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The Relationship Between Glucose Levels and Physical Activity

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Abstract

Background/Introduction: Elevated glucose levels can increase the risk of diseases, such as metabolic syndrome and Type 2 Diabetes. Thus, knowing glucose levels is important to indicate the likelihood of future health complications. Unfortunately, many young adults do not know their glucose levels. **Purpose:** The purpose of this research study was to complete a cross-sectional study and determine associations between fasting glucose with physical activity, and fitness. I hypothesized more physical activity, and higher fitness, will result in a lower, fasting glucose level. **Methodology:** This study examined 26 participants aged 18-25. The participants completed an 8-hour fasted glucose measurement, and treadmill testing. A GT9X accelerometer measured the participants' 24-hours, 7 days of activity. Glucose levels were compared to VO2max, maximum rate of oxygen consumption, from the treadmill test and their daily activity for 7 days. The relationship between fitness and physical activity with blood glucose was assessed using linear regression, additionally adjusted for age, sex and BMI. **Results:** The women had the following averages: age 21years, height 65 inches, weight 148 lb, BMI 24 lb/in^2, fasting blood glucose 88mg/dL, VO2max 36ml.kg/min, physical activity (CPM) 1922 and step count 11,846. The men had the following averages: age 21 years, height 71 inches, weight 183 lb, BMI 26 lb/in^2, fasting blood glucose 100 mg/dL, VO2max 43 ml.kg/min, physical activity (CPM) 2080, and step count 11,495. In unadjusted models, VO2max was positively associated with blood glucose ($p=0.039$) and step count was negatively associated with blood glucose ($p=0.02$). When adjusted for age, sex, and BMI, VO2max was not statistically associated with blood glucose ($p=0.668$), but step count remained negatively associated ($p=0.038$). **Discussion/Conclusion:** Higher step count showed associations with lower blood glucose. This correlates with my hypothesis that more physical activity will result in

lower glucose values. However, higher VO2max showed an association with a higher blood glucose. This goes against my hypothesis of higher fitness resulting in lower blood glucose. A potential limitation to this finding could be that not all the participants came in completely fasted. The associations between physical activity and blood glucose were different when adjusted for age, sex, and BMI. Non-significant findings could be related to a small population size, creating a limitation in the study. Based on these findings the more steps you take per week, the better, more normalized blood glucose will be. The increase in weekly steps lowering blood glucose can also improve overall health. Continuous studies should build on this information and potentially monitor blood glucose levels before and after amounts of exercise.

Lit Review

Background of Glucose. Glucose is a necessary component of everyday life. Glucose is the main sugar of the body and the body's primary source of energy (Salmon, 2019). Glucose is broken down by the body's digestive system from carbohydrates or sugar, and then released into the blood stream (Salmon, 2019). Insulin helps the absorption of glucose into cells that the body will use for energy or storage (Higuera, 2018). In individuals with Type 2 diabetes, the body's cells are insulin resistant and have trouble absorbing glucose, requiring the pancreas to overproduce insulin (Salmon, 2019). Insulin is a hormone the body uses to enable glucose in muscles, fat, and liver to be used as energy (Salmon, 2019). If the body cannot absorb glucose, and is not responding to insulin, glucose can build up in the blood and raise the blood sugar level (Higuera, 2018). Continued elevated glucose levels that go untreated may lead to nerve damage, cardiovascular disease, vision problems, kidney disease and sometimes amputations (Salmon, 2019). Higher glucose levels in young adults can lead to lower cognitive performance later in life and various other diseases (Cohen-Manheim, Sinnreich, Doniger, Simon, Pinchas-Mizrachi, & Kark 2018). Hyperglycemia occurs when the body's blood sugar is too high and cannot properly use glucose for energy (Salmon, 2019). Early diagnosis and treatment of high glucose levels can help those with hypertension and reduce cardiovascular complications (Kidney, Peacock, Smith 2014).

Implications of Diabetes. Glucose levels are extremely important in regard to diabetes. Diabetes is diagnosed based off of blood glucose levels (Dhanya and Hedge, 2016). In Type 1 diabetes, the body does not make insulin or is not making enough insulin to control the amount of glucose in the blood (Salmon, 2019). In Type 2 diabetes, too much glucose causes the body to not use insulin effectively to control blood sugar (Salmon, 2019). Instances of diabetes and prediabetes are increasing at a rapid rate (Kidney, Peacock, Smith 2014). A few physical signs diabetes is occurring are skin darkening on the face, back of neck, hands, armpits, groin, or other areas in which the skin creases (Salmon, 2019). This darkened skin will take on a velvety or raised texture and could include skin tags and itching (Salmon, 2019).

Physical activity. Physical activity is an effective treatment option for many conditions, as it does not have the same harmful side effects like medications (ACSM 10th edition). It is a safe way of preventing many diseases such as, atherosclerosis, lung disease, diabetes, obesity, osteoporosis, and rheumatologic diseases (Americans Health Rankings, 2019). In 2018 in Arkansas, 32.5% of people reported doing no physical activity or exercise other than their regular job for the past 30 days. (Americans Health Rankings, 2019). Physical activity offers many benefits including lowering mortality rates, cardiovascular disease, hypertension, Type 2 diabetes, cancers, reduced risk of dementia, improved quality of life, reduced anxiety and depression, and improved sleep (Americans Health Rankings, 2019). In 2016, 21.7% of adults ages 18 and up met aerobic and muscle strengthening activity guidelines (Americans Health Rankings, 2019). Adults ages 65 and older reported the highest inactivity rates (Americans Health Rankings, 2019). In Arkansas 27.1% of people aged 18-44 are physically inactive, 34.9% of people aged 45-64 and 40.4% of people 65+ are physically inactive (Americans Health Rankings, 2019). Physical inactivity rates are highest among American Indian/Alaskan Native at 44.8% (Americans Health Rankings, 2019). Nationally, 1 in 4 adults meet federal guidelines for both aerobic and muscle-strengthening activity in the United States (Americans Health Rankings, 2019). However, the current physical activity levels of college students in Arkansas is unknown. Many adults need to change their eating habits to achieve a healthier lifestyle and prevent diseases such as metabolic syndrome. The ACSM recommendation for adults is at least 150 minutes of moderate-intensity exercise every week while including resistance training two or three days a week. There is limited research on the physical activity of college aged students related to their glucose levels. This study helped determine activity of college individuals and if activity played a part in their glucose levels.

Obesity. Obesity is a major health concern worldwide as the condition decreases life expectancy (Engin 2017). Mortality rates in obese young adults is higher than obese older adults (Engin 2017). Obesity increases a person's risk in developing several diseases (Enging 2017). Obesity leads to the risk of cancer, metabolic syndrome, hyperglycemia, hypertension, coronary heart disease, and cerebrovascular disease (Engin 2017). In the past year, the United States obesity rate rose by five percent and now, 1 in 3 adults experience obesity; 31.3% of the United States are obese (Americas Health Rankings, 2019). Adults aged 25 and older with a college degree have a lower prevalence of obesity compared to those without a college degree (Americas Health Rankings, 2019). Obesity is the leading cause of chronic diseases such as cardiovascular disease and cancer, which have an effect on premature death rates (Americas Health Rankings, 2019). Arkansas is ranked 46 out of 50 states with 35% of Arkansans having obesity (Americas Health Rankings, 2019). More females are obese in Arkansas than men (Americas Health Rankings, 2019). There are 32.6% of Arkansans aged 18-44 with obesity, 41.4% aged 45-64, and 30.5% aged 65+ with obesity (Americas Health Rankings, 2019). In the past five years, premature death rates before 75 years of age have increased by five percent and cardiovascular deaths have increased by six percent (Americas Health Rankings, 2019).

Individuals who are considered obese have a higher risk of developing diabetes and other related diseases (Goosens 2017). Body mass index (BMI) values above 30kg/m2 will be considered obese and BMI between 20-25kg/m2 is considered to have the lowest mortality rate (Goossens 2017). BMI and body fat mass values can help determine metabolic health by measuring weight relative to height (ACSM 10th edition). BMI does not distinguish between body fat, muscle mass, or bone; therefore, a DXA scan is more reliable and is able to provide these details. (ACSM 10th Edition). Obesity levels in college aged students are unknown and have not been compared to glucose levels. It is under researched and this study helped create a comparison between the two.

Fitness. Cardiorespiratory endurance, "the ability to perform dynamic exercise involving large muscle groups at moderate-to-high intensity for prolonged periods," is very important for physical fitness health (Funderburk, Peterson, Beretich, Shah, Grandiean, 2018). Adults with low levels of cardiorespiratory fitness are at an increased risk of cardiovascular disease (Baumann, Guertler, Weymar, Bahls, Dörr, Berg, Ulrich, Sabina, 2019). Sedentary behavior increases cardiovascular disease and mortality (Baumann, Guertler, Weymar, Bahls, Dörr, Berg, Ulrich, Sabina, 2019). People with higher sedentary behavior also have a higher BMI and history of chronic disease (Baumann, Guertler, Weymar, Bahls, Dörr, Berg, Ulrich, Sabina, 2019). The American Diabetes Association recommends that people with prediabetes lose 7% of their body weight and increase physical activity to at least 150 min/week of moderate activity (Lee, Cigolle, Ha, Min, Murphy, Blaum, Herman 2013). Those with less physical activity and more limitations have a higher glycosylated hemoglobin compared to those more active with less limitations (Lee, Cigolle, Ha, Min, Murphy, Blaum, Herman 2013). There is not an abundance of data depicting the fitness levels of college aged students. This thesis study was able to specifically see how physically fit college aged students are.

Glucose associated with physical activity. Physical activity can reduce blood glucose levels, improve cardio-respiratory fitness and increase muscle mass (V, Suganthi, S, Anu. and K, Vijaybabu). Various types of exercise training can have this effect (V, Suganthi, S, Anu. and K, Vijaybabu). The more time spent being sedentary with less high intensity physical activity or cardiorespiratory fitness will increase a person's risk of metabolic syndrome and Type 2 diabetes (Van der Velde et al., 2018). Therefore, a person needs to make sure they are getting an adequate amount of exercise throughout the week. This study aimed to gather enough information to come to a conclusion regarding college aged students and their glucose levels in relation to physical activity.

Glucose associated with obesity and fitness. Obese individuals are at a much higher risk for developing disease compared to those at normal weight and standard BMI (Orenstein, 2019). Glucose values have shown to decrease with increased physical activity and increase with sedentary behavior (Orenstein, 2019). Strength training and aerobic exercises should be incorporated together to maintain well-rounded fitness (Orenstein, 2019). Resistance bands, push-ups, and sit-ups qualify as strength training exercises (Orenstein, 2019). Strength training will help with effective insulin use, lower blood sugar, build muscle that will help with weight loss, lower risk for heart disease, and help strengthen bones (Orenstein, 2019). Using muscles during strength training helps the muscles absorb more glucose and ultimately, lowers blood sugar (Orenstein, 2019). The study hypothesized that participants who are more active will have lower glucose values compared to participants who are less active.

Methods

Participants. The goal of the study was to achieve 30 participants aged 18-25 years. The participants were students of the University of Arkansas part of the the larger Exercise is Medicine (EIM) study. The participants needed to be able to complete the questionnaire in English. The participants who completed the fitness assessment could not have any physical or mental limitation, including pregnancy. All participants completed a health screening and did not complete the maximal testing if it was contraindicated according to the American College of Sports Medicine Guidelines.

Recruitment. Participants were recruited through flyers on campus, newswire, word of mouth, social media, and visiting various classes to seek participants. Social clubs on campus were informed about opportunities to participate and detailed explanations were distributed.

Procedures. The participants completed the fitness assessments at the HPER building with supervision from the Exercise Science Research Center. Participants could either complete the physical activity and medical history questionnaires at home before coming to the HPER or at the HPER before the assessments began. The participants first completed glucose testing because they came in fasted. The participants then completed a 24-hour diet recall. Next, the participants completed cognitive testing, a DXA scan, height and weight measurements, followed by flexibility, muscular strength, and muscular endurance. Finally, the participants completed the treadmill test to measure cardiovascular endurance.

Measures. This research study was part of the larger Exercise is Medicine data collection. Fasting glucose. The participants came in 8 hours fasted in order to measure accurate glucose values. The Cholestech LDX machine measured the participant's glucose values through a finger prick, using the Lipid Profile + Glucose test cassettes. A comparison of glucose values to the physical activity of college students aged 18-25 years was made.

Fitness assessment. Before testing began all participants completed an Exercise Science Research Center medical history to gage the ability of the participant, to ensure they were safe to exercise. Participants unable to perform the maximal exercise without medical clearance could not continue with the study until approved by a medical professional. For this study, participant's cardiorespiratory fitness was measured with a treadmill test using Bruce protocol (ACSM 10th edition). The treadmill test measured the circulatory and respiratory system's ability to supply oxygen during sustained physical activity (ACSM 10th edition). According to ACSM stratification, a participant could perform a submaximal treadmill test to 70% of their Heart Rate or 85% of age-predicted heart rate max if they need medical clearance for high intensity exercise (ACSM 10th edition). The level of obesity was assessed via anthropometrics and a DXA scan. The participant's height, and weight was gathered according to standard procedures. Participants completed a DXA scan to assess total body and body region fat-free mass, fat mass, and bone density (ACSM 10th edition). The DXA scan was administered by a graduate student on the Exercise is Medicine team. Muscular strength was measured by a hand grip dynamometer to test the ability of a muscle to exert force (ACSM 10th edition). The flexibility test was measured by Canadian Trunk Forward Flexion sit-and-reach protocol to test the range of motion available at a joint (ACSM 10th edition). Muscular endurance was measured as a push-up test until failure, to test the ability of a muscle to continue to perform without fatigue (ACSM 10th edition).

Physical Activity. Participants self-reported their physical activity for a 7-day 24hour cycle. Participants wore a GT9X accelerometer on their non-dominant hand to measure their physical activity, while also wearing the accelerometer during sleep. A computer program, Actigraph, was used to measure the activity from the accelerometers, and was then analyzed by the research assistants. The accelerometer was to be worn during all times of the day except during showers or anytime where it was to be submerged in water, ex: swimming. Aside from wearing an accelerometer, participants completed a physical activity questionnaire giving the times of rest and wake, and other times, if the accelerometer was taken off.

Statistical Analysis. A fasted Glucose level less than 100mg/dL was considered normal, prediabetes was considered 100-125mg/dL and diabetic was considered 126mg/dL or over (Mayoclinic.org, 2019). Blood Glucose levels were compared to the amount of physical activity participants performed in the week and to the treadmill test. In this study the dependent variable was glucose levels and the independent variables were fitness and physical activity.

Results: This study had a total of 26 student participants aged 18-25 years; 14 females and 11 males. The women had the following averages: age 21years, height 65 inches, weight 148 lb, BMI 24 lb/in^2, fasting blood glucose 88mg/dL, VO2max 36ml.kg/min, physical activity (CPM) 1922 and step count 11,846. The men had the following averages: age 21 years, height 71 inches, weight 183 lb, BMI 26 lb/in^2, fasting blood glucose 100 mg/dL, VO2max 43 ml.kg/min, physical activity (CPM) 2080, and step count 11,495. In unadjusted models, VO2max was positively associated with blood glucose (p=0.039) and step count was negatively associated with blood glucose (p=0.02) as seen in Table 2. When adjusted for age, sex, and BMI, VO2max was not statistically associated with blood glucose (p=0.668), but step count remained negatively associated (p=0.038) as seen in Table 3.

Table 1: Averages and Standard Deviation

	Men	*Women*	*p-value comparing*
Age years	21.3; (1.3)	21.2; (0.9)	.835
Height inches	70.7; (2.0)	65.3; (3.1)	<.001
Weight pounds	182.8; (25.3)	147.5; (29.6)	.005
BMI lb/in^2	25.7; (3.4)	24.2; (3.8)	.320
Fasting blood glucose mg/dL	100.0; (17.7)	88.4; (7.0)	.041
VO2 ml.kg/min	42.7; (6.9)	36.0; (4.2)	.007
Physical Activity (CPM)	2080.4; (2080.5)	1922.2; (374.8)	.333
Step Count	11,494.5; (3503.1)	11,846.2; (2273.2)	.764

Table 2: Associations between physical activity and blood glucose unadjusted, n=26

	Estimate (β)	**Standard Error**	**95%CI**	**p-value**
VO2	**0.9**	**0.4**	**0.05, 1.7**	**0.039**
Physical Activity (CPM)	0.002	0.007	-0.01, 0.02	0.716
Step Count	**-0.002**	**0.001**	**-0.004, -0.0004**	**0.02**

Table 3: Associations between physical activity and blood glucose adjusted for age, sex, BMI

	Estimate (β)	Standard Error	95%CI	p-value
VO2	0.2	0.5	-0.9, 1.3	0.668
Physical Activity (CPM)	0.01	0.01	-0.01, 0.02	0.434
Step Count	**-0.002**	**0.001**	**-0.003, -0.0001**	**0.038**

Discussion/Conclusion: Higher step count showed associations with lower blood glucose. This correlates with the hypothesis that more physical activity will result in lower glucose values. However, higher VO2max showed an association with a higher blood glucose. This goes against the hypothesis of higher fitness resulting in lower blood glucose. The associations between fitness and blood glucose were different when adjusted for age, sex, and BMI. The fitness was no longer associated with glucose when adjusted for age, sex, and BMI indicating those variables have an effect on glucose levels. Based on these findings the more steps you take per week, the better, lower blood glucose will be. The increase in weekly steps lowering blood glucose can also improve overall health. Future studies should build on this information and potentially monitor blood glucose levels before and after amounts of exercise.

<u>Comparison of findings to literature:</u> There are few articles comparing glucose values to physical activity and fitness in college aged students. There are research articles stating exercise, such as aerobic and resistance training, can help metabolic disease and Type 2 Diabetes (Evans, Weyrauch, and Witczak, 2019). According to a study from the Journal of Sports Science and Medicine (JSSM), VO2peak improved in pre-diabetic populations after 2-weeks of interval training but not after continuous exercise (Gaitán, Eichner, Gilbertson, Heiston, Weltman, Malin, 2019). The study by, Gaitán, Eichner, Gilbertson, Heiston, Weltman, and Malin can be compared

to the current study because it found step count to be related to lower glucose levels and their study found 2-hour glucose levels to be reduced after interval training (Gaitán, Eichner, Gilbertson, Heiston, Weltman, Malin, 2019). Further proving, exercise could prevent disease and help improve diabetes. An article by Amri, Parastesh, Sadegh, Latifi, and Alaee at the University of Medical Sciences, Arak, Iran, found a significant decrease in fasting blood levels after 10 weeks of high-intensity interval training (HIIT) in diabetic mice (Amri, Parastesh, Sadegh, Latifi, & Alaee, 2019).

An article by, Knowler, Barrett-Connor, Fowler, Hamman, Lachin, Walker, & Nathan found that lifestyle changes of 150 minutes of activity per week reduced the incidence of diabetes by 58 percent, and placebo treatment by 31 percent (Knowler, Barrett-Connor, Fowler, Hamman, Lachin, Walker, & Nathan 2002). Authors Chiang, Heitkemper, Hung, Tzeng, Lee, and Lin conducted a 12-week program of moderate-intensity exercise training that resulted in lowering glucose values, and improved metabolic control in patients with Type 2 Diabetes (Chiang, Heitkemper, Hung, Tzeng, Lee, & Lin, 2019). Higher blood glucose levels before exercise reduced through the 12-weeks, as did post exercise blood glucose values (Chiang, Heitkemper, Hung, Tzeng, Lee, & Lin, 2019). The current study helps to close the population gap between the age group of 18-25 years. As well as, close the gap between studies comparing glucose levels to physical activity using accelerometers analyzing for step count.

Discussion of the mechanisms: The current study found there was a relationship between physical activity and lower glucose values because an increase of step count was associated with better glucose levels. This finding can be due to the fact that aerobic exercise can lead to better insulin sensitivity (Coldberg, Sigal, Yardley, Riddell, Dunstan, Dempsey, Horton, Castorino, Tate, 2016). Therefore, the insulin the body is producing is better able to absorb the glucose and use it for energy. Regular exercise training will improve blood glucose control, reduce A1C, triglycerides, blood pressure, and insulin resistance (Coldberg, Sigal, Yardley, Riddell, Dunstan, Dempsey, Horton, Castorino, Tate, 2016). From the Bruce Treadmill test the study found the participants VO2max value and associated that with the participants' glucose level. However, the VO2 max was proven nonsignificant when adjusted for age, sex, and BMI in this study.

Strengths and limitations: This study had both strengths and limitations. The research team successfully completed the fitness assessments and obtained glucose samples according to standardized protocol. There were participants who did not comply with wearing the accelerometers all 7 days. Therefore, analyzing the accelerometers could have been skewed for participants who did not wear the accelerometer because they did not have an accurate step count. Also, a few participants did not note the exact times they took off the accelerometer on their physical activity sheet; leaving the researchers to analyze the accelerometers to the best of their capability. Using best judgement, the researchers marked wear time and not wear time for accelerometer processing. Step counts were not completely accurate for the participants who did not wear the accelerometer for the full 7 days. Therefore, a big limitation to the study was compliance. Besides the limitation of accelerometer compliance, there were a few participants who may not have been completely fasted and one participant who was unable to give blood due to fainting. This study was cut short due to the COVID-19 virus. Participants were suspended and we were unable to gather more data because of the University closure.

Conclusion: In conclusion, the data supported one hypothesis; step count was associated with lower glucose levels. Testing glucose levels before and after bouts of exercise, and potentially having participants reach a certain of amount of steps each week could be implemented in future studies. Glucose testing before and after exercise would add onto this study and show a more accurate response of glucose levels to physical activity. Requiring a certain amount of steps per week would also be beneficial to show how much aerobic fitness could reduce glucose levels over time. This finding would especially be beneficial to implement to diabetic participants, but future studies are needed to determine this. A future test consisting of all diabetic participants measuring their step count and glucose levels could potentially lead to improving their diabetes and minimizing future health risks. Health is one of the most important aspects in today's society and physical activity is one way to maintain a healthy lifestyle.

Timeline. This study was completed from the months of October 2019 to March 2020. It began by recruiting participants to the study until 20-30 participants completed the study.

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