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ASSOCIATION OF FRUIT AND VEGETABLE  
INTAKE WITH CARDIORESPIRATORY  
FITNESS IN ADOLESCENTS

Jonathan C. Grimwood

45 Pages

An association has been established between total dietary energy intake and cardiorespiratory fitness (CRF) in adolescents. However, there is little research examining specific dietary components, such as fruit and vegetable intake. **PURPOSE:** The primary purpose of this research is to determine if an association exists between fruit and vegetable (F/V) intake and CRF in adolescents. A secondary purpose of this study is to determine if an association exists between F/V intake and body mass index (BMI). **METHODS:** A sample of 424 adolescents (234 males and 190 females), age 10-18 years, completed the Dietary Behavior section of the Youth Risk Behavior Survey (YRBS) and the FITNESSGRAM 20-meter Pacer test (PACER). Height and weight were also measured to determine BMI. This section of the YRBS assesses F/V intake based on intake frequency over a one-week period. Peak oxygen consumption ( $VO_{2peak}$ ) was estimated from the PACER results and categorized based on the FITNESSGRAM aerobic standards, placing individuals into one of three categories: Healthy Fitness Zone (HFZ), Needs Improvement (NI), and Needs Improvement – Health Risk (NI-HR). Body composition was estimated using Body Mass Index (BMI), which was calculated from participants' height and weight, and categorized based on the FITNESSGRAM BMI standards, placing individuals into one of four categories: Very Lean (VL), HFZ, NI, and NI-HR. Mean

differences in total F/V intake for participants in each of the CRF and BMI categories were assessed using a one-way ANOVA. RESULTS: The mean total F/V (F/V) intake values (times per week) showed slight differences between each of the CRF categories. For male participants, the F/V intake values in the HFZ, NI, and NI-HR CRF categories were 19.9 (SD 15.2), 15.8 (SD 19.2), and 19.1 (SD 13.8) respectively. The mean F/V intake for female participants in the HFZ, NI, and NI-HR categories were 20.9 (SD 16.2), 20.3 (SD 19.6), and 15.9 (SD 9.6) respectively. However, none of these differences were statistically significant (all  $p > 0.05$ ). Average F/V intakes were also individually analyzed, but with similar results (all  $p > 0.05$ ). Similar results were found for mean F/V intake between each of the BMI categories. F/V intake for male participants in the VL, HFZ, NI, and NI-HR categories were 19.6 (SD 13.1), 18.9 (SD 16.1), 20.3 (SD 14.6), and 17.5 (SD 18.1) respectively. The mean F/V intake for females in the VL, HFZ, NI, and NI-HR categories were 25.6 (SD 16.1), 19.6 (SD 15.2), 24.5 (SD 22.1), and 15.4 (SD 11.6) respectively. Likewise, none of these differences were significant (all  $p > .05$ ). CONCLUSION: F/V intake does not have a significant association with CRF or BMI values in adolescents.

KEYWORDS: Cardiorespiratory, Aerobic, Fitness, Fruit, Vegetables, Adolescents

ASSOCIATION OF FRUIT AND VEGETABLE  
INTAKE WITH CARDIORESPIRATORY  
FITNESS IN ADOLESCENTS

JONATHAN C. GRIMWOOD

A Thesis Submitted in Partial  
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ASSOCIATION OF FRUIT AND VEGETABLE  
INTAKE WITH CARDIORESPIRATORY  
FITNESS IN ADOLESCENTS

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CHAPTER I  
ASSOCIATION OF FRUIT AND VEGETABLE  
INTAKE WITH CARDIORESPIRATORY  
FITNESS IN ADOLESCENTS

Introduction

Physical fitness plays a large role in preserving optimal health throughout the lifetime for individuals of all ages. Maintaining cardiovascular fitness and a healthy lifestyle can help an individual remain independent and functional for much longer in life, as well as increase overall life expectancy (Kaeberlein, Rabinovitch, & Martin, 2015; Mercken, Carboneau, Krzysik-Walker, & de Cabo, 2012; Wang, Ramey, Schettler, Hubert, & Fries, 2002). As the prevalence of chronic diseases such as obesity, cardiovascular disease (CVD), and type II diabetes increases, it is important to start taking a preventative approach to decrease the number of cases. “Diet and exercise” is a common phrase heard in a discussion on improving overall fitness. A meta-analysis by Johns, Hartmann-Boyce, Jebb, and Aveyard (2014) found that a combination of exercise and healthy diet showed significant, long-term improvements in body composition and cardiorespiratory fitness (CRF) when compared to diet or exercise alone. Increased fruit and vegetable (F/V) intake and CRF both have positive and protective effects against future health complications. Cardiorespiratory fitness in both adolescents and adults has been found to have an inverse relationship with diseases such as obesity, CVD, type II diabetes, and other chronic diseases associated with low activity (Boreham & Riddoch, 2002; Carnethon, Gulati, & Greenland, 2005; Hogstrom, Nordstrom, & Nordstrom, 2014; Kodama et al., 2009; Ruiz, Castro-Pinero, & Artero, 2009). Similarly, an inverse relationship was also found between F/V intake

and these same chronic diseases, primarily CVD (He, Nowson, Lucas, & MacGregor, 2007; Nikloic, Nikic, & Petrovic, 2008; Panagiotakos et al., 2003). Therefore, this study attempts to establish a more direct association between these variables.

While children and adolescents are among the most physically active populations, over the past few decades, studies have shown a noticeable decrease in CRF and physical activity. A publication by Dollman, Norton, and Norton (2005) stated that CRF in children has decreased by about 1% per year over the previous twenty years. Children also are becoming less active overall, resulting in decreased physical fitness as they grow older. Troiano et al. (2008) found that 42% of children (6-11 years) met the physical activity recommendations of 60 minutes/day, while only 8% of adolescents achieved the same goal. This study also found that less than 5% of adults adhered to the recommendations of 30 minutes of physical activity. The issue here is the consistent decline in amounts of physical activity occurring with increasing age over the past few decades (Barte, Veldwijk, Teixeira, Sacks, & Bemelmans, 2014; Brownson, Boehmer, & Luke, 2005; Ho et al., 2012; Nader, Bradley, Houts, McRitchie, & O'Brien, 2008; Toji et al., 2012). With the growing prevalence of chronic diseases caused by decreased CRF and physical activity, the need for effective options for improving CRF and physical activity is critical during adolescence.

A good approach for combating this decline in physical activity and fitness is to promote physical fitness in adolescents to form habits that they will carry with them into adulthood. Fortunately, most schools perform physical fitness testing on their students using programs such as FITNESSGRAM to assess fitness. Fitness scores, especially CRF, throughout adolescence are key predictors of future health. Not only does high CRF have a protective effect against CVD, type II diabetes, and obesity in adolescents, it significantly decreases the risk of developing these

chronic diseases later in life (Boreham & Riddoch, 2002; Carnethon et al., 2005; Ho et al., 2012; Kohl III & Cook, 2013; Minasian, Marandi, Kelishadi, & Abolhassani, 2014; Ruiz et al., 2009). The chances of several risk factors associated with these diseases, such as hypertension and dyslipidemia, are also reduced (Jette, Sidney, Quenneville, & Landry, 1992; Sallis, Patterson, Buono, & Nader, 1988).

Physical fitness testing will assess fitness levels, but may not be the only key to improving CRF. A study by Van Duyn and Pivonka (2000) stated that consuming adequate amounts of fruits and vegetables has a preventative effect against heart disease, which according to the Centers for Disease Control and Prevention (CDC) (2017) is the leading of death in the United States. This emphasizes the importance of adequate F/V consumption on a regular basis. Researchers have also long recognized the importance of eating an overall healthy diet and it influences the development or prevention chronic diseases, such as the ones listed above (He et al., 2007; Nikloic et al., 2008; Nothlings, Schulze, Weikert, Boeing, & Van Der Schouw, 2007; Panagiotakos et al., 2003; Tam & Ravussin, 2012). Willett et al. (2006) discuss the relationships between dietary and lifestyle factors with chronic diseases. These dietary and lifestyle factors include physical activity, being overweight/obese, smoking, consumption of fruits and vegetables, and limiting excessive calories. Similar dietary and lifestyle components are analyzed with similar findings by Forman and Bulwer (2006) and supported by other publications (Appel, 1999; Appel, 2000; Campbell et al., 1999; Srinath-Reddy & Katan, 2004). Research also shows that fruits and vegetables provide the body with antioxidants (Vitamins C and E) and fiber. Antioxidants reduce the amount of reactive oxidative species (ROS) in the body, which are produced through oxidative metabolism (Clarkson & Thompason, 2000). High levels of ROS have their own set of risks associated with them, including increased risk factors

for chronic disease, damage to DNA, and apoptosis (Lau, Wang, & Chiu, 2008; Liu, 2003; Shin, Kim, Kang, Han, & Shim, 2015). Soluble fiber improves glycemia and insulin sensitivity in adults and children (Anderson et al., 2009). The CDC defines a healthy eating pattern as one including a variety of vegetables, whole fruits, whole grains, fat-free or low-fat dairy, variety of proteins, and oils. The CDC (2016) also recommends limiting saturated and trans fats, added sugars, and sodium, as these are linked to increases in cardiovascular disease, type II diabetes, obesity, and risk factors associated with these diseases. Many studies have shown how different dietary patterns can negatively impact overall health, but this investigation will focus on fruits and vegetable intake (Astrup, 2005; Bantle, 2009; DiNicolantonio & Lucan, 2015; Reddy, Srdhar, Machado, & Chen, 2015). In 2014, the CDC (2014) shared a press release stating that children and adolescents should be consuming 1-2 cups of fruit and 1-3 cups of vegetables per day, although values do vary based on age, gender, and physical activity. Reaching these recommendations every day provides them with adequate vitamins, minerals, antioxidants, anti-inflammatory agents, and phytochemicals that may help prevent cardiovascular disease and stroke (Lamprecht, 2012; Liu, 2003; Slavin & Lloyd, 2012; Van Duyn & Pivonka, 2000).

Both CRF and F/V intake share similar outcomes related to reducing the risk of chronic disease in the present, and later in life. The next step is to see if there is a direct association between the two. While a relationship between energy balance and physical fitness has been found, they mainly note that a positive energy balance (intake > expenditure) may increase the risk of obesity in children. Seeing as how obesity is inversely correlated with CRF, the connection can be made between caloric intake and fitness (Hall et al., 2012; Tam & Ravussin, 2012; Tyson, Nwankwo, Lin, & Svetkey, 2012). This does not speak for F/V intake alone, however.

Therefore, the primary purpose of this research is to examine the relationship between F/V intake and CRF in adolescents. The secondary purpose is to examine the relationship between F/V intake and BMI. Establishing these connections may help take the next step in improving the quality of life for children as they continue into adolescence and adulthood by decreasing the risk of chronic diseases.

## Methods

*Subjects and Procedures:* The subjects in this study included 424 students from seven elementary schools, three middle schools, and one high school in several Midwest U.S. school districts. Data were collected as part of the Physical Education Program (PEP) Grant over two six-week sampling periods: one in the fall and one in the spring. This sample included 234 males and 190 females aged 10-18 years. Each student participated in the FITNESSGRAM battery of tests and completed the 20-meter Pacer test (PACER), as per the school's typical testing protocol. The PACER is regarded as an effective way of assessing aerobic fitness (Mayorga-Vega, Aguilar-Soto, & Vician, 2015). Height and weight were also measured at the time of fitness testing. All tests were administered by licensed physical education (PE) teachers at each school. Student PACER laps were recorded and de-identified by the school staff using a predetermined identification (ID) number.

Students then completed the Dietary Behavior section of the Youth Risk Behavior Survey (YRBS) to the students. This section of the YRBS assesses F/V intake frequency over a one-week period. Participants completed these surveys around the midpoint of each data collection period. Elementary students took the surveys home to complete, while junior high and high school students completed the surveys at school. The YRBS responses were then de-identified by the school staff with the same ID number as their PACER scores. At the end of the data

collection period, the PACER scores and YRBS responses were compiled into spreadsheets. Once all the student data were de-identified and compiled, it was provided to the primary researcher who matched the PACER scores with the YRBS responses. The data was then analyzed by the primary researcher to determine if an association between F/V intake with CRF.

*Data/Statistical Analysis:* Data from this study was analyzed using IBM SPSS Statistics Version 21 (Armonk, New York) and Microsoft Excel. Data were screened to look for missing values, such as age, sex, height, weight, unanswered YRBS questions, or aerobic assessment scores. Exclusions included any student missing any of the values listed. Descriptive statistics were used to provide the demographics of the sample.

To analyze CRF, the number of PACER laps for each student were converted to relative peak oxygen consumption ( $VO_{2\text{peak}}$ ) values using the most recent FITNESSGRAM PACER-to- $VO_{2\text{peak}}$  conversion equation (Saint-Maurice, Anderson, Bai, & Welk, 2016). Estimated  $VO_{2\text{peak}}$  values were then categorized based on the FITNESSGRAM aerobic standards, placing individuals into one of three categories: Healthy Fitness Zone (HFZ), Needs Improvement (NI), or Needs Improvement – Health Risk (NI-HR) (Table 2). Exclusions included those under the age of 10 years. FITNESSGRAM does not classify  $VO_{2\text{peak}}$  values for adolescents ages 9 and under.

The Dietary Behavior section of the YRBS was used to determine F/V intake frequency over a one-week period. This section of the survey consists of five questions concerning frequency of consumption. Questions asked the students to respond with how many times over the past seven days they consumed fruit (not counting fruit juice), green salad, potatoes, carrots, or other vegetables. Each question contained five responses intended to identify the frequency of F/V consumption over the previous seven days. Students were asked to respond with 0 times

during the past seven days, 1-3 times during the past seven days, 4-6 times during the past seven days, once per day, twice per day, three times per day, or four or more times per day (Appendix). A number value was assigned to each response. If the student responded with “I did not eat any during the past seven days,” the number assigned was 0. For the “1-3 times” and “4-6 times” responses, the values associated with each response were 2 and 5 respectively. For the responses “once per day,” “twice per day,” “three times per day,” and “four or more times per day,” the associated values were 7 (one for each day of the week) and 14 (two for each day of the week), 21 (three for each day of the week), and 28 (four for each day of the week) respectively. All the frequency values were then combined to determine the total frequency of F/V intake over the course of one week. Exclusions included those who were missing one or more of the responses to the YRBS questionnaire.

The F/V consumption was calculated as a raw score as number of times consumed per week. Raw scores for F/V intake were then averaged for category in the FITNESSGRAM aerobic fitness standards. F/V scores were also categorized based on FITNESSGRAM BMI classifications. Mean F/V scores for each category were compared between the fitness and BMI classifications to examine if there were significant differences.

Body Mass Index (BMI) was calculated to determine if an association exists between body composition and F/V intake. Students’ height ( $m^2$ ) and weight (kg) were used to calculate BMI scores. They were then categorized per the FITNESSGRAM BMI standards, placing individuals into one of four categories: Very Lean (VL), HFZ, NI, or NI-HR. Exclusions included those under the age of 10 years.

In order to examine the relationship between F/V intake and CRF, a one-way analysis of variance (ANOVA) was performed. The ANOVA compared mean differences for total F/V



intake across each of the CRF categories to look for a significant association. A secondary analysis was performed to compare mean differences for total F/V intake across each of the BMI categories.

Pearson correlation analyses were completed to examine the relationship between raw F/V scores and estimated  $VO_{2\text{peak}}$ , as well as BMI scores. Males and females were analyzed individually and as a whole. Participants were then placed into groups based on their age and analyzed among their age group to examine the relationship at each age (10-year-olds with 10-year-olds, 11-year-olds with 11-year-olds, etc.).

## Results

This study's sample consisted of 424 adolescents with 234 males and 190 females. The subjects combined had a mean age of  $13.3 \pm 2.5$  years, with a range of 10 to 18 years, mean  $VO_{2\text{peak}}$  of  $44.2 \pm 7.4$  ml/kg/min, and mean BMI of  $21.9 \pm 5.2$  kg/m<sup>2</sup>. For males, mean age,  $VO_{2\text{peak}}$ , and BMI were  $13.3 \pm 2.5$  years,  $45.5 \pm 7.9$  ml/kg/min, and  $21.9 \pm 5.6$  kg/m<sup>2</sup> respectively. For females, mean age,  $VO_{2\text{peak}}$ , and BMI were  $13.3 \pm 2.5$  years,  $42.6 \pm 6.4$  ml/kg/min, and  $21.9 \pm 4.7$  kg/m<sup>2</sup>, respectively. Descriptive statistics of subjects are shown in Table 1.

Distribution of subjects into the FITNESSGRAM CRF and BMI classifications are shown in Table 2 and Table 3. The male distribution into the NI-HR, NI, and HFZ categories were 19.6%, 16.7%, and 63.7%, while females were distributed 14.2%, 20.5%, and 65.3%, respectively. For male BMI classifications, 17.1% were classified as VL, 52.6% as HFZ, 14.9% as NI, and 15.4% as NI-HR. Females were distributed as 4.2% in the VL category, 68.4% in HFZ, 15.3% in NI, and 12.1% in NI-HR.

Frequency of fruit, vegetable, and combined F/V intake in each gender and total combined are shown in Table 4 as a measure of number of times consumed in the past week. It was found that on average males consumed fruits, vegetables, and combined F/V an average of  $6.7 \pm 6.2$ ,  $12.3 \pm 11.3$ , and  $19.1 \pm 15.7$  times per week, respectively. Females consumed fruits, vegetables, and combined F/V an average of  $8.1 \pm 7.0$ ,  $12.0 \pm 11.3$ , and  $20.1 \pm 16.2$  times per week. The females tended to consume slightly more fruits than the males, which also influenced the frequency of combined F/V intake. However, several T-tests revealed that these differences were not significant ( $p > .05$ ).

The mean total F/V intake values (times per week) showed slight differences between each of the CRF categories (Table 5). For combined male and female participants, total F/V intake increased slightly from the NI-HR, NI, and HFZ categories ( $17.9 \pm 12.4$ ,  $18.0 \pm 19.4$ , and  $20.4 \pm 15.6$ , respectively). While there were no significant differences between the groups (all  $p > .05$ ), participants in the HFZ category averaged 13.9% more F/V than those in NI-HR category. When males and females were analyzed individually, non-significant results were also found. For male participants, the F/V intake values in the NI-HR, NI, and HFZ categories were  $19.1 \pm 13.8$ ,  $15.8 \pm 19.2$ ,  $19.9 \pm 15.2$ , and respectively. The mean F/V intake for female participants in the NI-HR, NI, and HFZ categories were  $15.9 \pm 9.6$ ,  $20.3 \pm 19.6$ , and  $20.9 \pm 16.2$  respectively. On average, females consumed slightly more fruits and vegetables than males in each of the CRF categories. However, none of the differences between CRF groups or genders were statistically significant (all  $p > 0.05$ ). Average F/V intakes were also individually analyzed, but with similar results. Mean fruit intake for males in the NI-HR, NI, and HFZ categories were  $6.5 \pm 4.7$ ,  $6.1 \pm 7.7$ , and  $6.9 \pm 6.2$  respectively, while mean vegetable intake was  $12.6 \pm 11$ ,  $9.7 \pm 13.2$ , and  $12.9 \pm 10.9$  for each category. Similarly, mean fruit intake for females in the NI-HR,

NI, and HFZ categories were  $6.3 \pm 5.4$ ,  $7.8 \pm 7.7$ , and  $8.5 \pm 7.1$  respectively, while mean vegetable intake was  $9.5 \pm 6.6$ ,  $12.5 \pm 13.8$ , and  $12.4 \pm 11.3$  for each category. None of the differences between groups were significant (all  $p > 0.05$ ). Additional correlational analyses were run to examine the relationship between estimated  $VO_{2\text{peak}}$  and raw F/V scores. Non-significant correlations were found in both males and females when controlling for age (.078 and .132 respectively, both  $p > 0.05$ ). When analyzed individually, a significant correlation was found between fruit consumption and estimated  $VO_{2\text{peak}}$  ( $r = .144$ ,  $p < 0.05$ ). However, with a fairly weak correlation coefficient of .144, these results do not carry much weight. Results of these analyses are found in Table 7.

A secondary analysis was performed to compare the mean total F/V intake values in each of the BMI categories (Table 6). For male participants, the F/V intake values in the VL, HFZ, NI, and NI-HR categories were  $19.6 \pm 13.1$ ,  $18.9 \pm 16.1$ ,  $20.3 \pm 14.6$ , and  $17.5 \pm 18.1$  respectively. Female participants had similar results with F/V intake values in the VL, HFZ, NI, and NI-HR categories of  $25.6 \pm 16.1$ ,  $19.6 \pm 15.2$ ,  $24.5 \pm 22.1$ , and  $15.4 \pm 11.6$  respectively. All differences between groups were not statistically significant (all  $p > 0.05$ ). Additional correlational analyses were run to examine the relationship between BMI and raw F/V scores. Non-significant correlations were found in both males and females when controlling for age (.042 and -.076 respectively, both  $p > 0.05$ ). When analyzed individually, fruit and vegetable intake also yielded no significant correlations with BMI in both males and females. Results of these analyses are found in Table 8.

Analyses were run for each individual age group to examine any differences between the ages in males and females. No significant differences were found when comparing mean fruit, vegetable, and total F/V intake between CRF or BMI classifications in both males and females at

each age. Additional correlational analyses were performed to examine the relationship between total F/V intake and estimated  $VO_{2\text{peak}}$  at each age, but had inconsistent findings. A significant correlation was found between  $VO_{2\text{peak}}$  and total F/V intake (.447,  $p = .012$ ) in 11-year-old males. Females had a significant correlation between total F/V intake and  $VO_{2\text{peak}}$  in 14-year-olds (.811,  $p < .001$ ). When analyzing BMI values and total F/V consumption a significant correlation was only found in 10-year-old males (.358,  $p = .024$ ).

### Discussion

Based on the data analyzed in this study, an association between frequency of F/V consumption and CRF cannot be established. While a 13.9% increase in the average F/V intake was noticed in the HFZ group when compared to the NI-HR group, the difference is not statistically significant. The non-significant results may be due to the large standard deviation for the mean F/V intake scores. A large standard deviation could alter the effect size, resulting in non-significant findings. The results also did not show a noticeable trend between the groups when males and females were analyzed separately. There seems to be no difference in the number of times fruits and vegetables are consumed between those with different CRF.

Much research has been done on the relationship between amount of F/V intake and physical activity and overall cardiovascular health, but not much has been done to establish an association between F/V intake and physical fitness. One rationale for F/V consumption affecting physical fitness, specifically CRF, is the added antioxidants they provide. A study by Esfahani et al. (2011) showed that consuming adequate amounts of fruits and vegetables increased the serum levels of antioxidant pro-vitamins, as well as reduced levels of homocysteine and other markers of oxidative stress. Several other publications had similar findings (Liu, 2003; Slavin & Lloyd, 2012; Van Duyn & Pivonka, 2000). The idea behind this is that regularly

consuming fruits and vegetables will provide the body with adequate amounts of antioxidants to buffer the ROS and inflammatory chemicals and reduce the potential damage these may have on cells in the body. Since ROS production is increased during cardiorespiratory activities, it was expected that an association would be identifiable between the F/V intake and CRF. While research supports a link between F/V intake, antioxidants, and anti-inflammatory chemicals, this study cannot establish a direct association between F/V intake and CRF (Esfahani et al., 2011). Most research that has been published regarding specific dietary components focus on carbohydrates, lipids, and proteins rather than food group consumption patterns. This makes it difficult to find results supporting or opposing the findings of this study. This study helps expand research in the direction of analyzing F/V intake and seeing if the benefits they provide influence CRF.

The secondary aim of this study was to examine the relationship between F/V intake and BMI. Similar to the primary aim, the results were non-significant. The slight differences in F/V intake between each of the BMI categories did not prove to be significant, nor did they follow a trend between the different categories. These results are consistent with Field, Gillman, Rosner, Rockett, and Colditz (2003) who did not find significant differences between F/V intake and different BMI classifications in both males and females. This implies that while recommendations for F/V consumption may be valuable due to their preventive properties, they may not have a direct effect on body composition in adolescents. Other dietary factors may play a more important role than F/V alone, energy balance for example. Energy balance is the key component of weight management and body composition in both adolescents and adults, and is therefore examined more frequently than F/V alone (Hall et al., 2012; Tam & Ravussin, 2012;

Van Baak, 1999). The findings in the studies on adolescents are not consistent with what research has shown in adults.

Charlton et al. (2014) examined the same relationship in adults, examining how the amount of F/V consumption varies between different BMI classifications and found results conflicting with those from studies on adolescents. They found that overweight and obese men and women were more likely to consume higher intakes of F/V than normal weight individuals. However, this was attributed to the general overconsumption of food by the overweight and obese individuals, which resulted in an energy imbalance, not F/V consumption alone. This conflicts with what was found in a similar study by Heo et al. (2011), who found an inverse relationship between F/V intake and BMI classification. These inconsistencies between adults and children show the need for more research examining specifically F/V consumption in both adults and adolescents.

The underlying question is whether physically fit people tend to eat healthier. The correlational analyses examined the relationship between CRF or BMI and F/V intake. While none of the relationships were significant, there is no set explanation. One idea is that individuals who are physically fit do not feel the need to consume F/V regularly. They may feel that F/V are only required to help improve fitness, which is not as much of an issue for them compared to individuals with low fitness. Individuals with low fitness may see benefits from increased levels of F/V consumption. However, research shows a large portion of both adolescents and adults, both fit and unfit, do not regularly meet recommended levels of F/V intake (Guenther, Dodd, Reedy, & Krebs-Smith, 2006; Kim et al., 2014; Kimmons, Gillespie, Seymour, Serdula, Blanck, 2009; Krebs-Smith, Guenther, Subar, Kirkpatrick, Dodd, 2010). Parental influence may also play role in younger individuals. Children and adolescents may not have much control over the food

that is provided for them. The amount of emphasis and parents place on F/V may also affect how a child perceives their importance.

Research on dietary information utilizes several different methods for measuring F/V intake. For example, both studies on adults mentioned above used a questionnaire to determine amount of F/V being consumed. Charlton et al. (2014) used servings per day as a raw value, while Heo et al. (2011) used number of servings to classify subjects into either  $\geq 5$  servings or  $< 5$  servings. Both studies classified a serving as a half-cup of either fruit or vegetables. This study utilized the Dietary Behavior section of the YRBS, which measures in frequency of consumption over the past week. The food frequency method has been used by many studies regarding adolescents, including Field et al. (2003) mentioned above. Food frequency questionnaires have been validated for both children, adolescents, and adults in several studies (Kobayashi et al., 2011; Kolodziejczyk, Merchant & Norma, 2012; Lorson, Melgar-Quinonez, & Taylor, 2009; Minaker & Hammond, 2016; Moghames et al., 2016; Watson, Collins, Sibbritt, Dibley, & Garg, 2009). Kolodziejczyk et al. (2012) found that the highest average validity correlations of food frequency questionnaires in children were obtained when the questionnaire did not assess portion size, measured a shorter time span (previous day/week), and was not administered to the child's parents. While the junior and high school students met these criteria, the elementary students completed the surveys at home with their families. These factors may have influenced the results for the elementary aged participants. It is important to note that food frequency questionnaires may be effective at measuring frequency of intake, but they are not able to assess quality of food intake or serving size. An individual may complete the questionnaire stating that they consumed potatoes five times in the past week, but four of those five servings may have been french fries or potato chips. Also, if an individual consumes less than a recommended serving of F/V, the data

will not be able to tell the difference with this method. The inability to measure food quality and servings size may cause problems when analyzing how diet influences factors like physical fitness or health.

In regards to F/V intake, the wide range of participant age may play a factor. With this relatively large sample size ( $n = 424$ ), subjects range from 10 to 18 years. When subjects were analyzed in separate groups based on their age, a correlational analysis yielded very inconsistent results. The majority had no significant results. The few that did for both  $VO_{2\text{peak}}$  and BMI values may be outliers and do not carry enough weight to rely on those results. A great deal of growth and development occurs between this time (Rosen, 2004). As children grow through adolescence, they tend to consume more food to keep up with the energy demands of their bodies (Birch, Savage, & Ventura, 2007). This increase in total food consumption may result in a higher F/V intake. Young and middle-aged adults may consume more fruits and vegetables than younger individuals due to the absolute increase in food consumption, while relatively the proportions may stay the same. The same principle Charlton et al. (2014) mentioned in their study of adults applies here, the increase in F/V intake may be accounted for by the total increased consumption of food. Field et al. (2003) took this into consideration and adjusted their analysis of adolescents for total caloric intake, which then yielded non-significant results. However, since the results of this study were not able to establish an association between F/V intake and CRF or BMI, no adjustment for total caloric intake was made.

### Conclusion

The present study does not establish a relationship between F/V intake and CRF in adolescents. These results, as well as the lack of previous studies on this topic, suggest more research should be conducted using different methods of measuring F/V intake to see if an



association exists. This study helps expand research in the direction of F/V intake and CRF analysis in an attempt to find if they may be utilized together to provide maximal benefits. The lack of an association between body composition and F/V intake in adolescents suggests that while fruits and vegetables provide humans with necessary vitamins and beneficial anti-oxidants, total body composition is ultimately determined by total caloric balance. Future research may determine whether an association truly exists.

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Table 1. Characteristics of Subjects

	Males (n=234)		Females (n=190)		Total (n=424)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	13.3	2.5	13.3	2.5	13.3	2.5
Height (cm)	160.0	16.5	158.2	10.9	160.8	14.0
Weight (lbs)	131.2	48.2	123.3	35.7	127.6	43.1
BMI (kg/m <sup>2</sup> )	21.9	5.6	22.0	4.7	21.9	5.2
VO <sub>2</sub> peak (ml/kg/min)	45.5	7.9	42.6	6.4	44.2	7.4

Table 2. Distribution of Subjects into Aerobic Fitness Classifications

	Males (n=234)	Females (n=190)	Total (n=424)
NI-HR	46 (19.6%)	27 (14.2%)	73 (17.2%)
NI	39 (16.7%)	39 (20.5%)	78 (18.4%)
HFZ	149 (63.7%)	124 (65.3%)	273 (64.4%)

Table 3. Distribution of Subjects into BMI Classifications

	Males (n=234)	Females (n=190)	Total (n=424)
VL	40 (17.1%)	8 (4.2%)	48 (11.3%)
HFZ	123 (52.6%)	130 (68.4%)	253 (59.7%)
NI	35 (14.9%)	29 (15.3%)	64 (15.1%)
NI-HR	36 (15.4%)	23 (12.1%)	59 (13.9%)

Table 4. Frequency of Fruit and Vegetable Intake in Previous Week

	Males (n=234)		Females (n=190)		Total (n=424)	
	Mean	SD	Mean	SD	Mean	SD
Fruits	6.7	6.2	8.1	7.0	7.3	6.6
Vegetables	12.3	11.3	12.0	11.3	12.2	11.3
Total	19.1	15.7	20.1	16.2	19.5	15.9



Table 5. Frequency of Fruit and Vegetable Intake in Aerobic Fitness Classifications

	Males (n=234)		Females (n=190)		Total (n=424)	
	Mean	SD	Mean	SD	Mean	SD
NI-HR	19.1	13.8	15.9	9.6	17.9	12.4
NI	15.8	19.2	20.3	19.6	18.0	19.4
HFZ	19.9	15.2	20.9	16.2	20.4	15.6

Table 6. Frequency of Fruit and Vegetable Intake in BMI Classifications

	Males (n=234)		Females (n=190)		Total (n=424)	
	Mean	SD	Mean	SD	Mean	SD
VL	19.6	13.1	25.6	16.1	20.8	15.6
HFZ	18.9	16.1	19.6	15.2	16.7	18.4
NI	20.3	14.6	24.5	22.1	22.2	15.9
NI-HR	17.5	18.1	15.4	11.6	19.2	13.6

Table 7. Pearson Correlation of raw Fruit and Vegetable Scores and VO2peak

Control	Gender		VO2peak (ml/kg/min)	Fruits	Vegetables	F/V Totals
Age	M	VO2peak (ml/kg/min)	1.00			
		Fruits	.040	1.00		
		Vegetables	.085	.547**	1.00	
		F/V Totals	.078	.794**	.943**	1.00
	F	VO2peak (ml/kg/min)	1.00			
		Fruits	.144*	1.00		
		Vegetables	.100	.533**	1.00	
		F/V Totals	.132	.807**	.930**	1.00

\*Correlation is significant at  $p < 0.05$

\*\*Correlation is significant at  $p < 0.01$

Table 8. Pearson Correlation of raw Fruit and Vegetable Scores and BMI

Control	Gender		VO2peak (ml/kg/min)	Fruits	Vegetables	F/V Totals
Age	M	BMI (kg/m <sup>2</sup> )	1.00			
		Fruits	.069	1.00		
		Vegetables	.020	.547*	1.00	
		F/V Totals	.042	.794*	.943*	1.00
	F	BMI (kg/m <sup>2</sup> )	1.00			
		Fruits	-.087	1.00		
		Vegetables	-.054	.533*	1.00	
		F/V Totals	-.076	.807*	.930*	1.00

\*Correlation is significant at  $p < 0.01$

## Appendix: YRBS Dietary Questions and Responses

### Questions

- 1) During the past 7 days, how many times did you eat fruit? (Do not count fruit juice.)
- 2) During the past 7 days, how many times did you eat green salad?
- 3) During the past 7 days, how many times did you eat potatoes? (Do not count french fries, fried potatoes, or potato chips.)
- 4) During the past 7 days, how many times did you eat carrots?
- 5) During the past 7 days, how many times did you eat other vegetables? (Do not count green salad, potatoes, or carrots.)

### Responses

- A) I did not eat fruit during the past 7 days
- B) 1 to 3 times during the past 7 days
- C) 4 to 6 times during the past 7 days
- D) 1 time per day
- E) 2 times per day
- F) 3 times per day
- G) 4 or more times per day

## CHAPTER II

### EXTENDED REVIEW OF THE LITERATURE

#### Specific Research

Physical fitness plays a large role in preserving optimal health throughout the lifetime for individuals of all ages. Maintaining cardiorespiratory fitness (CRF) and a healthy lifestyle can help an individual remain independent and functional for much longer in life, as well as increase overall life expectancy (Kaeberlein, Rabinovitch, & Martin, 2015; Mercken, Carboneau, Krzysik-Walker, & de Cabo, 2012; Wang, Ramey, Schettler, Hubert, & Fries, 2002). As the prevalence of chronic diseases such as obesity, cardiovascular disease (CVD), and type II diabetes increases, it is important to start taking a preventative approach to decrease the number of cases. “Diet and exercise” is a common phrase heard in a discussion on improving overall fitness, and research can support this phrase. A meta-analysis by Johns, Hartmann-Boyce, Jebb, and Aveyard (2014) found that a combination of exercise and healthy diet showed significant, long-term improvements in body composition and cardiorespiratory fitness when compared to diet or exercise alone. Increased fruit and vegetable intake and cardiorespiratory fitness both have positive and protective effects against future health complications. Cardiorespiratory fitness in both children and adults has been found to have an inverse relationship with diseases such as obesity, CVD, type II diabetes, and other chronic diseases associated with low activity (Boreham & Riddoch, 2002; Boreham, Robson, Gallagher, Cran, & Murray, 2004; Hogstrom, A. Nordstrom, P. Nordstrom, 2014; Panagiotakos et al., 2003). Similarly, an inverse relationship was also found between F/V intake and these same chronic diseases, primarily CVD (He, Nowson, Lucas, & MacGregor, 2007; Minaker & Hammond, 2016; Panagiotakos et al., 2003). Therefore, this review will analyze the benefits of each variable and provide rationale why this

research was conducted. The potential relationship between benefits of fruit and vegetable intake and cardiorespiratory fitness needs to be examined to try and establish a more direct link between the two.

Ruiz, Castro-Pinero, and Atero (2009) performed a systematic review of articles analyzing the relationship between cardiorespiratory fitness and CVD risk factors. This review looked over seventeen articles investigating whether physical fitness in childhood and adolescence is a predictor of CVD risk factors. They also examined quality of life, lower back pain, and other syndromes later in life. The studies included in their review had to be specifically looking at CVD risk factors and their association with cardiorespiratory fitness, as well as musculoskeletal fitness. CVD risk factors included abnormal blood lipids, high blood pressure, excess central adiposity, metabolic syndrome, and arterial stiffness.

Many of the studies reported that cardiorespiratory fitness in children and adolescents is a predictor of CVD risk factors. The consensus gathered from the seventeen reviewed articles was that increased cardiorespiratory fitness was associated with fewer risk factors for CVD listed above. One of these articles was Carnethon, Gulati, and Greenland (2005), which was looking to identify the prevalence of low fitness in the United States adolescent population.

Carnethon et al. (2005) examined 3,110 adolescents (age 12-19 years). Fitness was assessed by a submaximal treadmill test where maximal oxygen consumption was estimated from heart rate response and submaximal values. Low fitness was defined using percentile cut points of estimated  $VO_{2max}$  from referent populations. Results from this study showed that 33.6% of the sampled adolescent population had low fitness. In participants with lower fitness, total cholesterol levels and systolic blood pressure were higher, and HDL levels were lower.

Individuals in the high fitness category had values in the opposite direction for each of the variables.

What the results of this study showed were that low fitness in adolescents is common in the United States, even though they are not the majority. It also showed that low fitness is strongly associated with an increased prevalence of CVD risk factors in adolescents. This emphasizes the importance of CRF throughout childhood and adolescence. While this study did not use a maximal test to determine maximal oxygen consumption, the results still hold strong. Other studies use a maximally exhaustive test (PACER) to establish  $VO_{2peak}$ , which may result in discrepancies in the results. Results from this study are valuable since they specifically highlight the benefits of high physical fitness. It also shows how little of the adolescent population belongs to that category. Since there are so many short and long term benefits from high physical fitness, the goal is to reduce the percentage of the adolescent population that falls into the low fitness category.

A study by Sallis, Patterson, Buono, and Nader (1988) also examined the association of CRF with CVD risk factors. This study measured 148 male and 142 female children. Overall fitness was measured using a submaximal cycle ergometer test, while risk factors were determined using various measuring techniques. The risk factors examined included blood pressure, HDL, HDL/LDL ratio, and BMI. Like Carnethon et al. (2005), they found that fitness was strongly and significantly correlated with all the risk factors listed above. Both studies looked at almost the same risk factors with the results being almost identical. While these studies revealed the importance of CRF on the reduction of CVD related risk factors, the benefits are not short term only. They carry a lasting effect throughout the lifetime of the individual.

Hogstrom et al. (2014) demonstrates the relationship between high CRF in late adolescence and myocardial infarction (heart attack) later in life. While this is an extreme example, it still carries a lot of weight. In 1969, this Swedish study examined 743,498 men at the age of 18. Aerobic fitness was measured using a maximally exhaustive test using an electronically braked cycle ergometer. Resistance was increased linearly until the subject reached volitional exhaustion. The researchers followed up with these same individuals, who were linked by a unique personal identification (ID) number, in the year 1984. Information on heart attacks was collected via record linkage using that same ID number.

What they found was very interesting, but not surprising. After adjusting for age, BMI, diseases, education, blood pressure, and socio-economic factors, the researchers reported a significant association between aerobic fitness in late adolescence and heart attack later in life. A one standard deviation increase in the level of physical fitness was associated with an 18% decreased risk of heart attack later in life. These results were significant between all the BMI classifications. Basically, the higher an individual's CRF, the odds of them suffering a heart attack are significantly reduced.

The acute benefits of CRF (increased energy, improved body composition and sports performance) are not the only thing children have to gain from high CRF. High CRF will help improve quality of life and decrease the risk of developing chronic diseases later in life. These findings add to the research examining CRF and its influence on overall health. The present study analyzes CRF in adolescents as one of the main variables, so the supporting research is beneficial for knowing what to expect. While Hogstrom et al. (2014) focused specifically on CRF and CVD risk factors, other research has a wider scope.

In more general aspect, a review by Boreham and Riddoch (2002) examined all-cause mortality. The researchers' hypothesis had three main points they wished to analyze. The first is that they believed there would be a direct improvement in adult health and quality of life based on childhood health status. Meaning that an adult is more likely to have a more positive health and fitness status if their health status during childhood was also positive. The second is they believed the improvement in adult health status would come from a delaying in the onset of chronic diseases. The reason the adult's health and fitness status may improve could be due to the positive health status they had in childhood, which could delay the onset of potential chronic diseases. Lastly, if an individual is active throughout childhood, they are more likely to be getting adequate physical activity and exercise as an adult. Obtaining adequate amounts of physical activity and exercise attribute to the improved health status and decreased risk of chronic diseases.

Boreham and Riddoch (2002) found several key points through their research. They determined a dose-response relationship between physical activity and all-cause mortality. All-cause mortality decreased proportionally to the amount of physical activity the individuals were getting. Similar to Hogstrom et al. (2014), they found a relationship between activity and future health status. Analyses showed that insufficient physical activity was the prime indicator of childhood obesity, which then predicted a wide range of adverse health effects in adulthood. These remained true when adjusted for adult weight. Lastly, they found that establishing physical activity and exercise as a habit throughout childhood will help maintain those same fitness levels throughout adulthood, and prevent the onset on chronic diseases that may result in all-cause mortality.



As one of the variables in the presents study, CRF is not the only factor that has protective future health implications. Nikolic, Nikic, and Petrovic (2008) attempted to examine the relationship between dietary intake of F/V and risk of coronary heart disease (CHD). They randomly selected 290 middle-aged men who were admitted to health facilities for a first acute coronary event. Also selected were 290 middle-aged men who had no risks or suspicion of CHD. Each one of these groups completed questionnaires to assess F/V intake. From the results of these questionnaires the subjects were divided into tertiles, where odds ratios were determined to analyze the prevalence of developing CHD based on the amount of F/V consumption.

Per the findings, the benefits of F/V consumption increased proportionally by the number of servings consumed. F/V were each individually analyzed to pin-point where the benefits were coming from. The difference between the top and bottom tertiles in both fruits and vegetables were separately and extremely significant. Those in the upper tertile of fruit consumption ( $\geq 5$  items/day) had 60% lower risk of developing CHD when compared to the lowest tertile ( $< 1$  item/day). Vegetables had findings that were just as significant. Those in the upper tertile of vegetable consumption ( $\geq 3$  items/day) were associated with a 70% lower risk of CHD compared to people in the lowest tertile (0 items/day).

This results showed that consumption of F/V seemed to provide significant protection against CHD. The protective effect that F/V have on CHD is similar to that of the protective effect of CRF. However, Nikolic et al. (2008) is not the only publication to find these significant results.

Panagiotakos et al. (2003) evaluated the association between CHD risk and consumption of F/V in a large sample. Participants included both cardiac patients and individuals with no clinical suspicion of CHD as a control. The sample consisted of 848 males and females admitted

to the hospital after experiencing their first acute cardiac event, and 1,078 males and females with no clinical suspicion of CHD. They completed a food frequency questionnaire on a weekly basis that assessed total dietary intake, including F/V.

After collecting the data, the subjects were broken down into quintiles based on F/V intake. Analysis of the data revealed a significant benefit from increased F/V consumption. This benefit increased proportionally to the number of servings of F/V consumed per week ( $p < 0.001$ ). Those in the upper quintile ( $\geq 5$  items per day) had a 72% lower risk for CHD than the lowest quartile ( $< 1$  item per day). These results are almost identical to what was found in Nikolic et al. (2008). These two articles suggest that there is a significant dose-response relationship between F/V intake and the protective effects against CHD.

A meta-analysis by He et al. (2007) quantitatively assessed the relationship between F/V intake and the incidence of CHD and produced very similar findings. This publication looked at twelve published cohort studies examining this relationship. Articles were included if they used relative risk and corresponding confidence intervals with respect to frequency of F/V intake. The total number of participants was 278,459 with a median follow-up time of 11 years. What they found reinforced the dose-response relationship found by Panagiotakos et al. (2003).

After analyzing the data from all twelve articles, they found a significant relationship between the amount of F/V intake and risk of CHD in individuals. The relative risk for CHD in those with  $> 5$  servings per day was .83 (95% CI: 0.77–0.89,  $p < 0.0001$ ), when compared to those with  $< 3$  servings per day. However, the findings for those with 3-5 servings per day were not significant with a relative risk of .93 (95% CI: 0.86-1.00,  $p = 0.06$ ) when compared to those with  $< 3$  servings per day. These findings show that the higher the F/V intake, the more significant the protective effect against CHD will be. It seems that  $\geq 5$  servings per day will

produce the best results from a cardiovascular health perspective. This agrees with ChooseMyPlate.gov which recommends about 2.5-3 cups of vegetables and 2 cups of fruit each day. Combining those two recommendations equates to about 4.5-5 servings of F/V per day.

Nothlings, Schulze, Weikert, Boeing, and Van Der Schouw (2007) took F/V intake and looked at all-cause mortality (ACM) instead of only CHD. They analyzed the association of fruit, vegetable, and legume intake in ACM in a diabetic population. This study looked to see if F/V intake would have a medicine-type effect on a population that is already at an increased risk for CHD (diabetic population). The sample consisted on 10,449 participants in Europe and the data were collected from 1992 to 2000. Dietary intake was evaluated using validated country specific questionnaires based on culture and typical diet.

They found that an increase of 80 grams per in fruit, vegetable, and legume intake was associated with a relative risk of ACM of 0.94 (95% CI: 0.90-0.98). Inverse relationships were individually found for fruits, vegetables, and legumes. However, only relationships for vegetables and legumes were significant. Inverse associations were found between CVD mortality, as well as non-cancer ACM, and total vegetable, legume, and fruit intake (RR 0.88 (95% CI: 0.81-0.95) and 0.90 (0.82-0.99) respectively). Intake of all three variables was also associated with reduced risks of CVD and ACM in the diabetic population. This reveals two valuable points. The first one is that it supported popular research that F/V intake has a strong protective effect against CVD. The second is that it suggested that the diabetic population may see benefits from a diet high in F/V.

Findings from the articles listed above show similar, if not the same, results. The benefits of F/V intake on cardiovascular health almost mirror those of CRF. These significant finding

support the general population research, and support the important of a healthy diet with many F/V.

For the secondary purpose of this study, we examined the relationship between CRF and body composition. Nassis, Psarra, and Sidossis (2005) touches on the topic of CRF in obese youth. They looked at central and total adiposity in overweight and obese children with high CRF. One thousand three hundred and sixty-two children between the ages of 6 and 13 participated in the study. Skinfold measurements were administered to each child to determine body fat percentage (BF%), and each one participated in a 20-meter multi-stage shuttle run test (20mMST) to determine CRF. They were placed into non-overweight and overweight/obese categories based on BMI. Each group was then broken down into sub-groups classifying them as unfit or fit. The children were divided into quintiles based on their CRF. Those in the first and second quintile were classified as unfit, while those in the fourth and fifth quintile were classified as fit. The skinfold measurements were used to determine the BF% of each individual. That information was used to compare BF%s between the fit and unfit groups of each BMI category.

The results showed significant differences between comparisons of fit and unfit in both the non-overweight and overweight/obese groups. The BF%s of the unfit and fit groups averaged out to around 20% and 17% respectively. The unfit group had a significantly higher BF% than those who were fit and in the non-overweight category. Those in the unfit and fit groups had average BF%s of around 34% and 26% respectively. These data show that even those in the overweight/obese category can see a noticeable difference in BF% based on CRF.

S. Chatterjee, P. Chatterjee, & Bandyopadhyay (2005) looked at the CRF of obese boys. Their study contained 119 sedentary boys ages 10 to 16 years. They were all from the same socio-economic background and from the same sample to increase validity. Skinfold

measurements were used to determine the lean body mass (LBM) of the participants. This measurement was used to adjust aerobic capacity for LBM. Absolute and relative VO<sub>2</sub> were also measured using a Queen's College Step Test. After taking the initial measurements, it was noted that body weight, LBM, and BMI score were all significantly higher in the obese group.

The results of this study showed significant differences between the obese and non-obese groups. The obese group had an average absolute VO<sub>2</sub>max of 2.5 L/min, while the non-obese group was 1.7 L/min. This agrees with results of other studies stating that obese individuals registered significantly higher absolute VO<sub>2</sub>max. The relative VO<sub>2</sub>max of the obese and non-obese groups were 39.6 ml/kg/min and 48.4 ml/kg/min, respectively. This shows the opposite of the absolute VO<sub>2</sub>max. Relative VO<sub>2</sub>max has an inverse relationship with BF%. As BF% increases, the relative VO<sub>2</sub>max will decrease. For absolute VO<sub>2</sub>max, as the total body mass increases, the absolute VO<sub>2</sub>max will also increase, showing a positive correlation. When the VO<sub>2</sub>max scores are adjusted for LBM, there is no significant difference between the results. The obese and non-obese groups measured 54.5 ml/kgLBM/min and 55.8 ml/kgLBM/min, respectively. While the non-obese group does show a slightly higher VO<sub>2</sub>max, the results are not statistically significant. The results are virtually the same.

An article published by Boreham et al. (2004) tracked the physical activity of adolescents over seven years. At the beginning of the study, the almost 500 subjects participated in fitness and body composition testing. The tests included cycle ergometry and 20-meter shuttle run tests for CRF and skinfold measurements for body composition. After seven years, the participants completed the same fitness and body composition tests. Any changes in CRF and body composition were noted. The changes in the anthropometric measurements and VO<sub>2</sub> were noted and then compared to each participants' nutrient intake from the previous years. This study

focuses largely on macronutrient/energy intake, components of fitness, body composition and its relationship to a shift in macronutrient intake in later years. Boreham et al. (2004) tried to find a correlation between the amount of physical activity, energy intake, CRF, and body composition. They then looked at any significant differences between the two tests and checked to see if there were any changes in nutrient intake from the time of the first test, to the time of the second test. The results could then be used to determine behaviors that caused shifts in dietary intake as children progressed through adolescence and into young adulthood. The discussion section of the article mentions that it was difficult to acquire accurate dietary logs from the participants. It also mentions that the dietary logs were subject to many changes based on socially desirable responses and memory or perception. Therefore, it is safe to assume that the diets of the participants did not track well over the course of the study.

While this study had difficulty tracking macronutrient intake over the course of the study, the pre-and post-test results did show a relationship between CRF and body composition. If you look at the results from each of the screenings, the mean sum of skinfolds increases in both males and females. In the male subjects, the average sum of the skinfolds increased from 32 to 44.63 millimeters (mm). The female group showed similar results, with the average sum of skinfolds increased from 49.61 to 58.56 mm. There is also a noticeable decrease in relative VO<sub>2</sub>max (ml/kg/min) between the first and second screening. For the male subjects, the average VO<sub>2</sub>max decreased from 52.07 to 38.93 ml/kg/min, while the average VO<sub>2</sub>max decreased from 41.05 to 26.90 ml/kg/min in females. These results show an inverse relationship between those two variables. Malina, Bouchard, and Bar-Or (2004) explain how children's relative VO<sub>2</sub>max decreases with age, but differences in the skinfold measurements depicts a relationship. Since the sum of skinfolds can be plugged into a regression equation to determine the average percent of

body fat for the subjects, it is safe to say that there is a relationship between body composition and CRF. Another contributing factor is the physical activity score. The participants also kept a physical activity log over the course of the study. There is a noticeable drop in these scores in both groups. A higher number represents increased amounts of physical activity. Males see a drop from 28.27 to 7.95, and women see a drop of 17.71 to 7.4. There is a significant decrease in the amount of physical activity for each group. These data support the idea that there is a correlation between the sum of skinfolds and VO<sub>2</sub>max results. If the adolescents spend less time being physically active, chances are that the change in their body composition is due to a lack of exercise and increase in body fat.

A study by Lee & Arslanian (2007) looked at differences in body composition and aerobic fitness in children and adolescents 8 to 17 years of age. This article is similar to the Boreham et al. (2004) article because it incorporates a third variable. The third variable in this study is leisure time activity. One hundred and thirteen children and adolescents participated in a Bruce multistage treadmill test to measure CRF, and underwent dual energy X-ray absorptiometry (DEXA) to measure body composition. There was also a CT scan to measure abdominal adiposity. The subjects' physical activity levels were then determined by a questionnaire.

The results showed that there was a statistically significant inverse relationship between CRF and body mass index (BMI) percentile. That inverse relationship applied to CRF and total adiposity, waist circumference, and both visceral and subcutaneous adipose tissue. Youth in the moderate and high CRF categories showed significantly lower levels of visceral and abdominal subcutaneous adipose tissue. These findings remained true even after the findings were adjusted based on age, gender, race, and pubertal status. Essentially what this study determined is that the

amount of adipose tissue in the body has a significant inverse relationship with the CRF of the individual. The results show that as total body fat increases, CRF decreases. Adipose tissue in the abdominal region poses a higher risk for developing chronic diseases than adipose in other locations. When looking at abdominal adipose tissue, the people in the moderate and high CRF categories had significantly lower levels of visceral and subcutaneous adipose tissue. The results show that CRF is related to abdominal adiposity. This information can be used in the future to help focus prevention techniques and decrease the risk of obesity and chronic diseases in children.

While these articles used different methods than the present study for measuring CRF and body composition, the outcomes were very similar. Adolescents with higher CRF with have better body composition values. CRF is inversely and significantly correlated with body composition and BMI in adolescents. Unfortunately, the findings in the present study were not able to establish the same significant relationship. The differences in methodology may have played a role in the discrepancy.

Since the research shows a relationship between CRF and BMI, we researched the effects of F/V intake on BMI. A few publications examined the relationship between these two variables. Charlton et al. (2014) attempted to describe the association between BMI and habitual F/V intake. The sample consisted of 246,995 Australian adults. BMI was measured using height and weight data and F/V intake was assessed using a short questionnaire about regular fruit and vegetable consumption. The results were inconsistent, as there was a lack of a clear association between F/V intake and weight status for both men and women. However, the data show that while both relationships were non-significant, they were slightly stronger in women. Overweight and obese men and women were more likely than their normal weight counterparts to consume



the recommended values for F/V. The authors attributed this distinction to the overconsumption of food, both nutrient and calorie dense. An increase in total energy intake may potentially increase total F/V intake proportionally to the total amount of food being consumed. This overconsumption may contribute to an energy imbalance and influence BMI.

Field, Gillman, Rosner, Rockett, and Colditz (2003) found conflicting results to the findings of Charlton et al. (2014). Their objective was to assess whether intake of F/V was associated with change in BMI in adolescents. A large sample of 6,715 males and 8,203 females (age 9-14 years) assessed F/V intake with a validated food frequency questionnaire. Height and weight were self-reported to calculate BMI. After a three-year follow-up (adjusting for Tanner stages of development, age, height change, and activity levels) there was no relationship found in girls, while boys had an inverse relationship with vegetables and BMI values ( $p < 0.003$ ). Once the values were adjusted for total caloric intake, the significance of this relationship diminished. The take-away message from this study was that the recommendations for F/V intake are well-founded, but they may not be beneficial for weight regulation.

Lastly, Heo et al. (2011) stated that 23.9% of overweight and 21.9% of obese individuals consumed adequate fruit and vegetable, while 27.4% of normal weight individuals met the recommendations of >5 servings per day ( $p < 0.0001$ ). After adjusting for demographics, socioeconomic status, and lifestyle factors, this inverse relationship was still significant. The research also stated that physically inactive obese individuals consumed the least amount of F/V, with only 14.7% meeting the recommendations. Much of the U.S. population is not reaching the recommended levels of F/V intake. While this conflicts with other research out there, it should be considered when developing policies to increase the amount F/V intake in the general

population. The lack of a significant association between F/V intake and BMI in the study in Chapter 1, adds to the conflicting results of several publications.

Many of the articles, including the present study, utilized a food frequency questionnaire (FFQ) to measure F/V consumption. Several studies have been published validating this method of analyzing dietary intake (Kobayashi et al., 2011; Kolodziejczyk, Merchant, & Normal, 2012; Lorson, Melgar-Quinonez, & Taylor, 2009; Minaker & Hammond, 2016; Moghames et al., 2016). Kobayashi et al. (2011) looked to examine the reproducibility and validity of FFQ to assess dietary intake in children and adolescents. The sample consisted of 103 children whose responses to several different FFQ were compared and analyzed using correlation coefficients. The results found a strong correlation (.76,  $p < 0.01$ ) between the FFQ and actual dietary intake. From their research, they found that FFQ can be a useful tool for assessing habitual dietary intake in youth.

Watson, Collins, Sibbritt, Dibley, and Garg (2009) also evaluated the reproducibility and comparative validity of FFQ, using assisted food records as a reference method. Sixty-one students (9-16 years) completed a FFQ twice with an interval of five months between. Subjects also completed four one-day assisted food records. Validity was determined by comparing the average intake values of the assisted food records and the FFQ. They found that FFQ are fairly accurate, establishing that 50% of participants were classified within one quintile of their values from the assisted food records, with only 0-7% being misclassified.

Finally, Kolodziejczyk et al. (2012) found that the highest average validity correlations of food frequency questionnaires in children were obtained when the questionnaire did not assess portion size, measured a shorter time span (previous day/week), and was not administered to the child's parents. While the junior and high school students met these criteria, the elementary

students completed the surveys at home with their families. This may have influenced the results for the elementary aged participants.

### Summary

The articles above examine different variables. The first several articles focus on the benefits of CRF on the risk of CVD and the long-term benefits of increased CRF. The next several articles look at benefits of increased F/V consumption. Both of which seem to have similar outcomes: a protective effect against CVD and improvement of overall health. Seeing as how both CRF and F/V intake produced similar outcomes, it is important to attempt to establish a direct link between the two. Research supports that both CRF and F/V intake have a significant relationship with body composition, BMI in this case. While the study mentioned in Chapter 1 may not have resulted in significant findings, it is a step in the direction of further research. Attempting to find a link between these two variables should continue to be researched to potentially establish an association and maximize the benefits (present and future) that these variables may offer our youth.

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