Metabolic Response During

Simulated Marching Band

BY

KIERSTEN META McCARTNEY
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THESIS

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Defense Committee:

Dr. Craig Horswill, Chair and Advisor
Dr. Jane Marone, Kinesiology and Nutrition
Dr. Charles Walter, Kinesiology and Nutrition

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I. INTRODUCTION

A. Background

Pediatric and adolescent obesity is a rapidly expanding phenomenon in the United States and across the world. According to the 2013 Heart Disease and Stroke Statistics Update, 23.9 million children (31.8%) aged 2-19 are classified as either overweight or obese with 12.7 million (16.9 %) obese[20]. Overweight and obese adolescents have been found to be at a higher risk for premature cardiovascular disease, Type 2 Diabetes, musculoskeletal disorders, accelerated development of atherosclerosis, hypertension, decreased development of important nerve function, hyperlipidemia and metabolic syndrome[2,10,20,21,31,37,38].

Increasing total daily energy expenditure has been found to curb the negative health consequences of obesity and metabolic syndrome[21,37]. Programs aimed at maintaining higher adolescent physical activity levels have led to decreased obesity and cases of Type-2 Diabetes in adulthood. Recommendations from the American College of Sports Medicine call for 30 minutes of moderate-to-vigorous intensity exercise for adults 5 days per week, accumulating to a minimum of 150 minutes per week[25,36,76]. It is recommended that children accumulate 60 minutes of moderate-to-vigorous intensity exercise every day[25,36,76]. These recommendations can be met through traditional bouts of physical activity such as walking, running, biking, hiking and participation in varsity or recreational sports.

The American College of Sports Medicine (ACSM) has reported that an energy expenditure of approximately 1000 kilocalories per week during moderate-

intensity physical activity is associated with lower rates and risk of cardiovascular disease[25,36]. ACSM defines the level of "moderate-intensity" exercise as achieving levels of 3-5.9 metabolic equivalents (MET) and "vigorous-intensity" as achieving levels of 6-8.7 METs. A MET is a physiological measure of metabolic rate during various physical activities. At standard resting values, one MET is equivalent to 3.5 mL O_2/kg/min. This correlates to a range of 52-67% of an individual's maximal volume of oxygen consumption and 64-75% of maximal heart rate[25]. These guidelines aim to reduce the risk factors and help prevent cardiovascular and other chronic diseases due to increased sedentary behavior.

It is known that psychological drive and desire to partake in a given physical activity play a role in the continued participation of said activity[78]. Adolescents, who lack a desire to join recreational or school sport teams, may have the opportunity to gain similar fitness benefits through other extra-curricular but physically demanding activities of their interest. Novel forms of exercise, such as participation in marching band, have not been studied in depth to determine if they have the same physiological benefits as traditional sports. Marching band requires similar disciple, practice time, attention to detail, teamwork and competition time as traditional high school sports, however the merits or lack thereof, of participating in marching band have been challenged recently as an alternative form of physical activity[84,97].

According to the U.S. Department of Education, 21% of high school students partake in school-run band programs[90]. In addition, there are tens of thousands of

students who partake in year-round, extra-curricular marching bands and drum and bugle corps through organizations such as Drum Corps International (DCI) and Winter Guard International (WGI)[26,97,111]. DCI, known as "Marching Music's Major League", currently has 634 music programs across 44 states participating in their "Commitment to Excellence" program with over 25,000 high school students attending at least 1 of 10 major events per year[26]. WGI is the leading body of winter guard and indoor percussion activities, and at its 38th annual "Sport of the Arts", it had over 36,000 participants at the regional level and over 12,000 at the World Championships[109]. These statistics indicate a large number of adolescents participating in marching band or drum and bugle corps, with seasons that span several months to year-round, however the physiological demands of this physical activity are not fully elucidated.

In a recent but as yet unpublished study performed at the University of Rhode Island, 21 marching band members (age 20.2 $\pm$ 2.97 years) were tested pre- and post-season to evaluate fitness gains[101]. The maximal volume of oxygen consumption, determined by a graded treadmill test, did increase in participants from the beginning to the end of the season. However no differences were found in body mass index (BMI) or body fat percentage. Without accounting for other physical activity outside of marching band participation, the lack of a control group, and not assessing energy expenditure during the activity of marching it is difficult to conclude whether marching was the main contributor to the improved fitness levels[101]. Erdmann et al. examined simulated marching band in a group of high school students at two different treadmill speeds, and indicated a change in volume

of oxygen consumption (VO_2) and heart rate (HR) between the two different marching speeds[28]. However, this study did not measure actual resting metabolic rate of the subjects to confirm the bases for MET levels. Moreover, the authors did not report respiratory exchange ratio and its use with VO_2 data to estimate energy expenditure for the marching speeds.

B. **Purpose of the Study**

Due to the number of adolescents in the United States participating in marching band each year, the metabolic effects of marching band may allow it to be recognized by sports medicine organizations and school districts as alternative form of physical activity that elevates daily energy expenditure. The purpose of our study is to assess the effects of simulated marching band on energy expenditure by determining the changes in metabolic rate and heart rate. A secondary purpose of our study is to generate more data on the effects of marching band participation to determine whether marching band participation may serve as an alternative form of physical activity to increase weekly energy expenditure. We hypothesize that simulated participation in marching band will indicate a moderate level of exercise, according to ACSM guidelines, through assessment of metabolic rate and heart rate, therefore indicating marching band as an alternative form of physical activity.

II. LITERATURE REVIEW

A. The Obesity Epidemic

According to the World Health Organization (WHO), the number of individuals who are classified as obese has doubled since 1980[108]. This global epidemic has led to increased mortality rates in most of the countries in the world due to the comorbidities associated with being overweight and obese. In developed countries, mortality due to obesity is higher than mortality due to malnourishment. Obesity is a preventable, non-communicable disease, and has manifested primarily due to an overall decrease in physical activity and an increase in the consumption of energy-dense food[4,6,7,16,20,31,96,107,108]. This leads to a severe imbalance in energy homeostasis, with intake far exceeding output. Obesity is a primary risk factor for a multitude of disorders and diseases including Type 2 diabetes mellitus, cardiovascular disease, hypertension, stroke, atherosclerosis, coronary heart disease, chronic heart failure, kidney disease, sleep apnea, respiratory disorders, non-alcoholic fatty liver disease (NAFLD), chronic inflammation, osteoporosis, hyperlipidemia, metabolic syndrome, multiple forms of cancer, depression and decreased quality of life[7,16,20,21,31,37,38,96,100,107,108].

Associated chronic diseases and lifestyle changes in part cause the increased mortality associated with obesity. Obesity, physical inactivity and inadequate diet have been cited as the prominent risk factors for the four main chronic illnesses, including diabetes and cardiovascular disease, which contribute to more than 50% of global deaths[93]. Eighty-five percent of all diabetes mellitus diagnoses are type 2, and of the diagnosed population, 90% of patients are obese[93]. The World Economic

Forum in Geneva in 2011, also noted 63% of global deaths occur from non-communicable diseases, primarily cardiovascular disease, respiratory diseases, diabetes, and cancer[7], all of which are associated with increased weight. Lifestyle interventions can reduce or reverse the prevalence of these non-communicable diseases by decreasing physical inactivity, correcting poor diet habits, and avoiding tobacco use[37]. Altering activity level and diet, which are within individual control, decrease weight gain and can prevent premature cardiovascular disease, stroke and Type 2 Diabetes by up to 80%[4,20,37]. One study examined 184,450 adults in the United States of America (U.S.) and found each 1-kilogram (kg) increase in body weight increased the risk of diabetes by 4.5%[70]. Data from the U.S. National Health and Nutrition Examination Survey (NHANES) determined obesity was directly linked to 187,246 preventable deaths from cardiovascular disease, diabetes, kidney disease, and cancer in over 570,000 people[32,33]. A longitudinal study of 750,000 men and women over 13 years indicated the lowest mortality was found in people who were 10-20% lower or average weight. A 30-40% increase in weight from the normal age weight came with a 50% increase in mortality, caused primarily from diabetes and coronary heart disease[62].

Beyond the list of obesity related physiological problems are profuse economic ramifications for health care systems, companies, and individuals. The World Economic Forum estimated that diabetes cost the global economy approximately US$500 billion in 2010 and projected this number to increase by an additional US$250 billion by 2030, with cardiovascular disease expected to cost the world over US$1 trillion by 2030, a 22% increase from its US$863 billion expense in

2010[7]. In the United States alone, obesity puts an almost $240 billion price tag on annual health care costs. Increases in weight are associated with decreased job performance and increased in days missed due to illness. Suhrcke et al found men with chronic diseases related to obesity worked 6.1% fewer hours than their healthy counterparts[93]. Data from a 2-year survey of a nationally representative sample of the U.S. adult population estimated a 37.4% (over $700) increase in individual annual medical expenses related to obesity compared to their healthy complements[31,93]. In another 2-year study, Trasande and Chatterjee found obese children had an individual increase in costs for outpatient visit costs and prescription drugs ($194 and $114 per patient, respectively)[101]. The association of obesity to several chronic diseases and their resultant economic costs makes this a case that obesity is more than an individual problem, but one for which the adverse effects will be felt at all levels of the community, making it a global public health crisis.

According to the Center for Disease Control and Prevention (CDC), in adults 20 years of age or older, obesity is defined as having a Body Mass Index (BMI) $\geq$ 30 kg/m^2 and overweight as a BMI $\geq$ 25 kg/m^2. Children and adolescents in the 5th to 85th percentile classify as normal weight; $\geq$ 85th percentile, overweight; $\geq$ 95th percentile, obese[16]. The United States has the highest obesity rates of any industrialized country, with one third of its population over the age of 20, obese, and two thirds overweight [47,71,74,75]. In 1980, the proportion of obese people was 15% or less in all states. By 2014, 20% of the population in *every* state was obese, with 42 states having obese populations of $\geq$ 25%[96]. Unfortunately, but not surprising, the

obesity epidemic is not exclusive to adults. As of 2013, globally, 42 million children under the age of 5 were classified as overweight or obese[107,108]. In the U.S., 25% of preschool children are overweight and more than one in ten children are classified as obese before reaching their fifth birthday[6,96]. Currently, 16.6% of all U.S. high school students are overweight and only 25.4% reported engaging in 60 minutes of daily physical activity[16,71,74].

There are limited longitudinal data regarding the cumulative effects of obesity from childhood to adulthood. However, recent studies have confirmed many risks factors for chronic diseases found in obese adults are now presenting in overweight and obese children[4,6,7,16,21,38,65,96,107,108,]. One of the most notable projected consequences of the exponential rise in pediatric obesity is the decrease in life expectancy of these children compared to their parents[21]. This marks the first time in the post-industrialized era for the shift in life expectancy for the next generation. Whitaker et al conducted a retrospective study of 854 subjects to determine if adult obesity could be predicted from childhood and parental obesity[106]. All subjects had an average of nine BMI measurements beginning between the ages of 1-17, with the average age of the last measurement, 24.5 years old[106]. These researchers found overweight children have a significantly higher risk (>50%) of becoming overweight adults compared to a 10% chance of their healthy weight counterparts. Throughout childhood and adolescents, children with at least one obese parent, were at a greater risk of developing obesity in adulthood. With studies indicating childhood obesity is associated with diabetes, sleep apnea, breathing difficulties, hypertension, cardiovascular disease, musculoskeletal

disorders and psychological disorders, it can be called into question whether the quality of life of children today is less than that of prior generations[7,32,108]. Baker et al. noted in over one quarter million school children that a higher BMI between ages 7-13 increased their risk of any heart disease in adulthood, fatal and non-fatal[4]. The American Heart Association stated that obesity at a younger age starts the inflammatory process sooner, setting up atherosclerosis and coronary heart disease[20]. Due to this, both atherosclerosis and coronary heart disease are showing up sooner in the lifespan. Freedman et al conducted a longitudinal study over 23 years (subjects aged 4-35 years) to examine the effects of childhood obesity on adult health, specifically the carotid intima-media thickness (IMT), as part of the Bogalusa Heart Study[34]. BMI and skin folds (SF) were used as predictors for changes in carotid IMT, which is a measure of vascular diseases including atherosclerosis, coronary artery disease, heart attack and stroke. Obese adults had a higher probability statistically of developing vascular disease if they had a higher BMI and SF as a child[34].

Besides the morbidities associated with childhood obesity, there are other lifelong consequences, which should not be taken lightly. Childhood and adolescent obesity is linked to lower levels of self-esteem, education attained, learning ability, earning power, increased rates of poverty, and, in females, decreased chances of marriage[21,39]. The socioeconomic, racial, and ethnic status a child is born into significantly influences their risk for becoming obese[96]. Children who are black or Latino, poor, and whose parents have attained little education are the most at risk for obesity[100,107,108]. A recent survey found 35.3% of individuals with no high school

diploma were obese compared to 22.1% who had completed a college degree being obese[96]. In addition, childhood and adolescent obesity contributes to $14.1 billion in health care costs related to obesity in the U.S.[100]. If those of low socioeconomic levels are more predisposed to obesity, they are likely unable to afford the costs which supplement the chronic disease, ultimately leaving the expense to rest on public sector.

B. **Physical Inactivity, Sedentary Lifestyle and Obesity**

Due to extensive literature available across multiple fields on the negative effects of obesity, intervention programs have been created in an effort to reduce the comorbidities of obesity. There is literature on the reduction of body fat through caloric restriction, physical activity, and a combination of both[1,12,18,25,36,75,76,81,94]. These studies aim to combat the negative effects of increased sedentary activity on the metabolic profiles of both children and adults[6,18,23,34,46,52,56,59]. It has been noted that sedentary behavior is a key element connecting the cascade of obesity, inflammation, insulin resistance and endothelial dysfunction. Borrell found that physical inactivity decreased a person's life span by an average of 4.0 years[8]. Physical activity recommendations range in volume, intensity, type, duration, and frequency. A common theme throughout the literature is that significant changes in body composition and risk factors related to cardiovascular and metabolic diseases can be made through low cost, convenient, and easy changes incorporated into daily life.

Several studies in children have indicated a relationship between sedentary activities and obesity[2,18,23,46,52,56,59]. There is a positive relationship between time

spent watching TV and prevalence of obesity[2,18,23]. Anderson et al conducted a nationally representative cross-sectional survey of 4063 children between the ages of 8-16 to assess physical activity levels and TV habits[2]. Their results indicated BMI and body fat percentage increased with each additional hour spent watching TV, with 67% of children who reported watching at least 2 hours of TV per day. Similarly, Crespo et al. conducted a similar nationally representative survey and noted the prevalence of obesity was lowest among children watching $\leq$ 1 hour of TV per day[18]. Lastly Dietz and Gortmaker conducted a longitudinal study of nearly 14,000 children, (approximately 50% 6-11 years old, 50% 12-17 years old) and noted the prevalence of childhood obesity increased 2% for each hour of TV viewed per day[23]. Notably, they determined that the average number of hours watching TV daily was equivalent to the number of hours students spent in school (6 hours on average), especially among the older cohort.

C. **Activity Recommendations and Rationale for Recommendations**

The American College of Sports Medicine (ACSM) and American Heart Association (AHA) have created physical activity recommendations for all ages in order to prevent and combat the obesity epidemic[25,36,76]. Increasing total daily energy expenditure has been found to curb many of the negative health consequences of obesity[21,25,31,36,37,76]. ACSM has reported an energy expenditure of approximately 1000 kilocalories per week of moderate-intensity physical activity is associated with lower rates and risk of cardiovascular disease[25,36]. ACSM defines the level of "moderate-intensity" exercise as achieving levels of 3-5.9 metabolic

equivalents (MET) and "vigorous-intensity" as achieving levels of 6-8.7 METs. A MET is a physiological measure that quantifies the energy cost of physical activities and is defined by multiples of resting metabolic rate. One MET is equivalent to the resting oxygen consumption rate, which is set at 3.5 mL O_2/kg/min. Therefore, two METs would be assigned to a physical activity that requires twice the amount of resting energy. This equates to a range of 52-67% of an individual's maximal volume of oxygen consumption and 64-75% of maximal heart rate[25]. ACSM's position stand that recommends exercising 5 days per week for a minimum of 150 minutes, is based on research and literature reviews regarding frequency, intensity, time, type and volume of exercise[25,36]. ACSM states:

> "*A program of regular exercise that includes cardiorespiratory, resistance, flexibility, and neuromotor exercise training beyond activities of daily living to improve and maintain physical fitness and health is essential for most adults*[25]".

These guidelines aim to reduce risk factors associated with cardiovascular disease, obesity, and diseases due to increased sedentary behavior and can be met through traditional bouts of physical activity such as walking, running, biking, hiking, and recreational sports.

In the 2008 Physical Activity Guidelines for Americans, youth were recommended to spend *at least* 60 minutes per day in moderate or vigorous aerobic activity that is both muscle and bone strengthening[76]. This recommendation would lower the risk of all-cause mortality by 30% and of coronary heart disease and cardiovascular disease by 20%. In addition to these benefits, type 2 diabetes and

symptoms of depression were decreased with regular physical activity[76]. Additional reviews have noted that physical activity levels increased to twice the ACSM recommended levels, even at mild intensities of exercise, have potential to provide additional protective health benefits[7,25,36,75,76,86]. ACSM noted in a position stand for prevention strategies for weight loss and regain that 200-300 minutes of moderate activity per week (up to double their 150 min/week standard recommendation) would be necessary for long-term weight loss[25]. In a review of 13 papers, Atlantis et al. examined exercise intervention programs on 481 overweight boys and girls. The pooled effects of these studies found as exercise duration increased, weight loss also increased[3]. These researchers concluded that 155-180 minutes of aerobic exercise per week of moderate intensity were most effective for reducing body weight, compared to 120-150 minutes per week of similar intensity. Saris et al., also concluded physical activity recommendations were not enough for weight loss or weight maintenance in previously obese subjects, and recommended 45-60 minutes per day, 6 days per week of moderate activity[86].

Studies on interventions using moderate-intensity exercise among obese children and adults have shown improvements in hypertension, heart rate, endothelial function, arterial stiffness, carotid IMT, resting metabolic rate, total energy expenditure, insulin sensitivity, blood pressure, cholesterol, abdominal, visceral and total fat, aerobic capacity, metabolic syndrome, lipoprotein and inflammatory profiles, bone density and muscular strength both with and without changes in weight[3,5,15,22,27,29,30,33,35,43-46,50,53-58,60,66-69,72-75,78,82,83,85,86-89,99,101,104,110]. Intervention protocols span 8 weeks to one year and incorporate aerobic and/or

resistance exercise with some in combination with caloric restriction. A key component of most of these interventions is that they were performed at a moderate intensity level and were accomplished with activities such as walking, stair climbing, basketball, volleyball, handball, jump rope, stationary cycling and rowing. These are all examples of activities that can easily be accomplished through community recreation leagues, not necessarily with fitness-center equipment, and are relatively easily accessed at minimal costs, therefore making them ideal to incorporate through everyday life.

Physical activity can attenuate the risk factors produced by obesity, including type-2 diabetes, which develops in association with prior insulin resistance. Bell et al. looked at effects of an 8-week circuit-based exercise intervention program on insulin sensitivity in 14 obese children (12.70 $\pm$ 2.32 years old, 44% body fat)[5]. Exercise sessions were 60 minutes long, 3 times per week at a moderate intensity, as determined by heart rate (HR). After 8 weeks of training, significant improvements in insulin sensitivity and submaximal heart rate occurred without changes in body mass or abdominal fat mass[5.] Davis et al. had similar improvements in insulin sensitivity after a 3-month exercise program of 222 boys (8-10 years old, BMI 26 $\pm$ 4 kg/m^2, 85% obese)[22]. Subjects were randomly selected to a control (no exercise), low or high dose exercise group. The exercise groups kept an average HR of 150 beats per min (bpm) for 20 (low) or 40 (high) minutes per session, 5 days/week, resulting in improved aerobic fitness and reductions in insulin resistance and visceral fat[22]. One hundred seventy three sedentary, overweight subjects underwent a 12 month moderate-intensity exercise group saw significant

changes in total body fat, visceral abdominal fat, and subcutaneous abdominal fat, by exercising an average of 3.5 days/week for 176 minutes/session[50]. Notably, the most often sited activity to achieve this was walking, with a significant dose response for greater weight loss with increased exercise duration.

Physical activity is key to combating obesity is long-term, lifestyle changes to improve health and reduce risk factors associated with various chronic diseases. Gutin et al. were able to test longer effects of physical activity, followed by an equal period of inactivity on percent body fat, bone density, cardiovascular fitness, body composition, visceral adiposity, and heart rate variability[43-45]. 79 obese children (9.5 $\pm$ 0.97 years old, BMI 28.4 $\pm$ 6.2 kg/m^2) completed an 8-month treatment comprised of a 4-month aerobic training regiment followed by 4 months of physical inactivity. Subjects exercised for 40 min/day, 5 days/week at 55-80% of their peak VO_2 for an average HR $\geq$ 152 bpm. The 4-month aerobic training regiment improved body composition (with no change in diet), cardiovascular fitness, 1.6-4.4% decrease in body fat, 3.3% decrease in submaximal HR, and increased vagal tone[43,44,45]. After 4 months of inactivity, these positive results were negated, and returned to baseline values. Ferguson et al. induced a similar 8-month (4-months exercise, 4-months no exercise) protocol, 5 days/week, 40 min/session (avg. HR 157 bpm), in obese boys (7-11 years old, 27-61% body fat)[30]. Insulin sensitivity, triglyceride levels, and body fat % improved by 25.4%, -24%, and -1.6%, respectively, however after 4-months of no exercise, insulin resistance and body fat increased by 26.6% and 1.3%, respectively[30]. Lastly, Farpour-Lamber et al. conducted a 6-month randomized control study on 44 obese children (8.9 $\pm$ 1.5 years old) and 22 lean children (8.5 $\pm$

1.5 years). The control group was inactive for the first 3-month period, while the intervention group, exercised for 60 min/day, 3 days/week[29]. For the last 3-month period, all subjects trained 60 min/day, 2 days/week. At baseline, obese subjects had increased blood pressure, arterial stiffness, body weight, BMI, abdominal fat, and insulin resistance, and decreased flow mediated dilation, VO_2 max, and high density lipoprotein (HDL) cholesterol[29]. After 3-months, a significant decrease in systolic and diastolic blood pressure, BMI, abdominal fat, and increased VO_2 peak were present. At 6 months, significant changes in arterial stiffness and IMT indicating a cumulative positive effect of regular aerobic exercise[29]. Cumulatively these results indicate a vast array of benefits following consistent, moderate-intensity physical activity on moderating obesity[29,30,43-45].

D. **Engaging Adolescents through Novel Forms of Physical Activity**

From a review of current literature, adolescence is a key time for intervention programs to take root as this timing coincides with noticeable decreases in physical activity and increases in obesity, leading into adulthood [1,12,59,81]. A study of nearly 3,000 adolescents 16-18 years old, noted that activity levels decreased over 2 years in both males (53.5% less active at 18 vs. 16) and females (53.7%)[1]. It was also noted that the use of leisure-time for physical activity was greatest when participants were included in several organized sports. Casperson et al. compiled data from the National Health Interview Youth Risk Behavior Survey over a year, and noted consistent activity decreased 10-16% from ages 12-18 concurrent with a 6-24% increase in sedentary time[12]. Levels of vigorous

physical activity began to plummet between ages 12-14 in boys and girls, indicating ages 15-18 are key to reducing decline in activity levels and preventing the development of obesity[12,81]. Therefore intervention programs aimed at late middle school and high school students, which peak student's interest have the potential to induce life-long, healthy habits.

It is known that psychological drive and desire to partake in a given physical activity plays a role in the continued participation of said activity[84]. Adolescents, who lack a desire to join recreational or school sport teams, may have the opportunity to gain similar fitness benefits through other extra-curricular activities of their interest. These activities and interventions include exercise video games, playing an instrument, pedometer use, motivational texts, marching band and drum and bugle corps [14,17,24,28,48,49,63,101]. Obese adolescents scored significantly higher in their expectations and satisfaction during walking with an exercise based video game versus walking on a treadmill at matched intensity[14]. Horswill et al. placed 8 adolescents (14.2 $\pm$ 2.1 years old) of normal weight (BMI: 22.2 $\pm$ 5.2 kg/m2) through 4 different activities (watching TV, playing a string instrument, walking at 2 different intensities) to examine energy expenditure for 120 minutes[49]. The walking protocols were at ~40% peak VO_2 (avg. 43.1 min. walking, sit remainder of time) and ~73% peak VO_2 (avg. 22.1 min. walking, sit remainder of time). A positive relationship was identified between each progressive physical activity and increasing energy expenditure. Playing a stringed instrument while sitting led to a 30% increase in energy expenditure compared to watching TV, while walking produced a 90-110% increase versus that during watching TV[49]. They also found

energy expenditure increased 41% when playing a stringed instrument versus watching TV[49]. These results indicate there is benefit involved with any movement, no matter how light, and may play an extensive role in overall energy homeostasis.

Marching band is a novel form of exercise, but has not been studied in depth to determine whether it has the same physiological benefits as traditional sports. Non-physiological effects of participation in music are abundant. Preschool children with early exposure to music lessons had long-term modifications in neural brain pathways associated with math, science, and engineering[80]. Students involved in music programs have significantly better SAT scores, reading proficiency, achievement in math and science, social, problem solving, and creative thinking skills, and self-expression[11,13,40,80,105]. Marching band and drums and bugle corps require similar disciple, practice time, attention to detail, teamwork and competition time as traditional high school sports, however the merits or lack thereof, of participating in marching band have been challenged recently as an alternative form of physical activity[84,97].

According to the U.S. Department of Education, 21% of high school students partake in school-run band programs[55,90]. Since 1907, college or university marching bands have been the center focus of halftime shows across the country. These shows are high energy with members moving at varying step counts up to 250 steps/minute for 10-15 minutes[84,97]. The average size of a Big Ten (B1G) or South Eastern Conference (SEC) university marching band is 294 members and 362 members, respectively. In addition, there are tens of thousands of students who

partake in year-round, extra-curricular marching bands and drum and bugle corps through organizations such as Drum Corps International (DCI) and Winter Guard International (WGI) [9,26,109]. DCI, known as "Marching Music's Major League", currently has 634 music programs across 44 states participating in their "Commitment to Excellence" program with over 25,000 high school students attending at least 1 of 10 major events per year[26]. WGI is the leading body of winter guard and indoor percussion activities, and at its 38th annual "Sport of the Arts"; it had over 36,000 participants at the regional level and over 12,000 at the World Championships[109]. These statistics indicate a large number of adolescents participating in marching band or drum and bugle corps, with seasons that span several months to year-round, however the physiological demands of this physical activity are not known, nor are the benefits for curbing disease risks factors associated with obesity.

Although marching band has been challenged as a form of physical activity, the effects of marching in other situations with and without loads has indicated its ability to increase metabolic rates to those prescribed by ACSM[19,42,77,79]. In a study conducted on marching soldiers (19.4 $\pm$ 1.1 years old; max HR, 192.9 $\pm$ 6.2), VO_2 and HR levels reached corresponded to 42 $\pm$ 7% and 55 $\pm$ 3% of max levels, respectively, when unloaded, and 47 $\pm$ 6% and 64 $\pm$ 4% of max levels, respectively, when loaded with 24.4 kilograms (53.68 pounds) of gear[77]. Crowder et al. demonstrated soldiers marching at 3.5 miles per hour (mph) and 0% grade while carrying 25.2 and 32.7 pounds of gear reached relative VO_2 levels of 16.3 $\pm$ 1.0 and 17.4 $\pm$ 1.1, respectively, with heart rates of 106 $\pm$ 12 and 116 $\pm$ 8.4, respectively[19]. Students involved in

marching band can carry upwards of 30 or more pounds of extra weight, including instrument and uniform, indicating that their VO_2 and HR may reach levels similar in intensity to marching soldiers.

The limited work directly on marching band suggests it would contribute to increasing weekly physical activity in adolescents. Erdmann et al. examined simulated marching band in a group of high school students at two different treadmill speeds, and indicated a change in volume of oxygen consumption (VO_2) and heart rate (HR) between the two different marching speeds[28]. The energy demand for students while marching reached 4.5-6 METs, deemed as moderate intensity exercise by ACSM. These results indicate marching band would significantly contribute to overall physical activity profiles if practices cumulate this intensity of exercise for 150 minutes/week. Cowen et al., also noted daily steps increased from 8,337.5 $\pm$ 4,015.7 on non-marching band rehearsal days to 13,258.8 $\pm$ 4,842.7 on rehearsal days and 16,174.6 $\pm$ 6,456.4 on game days indicating a huge contribution of participation on overall energy expenditure and physical activity[17]. In a recent study performed at the University of Rhode Island, 21 marching band members (20.2 $\pm$ 2.97 years old) were studied pre- and post-season[101]. The maximal volume of oxygen consumption, determined by a graded treadmill test, did increase in participants, however no differences were found in Body Mass Index (BMI) or body fat percentage. Without accounting for other non-marching factors or measuring energy expenditure during marching band training it is difficult to conclude if marching was the main contributor to the improved fitness levels[101]. Members of the Avon High School marching band in Indiana reported physiological

and mechanical symptoms similar to those reported by individuals partaking in traditional sports, such as muscle fatigue, injury and soreness[41]. BMI values significantly decreased for 501 marching artists from 4 world-class drum and bugle corps throughout the course of a season[61].

Due to the number of adolescents in the United States participating in marching band each year, the physiological effects of marching band may allow it to be viewed as alternative form of energy expenditure, and a novel form of exercise to help combat the obesity epidemic. High school marching band programs have a unique opportunity to engage students, who are not compelled to participate in traditional sports, in an alternative activity that may have health benefits. Additional studies that characterize the acute metabolic demands might help clinicians and school administrators realize the benefits of marching band. This could lead to recommendations by clinicians when providing treatment and public policy that recognizes marching band as an activity equivalent to sport participation.

III. METHODS

A. Subjects

Eleven college pep-band members aged 19-24 years old volunteered to participate. The eligibility criteria including being 18 to 30 years old at the start of the study, a former member of marching band, and/or a current member of the University of Illinois at Chicago Pep Band. Subjects were required to be former members of marching bands so that marching technique was already known. Participants were excluded from the study if they answered yes to any questions on the PAR-Q survey, had previously diagnosed orthopedic problems or heart disease, and/or noted hypertension at rest. Written informed consent was obtained from each subject after the study was explained. The protocol and consent form were reviewed and approved by the Institutional Review Board at the University of Illinois at Chicago.

B. Experimental Protocol

Testing occurred during two, 60 to 90 minute sessions in a laboratory at the University of Illinois at Chicago (UIC). Upon reporting to the laboratory, subjects completed the informed consent form and survey, experimental procedures were fully explained and subjects were familiarized with the lab equipment and environment. Anthropometric measurements including height (stadiometer, Health-o-Meter), weight (Toledo-Mettler, Toledo, OH), body fat percentage using densitometry (Bod Pod, COSMED, Chicago, IL), and resting heart rate were recorded.

The type and weight of the participant's instrument was recorded. Participants were then fitted to a heart rate monitor (Polar FT1, Kempele, Finland) and mouthpiece and valve that was attached to the metabolic cart (Parvo Medics TrueOne 2400, Sandy, Utah). The system was calibrated to known gas concentrations and air volumes prior to the beginning of each subject testing.

Participants were randomly selected to complete the first trial with or without their instrument in order to neutralize the possibility of a small but measureable change in energy expenditure due to acclimation to the lab setting and improved marching efficiency on the treadmill. Measurements of expired gases and heart rate were obtained during the four phases of activity – seated at rest, standing, and marching on the treadmill at two speeds. All subjects were tested in that order of phases. For the marching phases, step counts were recorded for 9 subjects to determine the average steps per minute for each marching speed. Counting was done by two researchers to obtain confirmatory measurements. Steps were counted by noting each step of the left leg. Steps were then doubled to determine the total amount of steps per minute. The participant then returned for a second visit and repeated all measurements so data was collected for each participant with and without their respective instrument.

C. **Indirect Calorimetry Measurements and Analyses**

Resting metabolic rates (RMR) were measured with the participant in a seated position for 15 minutes, during which the last 10 minutes of data collected for the steady-state rate for sitting RMR. Participants then stood in attention for 10

minutes, with the last 5 minutes averaged and used as the steady-state rate. Marching was done for 15 minutes at each pace (3.2 mph and 4.0 mph) for a total of 30 minutes. The measured values for VO_2 and RER last 10 minutes of each pace were averaged and used as the steady-state rate. These speeds were chosen to approximate speeds of marching during marching band shows, competitions, and/or parades.

As an index of reliability of achieving steady state in each phase, the lowest and highest coefficient of variation for an individual are presented in Table 2. Oxygen consumption was used to determine the metabolic equivalent (MET) at each phase of exercise, and the secondary outcome measure was heart rate (HR). As the frame of reference for rest, 1 MET equaled 3.5 mL/kg/min. The conversion of VO_2 to energy expenditure was calculated by the following equation:

$$\textit{Energy Expenditure (EE, kcal/min)} = (L\ O_2\ /min) \times (kcal/L\ O_2)$$

with kcal/L of O_2 calculated from respiratory exchange rate using the following values from the table of Lusk, 1928:

RER	kcal/L O_2
0.7	4.686
0.75	4.739
0.80	4.801
0.85	4.862
0.90	4.924
0.95	4.985
1.0	5.057

The Siri equation was used to calculate percentage body fat using body density from the BodPod (Siri, 1961).

Table I. *Coefficient of Variant extremes in individuals*

	With Instrument	With Instrument	Without Instrument	Without Instrument
Phase	Low CV	High CV	Low CV	High CV
SIT	7.67%	22.29%	5.65%	30.94%
STAND	5.24%	46.88%	4.86%	26.3%
3.2 MPH	4.45%	10.44%	3.24%	8.18%
4.2 MPH	1.87%	10.58%	1.12%	8.46%

D. **Statistical Analysis**

Results are presented as mean ± standard deviation. Dependent variables included volume of oxygen consumption (VO_2), heart rate (HR), respiratory exchange ratio (RER), MET level, and energy expenditure (EE). Two-way ANOVA adjusted for repeated measures was used to test the phase of activity (resting, standing, and marching at two speeds) and factor (with or without instrument). In lieu of post hoc multiple comparison tests, trend analysis was used to determine whether changes in the phases were linear, quadratic, or cubic for the phase of activity depending on the presence of the musical instrument. A probability level of 0.05 was selected to establish statistical significance.

IV. RESULTS

A. Subjects

Tables II and III summarize the physical characteristics of the subjects. One subject completed one trial and did not return for the second due to discomfort associated with the facemask and mouthpiece. Four subjects who responded to recruitment flyers were unable to participate due to their age and one subject had previous orthopedic and hypertension issues. Along with the subject who withdrew there were two test sessions in which technical challenges (loss of signal from heart rate monitor and missing nose clips during VO_2 measurement) resulted in a complete data set for nine subjects. Step counts for each respective marching speed can be found in Table IV.

Table II. *Subject Characteristics as mean ± standard deviation (SD)*

Anthropometric Measurement	Value (+ SD)
Age (years)	21.4 ± 1.7
Height (cm)	167.3± 9.6
Weight (kg)	79.0 ± 19.1
BMI (kg/m2)	28.2 ± 6.0
Body Fat %	25.2 ± 10.0
Resting Heart Rate (bpm)	79.1 ± 14.2
Instrument Weight (kg)	1.3 ± 0.55

Table 2: Subjects: n = 11

Table III. *Subject Characteristics Male and Female as mean ± SD.*

Measurement	Male (± SD)	Female (± SD)
Age (years)	20.8 ± 0.96	21.7 ± 2.0
Height (cm)	176.8 ± 4.4	161.4 ± 6.6
Weight (kg)	91.4 ± 22.4	71.4 ± 12.1
BMI (kg/m2)	29.2 ± 7.0	27.6 ± 5.5
Body Fat %	21.8 ± 14.3	27.1 ± 7.3
Resting Heart Rate (bpm)	86.9 ± 11.3	74.3 ± 14.1
Instrument Weight (kg)	1.4 ± 0.22	1.3 ± 0.68

Table 3: Male: n = 4 Female: n = 7

Table IV. *Steps*

Phase	Steps
3.2 mph	121.0 ± 5.2
4.0 mph	134.3 ± 7.8

Table 4: Steps are measured in steps/minute; presented as (mean ± SD)

B. **Volume of Oxygen Consumption (VO_2)**

The results for VO_2 are presented in Table V and Figure 1. The ANOVA revealed significant main effects for instrument and phase of the activity-sitting, standing, and marching 3.2 mph and 4.0 mph during both sessions. A significant interaction was found for VO_2 values with the trend analysis showing a linear relationship. In other words, with the instrument, VO_2 was progressively higher as the marching speed increased ($p = 0.008$). This might be expected, as the average instrument weight was 1.3 ± 0.55 kg. The interaction indicates the increase in

oxygen consumption in progressing from seated to standing to faster paces of marching increased more with the instrument than without it.

Table V. *Volume of Oxygen Consumption (VO_2 in mL/kg/min) (mean ± SD)*

Phase	VO_2 w/o	VO_2 w/ *
Sitting	3.6 ± 0.5	3.4 ± 0.4
Standing	4.0 ± 0.5	4.1 ± 0.4
3.2 mph	14.0 ± 1.1	16.0 ± 1.5
4.0 mph	20.1 ± 1.4	22.3 ± 0.9

VO_2 w/o = measurements without an instrument
VO_2 w/ = measurements with an instrument
** = Statistically significant interaction w/ or w/o instrument ($p < 0.05$)*

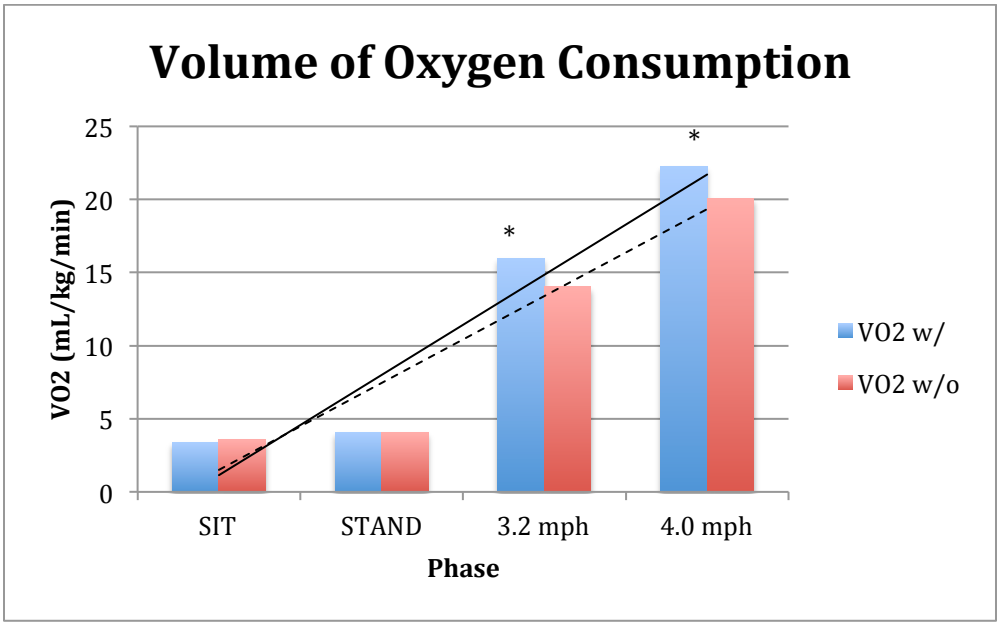

Figure 1. *Volume of Oxygen Consumption*
** = Statistically significant interaction with or without instrument ($p < 0.05$)*

C. **Heart Rate**

Descriptive statistics for HR are found in Table VI and Figure 2. The ANOVA showed a significant main effect for phase activity-sitting, standing, and marching 3.2 mph and 4.0 mph during both sessions but no main effect for with or without instrument. There was not a significant interaction for phase by instrument. Since there was not a significant interaction, heart rate might not accurately predict VO_2 if used in future marching band assessment or variability in the rest and standing phase may have distorted our ability to detect an interaction (Figure 2).

Table VI. *Heart Rate (HR)*

Phase*	**HR w/o**	**HR w/**
Sitting	85.9 ± 14.0	82.7 ± 14.1
Standing	95.5 ± 14.0	93.7 ± 14.9
3.2 mph	121.8 ± 21.2	130.2 ± 28.3
4.0 mph	153.5 ± 18.6	158.5 ± 25.7

Table 6: HR is measured in beats per minute; presented as (mean ± SD)

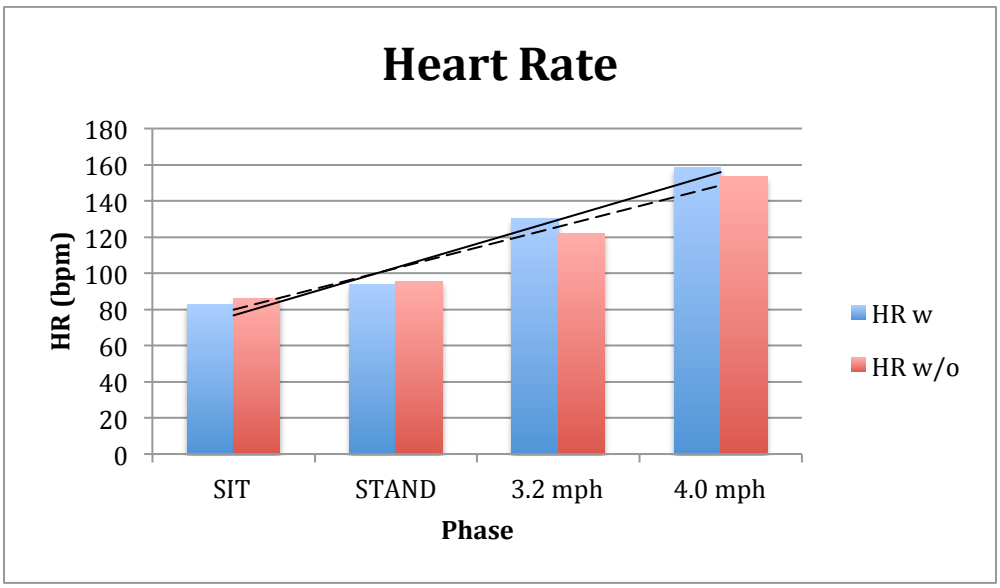

Figure 2. *Heart Rate*

D. **Respiratory Exchange Rate**

The results for RER are found in Table VII and Figure 3. The ANOVA revealed significant main effects for phase activity-sitting, standing, and marching 3.2 mph and 4.0 mph during both sessions. There was not a significant interaction for phases by instrument presence. The range of instrument sizes tested in this study was on the small end. A larger range of instrument weights including trombones and sousaphones may be needed in future studies to more clearly test for an interaction effect in substrate oxidation.

Table VII. *Respiratory Exchange Rate (RER)*

Phase	RER w/o	RER w/
Sitting	0.88 ± 0.065	0.90 ± 0.054
Standing	0.85 ± 0.050	0.90 ± 0.075
3.2 mph	0.90 ± 0.058	0.94 ± 0.049
4.0 mph	0.94 ± 0.073	0.99 ± 0.058

Table 7: RER is presented as (mean ± SD)
RER w/o = measurements without an instrument
RER w/ = measurements with an instrument

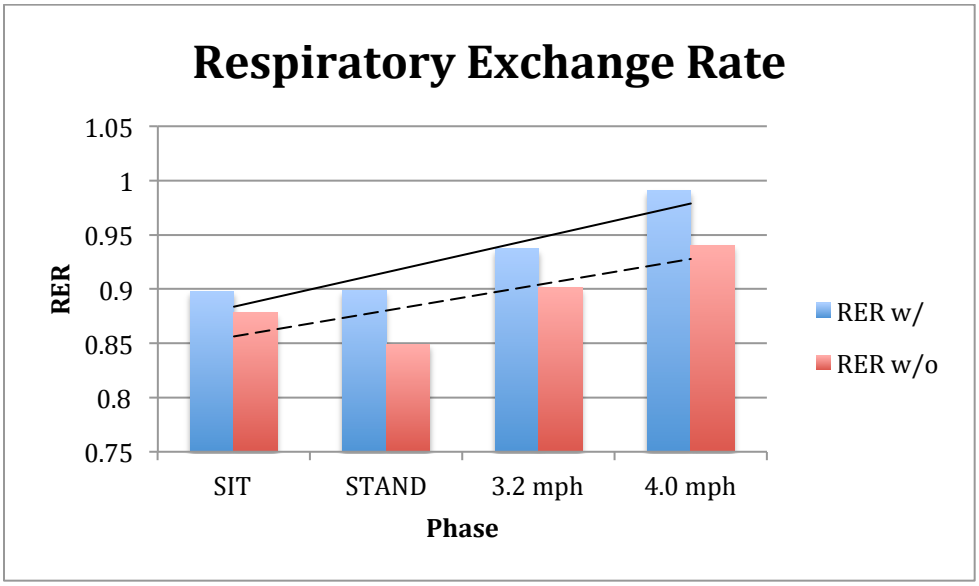

Figure 3. *Respiratory Exchange Rate*

E. **MET level**

The results for MET level are seen in Table VIII and Figure 4. The ANOVA revealed significant main effects for instrument and for the phase activity - sitting, standing, and marching 3.2 and 4.0 mph. A significant interaction was found for MET level ($p = 0.013$) with the trend analysis showing a linear relationship. This

interaction indicates that as the marching speed increases, the exercise intensity level increases, and is significantly higher when marching with an instrument (Figure 4).

Table VIII. *Metabolic Equivalent (MET)*

Phase	MET w/o	MET w/
Sitting	1.0 ± 0.15	0.97 ± 0.13
Standing	1.2 ± 0.16	1.2 ± 0.12
3.2 mph	4.0 ± 0.31	4.6 ± 0.44*
4.0 mph	5.7 ± 0.39	6.3 ± 0.30*

Table 8: MET equivalents: 1 MET = 3.5 mL/kg/min O_2; presented as (mean ± SD)
MET w/o = measurements without an instrument
MET w/ = measurements with an instrument

- *= Statistically significant interaction w/ or w/o instrument ($p < 0.05$)*

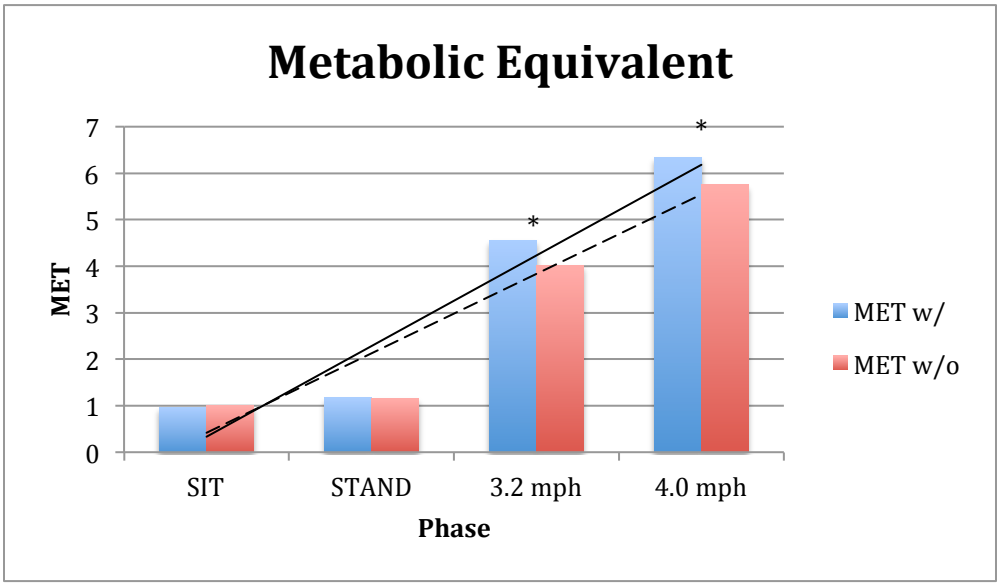

Figure 4. *MET Level*
** = Statistically significant interaction with or without instrument ($p < 0.05$)*

F. **Energy Expenditure**

Descriptive statistics for EE can be found in Table IX and Figure 5. The ANOVA revealed a significant main effect for phase activity, but no main effect with or without an instrument. There was not a significant interaction between phases with and without an instrument. Due to lack of variability in instrument size and potential subject aerobic capacity, we may not have been able to detect an interaction.

Table IX. *Energy Expenditure (EE)*

Phase	EE w/o	EE w/
Sitting	1.3 ± 0.26	1.2 ± 0.22
Standing	1.5 ± 0.41	1.5 ± 0.44
3.2 mph	5.2 ± 1.4	6.0 ± 1.7
4.0 mph	7.5 ± 1.8	8.5 ± 2.0

Table 9: EE is measured in kcal/min; presented as (mean ± SD)
EE w/o = measurements without an instrument
EE w/ = measurements with an instrument

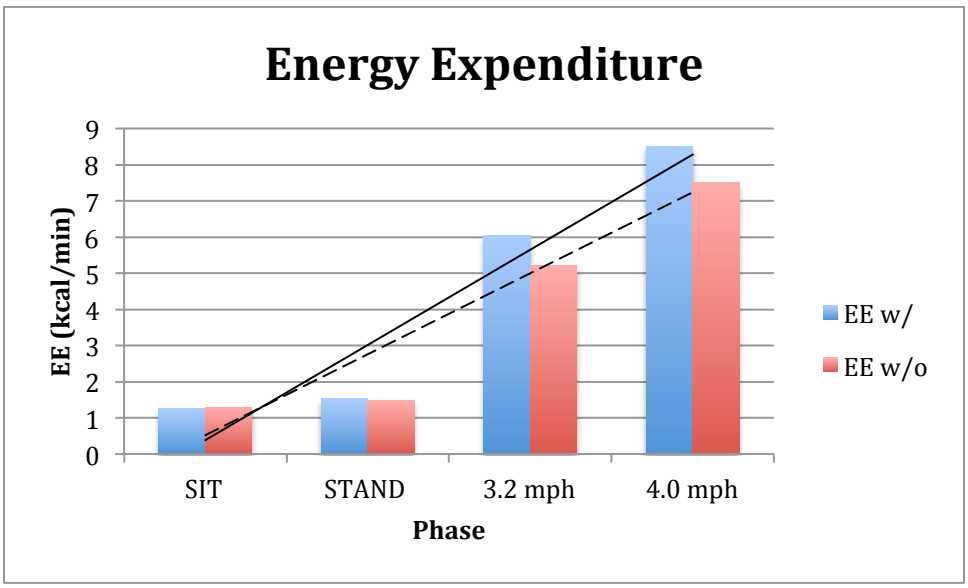

Figure 5. *Energy Expenditure*

V. DISCUSSION

A. Summary of Main Findings

The primary purpose of our study was to assess the effects of simulated marching band on oxygen consumed, metabolic rate (METS), and the translation into energy expenditure. On average marching without an instrument increased metabolic rate by 4 to 5.6 fold depending on the speed and by 4.6 to 6.5 fold for same speeds when the instrument was added. Marching with an instrument significantly increased the amount of oxygen consumed at each phase, beyond the increase of marching speed. Converting the VO_2 values to metabolic equivalents (MET), we found that the two speeds of marching (3.2 mph and 4.0 mph) with an instrument were 4.56 $\pm$ 0.44 and 6.33 $\pm$ 0.30, respectively. These findings suggest marching band elicits work of a moderate to vigorous intensity level, as prescribed by the American College of Sports Medicine.

B. Comparison to Literature

Our findings were comparable to those of Erdmann et al who described average MET levels of 4.5 $\pm$ 0.8 for a slower paced march (2.8 mph) and 6.0 $\pm$ 1.3 for a faster paced (3.4 mph) march[45]. The speeds used in that study were set at a specific stride length to elicit 132 steps/min (slow) and 160 steps/min (fast). Our speeds were decided through trial and error by a former marching band member who titrated speeds in order to simulate paces used in past marching practice sessions. We did not control our stride length, and obtained a rate of 121.0 $\pm$ 5.22 (3.2 mph) and 134.35 $\pm$ 7.97 (4.0 mph) steps per min. The difference in step counts,

despite a faster speed could be due to the age, of the subjects (15.2 ± 1.1 in Erdmann et al vs. 21.36 ± 1.69 year old in the present study), and therefore physical development, which would influence stride length. Interestingly, average heights did appear to differ (161 ± 4 cm for Erdmann et al vs. 167 ± 9.58 in the current study). The difference in step count may also be due to a different style of marching used by the subjects. Our subjects used the roll-step technique, which is different from the high-step technique. The style of marching used by the subjects of Erdmann et al was not identified.

Our study was designed to ensure subjects reached steady state during each phase of the protocol (see Appendices), and we used the last 10 minutes of each phase to calculate average values. This was done so metabolic changes in moving from one phase to the next did not influence the next phase of data. In support of this, the coefficients of variations were found to be reasonable for the marching phases (1.1 to 10.6%). Our subjects were randomly selected to perform the first trial with or without their instrument. This was to neutralize an effect of a small, but measureable change in energy expenditure due to acclimation to the lab setting and improved efficiency on the treadmill, whereas all subjects in the previous study began in the same order – first without and then with the instrument.

Marching with an instrument elicits similar responses in our late adolescent, young adult subjects as traditional exercise intervention programs with children and adolescents. The average age-predicted heart rate of our subjects was 199.13 bpm. Heart rate values of our subjects can be found in Table IV. These values equate to an average of approximately 65.4% (3.2 mph) and 79.6% (4.0) of maximum heart

rate. Adolescent's ages 7-11 exercising at an average heart rate of 157 bpm for 40 minutes a day, 5 days per week saw significant changes in visceral and subcutaneous abdominal fat, increased cardiovascular fitness, and decreased submaximal heart rate[60-62]. Lee et al, had subjects (ages 12-18), exercise for 60 min/day, 3 days/week and found average heart rate was 153.8 $\pm$ 7.2 bpm (~65% of VO_2), which aligns to our faster marching speed. Those exercise intensities were enough to prevent significant weight gain in their subjects, decrease adiposity, and improve insulin sensitivity by 27%, indicating a similar intensity evoked during marching band may provide beneficial to reducing or preventing adolescent obesity. Although our study viewed acute responses to exercise, if compounded overtime, may lead to the chronic improvements in body composition and risk factors associated with obesity seen in the intervention programs.

C. **Limitations**

There are several limitations to our study. Since this was a simulation of marching band on a treadmill, it may not have fully captured what would be seen in the field. Although we ensured that subjects achieved a steady state during each phase of the protocol, it is unclear if marching band is an activity that does achieve a steady state. During a marching band performance, members are moving at different speeds throughout with short breaks between new songs or formations. Further studies are needed in the field to determine whether band members are at a moderate or intense level of activity for a significant amount of time.

Several other factors also may limit the accuracy of our energy expenditure estimates. Without having subjects play their instruments while marching, it unclear how much the respiratory work would change and add to energy expenditure and metabolic rate. Our estimates may be low relative to marching and playing simultaneously. This, however, would be a limitation of any study that relies on indirect calorimetry to assess energy expenditure. An additional limitation of our study was the use of subjects who are former members of marching band. Since our subjects are no longer actively marching, their fitness levels may not be comparable to when they were in-season, leading to differences in heart rates recorded. Finally a wider array of instrument weights and a larger subject population would help to elucidate if there are energy expenditure differences between instruments.

Using data from our study, we were able to calculate energy expenditure for each subject during each phase using individual RER and liters O_2 consumed. The average energy expenditure while carrying an instrument during each phase can be found in Table IX. In surveys completed by subjects, the average time spent in each marching band practice was 94.10 $\pm$ 23.33 minutes. If subjects were in a moderate intensity, equivalent to our simulated 3.2 mph speed, throughout the entire practice, approximately 569 calories would be expended. With recognizing that marching band may not be a steady state activity, and breaks would be involved, if half of a practice were spent in moderate activity and the other standing in attention, approximately 357 calories would be expended.

Further research in the field to measure energy intensity levels during practices would confirm how much energy is expended over an extended period of

time. However, our subjects also reported an average season 5.14 ± 1.66 months in length with 3.41 ± 1.04 practices per week. This accumulates to 321 minutes spent at practice each week. If half of each practice were spent at a moderate intensity level, ACSM recommendations of at least 150 minutes of moderate activity per week would be met. These findings indicate that marching band has the potential to add to the overall physical activity profile of an adolescent and increase their weekly energy expenditure.

D. **Future Recommendations**

For further studies we would recommend a study in the field that is able to get a more realistic depiction of heart rate and energy expenditure during marching band practices. We suggest using members of a band currently in season and tracking their metabolic changes over a time period of approximately 2 weeks. We suggest a time period of this length so results can capture the day-to-day differences in practice intensity, and therefore find an average intensity reflective of what would occur throughout a season. We also suggest an experiment that identifies differences in body composition and aerobic capacity at the beginning and end of the season. Vallee and Leander researched the effects of marching band on body composition and aerobic capacity over the course of a season on 21 college-aged students. There were significant changes in VO_2 (38.5 ± 9.23 to 40.8 ± 8.5 mL/kg/min), but no changes in body composition[53]. Since researchers did not control for other forms of energy expenditure over the season, it can be concluded that marching band contributed, but may not be the sole source of change to the

overall physical activity profile of subjects. Future studies could control other outlets of physical activities to determine what the contribution from marching band is.

E. **Conclusion**

Marching band is an extra-curricular activity with significant adolescent involvement. Due to the obesity epidemic sweeping the United States, it is imperative that novel forms of exercise are made accessible to adolescents and that such an activities be recognized for the impact they may have on energy expenditure and fitness adaptations. Studies have shown that even moderate forms of exercise when performed at adequate duration reduce risk factors associated with obesity and chronic diseases[21,25,36,37]. In our study, simulated marching band induced moderate and vigorous intensity levels of activity, as prescribed by ACSM[25,36]. Our results indicate marching band participation could be an activity that elevates metabolic rate adequately. Further research may confirm if it is participated in frequently enough, marching band may have the potential to provide beneficial physiological effects and help reduce risk factors associated with obesity and sedentary lifestyle.

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APPENDIX A

Table IA. *Questionnaire Results*

Survey Question	Response (avg ± SD)
# Years Marching Band Participant	4.18 ± 2.14 years
Length of Season	5.14 ± 1.66 months
# Practices per Week	3.41 ± 1.04 practices
Length of each practice	94.09 ± 23.33 minutes

Note: For Figures 1A-10A, "minutes" correlate to the following:

0-5 min = last 5 minutes of sitting phase

6-10 min = last 5 minutes of standing phase

11-15 min = last 5 minutes of 3.2 marching phase

16-20 = last 5 minutes of 4.0 marching phase

Figure 1A. *Volume of Oxygen Consumption Steady State, Subject 1*

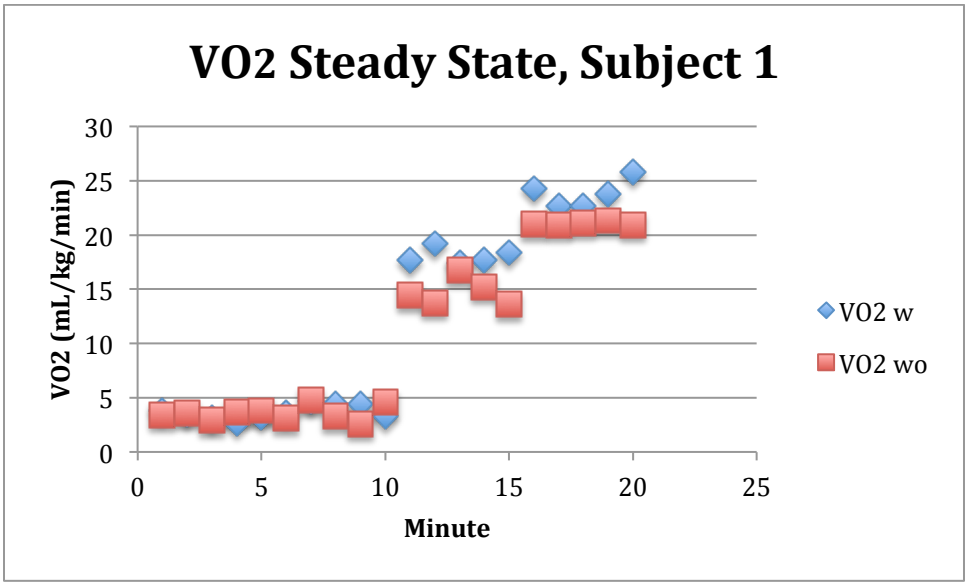


Figure 2A. *Volume of Oxygen Consumption Steady State, Subject 2*

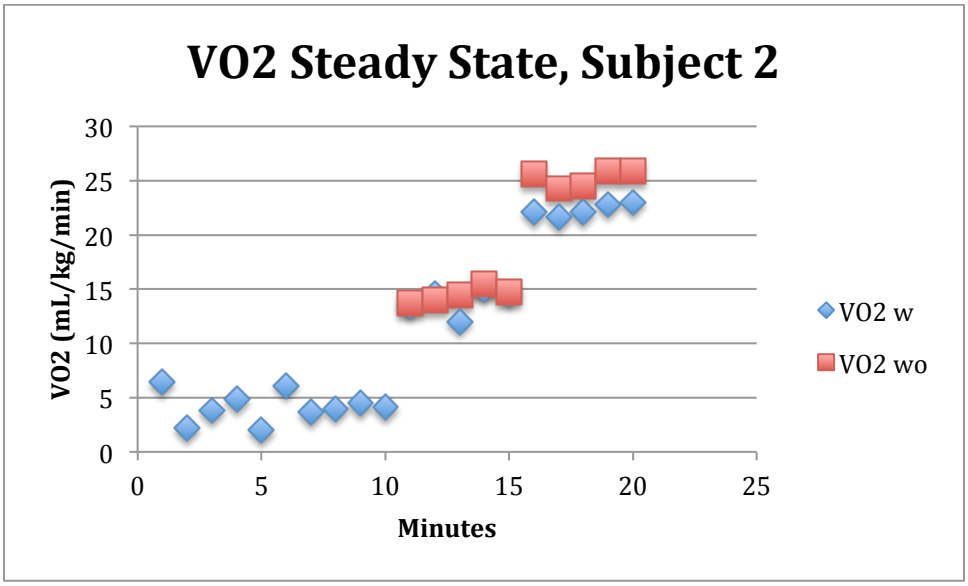


Figure 3A. *Volume of Oxygen Consumption Steady State, Subject 3*

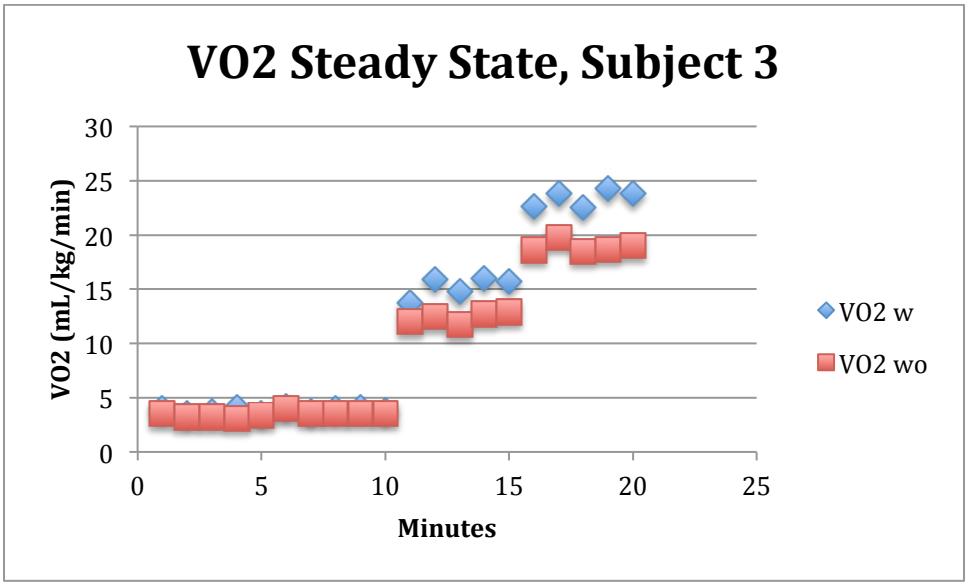


Figure 4A. *Volume of Oxygen Consumption Steady State, Subject 4*

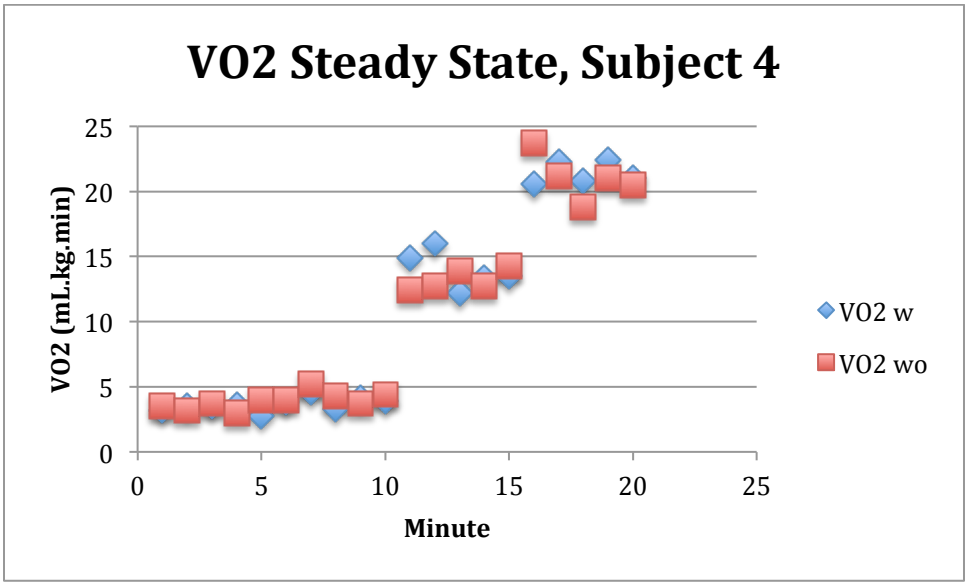


Figure 5A. *Volume of Oxygen Consumption Steady State, Subject 5*

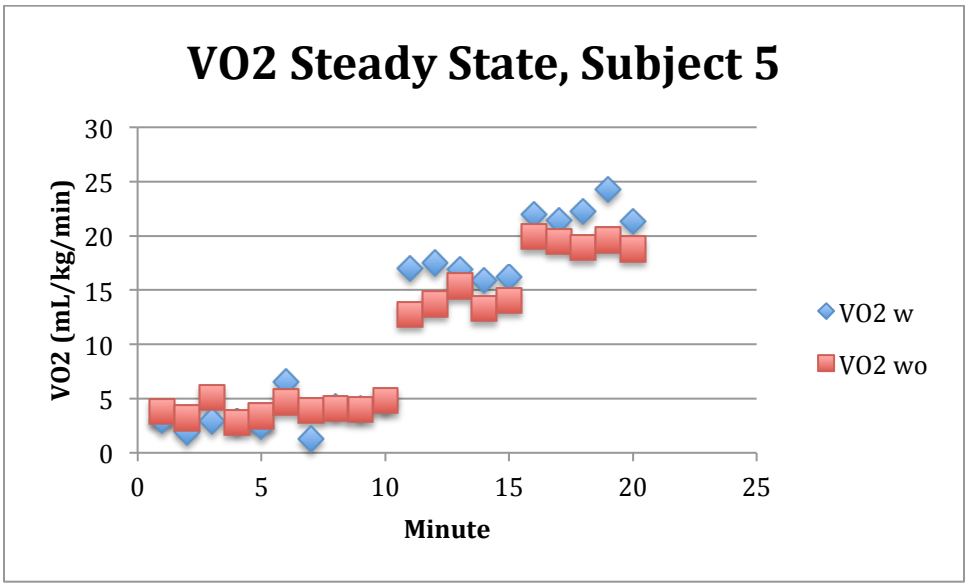


Figure 6A. *Volume of Oxygen Consumption Steady State, Subject 6*

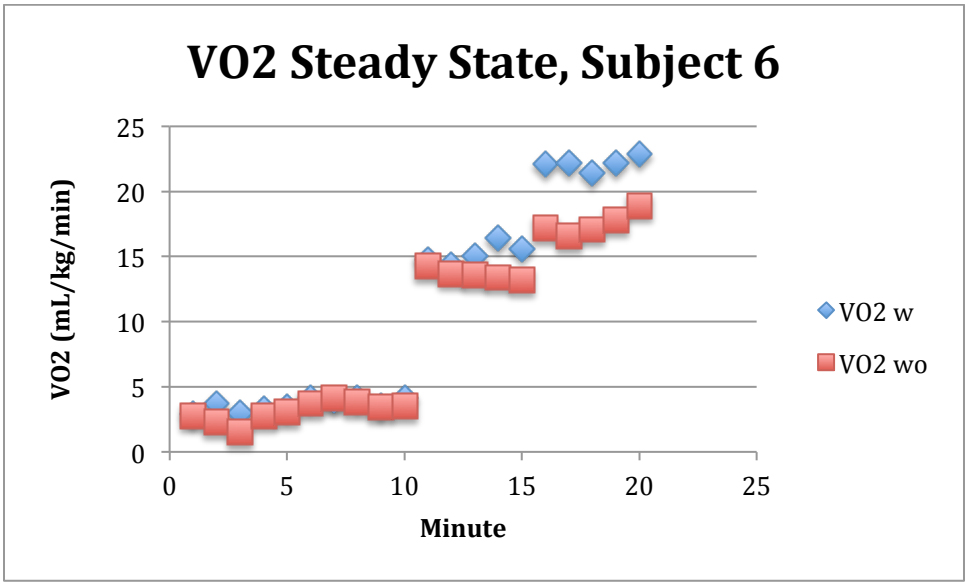


Figure 7A. *Volume of Oxygen Consumption Steady State, Subject 7*

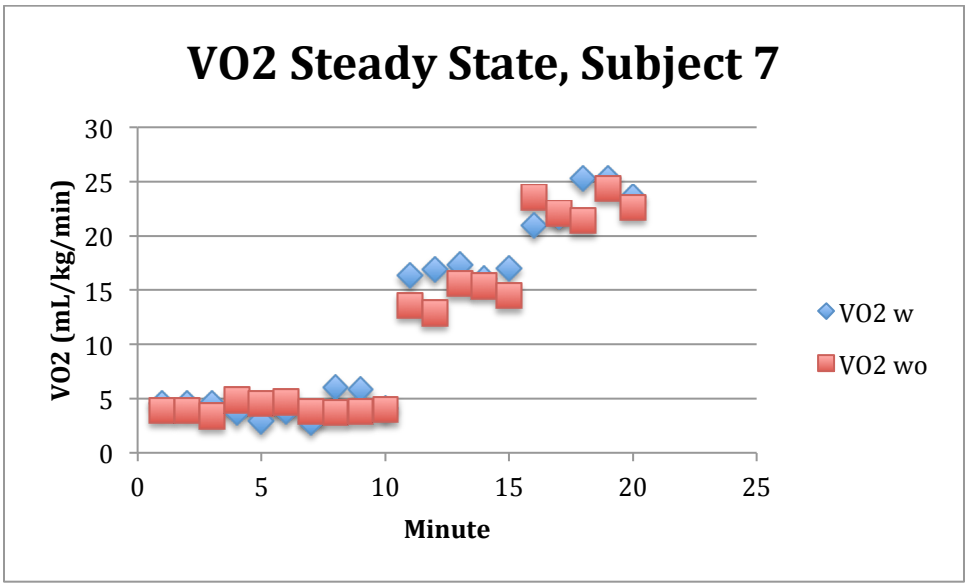


Figure 8A. *Volume of Oxygen Consumption Steady State, Subject 8*

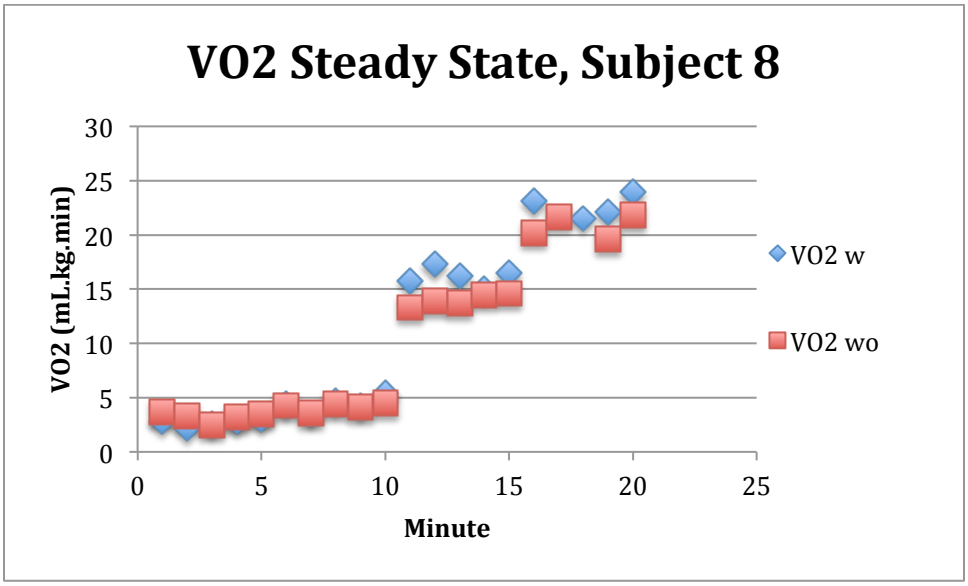


Figure 9A. *Volume of Oxygen Consumption Steady State, Subject 9*

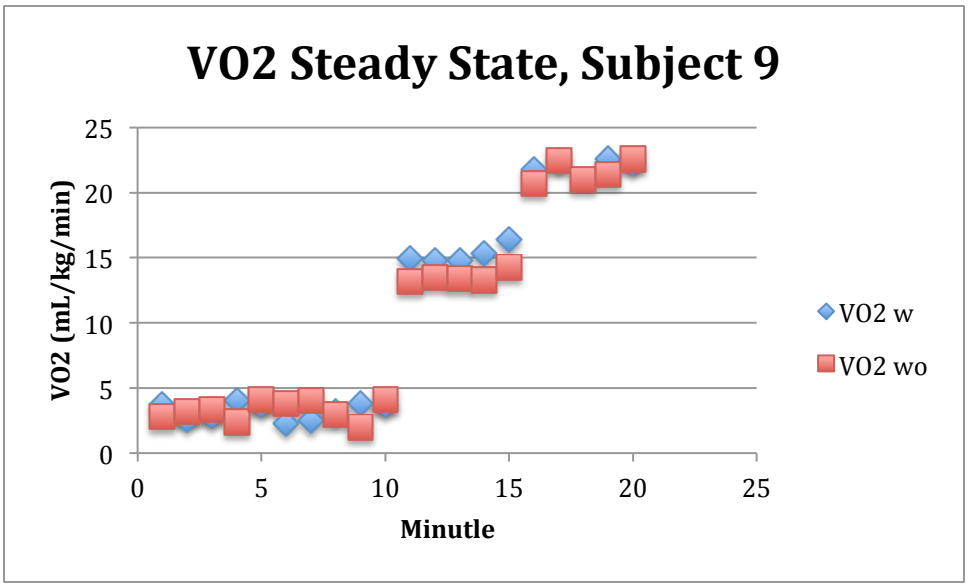
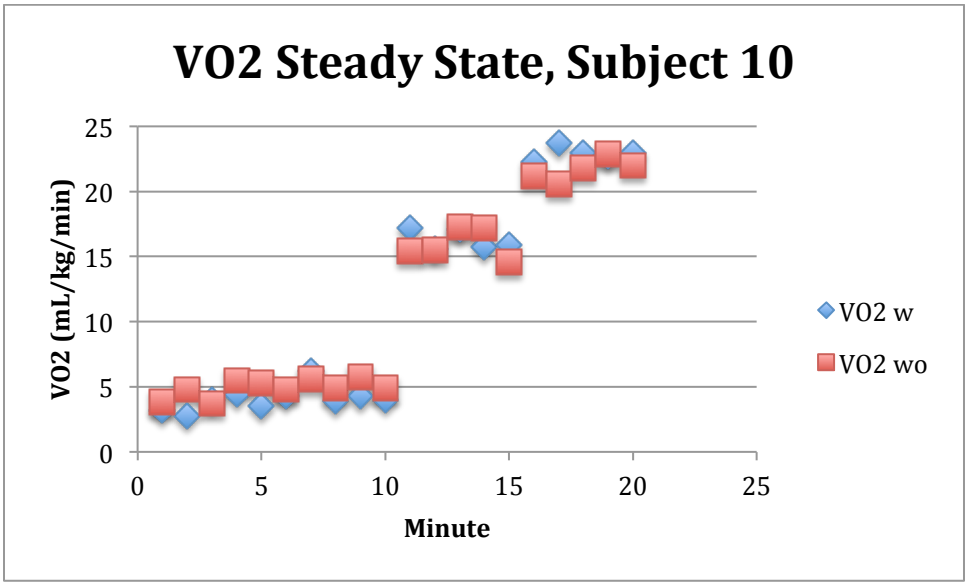


Figure 10A. *Volume of Oxygen Consumption Steady State, Subject 10*



VITA

NAME:	Kiersten Meta McCartney
EDUCATION:	B.S., Biology, The Ohio State University, Columbus, Ohio, 2013
	M.S., Kinesiology, University of Illinois at Chicago, Chicago, Illinois, 2015
TEACHING:	Department of Kinesiology and Nutrition, University of Illinois at Chicago, 2013-2015
	Department of Medicine, The Ohio State University, 2012-2013
EXPERIENCE:	Department of Kinesiology and Nutrition, University of Illinois at Chicago, Kinesiology Lab for Graduate Students, 2013-2015
HONORS:	Graduate College Fellowship, University of Illinois at Chicago, Chicago, Illinois, 2013-2015
	National Collegiate Athletic Association Scholar Athlete, The Ohio State University, Columbus, Ohio, 2009-2011
	Big Ten Conference Scholar Athlete, The Ohio State University, Columbus, Ohio, 2009-2011
	Sargent-at-Arms, Sphinx Senior Class Honorary, The Ohio State University, Columbus, Ohio, 2012-2013