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Exploration of Daily Sit Time among University Athletes

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Abstract No studies have determined sit time, association between sit time and moderate-to-vigorous physical activity (MVPA)/training time among college athletes, or differences between sexes among college athletes. Yet an independent relationship has been previously reported between MVPA and sedentary behavior, adiposity, as well as all-cause mortality and all-cause cardiovascular disease among active individuals, including recreational exercisers and professional athletes. Sit time data from 192 male and female full-time college athletes age 18-24 were collected from an electronic survey, the Multi-context Sit-Time Questionnaire (MSTQ). Mean sit times were analyzed for differences between total sit time on school days and non-school days, as well as differences between males and females. Correlation analysis was also completed to determine the relationship between exercise time and sit time. Final analysis of mean hours (from reported minutes) of total daily sit time for all participants was 10.47 ± 2.93 hours, 10.85 ± 2.70 hours for males, and 10.07 ± 3.15 hours for females. As a percentage of total time awake, the college athletes spent 61% of their waking hours sitting. Results showed no statistically significant difference in mean minutes of sitting between school days (M = 641.147, SD = 196.02) and non-school days (M = 613.8, SD = 201.51). There was no significant correlation between average total daily sit time and weekly exercise time, $r_s(70) = -0.196$, $p = 0.092$. Next, there was no significant difference between average total daily sit time between males (M = 650.85, SD = 162.11) and females (M = 604.236, SD = 189.19), $t(73) = 1.141$, $p = 0.258$. The outcomes support previous studies that athletes can be both highly active and highly sedentary because exercise was independent of excessive sitting. Future research must focus on determining the prevalence of high total daily sit time among athlete populations, and whether athletes are at a high risk, similar to physically inactive individuals, because on average, college athletes sit as much or more than individuals defined as physically inactive.

Keywords: *sit time, sedentary behavior, physical activity, physical inactivity, athletes*

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1. Introduction

Daily prolonged sedentary behaviors have been associated with increased cardiovascular and metabolic risk factors such as insulin resistance, impaired glucose tolerance, undiagnosed diabetes mellitus, obesity, large waist circumference, high systolic blood pressure, high triglycerides, low HDL-cholesterol, inflammation, and all-cause mortality [1-6]. Prolonged accumulated time in sedentary activities, termed sit time in the literature, is includes time spent sitting, reclining, and lying down (but not sleeping), while at work, school, or in transit, and during leisure time [4,6,7,8]. Leisure time activities may include screen time, eating, and socializing [3,6].

Physical activity (PA) has been well defined and specific recommendations for such have been established to decrease risk factors for all chronic health-related diseases [6,9,10,11,12]. Physical activity and physical exercise have been categorized from light to vigorous intensities and used to guide and measure physical output. While there is an abundance of literature on best practices for acquiring PA, more research must continue on daily sit time to create a consensus on how to reduce the risks from accumulated prolonged daily sit time (in addition to continued research on reducing daily sedentary behaviors).

The exploration of daily sit time is important because it is a risk factor for obesity and all-cause mortality, independent from PA no matter the activity level of an individual, as well as linked to the development of all chronic health-related diseases [3,4,6,7]. Sit time is defined in the literature as a measurement of the time individuals spend in sedentary behaviors (outside of sleep) that require no energy and movement beyond 1.0-1.5 Metabolic Equivalents (METs), or 100-150% of the resting metabolic rate [4,6,8]. A person can be in numerous reclined or sitting positions, expending 1.0-1.5 METs, when there is little to ambulation during common sedentary behaviors. While the most common terms used to refer to non-ambulatory movement is sit time or sitting time, it is important to include activities that are considered under the umbrella of sit time. Subject matter experts should consider editing the definition of sedentary behavior and physical inactivity to include standing still because current evidence has revealed that standing still and taking standing breaks from sitting does not reduce the negative health biomarkers associated with daily

prolonged sedentary behavior [13]. Mansoubi et al. [14] reported average METs of only 1.59 while standing still, i.e. no ambulation. Therefore, sedentary activities/behaviors could be activities done in a seated, standing, or an inclined position as long as little-to-no ambulation readily occurs.

Sitting time is equal in importance to PA because the amount of time spent in sitting time or PA can promote or decrease chronic disease [4,6,15]; yet there is no standard measure for sit time, given the number of surveys that have been developed on the topic. The multi-context sitting time questionnaire (MSTQ) has been used to assess total sitting time and sedentary behaviors of highly active individuals [6,16], as well as total sit time on work and non-work days, and stratify for the different domains of sedentary behavior such as television, video games, sitting while talking and texting, and transportation. The MSTQ included questions for both work and non-work days, because with PA, levels it is assumed that sedentary behaviors vary greatly between them due to sedentary work obligations. The MSTQ was developed out of a desire to measure sit time among recreational adult runners. The original population consisted of male and female long distance runners that engaged in running recreationally versus competitive status. At the time of this publication, no other survey instruments or college athlete populations have been studied regarding sit time, even though the research from measuring sit time suggests a link to chronic disease.

High levels of health and fitness among young collegiate athletes are commonly assumed; however, the literature demonstrates that individuals can be both highly active and highly sedentary, while having increased adiposity and increased risk factors for chronic health-related disease [6,7]. Time spent in sedentary non-ambulatory activities displaces higher-intensity activities; in fact, a mere 2 hours of sitting each day (in terms of energy expenditure) negates what is achieved metabolically though meeting the minimum PA guidelines through walking [17]. Consequently, many professional athletes spend an average of 2 hours training for, or practicing/competing in, their sport most days of the week, yet they still spend 8-9 hours (most of the rest of the day) in sedentary pursuits [6], with at least 4 times the sit time required to negate the minimum benefits of PA. This may be a significant health concern, even for young highly-active college students because Healy et al. [2] reported that MVPA is independently affected by excessive sitting, even with MVPA $\geq$ 2.5 hours per week. A meta-analysis performed by Chau et al. [18] reported a 5% increase in all-cause mortality risk for every hour of sitting when sitting more than 7 hours per day and 34% to 52% for every hour when sitting $\geq$ 10 hours per day, independent from MVPA. Ekeland et al [19] found that 8 hours is an important threshold, as all-cause mortality risk increased by 58% when accumulated daily sit time is $\geq$ 8 hours per day (or at least an average of 50% of waking hours), independent from high MVPA.

1.1. Problem

Despite the independent relationship that sedentary behavior, adiposity, and all-cause mortality have from MVPA, no studies have determined an association between sit time and MVPA/training time among athletes in a University setting [6,7]. Just as Whitfield et al. [6] determined there is a significant difference in sit time between work days and non-work days among recreational runners who are working professionals, it is important to note that no data have been collected on the differences in sit time among athletes during school days and non-school days. Athletes may be both highly active and highly sedentary and have an increased risk for high adiposity and all-cause mortality [6,7,8]. Clearly, the assumption of a highly active person's health is not adequate when factoring in the evidence that the negative health risks of prolonged sitting are independent of high MVPA. With only two previous studies discovering the high prolonged daily sit time of athletes, it is important to continue exploratory research on the sit time of active populations, including highly active competitive athletes to better determine both the prevalence of sedentary behavior as well as the risk of all active populations, and to (after extensive research) be able to better generalize the risk among athletes. Furthermore, research must continue (using both objective and subject methods) to determine sitting behavior, as well as cardiometabolic biomarkers of disease and mortality risk, among athletes, to determine whether high daily sedentary behavior still puts highly active individuals at greater risk of chronic health-related disease. Identifying the daily sitting time and sedentary behaviors of athletes is essential because of the relationship between all-cause mortality and MVPA that exists despite their very high activity levels [15,18,19].

In the present study, the authors first hypothesized that, there is a difference in sit time between school days and non-school days among college athletes. Secondly, it was hypothesized that there is an association between total daily sit time and weekly MVPA training time among college athletes. Lastly, it was hypothesized that there is a difference in total daily sit time between male and female college athletes.

2. Methods

The MSTQ was initially used to measure sit time of recreational marathon runners. In addition, the MSTQ has been used to survey workers, non-workers, students, and retired persons and has been validated with test-retest reliability, with intra-class correlations of greater than 0.70 for total sitting time and adequate convergent validity when compared to accelerometer-estimated sedentary time of 0.34 to 0.61 [6,16]. The MSTQ by Whitfield et al. [16] includes demographic questions from the Behavioral Risk Factor Surveillance System [20] that were adopted for this study including age, sex, and racial/ethnical heritage. Additional demographic questions were added to assess height and weight, weekly MVPA/training time (in hours and minutes), whether each athlete was participating in-season or off-season, as well as the sport(s) in which each athlete participates. All of the varsity sports offered by the university to males and females are represented in the demographic questions. Permission from the authors to adopt and modify the MSTQ was granted.

Modifications were created in the instrument to tailor it to the study population of full time male and female full-student athletes ages 18-24 years attending a Historically

Black College or University (HBCU). Content validity was assessed of the newly modified instrument by a panel of three content and research experts, each being an Associate Professor, in the health and exercises sciences. A Cronbach's alpha was performed to test validity of the changes.

Items were modified or removed on the MSTQ related to occupational status, work hours, and work days. Two items were removed from the MSTQ because the population was student athletes. These two items included employment status, and typical days spent working every week. The modification reflected hours and minutes spent in sedentary positions during school and leisure activities. The item addressing hours and minutes spent working per week was modified to hours and minutes per week spent doing school work. The item addressing hours and minutes spent in different domains of sedentary behavior during work and non-work days was modified to read school day and non-school day. The separate reporting of school and non-school days (similar to work and non-work days from the original study) was maintained to minimize modification of the original survey tool as to determine whether sedentary time varied significantly between the two days.

Data were collected following permission from the University's Athletic Director. Meetings were coordinated between the researcher and the head strength and conditioning coach at the University to introduce the survey to athletes in groups immediately prior to, or immediately following team workouts, to voluntarily complete the survey during the meetings. Prior to each meeting, the athletes were instructed to bring their smart phone, tablet, or any other portable mobile device with Internet access, or use an on-site desktop computer available in the meeting room to complete the survey. At the start of each meeting, the principal investigator introduced himself, explained he was completing a research study and explained the MSTQ to the participants. All participants voluntarily signed an informed consent prior to any data collection. During these meetings, the principal investigator informed the athletes attending the meeting about the protocol, the technology needs and time it would take to complete the survey.

Each participant was provided a link to use on a smartphone, tablet, any other portable mobile device with internet access, or on-site desktop computer to complete the MSTQ electronically. Once each participant accessed the REDCap link he or she was directed to an informed consent to agree to participate. If a participant agreed to the informed consent, an electronic signature was required and the MSTQ and demographic questions became available to complete through a link that did not identify the participant. Participants that did not want to participate in the study did not sign the informed consent and were asked to sit quietly through the duration of the data collection. Lastly, because the researcher was onsite to collect surveys via convenience sampling, each participant received a hard copy of the informed consent.

Descriptive statistics were examined for all demographic variables, including weekly MVPA/training time, and sitting time (as well as each individual sedentary behavior) on school days and non-school days. If the population was normally distributed, a t-test was used to examine the difference of sitting time between groups for school days and non-school days for total sit time (converted to minutes), and assessed for normality using Shapiro-Wilk tests. In addition, if the data were not normally distributed, a non-parametric Mann Whitney U test was performed to examine the differences between school days and non-school days, total sit time, and each domain of sedentary behavior.

If the population was normally distributed, to answer research question two, the Pearson product-moment correlation coefficient was used to determine any association between total daily sit time (average sit time between school and non-school days) and weekly MVPA/training time. If the population was not normally distributed, a Spearman's rank-order test was performed. For research question three, if the population was normally distributed, a t-test was performed to examine differences in sit time between male and female college athletes. If the data were not normally distributed, a non-parametric Mann Whitney U test was performed. Significance was set at $\alpha = 0.05$, and all calculations were conducted in IBM-SPSS Statistics for Windows Version 24.

All 307 male and female full-time athletes enrolled at the university as of the Spring 2017 semester, ages 18-24, were eligible for this study. This study population was comprised of athletes who attend an HBCU University campus and participated in varsity athletic sports, whether in or off-season, and volunteered to complete the MSTQ. The rationale to include all athletes regardless of in-season or off-season was because most athletes adhere to significant off-season conditioning and workouts that are both high frequency and high volume sport-specific and/or non-sport specific training sessions.

Table 1. Descriptive Characteristics Of Survey Sample

Demographic Variables	Number(n)
Age(mean)	19.65
Sex [n(%)]	
Females	36(48%)
Males	39(52%)
Race [n(%)]	
White/Caucasian	22(29.3%)
Black/African American	39(52.0%)
Hispanic or Latino	9(12.0%)
Other	5(6.7%)
Mean Height (in.)	68.8
Body Mass (lbs.)	179.12
Mean Body Mass Index (BMI)	26.19
Sport (n)	
Baseball	4
Basketball	4
Cross Country	8
Football	28
Indoor Track & Field	13
Outdoor Track & Field	13
Golf	1
Bowling	2
Equestrian	8
Lacrosse	3
Soccer	3
Softball	7
Volleyball	2
Season (n)	
Off-Season	40
In-Season	37
Mean Weekly MVPA/Training Time [min(hours)]	821.19 (13.69)

Expedited approval for the investigation was granted by the Institutional Review Board and Athletics Director to distribute the MSTQ survey. Informed consent was obtained from each participant prior to participation. The following table (Table 1) includes the descriptive statistics, including age, gender, height, weight, BMI, sport, off- or in-season, and weekly training time.

3. Results

A total of 192 of the 307 student athletes (male and female) agreed to participate in the survey. Of the 192 individuals surveyed from the population of interest, 43 did not complete both the MSTQ and/or the demographic questions, leaving 149 completed surveys. Next, 74 of the participants over-reported sit time as greater than total wake time and/or 24 hours (1,440 minutes) of one day, which required exclusion due to unreliable data. Finally, although 62.5% of the student-athlete population at the university was surveyed, only 24.4% were included in the data analysis. The final number of participant data available for the analysis was 75.

After the population of athletes were surveyed, the two-way mixed Intraclass Correlation Coefficient (ICC) was used with average measures and consistency to determine the mean ICC between all quantitative MSTQ assessed sleep time, sit time, and school work time [21], as well as Cronbach's alpha (α). The ICC between all sit time, school work, and sleep time items was $r = 0.344$, 95% CI [0.105, 0.543], $p = 0.004$, with Cronbach's $\alpha = 0.344$. However, the ICC between the school day and non-school day sit time items, including sleep time while excluding school work time, was $r = 0.719$, 95% CI [0.0617, 0.0804], $p \leq 0.001$, Cronbach's $\alpha = 0.719$, which is indicative of acceptable reliability [21]. Moreover, when removing the sleep items, only including sit time items, the ICC was $r = 0.745$, 95% CI [0.651, 0.823], $p \leq 0.001$, and Cronbach's $\alpha = 0.745$, demonstrating no difference between the reliability scores.

The population was found to be normally distributed for sit time on both school days and non-school days as assessed by the Shapiro-Wilks test ($p > 0.05$). However, exercise time was found to not be normally distributed as assessed by Shapiro-Wilks test ($p < 0.05$). Therefore, the Spearman-rho Rank Order correlation was performed to determine whether there was an association between weekly MVPA/exercise time and daily sit time.

A *t*-test was performed to determine if there were differences in total daily sit time between school days and non-school days for college athletes ($n = 75$). Total daily sit time on both school days and non-school days was normally distributed as assessed by Shapiro-Wilks tests ($p > 0.05$). There were no outliers in the data as assessed by inspection of a boxplot. As assessed by the *t*-test, it was determined that there were no significant differences between mean minutes of total daily sit time on school days ($M = 641.147$, SD = 196.02) and non-school days ($M = 613.8$, SD = 201.51), as the mean difference was $M = 29.347$, $t(73) = 1.375$, $p = 0.173$. The mean difference was not significantly different; therefore, the null hypothesis was not rejected. Sit time, as a percentage of wake time, is not different between school days and non-school days among college athletes.

The Spearman rank-order correlation was performed to assess the relationship between average total daily sit time and weekly MVPA/training time among college athletes (n = 75). Spearman was used instead of Pearson because exercise time was found to not be normally distributed as assessed by Shapiro-Wilks tests ($p < 0.05$). There was no significant correlation between average total daily sit time and weekly MVPA/training time, $r_s(73) = -0.136$, $p = 0.246$. There were 4 outliers, cases 57, 81, 99, and 203 (labeled numbers 10, 17, 22, and 67). When the 4 outliers were removed, there was no significant correlation between average total daily sit time and weekly MVPA/training time, $r_s(70) = -0.196$, $p = 0.092$. Therefore, the null hypothesis was not rejected whether or not the outliers were included in the data analysis. There is no correlation between average daily total sit time and weekly exercise time among college athletes.

A *t*-test was performed to determine if there were differences in average total daily sit time between male ($n = 39$) and female ($n = 36$) college athletes. Total daily sit time on both school days and non-school days were normally distributed as assessed by Shapiro-Wilks tests ($p > 0.05$). There were no outliers in the data, as assessed by inspection of a boxplot. As assessed by the *t*-test, it was determined that there was no significant difference of average total daily sit time between males ($M = 650.85$, SD = 162.11) and females ($M = 604.236$, SD = 189.19), $t(73) = 1.141$, $p = 0.258$. The mean difference was not significantly different; therefore, the null hypothesis was not rejected. Sit time, as a percentage of wake time, is not different between male and female college athletes. The following table (Table 2) includes mean minutes of total sit time on school days and non-school days, averaged mean sit time of school and non-school days, and mean MVPA/Training time.

The average daily total sit times were 10.72 hours on school days and 10.23 hours on non-school days, and the overall average was 10.47 hours. Sit time as a percentage of total time awake was 60% on school days and 62% on non-school days. In addition, the average weekly MVPA/training time was 13.69 hours.

Table 2. Sit Time and Exercise Time in minutes by Sex and Ethnicity

Sex	School Day (M and SD)	Non-School Day Minutes (M and SD)	Average Day (M and SD)	MVPA/Training Time (M and SD)
Female	609.03 (± 187.28)	599.04 (± 238.10)	604.24 (± 189.19	697.50 (± 550.95)
Male	674.64 (±201.00)	627.05 (±162.73)	650.85 (±162.11)	935.36 (±586.06)
Total	643.15 (±196.02)	613.80 (±201.50)	628.47 (±175.99)	821.19 (±578.15)

Regarding research question one, there was no statistically significant difference between total daily sit time on school days and on non-school days; therefore, the null hypothesis failed to be rejected. Regarding research question two, there was no statistically significant correlation, positive or inverse, between average total daily sit time and weekly MVPA/training time. Therefore, the null hypothesis failed to be rejected. Finally, regarding research question three, there was no statistically significant difference for average total daily sit time between males and females. Therefore, the null hypothesis failed to be rejected.

4. Discussion

Cumulative daily sit time is important to assess among all populations because of its negative health consequences. There is significant need for more evidence (and later) guidelines on the type and amount of sit time that is directly harmful, as well as the need to further develop instruments for the measure of sit time cannot be underestimated. The health consequences of chronic prolonged sit time include increased all-cause mortality from comorbid non-communicable health-related diseases [22,23,24].

The non-athletic population in western cultures spend at least 55-70% of their waking hours (9-11 hours) in sitting time activities [18]. Furthermore, contrary to common assumptions about active people, Owen et al. [4] reported that active individuals spend an average of 71% of their waking hours sitting, even if the PA guidelines were met or exceeded. Judice et al. [7] and Whitfield et al. [6] found athletes (both elite and recreational), who exercise for an average of 17.2 hours per week, sit for an average of 7 to 10 hours per day. Moreover, despite high levels of MVPA/training time, cardio-metabolic health markers, body composition, and abdominal adiposity were all adversely associated with the reported sit time of athletes. In the current study, the athletes were sedentary for 61% of their waking hours for an average of 10.47 hours, which is similar to the previous studies in the literature that reported 7 to 10 hours per day [6,7]. Finally, sit time and MVPA/training time showed to be independent behaviors in both the current study and Judice et al. [7], as there was no relationship.

These data suggest individuals can be both highly active and highly sedentary, and the health risks for apparently healthy active individuals are still significant despite high activity levels [4]. To the best of the researcher's knowledge, aside from the current study, the aforementioned studies are the only data collected on the sit time of athletes. More data on sit time and health must be collected on additional highly active populations to determine whether this trend in sit time and risk are truly prevalent. Furthermore, more extensive research must be completed on health biomarkers of chronic health-related diseases to determine the risks of high levels of sedentary time among highly active populations now that research has determined that highly active individuals sit as least as much as those who are identified as physically inactive, i.e. do not meet the PA guidelines.

Athletes were surveyed electronically using a convenience sample at an east-coast HBCU. One-hundred ninety-two of 307 athletes at the university responded to the survey, which was a 62.5% response rate. Only 75 were included (24.4% of the population) because 117 either submitted incomplete surveys or grossly over-reported sit time to be greater than wake time and/or 24 hours. Of the included participants, just over 50% were Black/African American, due to the universities status as a HBCU while 29% were White/Caucasian, with the remaining responders as either Hispanic/Latino, or Other.

The largest sample of athletes played football since the sport had the largest roster of players (n = 28). The second largest were the indoor/outdoor track and field, and cross-country athletes (n = 13). No tennis or cheerleading athletes volunteered. Larger samples from all but tennis and cheerleading were gathered, but many were excluded because of poor survey completion. Just over half of the athletes reported currently participating in off-season, while the remainder where in-season at the time the study was conducted.

Until the current study was conducted, no studies had assessed the daily sit time of collegiate athletes despite the evidence that highly active individuals can also be highly sedentary, and increased sit time greatly increases all-cause mortality and all-cause cardio-metabolic disease risk independent of MVPA [4,6,7,25]. In addition, the correlation of sit time and MVPA/training time was not known among athletes, nor was it known whether college athletes sit more on school days versus non-school days, or whether male and female sit times differ.

5. Conclusion

The purpose of this study was to explore the type and amount of sit time and exercise time among male and female varsity athletes attending school full time at a HBCU. Sit time, as a percentage of wake time, was not different between school days and non-school days, or males and females, among college athletes. In addition, sit time was not different between school days and non-school days among college athletes. There was no correlation between average daily total sit time and weekly exercise time among college athletes. Sit time was not different between male and female college athletes. The data from this study indicated that the average sit time was just over 10 hours/day, which was 61% of waking hours, and the average weekly exercise time was 13.69 hours/week.

When compared to the general population, college athletes are at least as sedentary as the general (non-athlete) population [4,6,7,18,26]. College athletes also reported similar sit time on school days and non-school days. This demonstrates that sitting behaviors are similar whether or not college athletes are in class and/or participating in their sport any day of the week. Furthermore, the data from this study revealed that sit time between male and female college athletes is similar. Therefore, males and females who participate in both a full-time college education and collegiate sport at a HBCU have similar sitting/sedentary time. It was also found that MVPA/training time and sitting/sedentary behavior are independent of each other, as they had no correlation. College athletes are not sitting less due to high MVPA/training time; therefore, they can be both highly active and highly sedentary. Previous research has

suggested that daily accumulated sitting hours of ≥ 8 per day greatly increases all-cause risk for every hour sitting, independent of all other health risk-factors, no matter an individual's activity level [18,19].

Many gaps in the research still remain. The study should be repeated at other colleges and universities, in addition to other athletic populations, including high school, professional, and recreational sports and activities to determine if whether the same findings are present when larger and more diverse participant populations are sampled. In addition, the MSTQ should be reduced to items asking only for an average of each sedentary behavior, not school days or non-school days, and weekly hours of school work should be removed if not included in the analysis. Furthermore, daily average MVPA/training time (from exercise days) including all contexts such as strength and conditioning sessions, sports practice, and competitions may need to be added to better compare and analyze with daily sitting behaviors (rather than weekly). More research needs to be devoted to developing survey instruments that accurately measure sedentary behavior time, in addition to concurrent use of objective measures, i.e. accelerometers.

Future research should also include not only sit time of males and females of additional and more diverse samples of populations, but also MVPA/training time, to discover whether the results would be similar or different from the above outcomes. Additional research on sit time and each type of sedentary behavior in the MSTQ must continue to be evaluated to not only collect important data on the sedentary behavior of athletes, but to also better inform public health professionals of the problem and assist in developing appropriate health intervention programs for athletes which address sedentary time and behaviors. Next, analysis of potential differences between off- and in-season MVPA/training time and sit time should be explored for comparison and potential differences in relationships. Moreover, future research must include the measurement of cardio-metabolic biomarkers to determine whether the high sit time of athletes truly is putting them at increased risk of all-cause mortality and all-cause cardiovascular disease independently from their high vigorous activity level.

Continuing sit time research longitudinally, as well as research on the associated risks, is necessary to discover a more specific sit time risk threshold. Consequently, public health guidelines could be published that recommend a maximum number of daily sitting hours per day, as well as the necessary frequency and length intermittent PA breaks from sitting required to reduce the health risks of sitting [2,4].

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References

[1] Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., & Alter, D. A. (2015). Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: A systematic review and meta-analysis. *Annals of Internal Medicine, 162*(2), 123-231.

[2] Healy, G. N., Dunstan, D. W., Salmon, J., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008). Television time and continuous metabolic risk in physically active adults. *Medicine & Science in Sport & Exercise, 40*(4), 639-645.

[3] Katzmarzyk, P. T., Church, T. S., Craig, C. L., & Bouchard, C. (2009). Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Medicine & Science in Sports & Exercise, 41*(5), 998-1005.

[4] Owen, N., Healy, G. N., Matthews, C. E., & Dunstand, D. W. (2010). Too much sitting: The population-health science of sedentary behavior. *Exercise and Sports Science Reviews, 38*(3), 105-113.

[5] Peterson, M. D., Sarma, A. V., & Gordon, P. M. (2012). Sitting time and all-cause mortality risk. *Archives of Internal Medicine, 172*(16), 1270-1272.

[6] Whitfield, G., Pettee Gabriel, K.K., & Kohl, H.W. (2014). Sedentary and active: Self-reported sitting time among marathon and half-marathon participants. *Journal of Physical Activity and Health, 11*(1), 165-172.

[7] Judice, P. B., Silva, A. M., Magalhaes, J. P., Matias, C. N., & Sardinha, L. B. (2014). Sedentary behaviour and adiposity in elite athletes. *Journal of Sports Sciences, 32*(19), 1760-1767.

[8] Pate, R. R., O'Neill, J. R., & Lobelo, F. (2008). The evolving definition of "sedentary". *Exercise and Sport Sciences Reviews, 36*(4), 173-178.

[9] Carson, V., Staiano, A. E., & Katzmarzyk, P. T. (2015). Physical activity, screen time, and sitting among US adolescents. *Pediatric Exercise Science, 27*(1), 151-159.

[10] Dunstan, D. W., Salmon, J., Owen, N., Armstrong, T., Zimmet, P. Z., Welborn, T. A., … Shaw, J. E. (2004). Physical activity and television viewing in relation to risk of undiagnosed abnormal glucose metabolism in adults. *Diabetes Care, 27*(11), 2603-2609.

[11] Hamilton, M. T., Healy, G. N., Dunstan, D. W., Zderic, T. W., & Owen, N. (2008). Too little exercise and too much sitting: Inactivity physiology and the need for new recommendations on sedentary behavior. *Current Cardiovascular Risk Reports, 2*(4), 292-298.

[12] Pescatello, L. S. (2014). *ACSM's Guidelines for exercise testing and prescription* (9th ed.). Philadelphia, PA: Wolters Kluwer.

[13] Hawari, N. A., Al-Shay, J, I., Wilson, J., & Gill, J. R. (2016). Frequency of breaks in sedentary time and postprandial metabolic responses. *Medicine & Science in Sports & Exercise, 48*(12), 2495-2502.

[14] Mansoubi, M., Pearson, N., Clemes, S. A., Biddle, S. J., Bodicoat, D. H., Tolfrey, K., … Yates, T. (2015). Energy expenditure during common sitting and standing tasks: examining the 1.5 MET definition of sedentary behaviour. *BMC Public Health, 15*, 516.

[15] Lin, T., Courtney, T. K., Lombardi, D. A., & Verma, S. K. (2015). Association between sedentary work and BMI in a U.S. national longitudinal survey. *American Journal of Preventive Medicine, 49*(6), 117-123.

[16] Whitfield, G., Pettee Gabriel, K. K., & Kohl. H.W. (2013). Assessing sitting across contexts: Development of the multicontext sitting time questionnaire. *Research Quarterly for Exercise and Sport, 84*(3), 323-328.

[17] Zhu, W. & Owen, N. (2017). *Sedentary behavior and health*. Champaign, IL: Human Kinetics.

[18] Chau, J. Y., Grunseit, A. C., Chey, T., Stamatakis, E., Brown, W. J., Matthews, C. E., …van der Ploeg, H. P. (2013). Daily sitting time and all-cause mortality: A meta-analysis. *Plos One, 8*(11), e80000.

[19] Ekelund, U., Steene-Johannessen, J. Brown, W.J., Fagerland, M. W., Owen, N., Powell, K. E., … Lee, I. (2016). Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonized meta-analysis of data from more than 1 million men and women. *The Lancet, 388*, 1302-1310.

[20] U. S. Centers for Disease Control and Prevention. (2014). *2015 behavioral risk factor surveillance system questionnaire* [PDF]. Retrieved from http://www.cdc.gov/brfss/questionnaires/pdf-ques/2015-brfss-questionnaire-12-29-14.pdf .

[21] Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2), 155-163.

[22] Bouchard, C., Blair, S. N., & Katzmarzyk, P. T. (2015). Less sitting, more physical activity, or higher fitness? *Mayo Clinic Proceedings, 90*(11), 1533-1540.

[23] Gibbs, B., B., Hergenroeder, A. L., Katzmarzyk, P. T., I-Min, L., & Jakicic, J. M. (2015) Definition, measurement, and health risks associated with sedentary behavior. *Medicine & Science In Sports & Exercise, 47*(6), 1295-1300.

[24] Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., & Katzmarzyk, P. T. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet, 380*(9838), 219-229.

[25] Koster, A., Caserotti, P., Patel, K. V., Matthews, C. E., Berrigan, D., Domelen, D. R., . . . Harris, T. B. (2012). Association of sedentary time with mortality independent of moderate to vigorous physical activity. *PLoS ONE, 7*(6).

[26] Harrington, D. M., Barreira, T. V., Staiano, A. E., & Katzmarzyk, P. T. (2014). The descriptive epidemiology of sitting among US adults, NHANES 2009/2010. *Journal of Science and Medicine in Sport, 17*, 371-375.