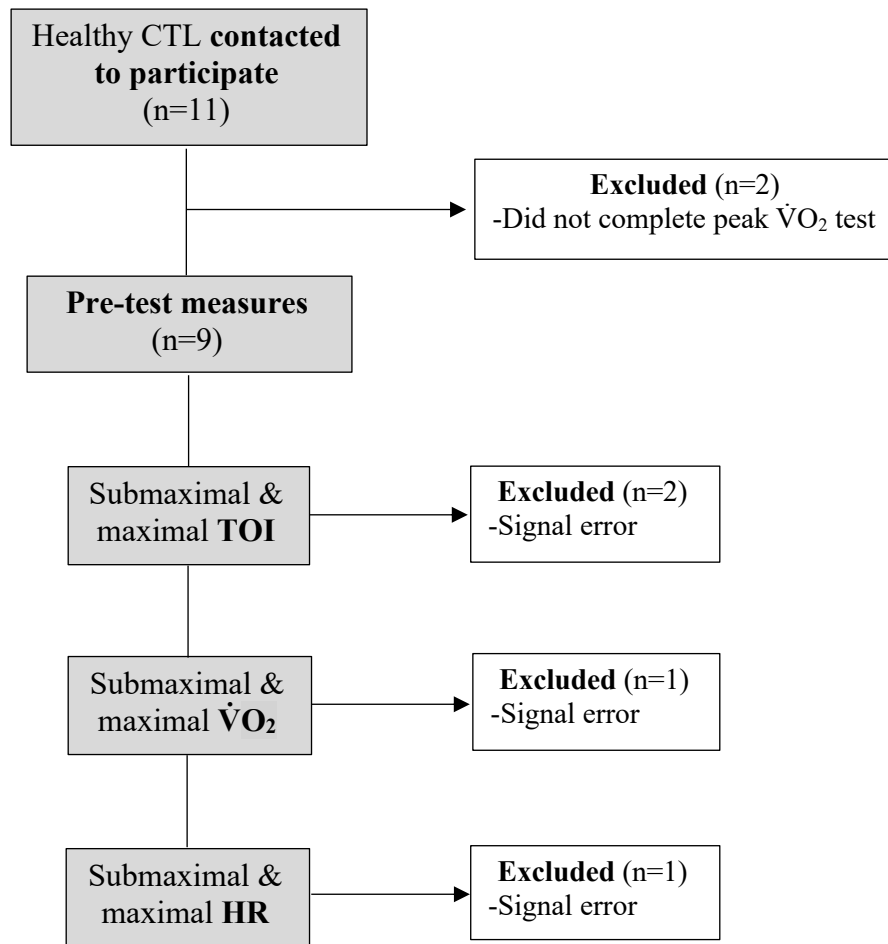


Figure 2.2: Study enrolment – healthy CTL group.

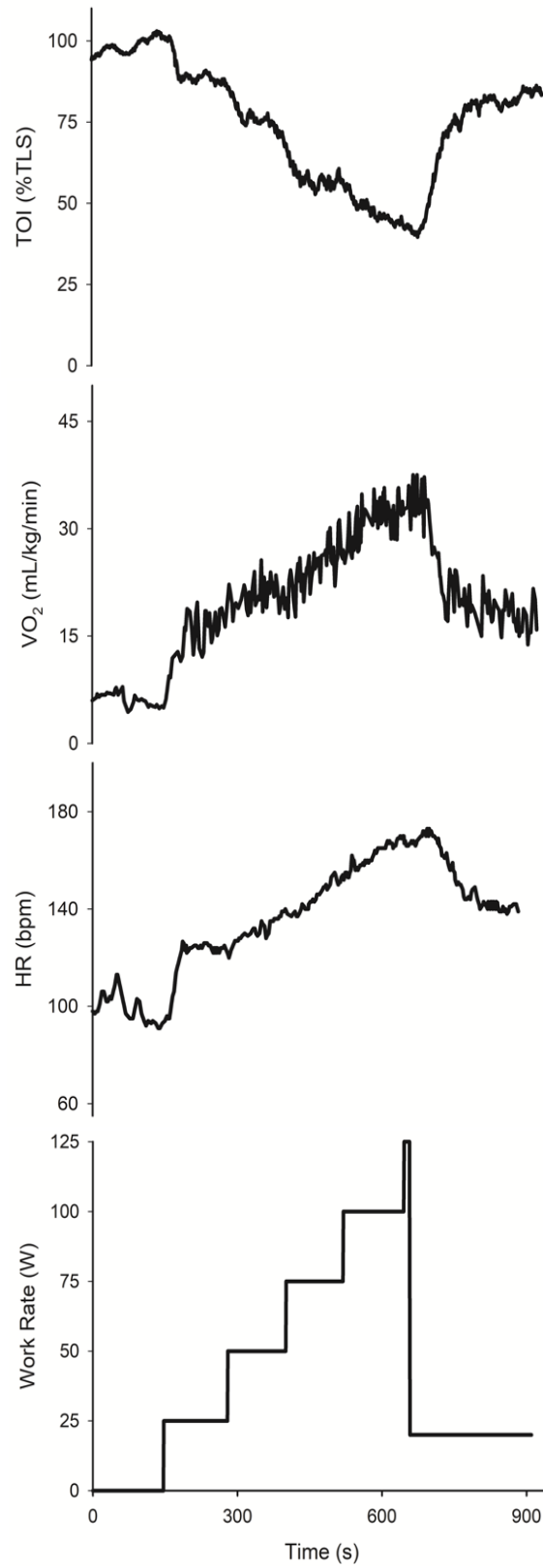


Figure 2.3: Representative data.

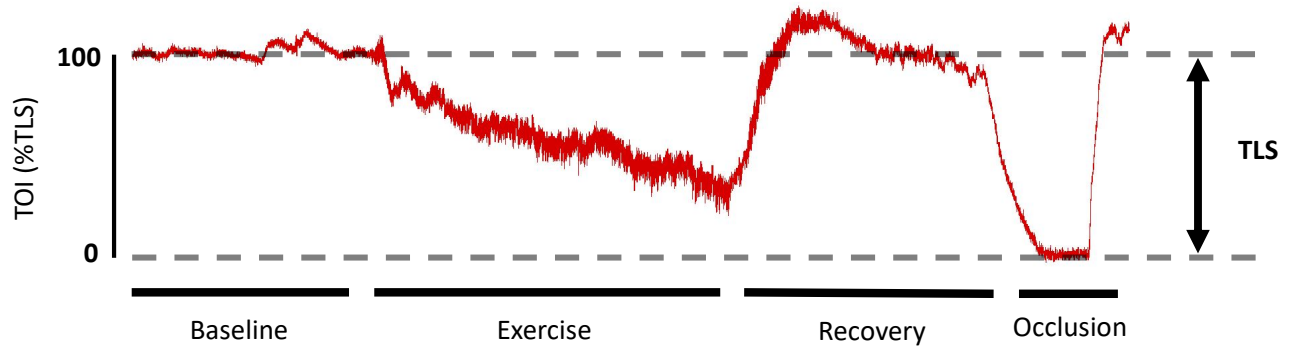


Figure 2.4: Representative data – total liable signal (TLS) calibration.

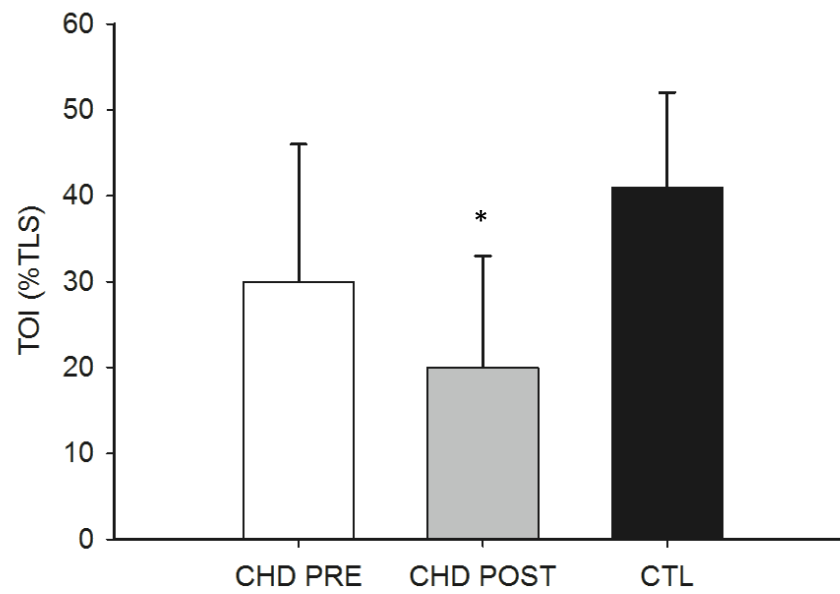


Figure 2.5: Tissue oxygenation index (TOI) at peak $\dot{V}O_2$. Pre- and post- training TOI at peak $\dot{V}O_2$ in children with CHD ($n = 7$) compared to CTL ($n = 7$). *Post-training significantly lower compared to CTL ($p = 0.02$; $d = 1.33$). Pre- vs post-training ($p = 0.09$; $d = 0.66$), pre-training vs CTL ($p = 0.11$; $d = 0.82$). Values are mean \pm SD.

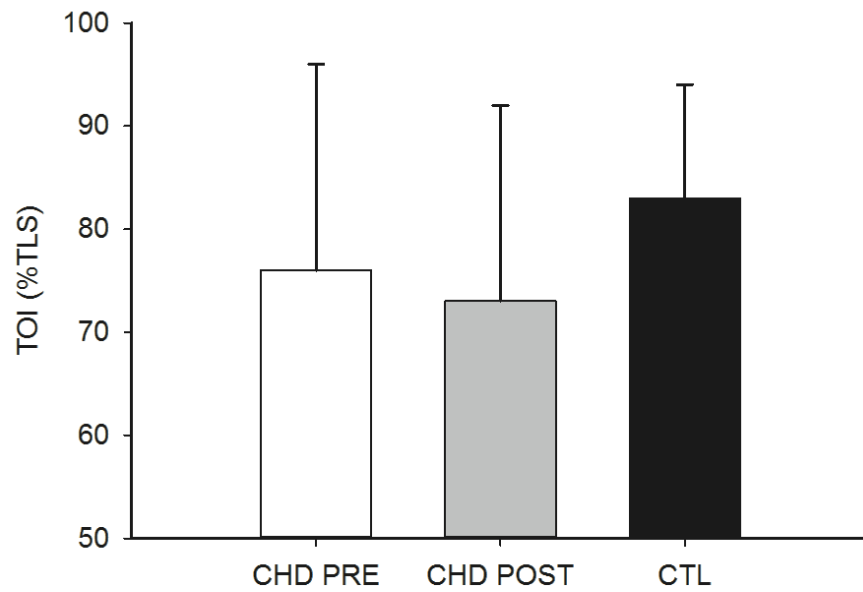


Figure 2.6: Submaximal tissue oxygenation index (TOI) at stage 1 (25W). TOI at stage 1 pre- and post- training in children with CHD ($n = 7$) compared to CTL ($n = 7$). Pre- vs post-training ($p = 0.60$; $d = 0.13$), pre-training vs CTL ($p = 0.68$; $d = 0.45$), post-training vs CTL ($p = 0.68$; $d = 0.62$). Values are mean \pm SD.

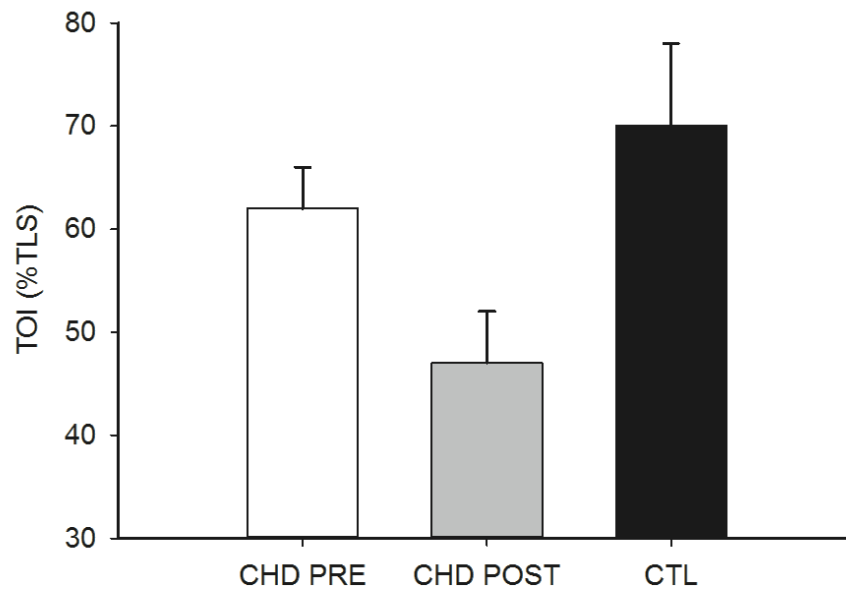


Figure 2.7: Submaximal tissue oxygenation index (TOI) at stage 2 (50W). TOI at stage 2 pre- and post- training in children with CHD ($n = 7$) compared to CTL ($n = 7$). Pre- vs post-training ($p = 0.06$; $d = 0.59$), pre-training vs CTL ($p = 0.16$; $d = 0.49$), post-training vs CTL ($p = 0.16$; $d = 0.95$). Values are mean \pm SD.

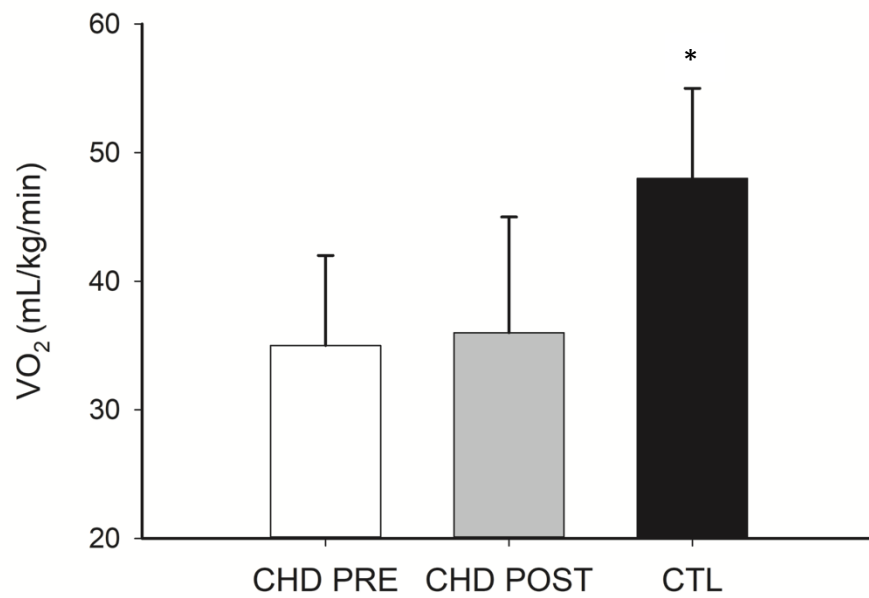


Figure 2.8: Relative peak $\dot{V}O_2$ (mL/kg/min). Pre- and post- training relative peak $\dot{V}O_2$ in children with CHD ($n = 10$) compared to CTL ($n = 8$). *CTL significantly higher than pre- ($p = 0.006$; $d = 1.28$) and post-training ($p = 0.005$; $d = 1.16$). Pre- vs post-training ($p = 0.56$; $d = 0.10$). Values are mean \pm SD.

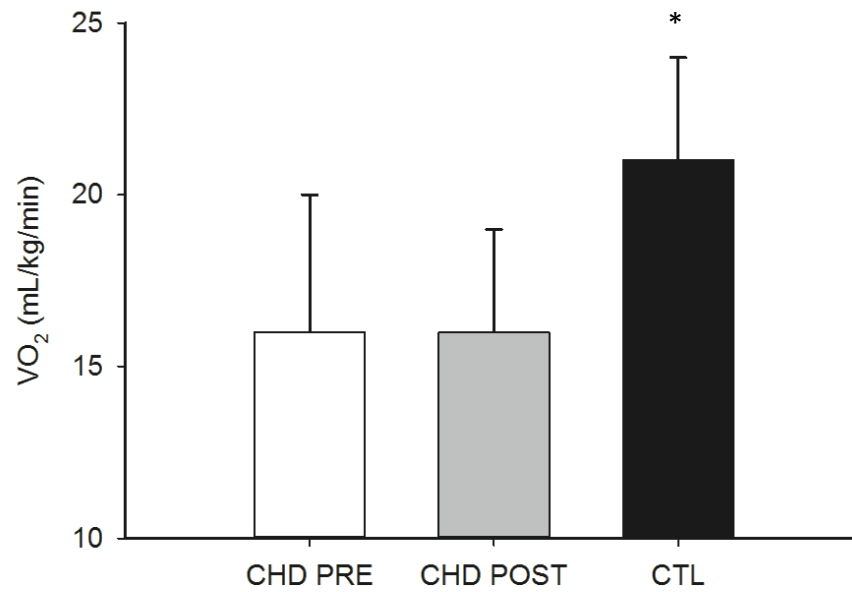


Figure 2.9: Submaximal $\dot{V}O_2$ (mL/kg/min) at stage 1 (25W). Pre- and post-training $\dot{V}O_2$ at stage 1 in children with CHD ($n = 10$) compared to CTL ($n = 8$). *CTL significantly higher compared to pre- ($p = 0.01$; $d = 1.10$) and post-training ($p = 0.01$; $d = 1.27$). Pre- vs post-training ($p = 0.87$; $d = 0.04$). Values are mean \pm SD.

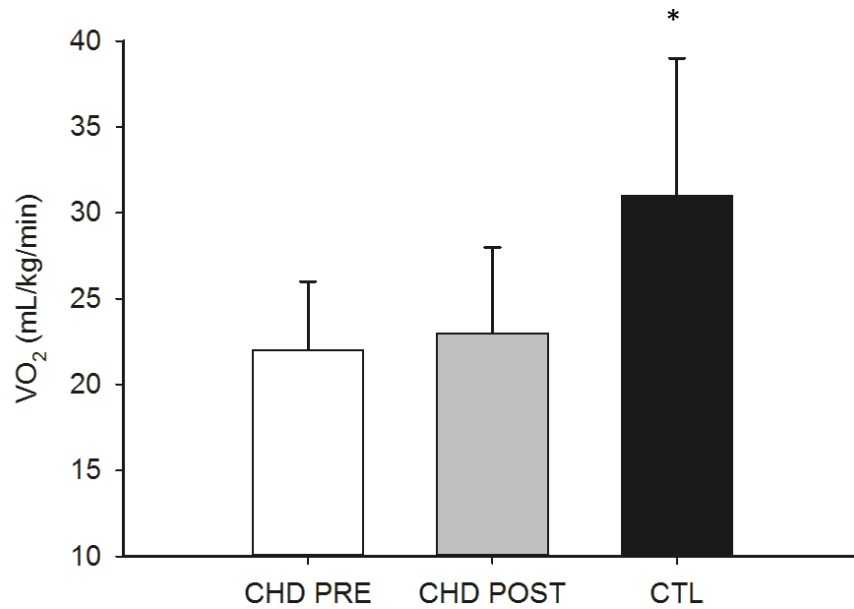


Figure 2.10: Submaximal $\dot{V}O_2$ (mL/kg/min) at stage 2 (50W). Pre- and post-training $\dot{V}O_2$ at stage 2 in children with CHD ($n = 10$) compared to CTL ($n = 8$). *CTL significantly higher compared to pre- ($p = 0.006$; $d = 1.19$) and post-training ($p = 0.01$; $d = 1.13$). Pre- vs post-training ($p = 0.52$; $d = 1.11$). Values are mean \pm SD.

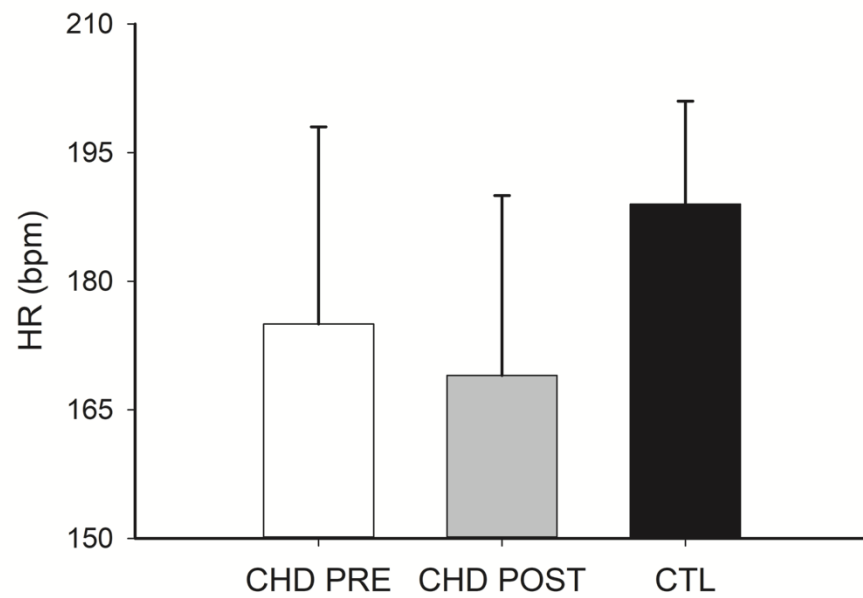


Figure 2.11: Heart rate (HR) at peak $\dot{V}O_2$. Pre- and post- training HR at peak $\dot{V}O_2$ in children with CHD ($n = 9$) compared to CTL ($n = 8$). Pre- vs post-training ($p = 0.18$; $d = 0.27$), pre-training vs CTL ($p = 0.06$; $d = 0.74$), post-training vs CTL ($p = 0.06$; $d = 1.03$). Values are mean \pm SD.

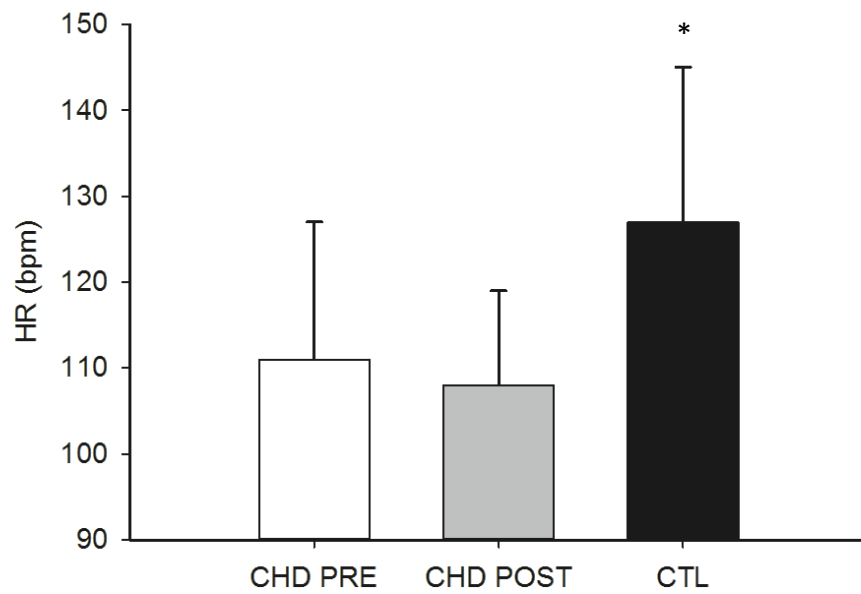


Figure 2.12: Submaximal heart rate (HR) at stage 1 (25W). Pre- and post- training HR at stage 1 in children with CHD ($n = 9$) compared to CTL ($n = 8$). *CTL significantly higher compared to pre- ($p = 0.04$; $d = 0.89$) and post-training ($p = 0.03$; $d = 1.11$). Pre- vs post-training ($p = 0.34$; $d = 0.22$). Values are mean \pm SD.

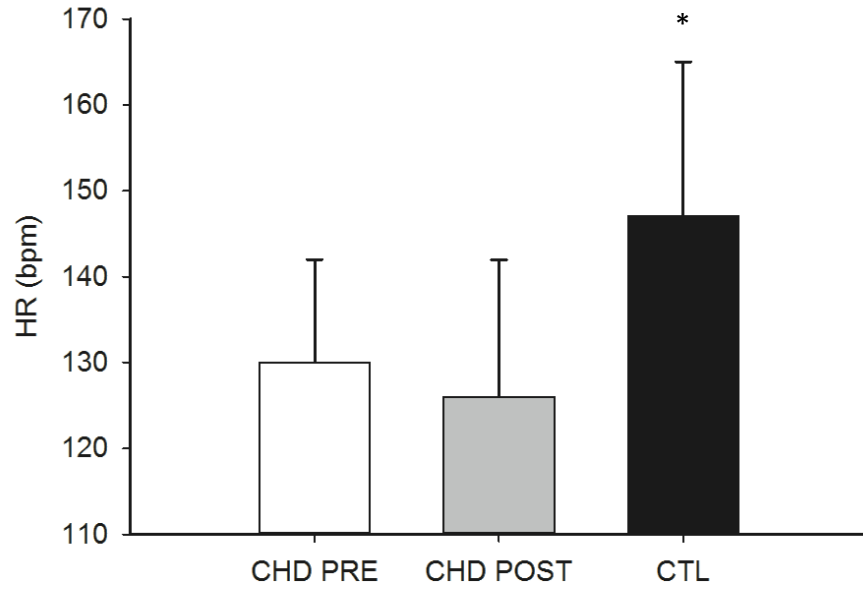


Figure 2.13: Submaximal heart rate (HR) at stage 2 (50W). Pre- and post- training HR at stage 2 in children with CHD ($n = 9$) compared to CTL ($n = 8$). *CTL significantly higher compared to pre- ($p = 0.04$; $d = 0.96$) and post- training ($p = 0.02$; $d = 1.07$). Pre- vs post-training ($p = 0.20$; $d = 0.33$). Values are mean \pm SD.

CHAPTER THREE: DISCUSSION

3.1 Main Findings

For the first time, we characterized TOI, $\dot{V}O_2$ and HR responses in children with CHD during submaximal and maximal exercise before and after a novel exercise intervention including primarily lower-body resistance training, supplemented with aerobic and play exercises. We found, contrary to previous research, that TOI was further decreased during exercise post-training compared to pre-training in children with CHD and compared to healthy CTLs. This response was demonstrated at maximal exercise (peak $\dot{V}O_2$), as well as submaximal exercise (stage 2, 50W). The exaggerated TOI decrease occurred without significant changes in submaximal or maximal $\dot{V}O_2$ or HR post-training, indicating a potential imbalance between central and peripheral adaptations to strength-based exercise training in children with CHD.

Our findings suggest that peripheral mechanisms associated with exercise intolerance in children with CHD can be isolated and manipulated using a strength-based exercise intervention. Our results add important information to a limited research area. The ability to determine mechanisms that may improve exercise tolerance, and subsequently isolate them is a vital tool in effective exercise rehabilitation for children with CHD.

3.1.1 Exercise adaptations in children with CHD compared to CTL

Comparing children with CHD to healthy peers serves as a benchmark for intervention effectiveness. In the present study, TOI was higher at all exercise time points in CTL compared to CHD. As we expected, our CTL group had little impairment in central (cardiac output, stroke volume) or peripheral (microvascular dysfunction) factors that may affect their ability to exercise. Despite no significant differences pre-training, post-training maximal TOI in children with CHD was significantly lower than CTL with a large effect size. This was contrary to our hypothesis, where we expected our exercise intervention to improve TOI values in children with CHD compared to CTL. This has not yet been demonstrated in children with CHD; however, it has been shown in healthy individuals. Both in young healthy males (5) and competitive cyclists (17), TOI decreased to lower levels during exercise after an exercise intervention. Similar to both Costes et

al. (5) and Neary et al. (17) we attribute our further impaired TOI response post-training to peripheral factors such as improved capillary and mitochondrial density, resulting in an increased O_2 flux and A-V O_2 difference. Our results are a positive indication that peripheral mechanisms can be altered in children with CHD similarly to that of healthy individuals.

Submaximal and maximal $\dot{V}\text{O}_2$ was unchanged pre- vs post-training in children with CHD. However, compared to our CTL group, children with CHD had a significantly lower peak $\dot{V}\text{O}_2$, as well as $\dot{V}\text{O}_2$ at stage 1 and 2 pre- and post-training, with large effect sizes. Our CTL group had an average peak $\dot{V}\text{O}_2$ of 48 mL/kg/min, representing a high fit sample which may have influenced our data comparisons. Previous studies have included a non-training group of children with CHD to act as the CTL group instead of healthy children (8, 15). In doing this, baseline $\dot{V}\text{O}_2$ levels were more closely matched, and comparisons were more applicable to specific CHD lesion type. However, comparisons to individuals without altered cardiac morphology are valuable in attempting to bridge the gap in exercise tolerance. Previous work has shown individuals with CHD tend to have peak $\dot{V}\text{O}_2$ values 50% lower than that of healthy age- and sex-matched controls (11). As exercise tolerance is a significant predictor of mortality (6, 16), future studies should continue to compare CHD and healthy CTL groups, and include better matching of physical activity between groups.

Similarly, despite no change in HR pre- vs post-training in children with CHD, HR at peak $\dot{V}\text{O}_2$, as well as stages 1 and 2, was lower pre- and post-training in children with CHD compared to CTL. This may be explained by differing baseline fitness levels, in addition to the cardiovascular structural differences present. Chronotropic incompetence is common in individuals with CHD (18); therefore, it may be more useful to compare HR responses to exercise training to a control group of children with CHD. Three CHD participants had a pacemaker, which may further influence HR responses to exercise. Therefore, our HR results are taken with caution.

3.2 Strengths of Exercise Prescription

Currently, there is no pediatric cardiac rehabilitation program established in Canada. Our study aim was to create an exercise intervention that would be effective in improving exercise tolerance, in addition to creating an enjoyable active environment for children with CHD. There are a limited number of studies that have designed their intervention around these considerations. Longmuir et al. (13) implemented a program focused on real-world play-based activities in addition

to healthy lifestyle education in a sample of children with the Fontan circulation (a complex CHD type). Although the program improved motor skill and moderate-vigorous physical activity minutes, there was no change in peak $\dot{V}O_2$ (13). This was likely due to the absence of a fitness training component within the program (13). Rhodes et al. (20) not only prioritized play-based activities, but also included bodyweight aerobic exercise and resistance exercise using weights and elastic bands in a heterogeneous group of children with CHD. The intervention increased peak $\dot{V}O_2$ by approximately 4 mL/kg/min (20), but did not directly measure peripheral mechanisms associated with exercise tolerance. The present study included similar components of exercise prescription and improved upon them by including gold standard direct measurements of central ($\dot{V}O_2$) and peripheral (TOI via NIRS) mechanisms associated with exercise tolerance. In addition, through observing measures during both submaximal and maximal exercise we covered a broad spectrum of exercise intensities that may be used for various tasks throughout daily life and therefore enhanced the applicability of our results. Our intervention also included lower-body resistance exercises that are important for numerous daily activities such as climbing stairs and playing on the playground. Using the results from our study, we are able to better understand how both peripheral and central mechanisms play a daily role in reduced exercise tolerance in children with CHD.

Accessibility was a strength of our exercise intervention. As many families with children with CHD live in rural and remote communities in Saskatchewan, they face additional barriers that need to be taken into account when designing an exercise program. Home-based exercise programming allowed our intervention to benefit a larger demographic in our province. Specifically, the sessions included bodyweight exercises and did not require large amounts of space to lessen the barriers of socio-economic status. In turn, we also aimed to give ample alternative options for exercise progressions. Education on household items that could be used to increase the intensity of an exercise gave the children an opportunity to be resourceful as well as creative in their own physical activity.

Our exercise program was straightforward and designed to be easy to understand for children and their parents. Children were given booklets with step-by-step instructions for each session to encourage independence and ownership of their own fitness. Exercise intensity followed descriptive ratings of perceived exertion scale, instead of heart rate range (7–9), dyspnea threshold

(1) or percentage of peak $\dot{V}O_2$ (4, 15) to avoid the reliance on parents/guardians to measure exercise intensity. This was also a key component in maintaining compliance to the program.

Parents, other family members, and friends were encouraged to get involved in the exercise program. Involving a social aspect to the program aided in motivation and compliance for those children who had additional supports. For children who completed the programming on their own, follow-ups and in-person sessions were prioritized to help guide them through the intervention.

Our patient-focused exercise intervention can serve as a model for future programs. Ensuring that the intervention can be applied to real-world programming and also translate into exercise tolerance benefits should be at the forefront of future study design of exercise prescription for children with CHD.

3.3 Clinical Relevance

The current study has the potential to influence future chronic disease management programming for children with CHD. We have shown that practical exercise programming, completed in the convenience of the participant's home may be effective in mitigating peripheral mechanisms related to exercise intolerance in children with CHD. Further investigation of these mechanisms before and after exercise training will aid in ensuring rehabilitation is effective in targeting and improving exercise limitations for these children. We demonstrate that the balance between creating an intervention focused on improving patient access and program feasibility, in addition to an intervention suitable for research design is possible. We hope that this program can serve a greater purpose as a model for a CHD-specific exercise rehabilitation program, as well as specific exercise guidelines for children with CHD. Development of such programs should be a priority, to ensure the health and well-being of the increasing population of individuals with CHD.

3.4 Areas for Improvement

3.4.1 Sample size and participant characteristics

The size of our sample could be perceived as a limitation. Recruitment proved to be a challenge due to a number of eligible participants living a substantial distance from the study location, rendering travel for pre- and post-testing unrealistic. Another limitation was our heterogeneous sample. Ideally, grouping participants based on lesion type or severity would allow for more precise and generalizable results. The advantages of a homogenous sample have been

previously demonstrated in children with Fontan circulation (4, 14, 19) and Tetralogy of Fallot (24). However, again due to the smaller population of children with CHD in our region, patients were grouped in order to increase the sample size.

3.4.2 Methodology

The addition of a CHD control group and a healthy CTL training group would have strengthened the results of our study by allowing further comparison of the effectiveness of the exercise intervention. To account for the potential influence of pre-study fitness, CHD and CTL participants should be matched for physical activity levels. Our study ran in two sections, beginning in two different seasons which may have also influenced pre-study fitness level. One group began the intervention in September after summer vacation, and the other began in January after school break. Including direct measures of muscle mass and strength such as dual x-ray absorptiometry (DEXA) and/or maximal voluntary contraction knee extension exercise would help to corroborate the effectiveness of our intervention as well as inferences about TOI post-training. A direct measure of blood flow would also strengthen our study by providing an additional measurement of cardiac mechanisms of exercise tolerance.

Our wide age range may also influence our results. The difficulty of obtaining and identifying peak data from young children due to short attention spans and poor motivation has been described previously (23). In the case of our participants younger than 10 years old, it was difficult to maintain maximal effort level and prevent the participant from stopping prematurely. There was also a learning curve in using the ergometer for the exercise test, as it was difficult for the younger participants to understand that they needed to maintain a consistent pedalling rate throughout the test. With varying participant ages, maturation and body size must also be taken into account when interpreting results. Armstrong et al. (2) classified boys and girls into appropriate maturity stages, and found that more mature boys and girls had significantly higher peak $\dot{V}O_2$ values compared to those less mature, likely due to a greater muscle mass (2). Although we did not account for maturation, exploratory analysis using allometric scaling was used to partition out any influence body size or lean mass had on peak $\dot{V}O_2$ values. Exploratory analysis did not reveal any differing trends between pre- and post-training in children with CHD and compared to CTL. It would be beneficial for future studies to incorporate a measure of maturity, and/or have more

stringent inclusion criteria for age, to reduce any potential influences maturity and body size may have.

3.4.3 Exercise intervention

An important factor to consider when designing an exercise program is whether the program can be generalized to all participating. It is well documented that individuals with low baseline fitness demonstrate the largest overall gains after a training program (3, 21), with the majority of improvement realized in the first 4-12 weeks of training (22). Exploratory analysis revealed children with CHD with a baseline peak $\dot{V}O_2$ less than 35 mL/kg/min tended to have an increase in peak $\dot{V}O_2$ of 2-3mL/kg/min post-training. In contrast, participants with a baseline peak $\dot{V}O_2$ greater than 35 mL/kg/min saw little to no improvement in peak $\dot{V}O_2$ scores. As our intervention was only 12 weeks long, it is possible that only those who had lower baseline fitness were able to gain more from our program. Interestingly, the majority of participants with low baseline fitness tended to have complex CHD lesions, whereas participants with higher baseline fitness tended to have simple CHD lesions. It has also been shown that patients in cardiac rehabilitation programming had greater gains in exercise tolerance when completing 36 or more exercise sessions (22). Our large inclusion criteria for compliance (60%, or 22/36 exercise sessions) may have masked any significant changes for those who completed all 36 sessions. Therefore, a larger sample size would allow more stringent inclusion criteria for compliance and may unmask further improvements in exercise tolerance. In the case of our least fit participant (baseline peak $\dot{V}O_2$ 24 mL/kg/min) with a complex CHD lesion (Tetralogy of Fallot), completed 100% of prescribed exercise sessions. Post-training, this participant increased their peak $\dot{V}O_2$ to 28 mL/kg/min. An increase of 4 mL/kg/min is significant, as every 1 mL/kg/min gain in $\dot{V}O_2$ has been shown to reduce cardiac mortality by 10% (10). Our data shows that not one size fits all when it comes to exercise prescription. Future work should consider baseline peak $\dot{V}O_2$ as an inclusion criterion, as well as more appropriate and specific programming to suit the needs of both low and high fit individuals with CHD and improve quality of life.

Including more frequent check-ins with the participants may have helped to increase compliance and reduce drop out from the program. Specifically, being able to communicate directly with the children, instead of through their parents may have increased motivation. Although videos and detailed cues were given for each of the different exercises, a follow-along

video of the entire exercise session may have made it easier for children to complete sessions independent of parental help. It would also be helpful if children were able to complete the exercise sessions with others participating in the intervention, even if they live in a remote area. Tele-health is a popular emerging format that allows health care to be more accessible to those who live rurally and remotely. Particularly for this demographic, mobile-based physical activity monitoring may be the way of the future in chronic disease management programming. A potential way to bridge these gaps in program administration is the creation of an online/mobile application. Previous studies have shown the effectiveness of mobile physical activity monitoring in patients with COPD (12, 25). An app specific to our children's needs might include secure instant messaging to help the children and the investigator communicate more frequently about questions or concerns regarding the program, as well as a video feature (similar to Facetime) to allow children to complete the exercise sessions together virtually. The application could provide easy access to exercise cues, follow along exercise videos, and could be expanded to include various education topics pertinent to children with CHD. Most importantly, a mobile-based program may help children with CHD feel a sense of community and support through regular interaction with others who have experienced similar physical and mental health challenges. In turn, this may positively influence children with CHD to be proactive about their health throughout their lifetime.

3.5 Future Directions

Future studies should utilize a homogenous sample based on CHD lesion type, baseline fitness level and maturity. Inclusion of a non-training CHD group, as well as a training CTL group to better compare adaptations to a home-based exercise intervention and pinpoint peripheral limitations to exercise intolerance in children with CHD. Measures of peripheral mechanisms, such as TOI via NIRS, should continue to be used to directly measure microvascular adaptations. Improvements to our novel exercise intervention should be taken into consideration for future work, and subsequently be used to create a sustainable evidence-based exercise rehabilitation program for children with CHD.

3.6 Conclusion

The present study demonstrated for the first time a further decrease in exercise TOI after a 12-week home-based exercise intervention, which may be due to improvements in O₂ extraction

and utilization. Our program did not elicit changes in $\dot{V}O_2$ or HR, identifying a potential mismatch in central and peripheral training adaptations. These findings show that feasible and applicable exercise rehabilitation may be effective in improving exercise tolerance in children with CHD. The importance of this research area is highlighted by the lack of rehabilitation resources available for children and adults with CHD, and the increased risk of further chronic disease development later in life. It is imperative that steps are taken promptly to mitigate this gap in health promotion for children with CHD, to increase quality of life and reduce cardiovascular and all-cause mortality risk.

3.7 References

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APPENDIX A: CHD Consent Form



PARTICIPANT INFORMATION AND PARENTAL CONSENT FORM

A Pilot Health Intervention Study of Children with Congenital Heart Defects: CHAMPS – Children’s Healthy Heart Camp in Saskatchewan

PRINCIPAL INVESTIGATOR:

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Dr. Kristi Wright, University of Regina

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Phone: 306-585-4772

Study funded by: Children’s Hospital Foundation of Saskatchewan

INTRODUCTION

Your child is invited to participate in this study because he/she is between the ages of 7-15 and has a clinical diagnosis of a congenital heart defect. This study is looking at the physical and mental health of children with congenital heart defects compared to children without congenital heart defects. The study is also examining a physical activity, heart health and psychological health intervention for children with congenital heart defects.

Your child’s participation is voluntary. It is up to him/her and you to decide whether or not he/she wishes to take part. If your child wishes to participate, you will be asked to sign this form. If he/she does decide to take part in this study, he/she is still free to withdraw at any time and without giving any reasons for the decision.

If your child does not wish to participate in the study, it will not affect his/her medical care in any way. Pediatric cardiologists and clinic staff will not know whether your child chooses to participate or not.

Please take time to read the following information carefully. You can ask the researcher to explain any words or information that you do not clearly understand. You may ask as many questions as you need. Please feel free to discuss this with your family, friends or family physician before you decide.

WHO IS CONDUCTING THE STUDY?

The study is led by Dr. Marta Erlandson, a faculty member in the College of Kinesiology at the University of Saskatchewan. This research is funded by the Children’s Hospital Foundation of Saskatchewan. Neither the University nor any of the investigators will receive any direct financial benefit for conducting this study.

WHY IS THIS STUDY BEING DONE?

Congenital heart defects are the world's leading type of birth defect. Children with congenital heart defects have higher rates of physical inactivity and obesity compared to healthy peers. This may mean that children with congenital heart defects are more likely to have chronic conditions such as heart disease and poor bone health (osteoporosis) later in life. It has also been found that children with congenital heart defects have high levels of anxiety around physical activity participation. While we know that children with congenital heart defects have higher rates of obesity little is known about their muscle, bone and heart health. This study will look at important aspects of the physical and mental health of children with congenital heart defects.

Past research has highlighted the need for programming for children with congenital heart defects that involves healthy lifestyle counseling and physical activity participation. Parents of children with congenital heart defects have reported having minimal resources for knowing how to establish safe levels of physical activity for their children. Currently, there is no such program in Saskatchewan or Canada to help parents and children with congenital heart defects. This study will be the first step in developing a physical activity, heart health and psychological health program for children with congenital heart defects and their families.

WHO CAN PARTICIPATE IN THE STUDY?

Your child is eligible to participate in this study if he/she is aged 7-15 years and has been cleared to participate by the pediatric cardiology team at the Royal University Hospital (RUH). Your child is not eligible if he/she: (1) had cardiac surgery in the last six months; (2) has cyanotic congenital heart disease; (3) has significant valve disease; (4) has any physical condition limiting physical activity; and/or (5) is unable to complete all the questionnaires.

WHAT DOES THE STUDY INVOLVE?

The study involves two or three parts.

Part 1 involves a single visit to the Physical Activity Complex (PAC) at the University of Saskatchewan in June, July or August. This visit will take approximately four hours. During this visit, your child will be asked to complete a form with his/her personal information (such as name, telephone number, and date of birth) and will also be asked to complete, with your assistance if needed, questionnaires about his/her general health history, physical activity, psychological well-being (health related anxiety questionnaires, mood (mood measurements will assess potential depressive symptoms of you child), and body appreciation), and dietary intake (24-hour recall). Self-reported parental heights and weights will also be recorded. We will measure the following:

- Your child's height, sitting height, weight, waist circumference, and limb length.
- Your child's body composition using DXA (dual energy x-ray absorptiometry). DXA is a scan that is done while your child lies on his/her back on what looks like a padded x-ray table. We will measure his/her total body, hip and spine. The scan assesses total body bone, muscle and fat tissues. The scans take approximately 10 minutes and will expose your child to a minimal amount of radiation (less than 5 μ SV).
- Your child's bone shape and strength using a peripheral quantitative computed tomography (pQCT) and a high resolution peripheral quantitative computed tomography (HRpQCT) scan of his/her non-dominant arm and lower leg (each scan takes about 2 minutes). For these scans your child will sit on a padded chair with his/her arm or leg resting on a support. All tests are painless and non-invasive. pQCT and HRpQCT are forms of x-ray and therefore do emit a small amount of radiation. The total radiation for all measurements (DXA, pQCT, and HRpQCT) is less than 6 μ SV; this is comparable to the amount of background radiation a person receives in five days from naturally-occurring sources in Saskatchewan. For reference a cross-country flight could

expose a person to about 30 μ SV of radiation (<http://www.hc-sc.gc.ca/hc-ps/education/respond/nuclea/measurements-mesures-eng.php>). All scans will be administered by trained and certified personnel.

- Your child's heart health using the following seven tests:
 1. Three small stickers connected with a wire to our computer will be attached to your child's shoulders and stomach. The information from the stickers will tell us about the activity of your child's heart. The stickers are gentle on the skin and are the same ones that the hospital uses when it measures your child's heart activity. We will measure your child's heart activity while he/she lies on his/her back for ten minutes. This test does not cause any discomfort and there are no health risks associated with it.
 2. The health of your child's blood vessels will be measured using a special machine at the same time as the first test. The machine uses a special pen that is placed on the skin to give a picture of your child's blood pressure. Your child will need to lie still for about 5 minutes. This test does not cause any discomfort and there are no health risks associated with it.
 3. Your child's nerves and blood vessels will be tested by having your child squeeze a hand gripper for two minutes. After this we will inflate a blood pressure cuff and will keep it inflated for two to three minutes. While the cuff is inflated we will monitor your child's blood pressure. The handgrip test will be repeated without inflating a blood pressure cuff. During both handgrip tests we will measure blood pressure. This test can cause a slight tingling sensation in the arm from the blood pressure cuff. The sensation goes away when the cuff pressure is released.
 4. Your child's fitness will be tested with a low-intensity walk test to see how far he/she can walk in 6 minutes. Your child will walk at his/her own speed back and forth in a hallway for 6 minutes. We will measure your child's heart rate and blood pressure before and after the walk test. The walk test is safe for those with heart problems because it is of low intensity and your child chooses how fast or slow he/she walks. We will closely monitor your child during the walk test.
 5. Your child's fitness will also be tested using a stationary exercise bike while they breathe through a special mouthpiece that measures how much oxygen they use during exercise. This test will take 5 to 10 minutes. We will measure your child's blood pressure and monitor their breathing and heart activity. This test is also safe for those with heart problems in whom their condition is stable. As an extra precaution, a pediatric resident will monitor this test. This test will take a total of 30 minutes.
 6. Your child's heart structure and function will be assessed using cardiac ultrasound. This assessment will entail your child lying restfully on their side for 30 minutes. During this time, Dr. Timothy Bradley (Pediatric Cardiologist) will use a special ultrasound machine to take pictures of your child's heart. The assessment will entail performing a series of images by placing a probe in different positions over your child's chest. This assessment is very safe, low risk, is entirely non-invasive, and places no stress on your child. This test will take a total of 30 minutes.
 7. Your child's blood vessel function will also be measured using vascular ultrasound. This assessment will be performed while your child is doing the handgrip exercise test described in #3 above. The assessment will entail placing a probe over your child's arm. This assessment is very safe, low risk, is entirely non-invasive, and places no stress on your child. This test will not add any time to your child's session.
- Your child's ability to utilize oxygen during exercise will be measured using near-infrared spectroscopy (NIRS). NIRS uses near-infrared light to provide a measurement of the amount of oxygen used in the muscle. We will place a small NIRS probe on the thigh and wrap it in a cloth to block out room light. NIRS is non-invasive and places no stress on your child. There are no health risks associated with this test.

After the visit to the University, your child will be asked to wear an accelerometer for 7 consecutive days. An accelerometer is a type of motion sensor that measures your child's physical activity. It is a small device that will be worn around your child's waist on an elastic belt. He/she will be asked to put it on first thing in the morning and wear it all day except when bathing, swimming or playing contact sports.

During your visit at the University, you will be provided with an addressed and stamped envelope to return the accelerometer after the seven days of wear.

Your child will also be asked to recall dietary intake in the past 24 hours on three occasions, a weekday and a weekend day prior to the Camp, and a weekday at the Camp, using an online tool called the ASA24-Canada-2016. Parental assistance may be required for younger children. Orientation, username and password will be provided by the researcher at your visit to the University.

Part 2 of the study involves a day-camp. This portion of the study will take place at the College of Kinesiology, University of Saskatchewan from August 10-14th, 2015. The program will run from 9am-5pm and will consist of three parts: (1) physical activity promotion and participation; (2) heart health and health behavior; and (3) psychological well-being. Your child will be grouped based on age: younger (7-12) and older (13-15) and take part in activities that are age-appropriate. The physical activity portion will be of low to moderate intensity and comply with established international recommendations for children with congenital heart defects. Example activities include: swimming and ball and racquet sports. Your child will wear an accelerometer for the week long camp to assess the amount of physical activity. Your child will also engage in sessions on healthy eating, heart health, and how to detect his/her physical limitations (heart health and health behavior part). The psychological wellbeing part will focus on teaching your child healthy psychosocial coping mechanisms with a special emphasis on understanding and coping with anxiety related to physical activity participation. The program will incorporate many important health aspects but will do so in a fun, summer camp style of programming. During the Camp we will also assess your child's physical literacy; their ability to run, jump, throw and catch and have you fill out a questionnaire about your perceptions of their ability to move confidently. To assess your and your child's satisfaction with the program we will ask both of you to fill out a short questionnaire when you pick your child up on the last day. At the end of the sessions, your child will be asked to complete the measures of psychological well-being once again, in the presence of a child psychologist. After the program your child will be mailed an accelerometer to once again wear for seven consecutive days along with an addressed and stamped envelope to return it after the seven days.

Part 3 of this study will include a small sample of parents and children so you may or may not be invited to participate in a focus group held at the Social Science Research Lab at the University of Saskatchewan in late August or early September. The focus group will look at satisfaction with the camp, what participants liked and would like to see changed in future programming.

Part 4 of this study will include home-based exercise sessions that last 20-30 minutes 3 times per week for 12 weeks, in addition to biweekly psychology and physical activity sessions led by researchers at the University of Saskatchewan. The researcher will conduct weekly follow ups by phone or in person to aid in adherence to the program, as well as assistance with program sessions. Detailed instructions for completing each session will be given to participants.

The pediatric cardiologist will be consulted prior to beginning the the home-based program to ensure there are no restrictions for exercise for your child.

Home exercise sessions will include both light aerobic and strength exercise components. Briefly, each session will include **20 minutes** aerobic exercises in the form of brisk walking or stationary bike riding (at the Physical Activity Complex when attending bi-weekly psychology sessions). Strength exercise will comprise of activities that utilize participant's own body weight (no equipment is required). Example exercises include squatting up and down, lunges (stepping forward with one leg), stair stepping (up 2 steps, down 2 steps), basic push ups, calf raises (standing on tip toes, return to flat footed position). Over

the course of 12 weeks these exercises will be increased for the number of repetitions completed and will take no longer than **10 minutes**. Total exercise time for a session will be at most 30 minutes.

The volume and type of physical activity performed is the same as what is commonly encountered during normal play activities and during physical education programming in school settings. We highlight that a pediatric cardiologist will confirm exercise suitability for your child before the program begins.

If you consent, we may take photographs of your child during the study that would be used only for research and/or teaching presentations. These photographs would be de-identified so your child's face would not be recognizable.

WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS STUDY?

There may be no direct benefit to your child from participating in this study. Your child will get to participate in the week long program aimed to teach your child how to detect his/her physical limitations with regard to physical activity and provide him/her with the tools cope with health related physical activity anxiety and hopefully empower him/her to be more physically active. It is hoped that the information gained from this study can be used in the future to create a sustainable program for children with congenital heart defects.

ARE THERE POSSIBLE RISKS AND DISCOMFORTS?

The risks of participating are minimal. The fitness test on a stationary bike will assess your child's exercise capacity. During this test, your child may feel a few minutes of physical fatigue that comes with exercise. They also may experience some leg soreness as a consequence of this test, but this should disappear within 2 days. This stationary bike test is safe and the intensity of how hard your child exercises is determined by your child. As an extra precaution, a pediatric resident will supervise the stationary bike test. As stated above, the bone measures (DXA, pQCT and HRpQCT) will expose your child to a minimal amount of radiation. These tests are very low risk; the total radiation dose for each study visit is less than half of that of a standard chest x-ray. As with any physical activity there is the potential of physical injury or discomfort. Your child may experience sore muscles after the six minute walk test. If your child experiences soreness it will not last very long. We have taken every precaution to ensure all physical activity during the camp will be safe for your child and a pediatric resident will be at the weeklong camp in the unlikely event that medical attention is needed. The depressive symptoms questionnaire will ask questions about your child's feelings and ideas and this may be a sensitive topic for some children. We will show you the questionnaire prior to your child completing it, in order to allow you to pre-screen your comfort level with the sensitive questions that will be posed to your child. You can choose to have your child not complete this questionnaires or specific questions within the questionnaire. If you choose this, your child can still participate in other aspects of the study.

WHAT HAPPENS IF I DECIDE TO WITHDRAW?

Your child's participation in this research is voluntary. He/she may withdraw from this study at any time. You do not have to provide a reason. Your child's relationship with the department of pediatric cardiology will not be affected and pediatric cardiologists and clinic staff will not be informed.

If your child chooses to enter the study and then decides to withdraw later, all data collected about him/her during his/her enrolment will be retained for analysis.

WHAT WILL THE STUDY COST ME?

You will not be charged for any research-related procedures and your child will not be paid for participating in this study. Your parking costs at the University for the Part 1 visit will be covered.

WHAT HAPPENS IF SOMETHING GOES WRONG?

In the unlikely event that your child is injured while participating in this research, appropriate medical care will be provided at no cost to you. By signing this document, you and your child do not waive any of your legal rights.

WILL MY TAKING PART IN THIS STUDY BE KEPT CONFIDENTIAL?

Your child's confidentiality will be respected. No information that discloses your child's identity will be released or published without your specific consent to the disclosure. The information collected in this study will be stored in the locked office of the PI, Dr. Marta Erlandson. The results of this study may be presented in a scientific meeting or published, but your child's identity will not be disclosed. If you consent we may use de-identified photographs of your child for the purpose of research and/or teaching presentations.

WHO DO I CONTACT IF I HAVE QUESTIONS ABOUT THE STUDY?

If you have any questions or desire further information about this study before or during participation, you can contact Marta Erlandson by phone at 306-966-1071 or by email at marta.erlandson@usask.ca.

If you have any concerns about your child's rights as a research participant and/or your experiences while participating in this study, contact the Chair of the University of Saskatchewan Research Ethics Board, at 306-966-2975(out of town calls 1-888-966-2975). The Research Ethics Board is a group of individuals (scientists, physicians, ethicists, lawyers and members of the community) that provide an independent review of human research studies. This study has been reviewed and approved on ethical grounds by the University of Saskatchewan Research Ethics Board.



A Pilot Health Intervention Study of Children with Congenital Heart Defect: CHAMPS – Children’s Healthy Heart Camp in Saskatchewan

- I have read (or someone has read to me) the information in this consent form.
- I understand the purpose and procedures and the possible risks and benefits of the study.
- I was given sufficient time to think about it.
- I had the opportunity to ask questions and have received satisfactory answers.
- I understand that my child is free to withdraw from this study at any time for any reason.
- I have been informed that there is no guarantee that this study will provide any benefits to my child.
- I give permission to the use and disclosure of my child’s de-identified information collected for the research purposes described in this form.
- I understand that by signing this document I do not waive any of my or my child’s legal rights.
- I understand I will be given a signed copy of this consent form.

I agree to allow de-identified photographs of my child to be used for research and/or teaching presentations:

☐ Yes

☐ No

I agree to allow my child to participate in this study:

Printed name of person providing consent: _____

Signature of Consenting Parent: _____ Date _____

Printed name of person obtaining consent: _____

Signature _____ Date _____

APPENDIX B: CTL Consent Form



PARTICIPANT INFORMATION AND PARENTAL CONSENT FORM

A Pilot Health Intervention Study of Children with Congenital Heart Defects: CHAMPS – Children's Healthy Heart Camp in Saskatchewan

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Dr. Kristi Wright, University of Regina

Email: Kristi.wright@uregina.ca

306-585-4772

Study funded by: Children's Hospital Foundation of Saskatchewan

INTRODUCTION

Your child is being invited to participate in this study because he/she is between the ages of 7-17 and is a healthy child with no history of heart problems. This study is looking at the physical and mental health of children with congenital heart defects compared to healthy children.

Your child's participation is voluntary. It is up to him/her and you to decide whether or not he/she wishes to take part. If your child wishes to participate, you will be asked to sign this form. If he/she does decide to take part in this study, he/she is still free to withdraw at any time and without giving any reasons for the decision.

Please take time to read the following information carefully. You can ask the researcher to explain any words or information that you do not clearly understand. You may ask as many questions as you need. Please feel free to discuss this with your family, friends or family physician before you decide.

WHO IS CONDUCTING THE STUDY?

The study is led by Dr. Marta Erlandson, a faculty member in the College of Kinesiology at the University of Saskatchewan. This research is funded by the Children's Hospital Foundation of Saskatchewan. Neither the University nor any of the investigators will receive any direct financial benefit for conducting this study.

WHY IS THIS STUDY BEING DONE?

Congenital heart defects are the world's leading type of birth defect. Children with congenital heart defects have higher rates of physical inactivity and obesity compared to healthy peers. This may mean that children with congenital heart defects are more likely to have chronic conditions such as heart disease and poor bone health (osteoporosis) later in life. It has also been found that children with congenital heart defects have high levels of anxiety around physical activity participation. While we know that children with congenital heart defects have higher rates of obesity little is known about their muscle, bone and

heart health. This study will look at important aspects of the physical and mental health of children with congenital heart defects compared to healthy peers.

WHO CAN PARTICIPATE IN THE STUDY?

Your child is eligible to participate in this study if he/she is aged 7-17 years and of good health. Your child is not eligible if he/she has any type of heart issues or other health condition that affects his/her ability to perform physical activity.

WHAT DOES THE STUDY INVOLVE?

If your child decides to participate in the study it will involve a single visit to the Physical Activity Complex (PAC) at the University of Saskatchewan. The visit will take approximately four hours. Your child will be requested to complete a form with his/her personal information (such as name, telephone number, and date of birth) and will also be asked to complete, with your assistance if needed, questionnaires regarding his/her general health history, physical activity, psychological well-being (health related anxiety and **body appreciation** questionnaires) and dietary intake (24-hour recall). Self-reported parental heights and weights will also be recorded. We will measure the following:

1. Your child's height, sitting height, weight, waist circumference, and limb length.
2. Your child's body composition using DXA (dual energy x-ray absorptiometry). DXA is a scan that is done while your child lies on his/her back on what looks like a padded x-ray table. We will measure his/her total body, hip and spine. The scan assesses total body bone, muscle and fat tissues. The scans take approximately 10 minutes and will expose your child to a minimal amount of radiation (less than 5 μ SV).
3. Your child's bone shape and strength using a peripheral quantitative computed tomography (pQCT) and **a high resolution peripheral quantitative computed tomography (HRpQCT)** scan of his/her non-dominant forearm and lower leg (each scan takes about 2 minutes). For these scans your child will sit on a padded chair with his/her arm or leg resting on a support. All tests are painless and non-invasive. pQCT **and HRpQCT are forms** of x-ray and therefore **do** emit a small amount of radiation. The total radiation for all measurements (DXA, pQCT, **and HRpQCT**) is less than **6** μ SV; this is comparable to the amount of background radiation a person receives in **five** days from naturally-occurring sources in Saskatchewan. For reference a cross-country flight could expose a person to about 30 μ SV of radiation (<http://www.hc-sc.gc.ca/hc-ps/ed-ud/respond/nuclea/measurements-mesures-eng.php>). All scans will be administered by trained and certified personnel.
4. Your child's heart health using the seven following tests:
 - A) Three small stickers will be attached to your child's shoulders and stomach. The stickers are connected with a wire to our computer and will tell us about your child's heartbeat. The stickers are gentle on the skin. They are the same stickers that the hospital uses when it measures heart activity. The stickers are thrown away after we are done the measure. With the stickers we will measure your child's heart activity while he/she lies on his/her back for ten minutes. This test does not cause any discomfort and there are no health risks associated with this test.
 - B) The second test will measure your child's blood vessels. This will be done using a special machine at the same time as the first test. The machine uses a special pen that is placed on the skin to give a picture of your child's blood pressure. The test will tell us about the health of the blood vessels and requires your child to lie still for about 5 minutes. This test does not cause any discomfort and there are no health risks associated with it.
 - C) The third test will measure how your child's nerves and blood vessels work. This will be done by having your child squeeze a hand gripper for two minutes. After this we will inflate a blood pressure cuff and will keep it inflated for two to three minutes. While the cuff is inflated we will monitor your child's blood pressure. The handgrip test will be repeated without inflating a blood pressure cuff. During both handgrip tests we will measure blood pressure. This test can cause a

slight tingling sensation in the arm from the blood pressure cuff. The sensation goes away when the cuff pressure is released.

D) Your child's fitness will be tested with a low-intensity walk test. We want to know how far your child can walk in 6 minutes. Your child will walk at his/her own speed back and forth in a hallway for 6 minutes. We will measure your child's heart rate and blood pressure before and after the walk test. The walk test is safe for most individuals because it is of low intensity and your child chooses how fast or slow he/she walks. We will closely monitor your child during the walk test and he/she will choose how fast or slow he/she walks.

E) Your child's fitness will also be testing using a stationary exercise bike while they breathe through a special mouthpiece that measures how much oxygen they use during exercise. This test will take 5 to 10 minutes. We will measure your child's blood pressure and monitor their breathing and heart activity. This test is also safe for the general population. This test will take a total of 30 minutes.

F) Your child's heart structure and function will be assessed using cardiac ultrasound. This assessment will entail your child lying restfully on their side for 30 minutes. During this time, Dr. Timothy Bradley (Pediatric Cardiologist) will use a special ultrasound machine to take pictures of your child's heart. The assessment will entail performing a series of images by placing a probe in different positions over your child's chest. This assessment is very safe, low risk, is entirely non-invasive, and places no stress on your child. This test will take a total of 30 minutes.

G) Your child's blood vessel function will also be measured using vascular ultrasound. This assessment will be performed while your child is doing the handgrip exercise test described in #3 above. The assessment will entail placing a probe over your child's arm. This assessment is very safe, low risk, is entirely non-invasive, and places no stress on your child. This test will not add any time to your child's session.

5. Your child's ability to utilize oxygen during exercise using near-infrared spectroscopy (NIRS). NIRS uses near-infrared light to provide a measurement of the amount of oxygen used in the muscle. We will place a small NIRS probe on the thigh and wrap it in a cloth to block out room light. NIRS is non-invasive and places no stress on your child. There are no health risks associated with this test.

After the visit to the University, your child will also be asked to wear an accelerometer for 7 consecutive days. An accelerometer is a type of motion sensor that measures your child's physical activity. It is a small device that will be worn around your child's waist on an elastic belt. He/she will be asked to put it on first thing in the morning and wear it all day except when bathing, swimming or playing contact sports. During your visit at the University you will be provided with an addressed and stamped envelope to return the accelerometer after the seven days of wear.

Your child will also be asked to recall dietary intake in the past 24 hours on three occasions, at the initial appointment and independently for a weekend and weekday. This will be done using an online tool called the ASA24-Canada-2016. Parental assistance may be required for younger children. Orientation, username and password will be provided by the researcher at your visit to the University.

WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS STUDY?

There may be no direct benefit to your child from participating in this study. It is hoped that the information gained from this study will positively affect the health of children with congenital heart defects and contribute to the development of a program to promote physical activity and healthy lifestyle counseling for this population.

ARE THERE POSSIBLE RISKS AND DISCOMFORTS?

The risks of participating are the minimal. The fitness test on a stationary bike will assess your child's exercise capacity. During this test, your child may feel a few minutes of physical fatigue that comes with exercise. They also may experience some leg soreness as a consequence of this test, but this should disappear within 2 days. This stationary bike test is safe and the intensity of how hard your child exercises is determined by your child. As stated above the bone measures (DXA, pQCT and HRpQCT) will expose your child to a minimal amount of radiation. The tests are very low risk; the total radiation dose for the study is less than half of that of a standard chest x-ray. As with any physical activity there is a slight risk that your child may experience sore muscles after the six minute walk test. If your child experiences soreness it will not last very long.

WHAT HAPPENS IF I DECIDE TO WITHDRAW?

Your child's participation in this research is voluntary. He/she may withdraw from this study at any time. You do not have to provide a reason.

If your child chooses to enter the study and then decides to withdraw later, all data collected about him/her during his/her enrolment will be retained for analysis.

WHAT WILL THE STUDY COST ME?

You will not be charged for any research-related procedures and your child will not be paid for participating in this study. Your parking costs at the University will be covered.

WHAT HAPPENS IF SOMETHING GOES WRONG?

In the unlikely event that your child is injured while participating in this research, appropriate medical care will be provided at no cost to you. By signing this document, you and your child do not waive any of your legal rights.

WILL MY TAKING PART IN THIS STUDY BE KEPT CONFIDENTIAL?

Your child's confidentiality will be respected. No information that discloses your child's identity will be released or published without your specific consent to the disclosure. The results of this study may be presented in a scientific meeting or published, but your child's identity will not be disclosed.

WHO DO I CONTACT IF I HAVE QUESTIONS ABOUT THE STUDY?

If you have any questions or desire further information about this study before or during participation, you can contact Marta Erlandson by phone at 306-966-1071 or by email at marta.erlandson@usask.ca.

If you have any concerns about your child's rights as a research participant and/or your experiences while participating in this study, contact the Chair of the University of Saskatchewan Research Ethics Board, at 306-966-2975(out of town calls 1-888-966-2975). The Research Ethics Board is a group of individuals (scientists, physicians, ethicists, lawyers and members of the community) that provide an independent review of human research studies. This study has been reviewed and approved on ethical grounds by the University of Saskatchewan Research Ethics Board.



A Pilot Health Intervention Study of Children with Congenital Heart Defects: CHAMPS – Children’s Healthy Heart Camp in Saskatchewan

- I have read (or someone has read to me) the information in this consent form.
- I understand the purpose and procedures and the possible risks and benefits of the study.
- I was given sufficient time to think about it.
- I had the opportunity to ask questions and have received satisfactory answers.
- I understand that my child is free to withdraw from this study at any time for any reason.
- I have been informed that there is no guarantee that this study will provide any benefits to my child.
- I give permission to the use and disclosure of my child’s de-identified information collected for the research purposes described in this form.
- I understand that by signing this document I do not waive any of my or my child’s legal rights.
- I understand I will be given a signed copy of this consent form.

I agree to allow my child to participate in this study:

Printed name of person providing consent: _____

Signature of Consenting Parent: _____ Date _____

Printed name of person obtaining consent: _____

Signature _____ Date _____

APPENDIX C: CHD Assent Form



PARTICIPANT INFORMATION AND ASSENT FORM

A Pilot Health Intervention Study of Children with Congenital Heart Defects: CHAMPS – Children’s Healthy Heart Camp in Saskatchewan

Researchers:

Dr. Marta Erlandson, College of Kinesiology
Email: marta.erlandson@usask.ca
Phone: 306-966-1071

Dr. Kristi Wright, University of Regina
Email: kristi.wright@uregina.ca
Phone: 306-585-4772

Dr. Corey Tomczak, College of Kinesiology
Email: corey.tomczak@usask.ca
Phone: 306-966-1066

Introduction

This form may use words you do not understand. Please ask the person explaining the study to explain any words or information that you do not clearly understand.

You are being asked to take part in a research study because when you were born your heart didn’t work exactly as it was supposed to. The study will help us find out more about your muscle, bone and heart health. It will also help us learn how you feel about participating in physical activity.

A research study is something like a science project in school. The people who are doing this study want to learn something new about children who are born with heart problems like the one you have and how you feel about physical activity and exercise. When the study is over, they will see what kinds of activities are the best for you to participate in. At the end of the study the researchers want you to feel more comfortable and confident in participating in different physical activities at school and with your friends.

What happens in this Study?

The study will be done at the College of Kinesiology on the University Campus. You will come to the university for two times. The first time you come the researchers will ask you to fill in some questionnaires which your parents can help you with if you would like. The researchers will then measure how tall you are, how much you weigh and how long your lower arm and leg are. The researchers will measure your bones using three special imaging machines. One of the machines will take a picture of your whole body while you lay on a bed and the other two will take a picture of your arm and leg bones. The researchers will also measure your heart and the veins and arteries that carry your blood around your body and to your heart using four different tests. For the first test they will put stickers on your shoulders and stomach while you lay on a bed. The stickers will read what your heart is doing, you will not feel anything. For the second test you will have to lie still while the researcher measures your blood vessels with a special pen. Again you will not feel anything while they take this measurement. For the third test, you will squeeze your hand on a special machine for two minutes while the researcher measures your blood pressure. The researcher will also take a picture of your blood vessels. For the fourth test you will be asked to walk at whatever speed you would like for 6 minutes. For the fifth test you will be asked to pedal on a bike your breathing is measured. For the

sixth test you will be asked to lie still while a researcher takes pictures of your heart. For the last test, you will be asked to pedal on a bike while special stickers measure how your muscles work during exercise. You will not feel anything. After finishing these activities the researchers will give you a small device (motion sensor) that you will wear on your hip for seven days.

For the second part of the study you will come back to the College of Kinesiology. This part of the study will be similar to a summer camp. Each day you will participate in different physical activities like swimming and playing in the gym. You will also learn skills to help you feel more comfortable about participating in physical activity as well as healthy eating, heart health, and emotional health.

You will be asked to wear the small motion sensor on your hip for seven days again after the camp has finished.

For the third part of the study, you will be asked to complete exercises at home with the help of your parents or camp counsellors. They will be similar to exercises you have done in gym class and at CHAMPS camp. You will also come back to the College of Kinesiology and participate in activities like swimming and rock climbing. You will also learn about your emotional health.

If you agree the researchers may also take pictures of you while are you participating in the study. The pictures would be used only for research or teaching presentations and your face would be blacked out so no one would be able to recognize you.

You do not have to agree to be in this study.

Withdrawal from Study

You do not have to be in this study and you can stop being in this study at any time. If you say yes now, but change your mind later, you can say no and that will be okay. If you decide not to participate, no one will be upset or disappointed.

ASSENT

I have read this paper or have had it read to me. I understand what I have to do in this study and I agree to take part in it.

Child's Name (Print)

Child's Signature

Date

- ☐ It is okay for the researchers to take my picture
- _____

Check which applies (to be completed by person administering assent):

- ☐ The subject is capable of reading and understanding the assent form and has signed above as documentation of assent to take part in this study.
- ☐ The subject is not capable of reading the assent form, however, the information was explained verbally to the subject who has verbally given assent to take part in this study.

Name of Person Administering Assent (Print)

Signature of Person Administering Assent

Date

APPENDIX D: CTL Assent Form



PARTICIPANT INFORMATION AND ASSENT FORM

A Pilot Health Intervention Study of Children with Congenital Heart Defects: CHAMPS – Children’s Healthy Heart Camp in Saskatchewan

Researchers:

Dr. Marta Erlandson, College of Kinesiology
Email: marta.erlandson@usask.ca
Phone: 306-966-1071

Dr. Kristi Wright, University of Regina
Email: kristi.wright@uregina.ca
Phone: 306-585-4772

Dr. Corey Tomczak, College of Kinesiology
Email: corey.tomczak@usask.ca
Phone: 306-966-1066

Introduction

This form may use words you do not understand. Please ask the person explaining the study to explain any words or information that you do not clearly understand.

You are being asked to take part in a research study because you are a healthy person. The study will help us find out more about your muscle, bone and heart health.

A research study is something like a science project in school. The people who are doing this study want to learn something new about children who are born with heart problems. When the study is over, they will see how muscle, bone and heart health is different in children with heart problems compared to healthy children.

What happens in this Study?

The study will be done at the College of Kinesiology on the University Campus. When you come in the researchers will ask you to fill in some questionnaires which your parents can help you with if you would like. The researchers will then measure how tall you are, how much you weigh and how long your lower arm and leg are. The researchers will measure your bones using **three** special imaging machines. One of the machines will take a picture of your whole body while you lay on a bed and the other **two** will take a picture of your arm and leg bones. The researchers will also measure your heart and the veins and arteries that carry your blood around your body and to your heart using **six** different tests. For the first test they will put stickers on your shoulders and stomach while you lay on a bed. The stickers will read what your heart is doing, you will not feel anything. For the second test you will have to lie still while the researcher measures your blood vessels with a special pen. Again you will not feel anything while they take the measurement. For the third test, you will squeeze your hand on a special machine for two minutes while the researchers measure your blood pressure. The researcher will also take pictures of your blood vessels. For the forth test you will be asked to walk at whatever speed you would like for 6 minutes. For the fifth test you will be asked to pedal on a bike your breathing is measured. For the **sixth** test you will be asked to lie still while a researcher takes pictures of your heart. **For the last test, you will be asked to pedal on a bike while special stickers on your leg measure how your muscles work during exercise. You will not feel anything.** After finishing these

activities the researchers will give you a small device (motion sensor) that you will wear on your hip for seven days. You will also be asked to remember what you ate over three different days and enter it into an online tracker. Your parents can help you fill this out. You will be asked to do this on two weekdays and one weekend day.

You do not have to agree to be in this study.

Withdrawal from Study

You do not have to be in this study and you can stop being in this study at any time. If you say yes now, but change your mind later, you can say no and that will be okay. If you decide not to participate, no one will be upset or disappointed.

ASSENT

I have read this paper or have had it read to me. I understand what I have to do in this study and I agree to take part in it.

Child's Name (Print)

Child's Signature

Date

Check which applies (to be completed by person administering assent):

- ☐ The subject is capable of reading and understanding the assent form and has signed above as documentation of assent to take part in this study.
- ☐ The subject is not capable of reading the assent form, however, the information was explained verbally to the subject who has verbally given assent to take part in this study.

Name of Person Administering Assent (Print)

Signature of Person Administering Assent

Date

Appendix E: Home-Based Exercise Program

2019 CHAMPS – 12 week home based exercise study

PHASE 1: 4 weeks, 3 times per week, 20-30 minute workouts

What is the Rating of Perceived Exertion (RPE) Scale?

- The **RPE** scale is used to measure the intensity of your **exercise**. The **RPE** scale scores how hard something feels to you from 0 – 10.
- “0” is no exertion / difficulty
- “10” is maximal effort / difficulty
- The RPE scale below provides phrases used to rate how easy or difficult you find an activity.

****Please ensure you or your child records the RPE value for each exercise day****

How do I make an exercise feel harder?

(if your RPE is less than 4 – you need to make your RPE between 4 and 6!)

- Try doing the exercise slower
 - o Count one-Mississippi, two-Mississippi, 3- Mississippi as you do your exercise (such as your squat)
- Do extra reps
 - o Do 12-15 reps instead of 10
- If the exercise is timed, do the exercise for longer
 - o Do 30 seconds instead of 20 seconds
 - o walk for 15 minutes instead of 10 minutes
- Reduce the amount of time of rest in between exercises!
 - o Instead of 30 seconds, only wait 15 seconds to begin the exercise again.
 - o Or, instead of 2 minutes, only wait 1 minute to begin the exercise again.

To view entire CHAMPS 12 week program exercises, follow this link:

<https://drive.google.com/open?id=1eSUVcjXiJuoDLyYccohMWWu15H4AkVSo>

Be sure to review your exercise cues for each exercise! These are important so you don't get hurt.

2019 CHAMPS – 12 week home based exercise study

RPE – RATING of PERCEIVED EXERTION SCALE

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

2019 CHAMPS – 12 week home based exercise study

DAY 1: OVERVIEW

WARM UP: Complete the warm up options listed below to get your body ready for exercise!

STRETCH: Then find a space in your home to complete warm up stretches listed on next page.

EXERCISE: Complete entire Day 1 program twice through. You will be doing exercises that target your lower body.

When you exercise, you want to exercise at an RPE intensity of 4-6

****Remember to mark your workout on your workout calendar with a sticker, and record how hard you were working (RPE=____)****

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

2019 CHAMPS – 12 week home based exercise study

DAY 1 – WARM UP & STRETCH

1. Go for a **10-minute brisk walk** or **10-minute jog** (RPE = 4-6). This should be how you would walk when you are in a rush to get somewhere.

OR:

Go up and down your stairs 8 times. Rest for 1 minute. Then go up and down your stairs 8 times **again.**

OR:

Alternate Warm Up

1. 50 jumping jacks
2. 20 high knees
3. 50 jumping jacks
4. 20 butt kicks
5. 50 jumping jacks
6. 20 high knees
7. 50 jumping jacks

https://drive.google.com/open?id=1jB4sFYKAwD2Wp33TSu3j_fhZz3N3H4w

2. Complete the stretches below.
 - Hamstring Stretch – hold for 30 seconds each leg
 - Thigh Stretch – hold for 30 seconds each leg
 - Butterfly Stretch – hold for 30 seconds
 - Calf Stretch – hold for 30 seconds each leg

<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBlBTf10hzQlVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

2019 CHAMPS – 12 week home based exercise study

STRETCHES

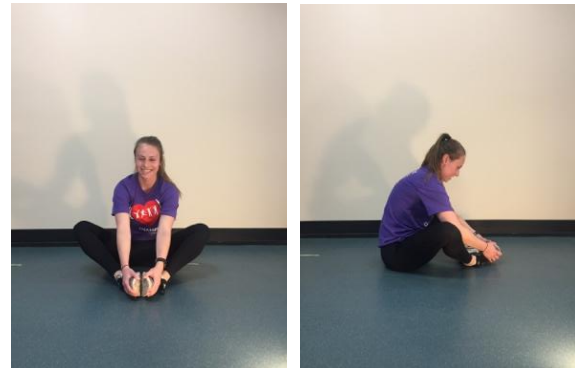
Hamstring Stretch – hold for 30 seconds each leg



Thigh Stretch – hold for 30 seconds each leg



Butterfly Stretch – hold for 30 seconds each leg



Calf Stretch – hold for 30 seconds each leg



2019 CHAMPS – 12 week home based exercise study

Day 1 EXERCISE #1 – SQUATS

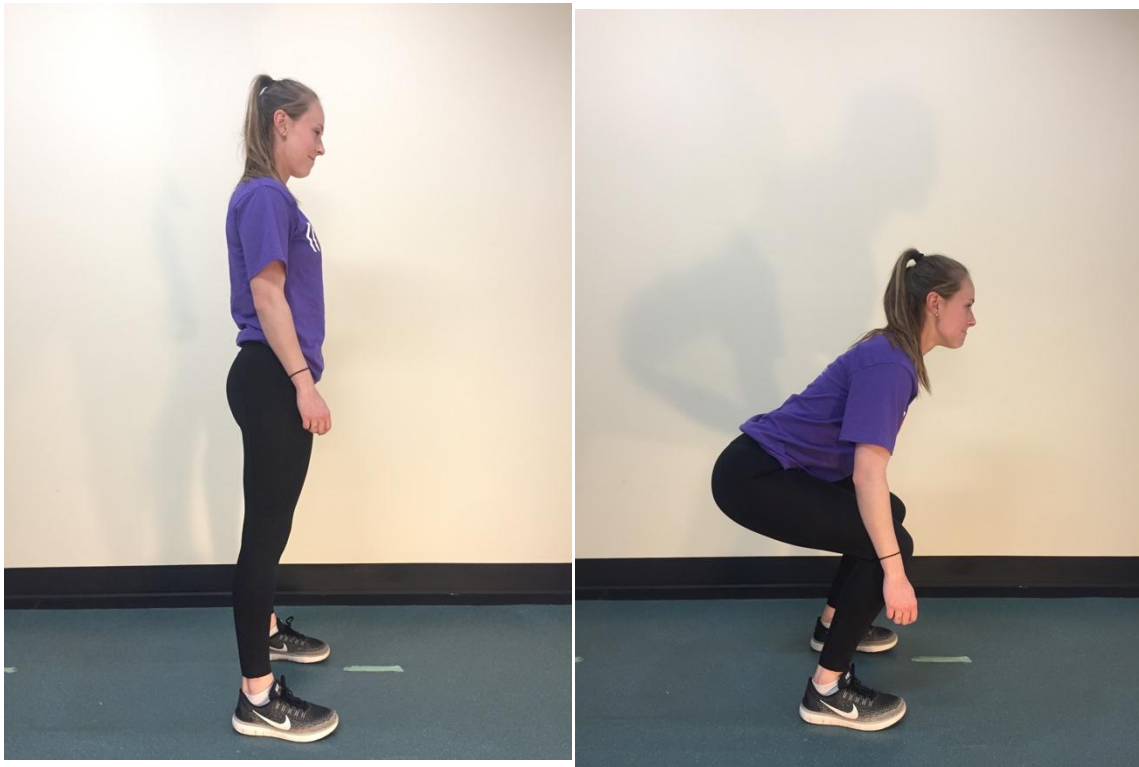
STEP 1 – Do 10 squats. RPE = 4-6.

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 squats.

STEP 4 – Rest for 2 minutes. Then move on to Day 1 Exercise 2.

<https://drive.google.com/open?id=16Yf4leip6wxa3XplGxLm-XXLQt9PpHAt>



Cues:

1. Feet shoulder width apart, or slightly wider than shoulder width apart
2. Stick your butt out, and lower your body as if you were sitting in a chair
3. Make sure your knees DO NOT pass your toes.
 1. If they do, try sticking your butt out more (so you aren't leaning too far forward) or do not go as low into your squat position
4. Try to go as low as a 90 degree angle in your squat position (your legs create a 90 degree angle)
5. Flat back

2019 CHAMPS – 12 week home based exercise study

Day 1 EXERCISE #2 – LUNGES

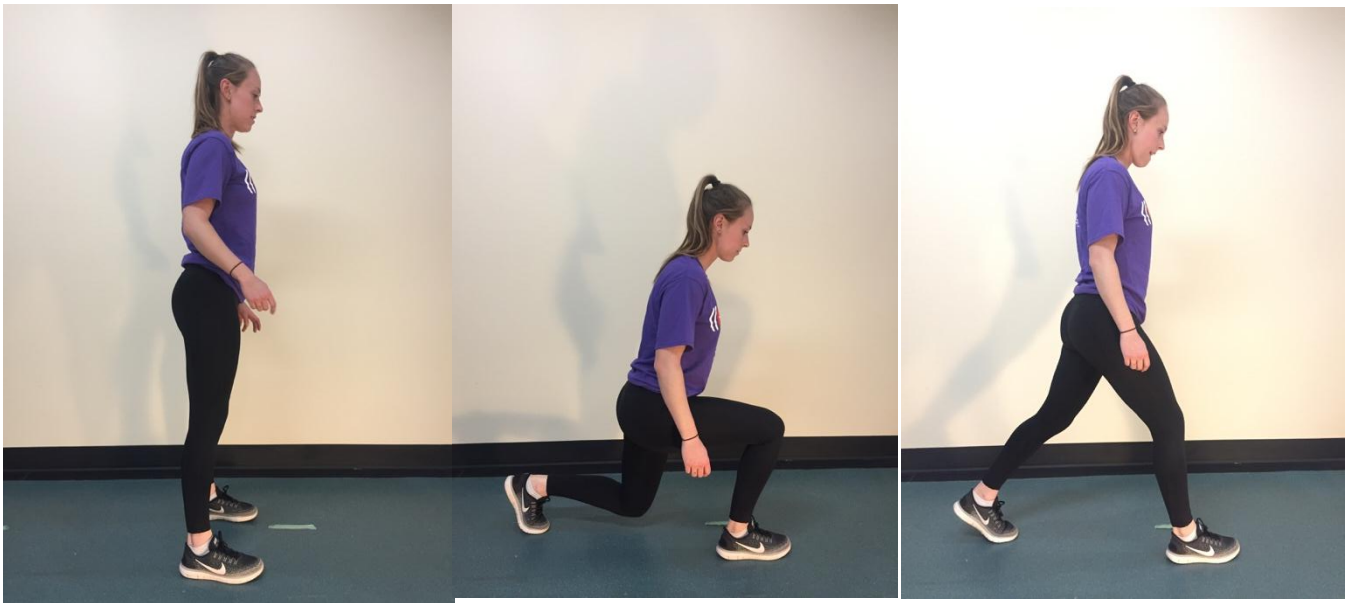
STEP 1 – Do 10 lunges on each leg. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Do another 10 lunges on each leg

STEP 4 – Rest for 2 minutes. Then move on to Day 1 Exercise 3.

<https://drive.google.com/open?id=1iax0ftYO9JZ25h5OirZAIHXNvFluWCE5>



Cues:

1. Make sure both toes pointed forward throughout the entire lunge
2. Make a 90 degree angle with both legs – don't step too far forward or not far enough
3. Drive through your heel and thigh muscle to bring yourself back up from the lunge
4. Flat back

2019 CHAMPS – 12 week home based exercise study

Day 1 EXERCISE #3 – SINGLE LEG SQUAT

STEP 1 – Do 10 single leg squats on each leg. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 single leg squats on each leg.

STEP 4 – Rest for 2 minutes.

https://drive.google.com/open?id=1vrpPQhbVQo2C6Gsu4ycUwOh6qW33_GEz



Cues:

1. Stick out your butt, as if you were sitting in a chair
2. Make sure your knees DO NOT pass your toes.
 - If they do, try sticking your butt out more (so you aren't leaning too far forward) or do not go as low into your squat position
3. The goal is to be able to create a 90 degree angle similar to the squat
 - However it is challenging for single leg squats
 - Only go as low as you can go before your knees pass your toes
4. Balance is important – use a chair or a wall to make sure the only part that is moving is your leg
5. Flat back

*****NOW REPEAT EXERCISES #1, #2, AND #3 ALL OVER AGAIN!***

Once you have done the Day 1 exercise two times then you are done.

Great Job!

2019 CHAMPS – 12 week home based exercise study

DAY 2: OVERVIEW

WARM UP: Complete the warm up options listed below to get your body ready for exercise!

STRETCH: Then find a space in your home to complete warm up stretches listed on next page.

EXERCISE: Complete entire Day 2 program twice through. You will be doing exercises that target your lower body.

When you exercise, you want to exercise at an RPE intensity of 4-6

****Remember to mark your workout on your workout calendar with a sticker, and record how hard you were working (RPE=____)****

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

2019 CHAMPS – 12 week home based exercise study

DAY 2 – WARM UP & STRETCH

1. Go for a **10-minute brisk walk** or **10-minute jog** (RPE = 4-6). This should be how you would walk when you are in a rush to get somewhere.

OR:

Go **up and down your stairs 8 times**. Rest for 1 minute. Then go up and down your stairs 8 times **again**.

OR:

Alternate Warm Up

- 50 jumping jacks
- 20 high knees
- 50 jumping jacks
- 20 butt kicks
- 50 jumping jacks
- 20 high knees
- 50 jumping jacks

https://drive.google.com/open?id=1jB4sFYYKAwD2Wp33TSu3j_fhZz3N3H4w

2. Complete the stretches below.

- Hamstring Stretch – hold for 30 seconds each leg
- Thigh Stretch – hold for 30 seconds each leg
- Butterfly Stretch – hold for 30 seconds
- Calf Stretch – hold for 30 seconds each leg

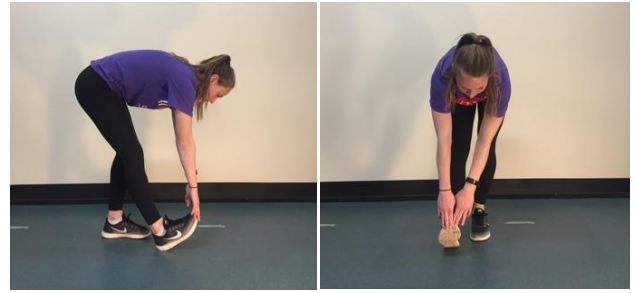
<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBIBTf10hzQIVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

2019 CHAMPS – 12 week home based exercise study

STRETCHES

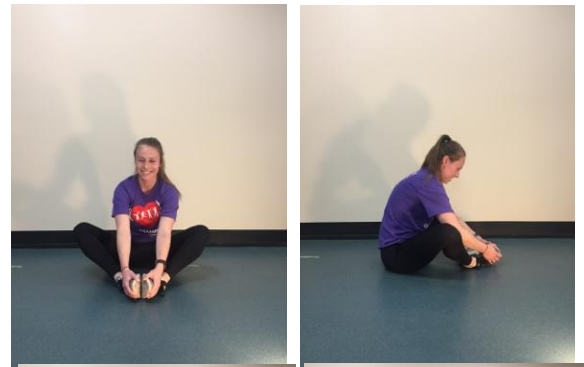
Hamstring Stretch – hold for 30 seconds each leg



Thigh Stretch – hold for 30 seconds each leg



Butterfly Stretch – hold for 30 seconds each leg



Calf Stretch – hold for 30 seconds each leg



2019 CHAMPS – 12 week home based exercise study

Day 2 EXERCISE #1 – SQUAT

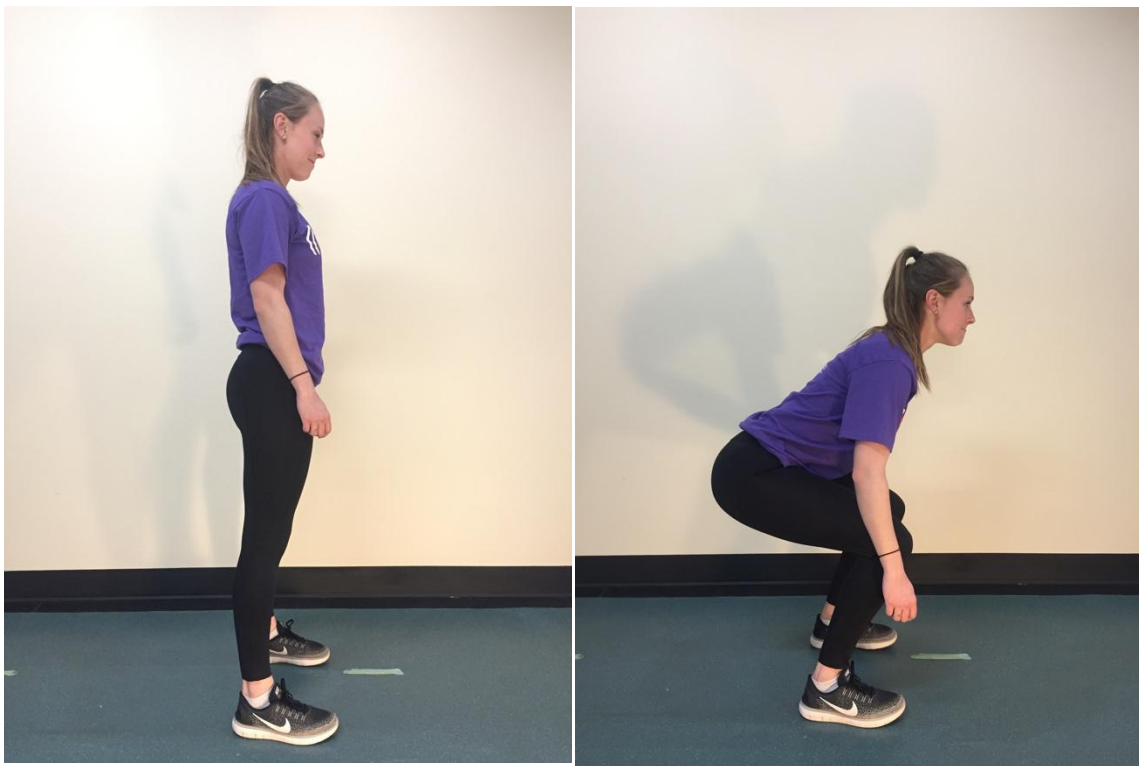
STEP 1 – Do 10 squats. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 squats

STEP 4 – Rest for 2 minutes. Then move on to Day 2 Exercise 2.

<https://drive.google.com/open?id=14ha5OeZqm76lpXnJl8XTYzh3F4L65xy8>



Cues:

1. Feet shoulder width apart, or slightly wider than shoulder width apart
2. Stick your butt out, and lower your body as if you were sitting in a chair
3. Make sure your knees DO NOT pass your toes.
 - If they do, try sticking your butt out more (so you aren't leaning too far forward) or do not go as low into your squat position
4. Try to go as low as a 90 degree angle in your squat position (your legs create a 90 degree angle)
5. Flat back

2019 CHAMPS – 12 week home based exercise study

Day 2 EXERCISE #2 – SINGLE LEG CALF RAISES

STEP 1 – Do 10 single leg calf raises on each leg. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 single leg calf raises on each leg

STEP 4 – Rest for 2 minutes. Then move on to Day 2 Exercise 3.

https://drive.google.com/open?id=1cil9AYBvWURtB0ZQZdW2GQZo4Tq9_Y_K



Cues:

1. Use your toes and the ball of your foot to raise your heel off the ground
2. Make sure toes are pointing forwards
3. Balance is important – use a chair or a wall to make sure the only part that is moving is your leg
4. Stand tall – be sure to be looking straight ahead, no slouching

2019 CHAMPS – 12 week home based exercise study

Day 2 EXERCISE #3 – WALL SIT

STEP 1 – Do a wall sit for 20 seconds. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another wall sit for 20 seconds

STEP 4 – Rest for 2 minutes.

https://drive.google.com/open?id=1A_G6lzx5uJkz19gG--wmz5mXjxcYr3vg



Cues:

1. Feet shoulder width apart
2. Use the wall to brace your back, while using your thighs to hold you up
3. Make a 90 degree angle with your legs
4. Toes pointed forwards

*****NOW REPEAT EXERCISES #1, #2, AND #3 ALL OVER AGAIN!***

Once you have done the Day 2 exercise two times then you are done.

Great Job!

2019 CHAMPS – 12 week home based exercise study

DAY 3: OVERVIEW

WARM UP: Complete the warm up options listed below to get your body ready for exercise!

STRETCH: Then find a space in your home to complete warm up stretches listed on next page.

EXERCISE: Complete entire Day 3 program twice through. You will be doing exercises that target your lower body.

When you exercise, you want to exercise at an RPE intensity of 4-6

****Remember to mark your workout on your workout calendar with a sticker, and record how hard you were working (RPE=____)****

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

2019 CHAMPS – 12 week home based exercise study

DAY 3 – WARM UP & STRETCH

1. Go for a **10-minute brisk walk** or **10-minute jog** (RPE = 4-6). This should be how you would walk when you are in a rush to get somewhere.

OR:

Go **up and down your stairs 8 times**. Rest for 1 minute. Then go up and down your stairs 8 times **again**.

OR:

Alternate Warm Up

- 50 jumping jacks
- 20 high knees
- 50 jumping jacks
- 20 butt kicks
- 50 jumping jacks
- 20 high knees
- 50 jumping jacks

https://drive.google.com/open?id=1jB4sFYKAwD2Wp33TSu3j_fhZz3N3H4w

2. Complete the stretches below.
 - Hamstring Stretch – hold for 30 seconds each leg
 - Thigh Stretch – hold for 30 seconds each leg
 - Butterfly Stretch – hold for 30 seconds
 - Calf Stretch – hold for 30 seconds each leg

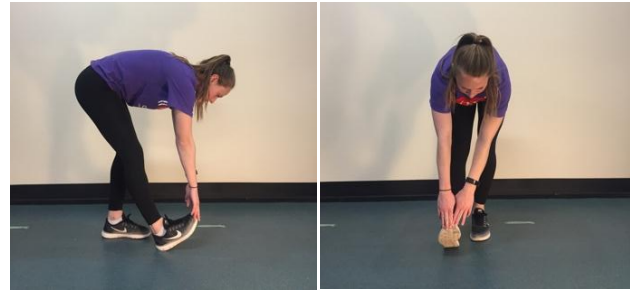
<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBIBTf10hzQIVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

2019 CHAMPS – 12 week home based exercise study

STRETCHES

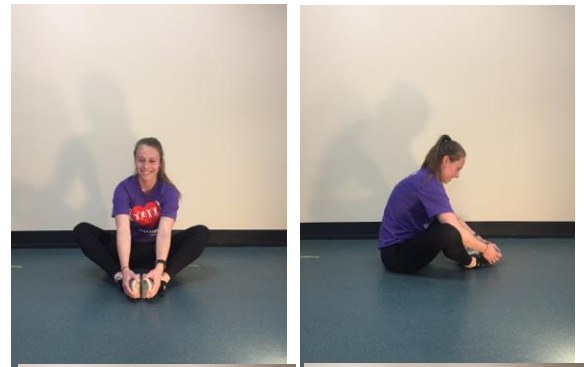
Hamstring Stretch – hold for 30 seconds each leg



Thigh Stretch – hold for 30 seconds each leg



Butterfly Stretch – hold for 30 seconds each leg



Calf Stretch – hold for 30 seconds each leg



2019 CHAMPS – 12 week home based exercise study

Day 3 EXERCISE #1 – MOUNTAIN CLIMBERS

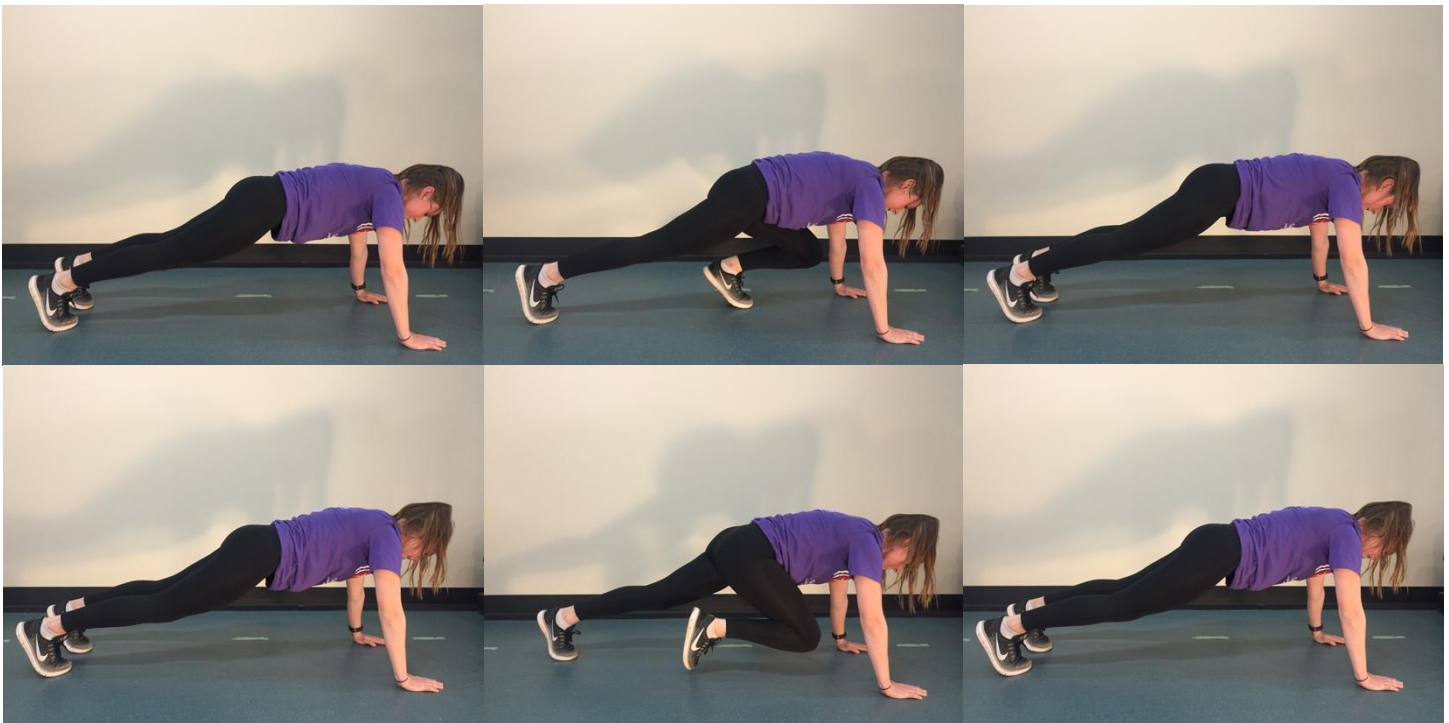
STEP 1 – Do 10 mountain climbers on each leg. RPE = 4-6.

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 mountain climbers on each leg.

STEP 4 – Rest for 2 minutes. Then move on to Day 3 Exercise 2.

https://drive.google.com/open?id=1AQbrdSe_Wis7--rt5tkFmq7OHREP_egI



Cues:

1. Get into a “plank” position
 - Hands should be in line with shoulders
 - Flat back – squeeze your core (no butts in the air!)
2. Drive your left leg (left knee) towards your left elbow – they don’t have to touch. Then switch legs
3. Try to do each leg consecutively – don’t take long pauses between switching legs

2019 CHAMPS – 12 week home based exercise study

Day 3 EXERCISE #2 – STAIR STEP UPS

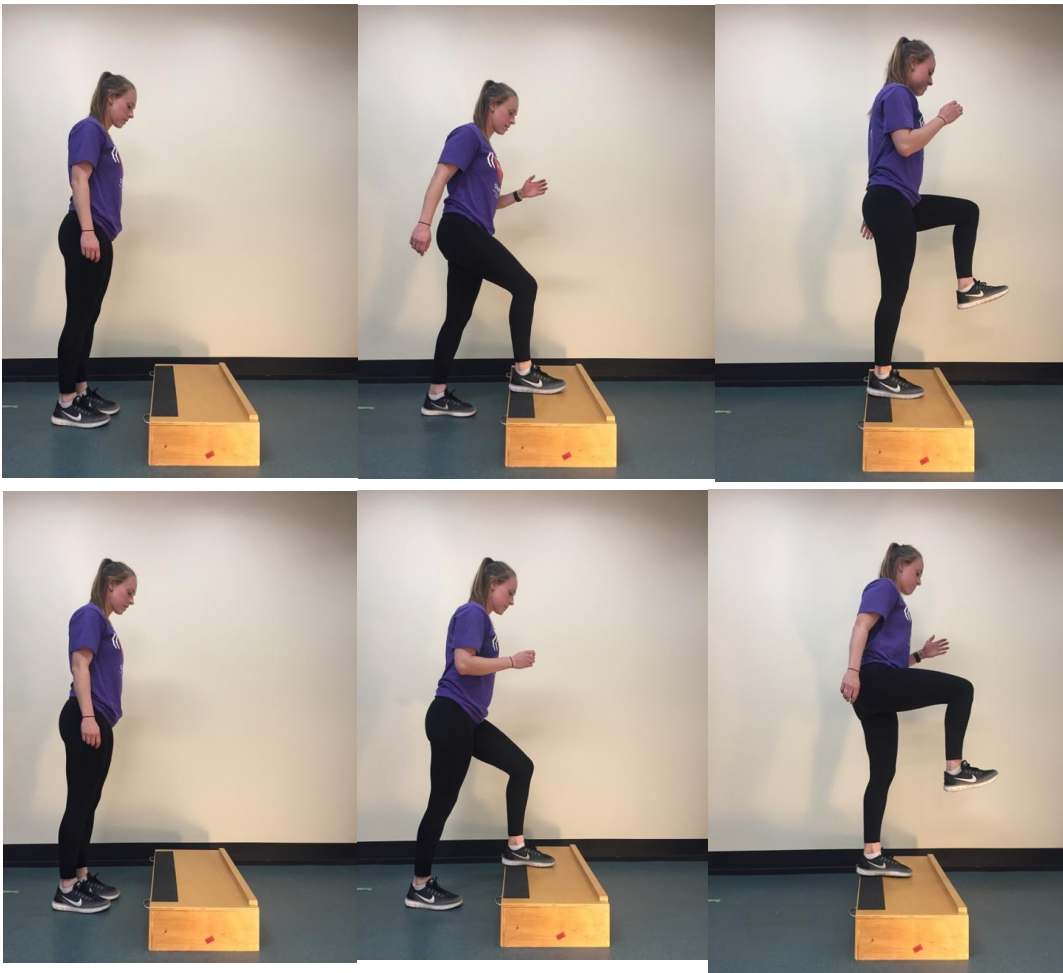
STEP 1 – Do 10 stair step ups on each leg. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 stair step ups on each leg.

STEP 4 – Rest for 2 minutes. Then move on to Day 3 Exercise 3.

<https://drive.google.com/open?id=1cFqPG0R4B56EHTnFXF-BeeW8UdxsEBLP>



Cues:

1. Toes pointed forwards
2. Drive one leg up so your lifted leg is in a 90 degree angle position
3. Use your arms for balance, and to help drive your leg up
4. Stand tall – no slouching. Look straight ahead when stepping

2019 CHAMPS – 12 week home based exercise study

Day 3 EXERCISE #3 – BURPEES

STEP 1 – Do 10 burpees. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 burpees

STEP 4 – Rest for 2 minutes.

<https://drive.google.com/open?id=1hgRN3Y2eqFmCSQIPd1lDyozuytacbraB>



Cues:

1. Jump as high as you can – both at the beginning and end of the burpee
2. When you come down from your jump, get into a “plank” position
 - Hands in line with shoulders
 - Flat back – squeeze your core (no butts in the air!)
3. Modification – if you are unable to “jump back” into the plank position as showed in the video, get into the plank by stepping back one foot at a time. Still ensuring that once you are in the plank to have the proper form as listed above

*****NOW REPEAT EXERCISES #1, #2, AND #3 ALL OVER AGAIN!***

Once you have done the Day 3 exercise two times then you are done.

Great Job!

2019 CHAMPS – 12 week home based exercise study

PHASE 2: 4 weeks, 3 times per week, 30-40 minute workouts

What is the Rating of Perceived Exertion (RPE) Scale?

- The **RPE** scale is used to measure the intensity of your **exercise**. The **RPE** scale scores how hard something feels to you from 0 – 10.
- “0” is no exertion / difficulty
- “10” is maximal effort / difficulty
- The RPE scale below provides phrases used to rate how easy or difficult you find an activity.

****Please ensure you or your child records the RPE value for each exercise day****

How do I make an exercise feel harder?

(if your RPE is less than 4 – you need to make your RPE between 4 and 6!)

- Try doing the exercise slower
 - o Count one-Mississippi, two-Mississippi, 3- Mississippi as you do your exercise (such as your squat)
- Do extra reps
 - o Do 12-15 reps instead of 10
- If the exercise is timed, do the exercise for longer
 - o Do 30 seconds instead of 20 seconds
 - o walk for 15 minutes instead of 10 minutes
- Reduce the amount of time of rest in between exercises!
 - o Instead of 30 seconds, only wait 15 seconds to begin the exercise again.
 - o Or, instead of 2 minutes, only wait 1 minute to begin the exercise again.

To view entire CHAMPS 12 week program exercises, follow this link:

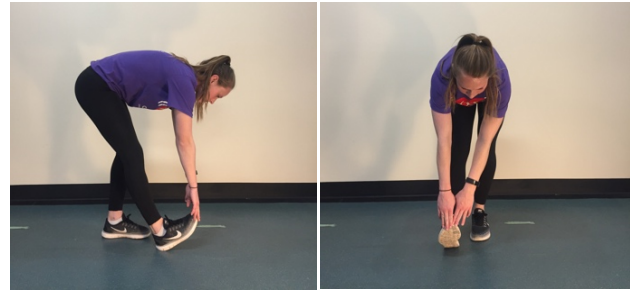
<https://drive.google.com/open?id=1eSUVcjXiJuoDLyYccohMWWu15H4AkVSo>

Be sure to review your exercise cues for each exercise! These are important so you don't get hurt.

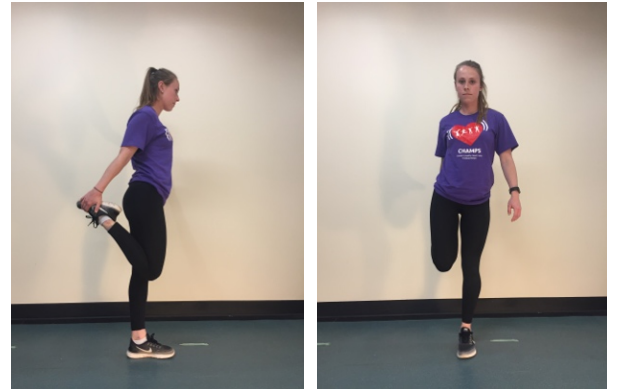
2019 CHAMPS – 12 week home based exercise study

STRECHES

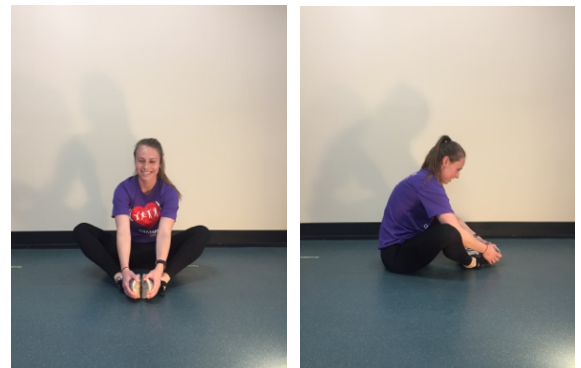
Hamstring Stretch – hold for 30 seconds each leg



Thigh Stretch – hold for 30 seconds each leg



Butterfly Stretch – hold for 30 seconds each leg
Dropbox link



Calf Stretch – hold for 30 seconds each leg



<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBIBTf10hzQIVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

2019 CHAMPS – 12 week home based exercise study

DAY 1: OVERVIEW

WARM UP: Complete the warm up options listed below to get your body ready for exercise!

STRETCH: Then find a space in your home to complete warm up stretches listed on next page.

EXERCISE: Complete entire Day 1 program twice through. You will be doing exercises that target your lower body.

When you exercise, you want to exercise at an RPE intensity of 4-6

****Remember to mark your workout on your workout calendar with a sticker, and record how hard you were working (RPE=____)****

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

2019 CHAMPS – 12 week home based exercise study

DAY 1 – WARM UP & STRETCH

1. Go for a **15-minute brisk walk** or **10-minute jog** (RPE = 4-6). This should be how you would walk when you are in a rush to get somewhere.

OR:

Go **up and down your stairs 10 times**. Rest for 1 minute. Then go up and down your stairs 10 times again.

OR:

Alternate Warm Up

1. 50 jumping jacks
2. 20 high knees
3. 50 jumping jacks
4. 20 butt kicks
5. 50 jumping jacks
6. 20 high knees
7. 50 jumping jacks

https://drive.google.com/open?id=1jB4sFYyKAwD2Wp33TSu3j_fhZz3N3H4w

2. Complete the **stretches** below.
 - Hamstring Stretch – hold for 30 seconds each leg
 - Thigh Stretch – hold for 30 seconds each leg
 - Butterfly Stretch – hold for 30 seconds
 - Calf Stretch – hold for 30 seconds each leg

<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBIBTf10hzQIVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

2019 CHAMPS – 12 week home based exercise study

Day 1 EXERCISE #1 – SQUAT AND HOLD

STEP 1 – Do 10 squats.

→ Hold the squat for **3 seconds** before standing up and starting the next squat.

OR: add weight to your squat. See video link for instructions.

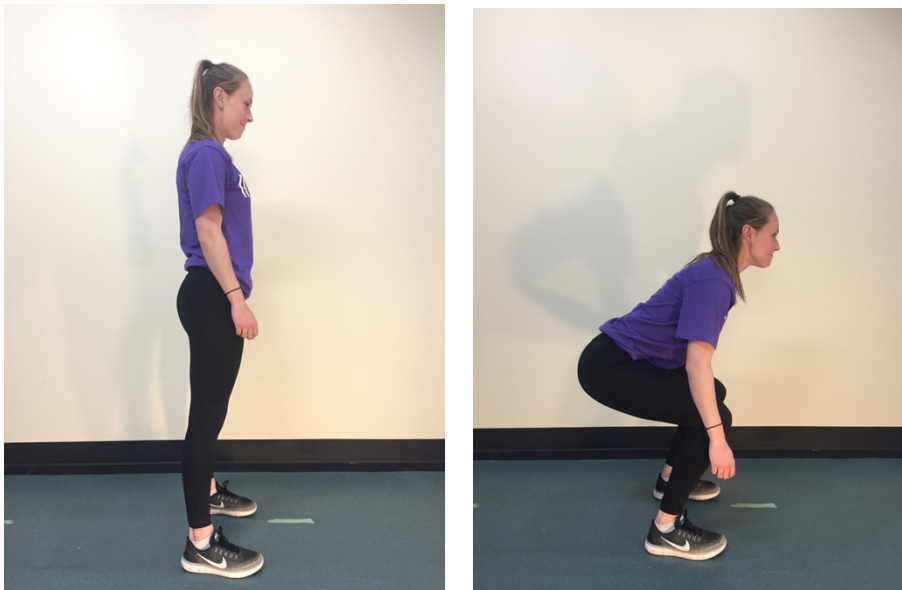
STEP 2 – Rest for 15 seconds

STEP 3 – Then do another 10 squats.

STEP 4 – Rest for 45 seconds. Then move on to Day 1 Exercise 2.

<https://drive.google.com/open?id=16Yf4leip6wxa3XplGxLm-XXLQt9PpHAt>

https://drive.google.com/open?id=1G6XkXFLCqoKgbGL7SU8aBF9rR_tXf87o



Cues:

1. Feet shoulder width apart, or slightly wider than shoulder width apart
2. Stick your butt out, and lower your body as if you were sitting in a chair
3. Make sure your knees DO NOT pass your toes.
 - If they do, try sticking your butt out more (so you aren't leaning too far forward) or do not go as low into your squat position
4. Try to go as low as a 90 degree angle in your squat position (your legs create a 90 degree angle)
5. Flat back

2019 CHAMPS – 12 week home based exercise study

Day 1 EXERCISE #2 – BURPEES

STEP 1 – Do 10 burpees. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 burpees

STEP 4 – Rest for 1 minute. Then move on to Day 1 Exercise 3.

<https://drive.google.com/open?id=1K0scGuD0kOYYu5PhCsXXaL8LJ1Cdip7R>



Cues:

1. Jump as high as you can – both at the beginning and end of the burpee
2. When you come down from your jump, get into a “plank” position
 - Hands in line with shoulders
 - Flat back – squeeze your core (no butts in the air!)
3. Modification – if you are unable to “jump back” into the plank position as showed in the video, get into the plank by stepping back one foot at a time. Still ensuring that once you are in the plank to have the proper form as listed above

2019 CHAMPS – 12 week home based exercise study

Day 1 EXERCISE #3 – LUNGES

STEP 1 – Do 10 lunges on each leg. RPE = 4-6

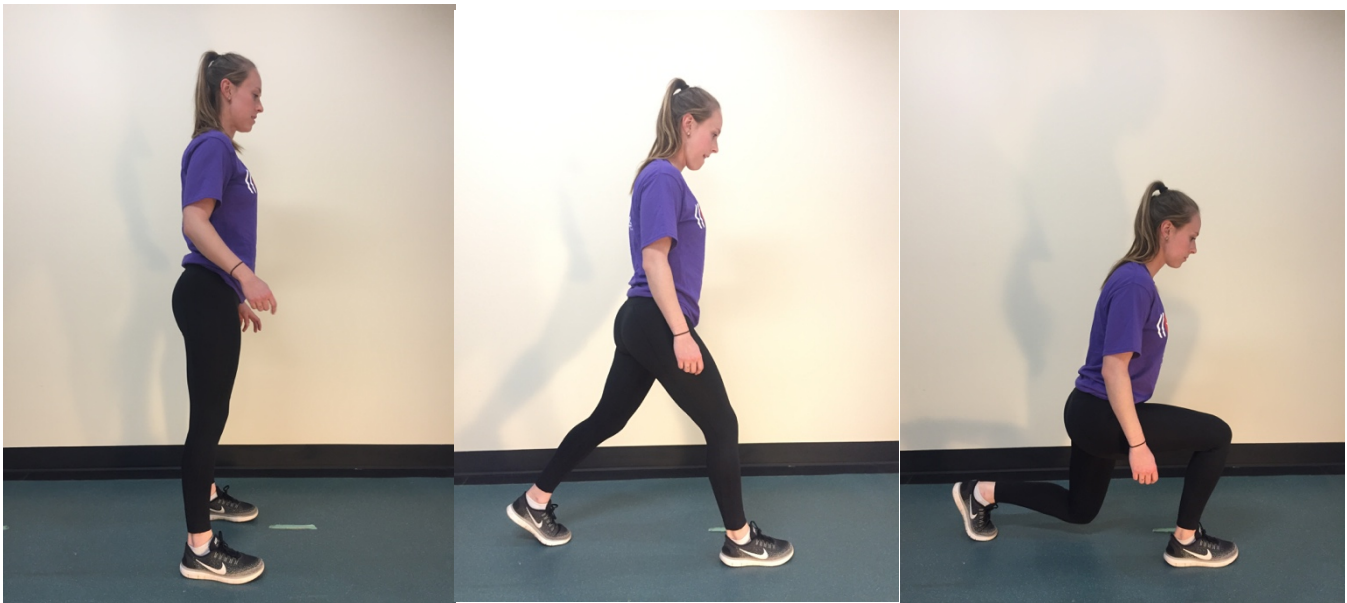
→ To make this exercise harder, you can add weight similar to how you did with the squats.

STEP 2 – Rest for 15 seconds

STEP 3 – Do another 10 lunges on each leg

STEP 4 – Rest for 45 seconds.

<https://drive.google.com/open?id=1LZuYyUkdQ6tqVTRHQuVssWbXwF3YWzef>



Cues:

1. Make sure both toes pointed forward throughout the entire lunge
2. Make a 90 degree angle with both legs – don't step too far forward or not far enough
3. Drive through your heel and thigh muscle to bring yourself back up from the lunge
4. Flat back

*****NOW REPEAT EXERCISES #1, #2, AND #3 ALL OVER AGAIN!***

Once you have done the Day 1 exercise two times then you are done.

Great Job!

2019 CHAMPS – 12 week home based exercise study

DAY 2: OVERVIEW

WARM UP: Complete the warm up options listed below to get your body ready for exercise!

STRETCH: Then find a space in your home to complete warm up stretches listed on next page.

EXERCISE: Complete entire Day 2 program twice through. You will be doing exercises that target your lower body.

When you exercise, you want to exercise at an RPE intensity of 4-6

****Remember to mark your workout on your workout calendar with a sticker, and record how hard you were working (RPE=____)****

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

2019 CHAMPS – 12 week home based exercise study

DAY 2 – WARM UP & STRETCH

1. Go for a **15-minute brisk walk** or **10-minute jog** (RPE = 4-6). This should be how you would walk when you are in a rush to get somewhere.

OR:

Go **up and down your stairs 10 times**. Rest for 1 minute. Then go up and down your stairs 10 times again.

OR:

Alternate Warm Up

- 50 jumping jacks
- 20 high knees
- 50 jumping jacks
- 20 butt kicks
- 50 jumping jacks
- 20 high knees
- 50 jumping jacks

https://drive.google.com/open?id=1jB4sFYKAwD2Wp33TSu3j_fhZz3N3H4w

2. Complete the **stretches** below.

- Hamstring Stretch – hold for 30 seconds each leg
- Thigh Stretch – hold for 30 seconds each leg
- Butterfly Stretch – hold for 30 seconds
- Calf Stretch – hold for 30 seconds each leg

<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBlBTf10hzQlVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

2019 CHAMPS – 12 week home based exercise study

Day 2 EXERCISE #1 – WALL SIT

STEP 1 – Do a wall sit for 30 seconds. RPE = 4-6

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another wall sit for 30 seconds

STEP 4 – Rest for 45 seconds. Then move on to Day 2 Exercise 2.

<https://drive.google.com/open?id=1j-46Flib295fCg1isF-BcpNH8B6jsl0n>



Cues:

1. Feet shoulder width apart
2. Use the wall to brace your back, while using your thighs to hold you up
3. Make a 90 degree angle with your legs
4. Toes pointed forwards

2019 CHAMPS – 12 week home based exercise study

Day 2 EXERCISE #2 – TUCK JUMP

STEP 1 – Do 10 tuck jumps. RPE = 4-6

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another 10 tuck jumps.

STEP 4 – Rest for 45 seconds. Then move on to Day 2 Exercise 3.

https://drive.google.com/open?id=1VWV8liYYyGltwYcDUh_ECKWsSPC4gyF2



Cues:

1. Bring knees as close to your chest as possible
2. Jump as high as you can
3. As soon as you land from your tuck jump, begin your next tuck jump

2019 CHAMPS – 12 week home based exercise study

Day 2 EXERCISE #3 – SINGLE LEG SQUAT

STEP 1 – Do 10 single leg squats on each leg. RPE = 4-6

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another 10 single leg squats on each leg.

STEP 4 – Rest for 45 seconds.

<https://drive.google.com/open?id=12fQNtTN6uNOWVAo30Metna86qTUP8nwy>



Cues:

1. Stick out your butt, and sit back into the chair
2. Make sure your knee DOES NOT pass your toes.
 - If they do, try sticking your butt out more (so you aren't leaning too far forward) or do not go as low into your squat position
3. Sit lightly onto the chair, do not completely sit down when you squat
4. Drive back up to a standing position using your single leg, ensuring you are standing up straight at the end
5. Flat back

*****NOW REPEAT EXERCISES #1, #2, AND #3 ALL OVER AGAIN!***

Once you have done the Day 2 exercise two times then you are done.

Great Job!

2019 CHAMPS – 12 week home based exercise study

DAY 3: OVERVIEW

WARM UP: Complete the warm up options listed below to get your body ready for exercise!

STRETCH: Then find a space in your home to complete warm up stretches listed on next page.

EXERCISE: Complete entire Day 3 program twice through. You will be doing exercises that target your lower body.

When you exercise, you want to exercise at an RPE intensity of 4-6

****Remember to mark your workout on your workout calendar with a sticker, and record how hard you were working (RPE=____)****

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

2019 CHAMPS – 12 week home based exercise study

DAY 1 – WARM UP & STRETCH

1. Go for a **15-minute brisk walk** or **10-minute jog** (RPE = 4-6). This should be how you would walk when you are in a rush to get somewhere.

OR:

Go **up and down your stairs 10 times**. Rest for 1 minute. Then go up and down your stairs 10 times again.

OR:

Alternate Warm Up

- 50 jumping jacks
- 20 high knees
- 50 jumping jacks
- 20 butt kicks
- 50 jumping jacks
- 20 high knees
- 50 jumping jacks

https://drive.google.com/open?id=1jB4sFYKAwD2Wp33TSu3j_fhZz3N3H4w

2. Complete the **stretches** below.
 - Hamstring Stretch – hold for 30 seconds each leg
 - Thigh Stretch – hold for 30 seconds each leg
 - Butterfly Stretch – hold for 30 seconds
 - Calf Stretch – hold for 30 seconds each leg

<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBIBTf10hzQIVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

2019 CHAMPS – 12 week home based exercise study

Day 3 EXERCISE #1 – MOUNTAIN CLIMBERS

STEP 1 – Do 15 mountain climbers on each leg. RPE = 4-6.

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another 10 mountain climbers on each leg.

STEP 4 – Rest for 45 seconds. Then move on to Day 3 Exercise 2.

<https://drive.google.com/open?id=1rNgT7mo6prmLrlbfXjoUJ9ezu1uk49Xr>



Cues:

1. Get into a “plank” position
 - Hands should be in line with shoulders
 - Flat back – squeeze your core (no butts in the air!)
2. Drive your left leg (left knee) towards your left elbow – they don’t have to touch. Then switch legs
3. Try to do each leg consecutively – don’t take long pauses between switching legs

2019 CHAMPS – 12 week home based exercise study

Day 3 EXERCISE #2 – SINGLE LEG CALF RAISES w/hold

STEP 1 – Do 10 single leg calf raises on each leg. RPE = 4-6

→ Hold for **2-3 seconds** before coming back down and beginning next calf raise.

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another 10 single leg calf raises on each leg

STEP 4 – Rest for 45 seconds. Then move on to Day 3 Exercise 3.

<https://drive.google.com/open?id=16M4zjUGMDArZmnUxbzluAjrQQ1h2nzVS>



Cues:

1. Use your toes and the ball of your foot to raise your heel off the ground
2. Make sure toes are pointing forwards
3. Balance is important – use a chair or a wall to make sure the only part that is moving is your leg
4. Stand tall – be sure to be looking straight ahead, no slouching

2019 CHAMPS – 12 week home based exercise study

Day 3 EXERCISE #3 – JUMP SQUATS

STEP 1 – Do 10 jump squats. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 jump squats.

STEP 4 – Rest for 1 minute.

<https://drive.google.com/open?id=1AH79mthtf6ZXAzQ3o9iY2JsWC4-HoDld>



Cues:

1. Make sure you are completing the proper squat technique
2. Jump as high as you can from your squat position
3. When you land, make sure you return to a full squat position, then immediately jump back up to complete another squat jump

*****NOW REPEAT EXERCISES #1, #2, AND #3 ALL OVER AGAIN!***

Once you have done the Day 3 exercise two times then you are done.

Great Job!

2019 CHAMPS – 12 week home based exercise study

PHASE 3 STARTS MARCH 24: 4 weeks, 3 times/week, 30-40 min

→ Please note the **changes** (longer duration or repeat more times) in the program for warm up and exercise sessions.

What is the Rating of Perceived Exertion (RPE) Scale?

- The **RPE** scale is used to measure the intensity of your **exercise**. The **RPE** scale scores how hard something feels to you from 0 – 10.
- “0” is no exertion / difficulty
- “10” is maximal effort / difficulty
- The RPE scale below provides phrases used to rate how easy or difficult you find an activity.

****Please ensure you or your child records the RPE value for each exercise day****

How do I make an exercise feel harder?

(if your RPE is less than 4 – you need to make your RPE between 4 and 6!)

- Try doing the exercise slower
 - Count one-Mississippi, two-Mississippi, 3- Mississippi as you do your exercise (such as your squat)
- Do extra reps
 - Do 12-15 reps instead of 10
- If the exercise is timed, do the exercise for longer
 - Do 30 seconds instead of 20 seconds
 - walk for 15 minutes instead of 10 minutes
- Reduce the amount of time of rest in between exercises!
 - Instead of 30 seconds, only wait 15 seconds to begin the exercise again.
 - Or, instead of 2 minutes, only wait 1 minute to begin the exercise again.

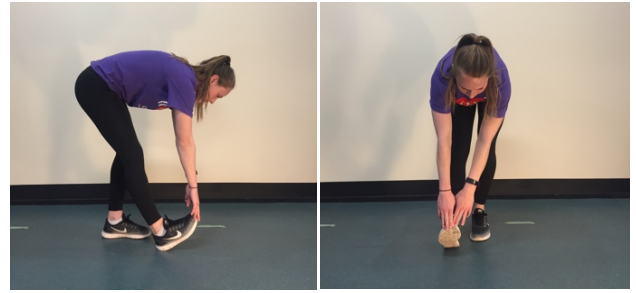
To view entire CHAMPS 12 week program exercises, follow this link:

<https://drive.google.com/open?id=1eSUVcjXiJuoDLyYccohMWWu15H4AkVSo>

2019 CHAMPS – 12 week home based exercise study

STRECHES

Hamstring Stretch – hold for 30 seconds each leg



Thigh Stretch – hold for 30 seconds each leg



Butterfly Stretch – hold for 30 seconds each leg



Calf Stretch – hold for 30 seconds each leg



<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBIBTf10hzQIVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

2019 CHAMPS – 12 week home based exercise study

DAY 1: OVERVIEW

WARM UP: Complete the warm up options listed below to get your body ready for exercise!

STRETCH: Then find a space in your home to complete warm up stretches listed on next page.

EXERCISE: Complete entire Day 1 program twice through. You will be doing exercises that target your lower body.

When you exercise, you want to exercise at an RPE intensity of 4-6

****Remember to mark your workout on your workout calendar with a sticker, and record how hard you were working (RPE=____)****

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

2019 CHAMPS – 12 week home based exercise study

DAY 1 – WARM UP & STRETCH

1. Go for a **20-minute brisk walk** or **15-minute jog** (RPE = 4-6). This should be how you would walk when you are in a rush to get somewhere.

OR:

Go **up and down your stairs 15 times**. Rest for 1 minute. Then go up and down your stairs 15 times **again**.

OR:

Alternate Warm Up

- 50 jumping jacks
- 20 high knees
- 50 jumping jacks
- 20 butt kicks
- 50 jumping jacks
- 20 high knees
- 50 jumping jacks

https://drive.google.com/open?id=1jB4sFYYKAwD2Wp33TSu3j_fhZz3N3H4w

2. Complete the **stretches** below.
 - Hamstring Stretch – hold for 30 seconds each leg
 - Thigh Stretch – hold for 30 seconds each leg
 - Butterfly Stretch – hold for 30 seconds
 - Calf Stretch – hold for 30 seconds each leg

<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBIBTf10hzQIVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

2019 CHAMPS – 12 week home based exercise study

Day 1 EXERCISE #1 – PULSE SQUATS

STEP 1 – Do 10 pulse squats.

→ Do a squat, come back up only halfway, go back down into the squat, come back up. Repeat.

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another 10 squats.

STEP 4 – Rest for 30 seconds. Then move on to Day 1 Exercise 2.

https://drive.google.com/open?id=1Dd_dcJWqjLX5JECb2YdXFqr37yevQwDf



Cues:

1. Feet shoulder width apart, or slightly wider than shoulder width apart
2. Stick your butt out, and lower your body as if you were sitting in a chair
3. Make sure your knees DO NOT pass your toes.
 - If they do, try sticking your butt out more (so you aren't leaning too far forward) or do not go as low into your squat position
4. Try to go as low as a 90 degree angle in your squat position (your legs create a 90 degree angle)
5. Flat back

2019 CHAMPS – 12 week home based exercise study

Day 1 EXERCISE #2 – SUPERHERO TAKEOFFS

STEP 1 – Do 5 lunge takeoffs on each leg. RPE = 4-6

→ Try the modified version first. Watch the videos closely for cues.

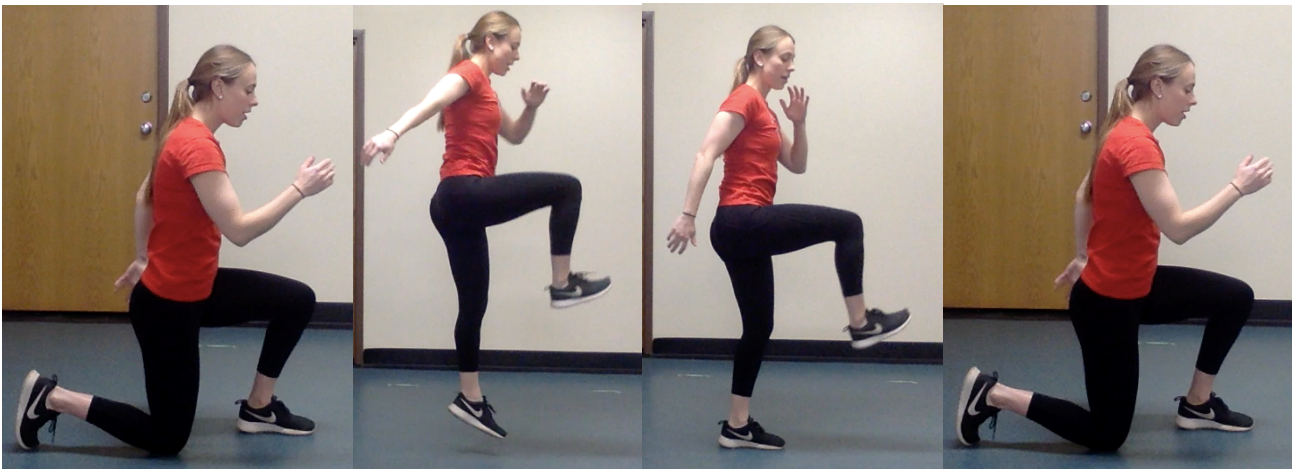
STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 5 lunge takeoffs on each leg.

STEP 4 – Rest for 1 minute. Then move on to Day 1 Exercise 3.

Modified - <https://drive.google.com/open?id=1IC5nJA0bXXCtpMUraXiha-ZzcjiQ25R>

https://drive.google.com/open?id=1IbTtZXFKXklo6_DpLpFRU3i0vQr6PfVG



Cues:

1. Ensure you are in a proper lunge position (legs at 90 degrees).
2. Use your front leg to push off the ground and lift your back leg up in front of you. Try to end with your knee in a 90 degree angle (similar to step-up exercise position).
3. Use your arms to help drive your leg up – try to make your movement controlled, but as explosive and powerful as you can.
4. Try to complete each repetition with as little time in between as possible. Don't take long breaks until you have completed all 5 on each leg.

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Day 1 EXERCISE #3 – SINGLE LEG CALF RAISES w/hold

STEP 1 – Do 15 single leg calf raises on each leg. RPE = 4-6

→ Hold for **2-3 seconds** before coming back down and beginning next calf raise.

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another 15 single leg calf raises on each leg

STEP 4 – Rest for 30 seconds.

<https://drive.google.com/open?id=19n0uXlzQIPa72Y15dnby8NPfzePcNX->



Cues:

1. Use your toes and the ball of your foot to raise your heel off the ground
2. Make sure toes are pointing forwards
3. Balance is important – use a chair or a wall to make sure the only part that is moving is your leg
4. Stand tall – be sure to be looking straight ahead, no slouching

*****NOW REPEAT EXERCISES #1, #2, AND #3 ALL OVER AGAIN!***

Once you have done the Day 1 exercise two times then you are done.

Great Job!

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DAY 2: OVERVIEW

WARM UP: Complete the warm up options listed below to get your body ready for exercise!

STRETCH: Then find a space in your home to complete warm up stretches listed on next page.

EXERCISE: Complete entire Day 2 program twice through. You will be doing exercises that target your lower body.

When you exercise, you want to exercise at an RPE intensity of 4-6

****Remember to mark your workout on your workout calendar with a sticker, and record how hard you were working (RPE=____)****

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

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DAY 2 – WARM UP & STRETCH

1. Go for a **20-minute brisk walk** or **15-minute jog** (RPE = 4-6). This should be how you would walk when you are in a rush to get somewhere.

OR:

Go **up and down your stairs 15 times**. Rest for 1 minute. Then go up and down your stairs 15 times again.

OR:

Alternate Warm Up

- 50 jumping jacks
- 20 high knees
- 50 jumping jacks
- 20 butt kicks
- 50 jumping jacks
- 20 high knees
- 50 jumping jacks

https://drive.google.com/open?id=1jB4sFYYKAwD2Wp33TSu3j_fhZz3N3H4w

2. Complete the **stretches** below.
 - Hamstring Stretch – hold for 30 seconds each leg
 - Thigh Stretch – hold for 30 seconds each leg
 - Butterfly Stretch – hold for 30 seconds
 - Calf Stretch – hold for 30 seconds each leg

<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBlBTf10hzQlVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

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Day 2 EXERCISE #1 – FORWARD/BACKWARD LUNGES

STEP 1 – Do 10 lunges on each leg. RPE = 4-6

→ To make this exercise harder add weight or hold the lunge for 2-3 seconds

STEP 2 – Rest for 15 seconds

STEP 3 – Do another 10 lunges on each leg

STEP 4 – Rest for 30 seconds. Then move on to Day 2 Exercise 2.

https://drive.google.com/open?id=1gqKxfP9mV23y0cBOhiyYXQwD9OSge_Ss



Cues:

1. Make sure both toes pointed forward throughout the entire lunge
2. Make a 90 degree angle with both legs – don't step too far forward or not far enough
3. Your knee should not go past your toes
4. Drive through your heel and thigh muscle to bring yourself back up from the lunge
5. Flat back
6. Controlled movement – stay balanced throughout entire repetition

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Day 2 EXERCISE #2 – JUMP SQUAT

STEP 1 – Do 10 jump squats. RPE = 4-6

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 10 jump squats.

STEP 4 – Rest for 1 minute. Then move on to Day 2 Exercise 3.

https://drive.google.com/open?id=1K9FuXDABPE7IYhbyz13nXFn_-YuTBGkj



Cues:

1. Make sure you are completing the proper squat technique
2. Jump as high as you can from your squat position
3. When you land, make sure you return to a full squat position, then immediately jump back up to complete another squat jump

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Day 2 EXERCISE #3 – WALL SIT

STEP 1 – Do a wall sit for 45 seconds. RPE = 4-6

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another wall sit for 45 seconds

STEP 4 – Rest for 30 seconds.

https://drive.google.com/open?id=1K9FuXDABPE7IYhbyz13nXFn_-YuTBGkj



Cues:

1. Feet shoulder width apart
2. Use the wall to brace your back, while using your thighs to hold you up
3. Make a 90 degree angle with your legs
4. Toes pointed forwards

*****NOW REPEAT EXERCISES #1, #2, AND #3 ALL OVER AGAIN!***

Once you have done the Day 2 exercise two times then you are done.

Great Job!

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DAY 3: OVERVIEW

WARM UP: Complete the warm up options listed below to get your body ready for exercise!

STRETCH: Then find a space in your home to complete warm up stretches listed on next page.

EXERCISE: Complete entire Day 3 program twice through. You will be doing exercises that target your lower body.

When you exercise, you want to exercise at an RPE intensity of 4-6

****Remember to mark your workout on your workout calendar with a sticker, and record how hard you were working (RPE=____)****

RPE Scale	Rate of Perceived Exertion
10	Max Effort Activity Feels almost impossible to keep going. Completely out of breath, unable to talk. Cannot maintain for more than a very short time.
9	Very Hard Activity Very difficult to maintain exercise intensity. Can barely breath and speak only a few words
7-8	Vigorous Activity Borderline uncomfortable. Short of breath, can speak a sentence.
4-6	Moderate Activity Breathing heavily, can hold short conversation. Still somewhat comfortable, but becoming noticeably more challenging.
2-3	Light Activity Feels like you can maintain for hours. Easy to breathe and carry a conversation
1	Very Light Activity Hardly any exertion, but more than sleeping, watching TV, etc

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DAY 3 – WARM UP & STRETCH

1. Go for a **20-minute brisk walk** or **15-minute jog** (RPE = 4-6). This should be how you would walk when you are in a rush to get somewhere.

OR:

Go **up and down your stairs 15 times**. Rest for 1 minute. Then go up and down your stairs 15 times again.

OR:

Alternate Warm Up

- 50 jumping jacks
- 20 high knees
- 50 jumping jacks
- 20 butt kicks
- 50 jumping jacks
- 20 high knees
- 50 jumping jacks

https://drive.google.com/open?id=1jB4sFYYKAwD2Wp33TSu3j_fhZz3N3H4w

2. Complete the **stretches** below.

- Hamstring Stretch – hold for 30 seconds each leg
- Thigh Stretch – hold for 30 seconds each leg
- Butterfly Stretch – hold for 30 seconds
- Calf Stretch – hold for 30 seconds each leg

<https://drive.google.com/file/d/1RPTtPZ7QOyKnMr1kb8jBIBTf10hzQIVL/view?usp=sharing>

<https://drive.google.com/open?id=12cFPiMly2nBCA-yYLZbpaBkpDUja709a>

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Day 3 EXERCISE #1 – SPLIT SQUATS

STEP 1 – Do 10 split squats on each leg (switching leg that is in front). RPE = 4-6.

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another 10 split squats on each leg.

STEP 4 – Rest for 30 seconds. Then move on to Day 3 Exercise 2.

<https://drive.google.com/open?id=1DW6rAXrSCcX4ad8CtleV0NO-H82H3wGw>



Cues:

1. Both feet face forwards – go down into your normal lunge position
2. Ensure your knee does not go past your toes
3. Keeping your feet in place, come up from the lunge. Legs straighten. Then go back down into the lunge.
4. Do not take a break in between each repetition

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Day 3 EXERCISE #2 – BURPEES

STEP 1 – Do 12 burpees. RPE = 4-6.

STEP 2 – Rest for 30 seconds

STEP 3 – Then do another 12 burpees.

STEP 4 – Rest for 1 minute. Then move on to Day 3 Exercise 3.

https://drive.google.com/open?id=1db0il03aWgsHfS-Y_cKBg4YtkQVlCxMq



Cues:

1. Jump as high as you can – both at the beginning and end of the burpee
2. When you come down from your jump, get into a “plank” position
 - Hands in line with shoulders
 - Flat back – squeeze your core (no butts in the air!)
3. Modification – if you are unable to “jump back” into the plank position as showed in the video, get into the plank by stepping back one foot at a time. Still ensuring that once you are in the plank to have the proper form as listed above

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Day 3 EXERCISE #3 – SUMO SQUATS

STEP 1 – Do 10 sumo squats. RPE = 4-6.

STEP 2 – Rest for 15 seconds

STEP 3 – Then do another 10 sumo squats.

STEP 4 – Rest for 30 seconds.

<https://drive.google.com/open?id=1DW6rAXrSCcX4ad8CtleV0NO-H82H3wGw>



Cues:

1. Feet slightly wider than shoulder width apart, feet pointed at a 45 degree angle
2. Same as normal squat – sit back in a chair, flat back, knees do not go over toes
3. Make sure knees do not “collapse inwards”. Try to keep them in line with your feet.

*****NOW REPEAT EXERCISES #1, #2, AND #3 ALL OVER AGAIN!***

Once you have done the Day 3 exercise two times then you are done.

Great Job!

APPENDIX F: Home-Based Exercise Program Logbook

PHASE 1	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
WEEK 1 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	January 27 START PHASE 1	28	29	30	31	February 1	2
WEEK 2 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	3	4	5	6	7	8	9 CHAMPS CAMP 11-3pm
WEEK 3 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	10	11	12	13	14	15	16
Week 4 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	17	18	19	20	21	22	23

PHASE 2	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
WEEK 1 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	Feb 24 START PHASE 2	25	26	27	28	March 1	CHAMPS CAMP 12-3pm 2
WEEK 2 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	3	4	5	6	7	8	9
WEEK 3 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	10	11	12	13	14	15	CHAMPS CAMP 11-3pm 16
Week 4 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	17	18	19	20	21	22	23

PHASE 3	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
WEEK 1 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	March 24 START PHASE 3	25	26	27	28	29	30 CHAMPS CAMP 12-3pm
WEEK 2 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	31	April 1	2	3	4	5	6
WEEK 3 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	7	8	9	10	11	12	13 CHAMPS CAMP 11-3pm
Week 4 <input type="checkbox"/> Day 1 - RPE: ____ <input type="checkbox"/> Day 2 - RPE: ____ <input type="checkbox"/> Day 3 - RPE: ____ <input type="checkbox"/> Psychology Homework	14	15	16	17	18	19	20