International Journal of EXERCISE SCIENCE

Original Research

The Impact of the COVID-19 Pandemic and a Physical Therapy Program on Students' Health Outcomes

KRISTIN MORENO[1†], CAITLYN FERGUSON[1†], VANESSA GARCIA[1†], MANUEL GOMEZ[2†], and ALVARO N GUROVICH[1, 2‡]

[1]Doctor of Physical Therapy Program, Department of Physical Therapy and Movement Science, The University of Texas at El Paso, El Paso, TX, USA; [2]Clinical Applied Physiology Lab, Department of Physical Therapy and Movement Science, The University of Texas at El Paso, El Paso, TX, USA

[†]Denotes graduate student author, [‡]Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(3): 199-211, 2024. The COVID-19 pandemic affected many aspects of everyday life including school, fitness regimens, and social interactions. The purpose of this study is to understand how COVID-19 restrictions affect the cardiovascular and mental health of Doctor of Physical Therapy (DPT) students as they progressed through the program. Data collection occurred in 16 DPT students (8F:8M, 24±3 years) over a total of 3 visits from 2020 to 2022, during high, moderate, and low COVID-19 restrictions. Outcome measures included VO2max, Venous Occlusion Plethysmography (VOP), %fat mass measured via DEXA, Perceived Stress Scale (PSS) and International Physical Activity Questionnaire (IPAQ). A RM-ANOVA with pairwise comparisons was utilized. Significance was set prior at an α level of 0.05. There was a significant increase ($p<0.05$) from visit 1 to 2 in VO2max, VOP baseline, BMI, and METs. There was a significant decrease ($p<0.05$) from visit 2 to 3 in VO2max. Finally, a significant increase in visit 3 was seen from visit 2 in VOP peak. Overall, there was no significant difference observed for PSS and %fat mass ($p>0.05$). Between high and moderate restrictions, there was an increase in VO2max, VOP baseline, and METs. However, between moderate and low restrictions, only VOP Peak increased. This could be attributed to gyms being closed and limiting the type of physical activity a person could do to exercises like running or walking. When restrictions were lifted, traveling to and from classes, traveling to gyms, and socializing all increased, limiting the time for physical activity.

KEY WORDS: VO_2max, fat mass, physical activity, graduate school, sedentary behaviors

INTRODUCTION

In December 2019, the world saw the start of a novel virus, severe acute respiratory syndrome coronavirus (SARS-CoV-2) that was characterized by its high infection and mortality rates (13, 29). This marked the outbreak of the third known coronavirus, causing the disease known as COVID-19 (17). In order to mitigate the spread of the disease, a myriad of non-pharmaceutical interventions (NPI) were implemented worldwide (7). The beginning of the pandemic was marked by restrictive NPIs that drastically changed the everyday routine of many individuals (20). As time went on, especially after the emergency approval of the vaccines for COVID-19, these restrictions tapered (7, 15).

The High Restriction (HR) period was defined from March 2020, when the United States declared COVID-19 a national emergency and the first lockdown orders were implemented, to December 2020, when the first COVID-19 vaccine was approved. These NPIs included international and national travel bans, closing of schools and non-essential businesses, mask mandates, social distancing, and stay-at-home orders (7). Additionally, gyms, restaurants, and bars were also closed and the number of people that were allowed in health care facilities were limited (1). Even though these kinds of restrictions varied by state and counties, El Paso, TX was under strict restrictions until vaccines were available and, in general, the end result was similar for the entire country.

The Moderate Restriction (MR) period was defined from December 2020, with the approval of the first COVID-19 vaccine, to September 2021, when the booster dose was administered. As the vaccine became more readily available to the general public, restrictions were decreased (7). In March of 2021, the CDC announced that social distancing in schools was decreased from 6 feet to 3 feet. Additionally, those who were fully vaccinated were allowed to gather indoors without the use of masks, were deemed safe to travel domestically without a COVID-19 test, and they no longer had to quarantine after coming in contact with someone that had contracted COVID-19 (6, 7). El Paso County in Texas followed the CDC recommendations. The Low Restriction (LR) period has been defined from September 2021 onwards, with the introduction of the booster continuing to decrease the use of NPIs.

Although necessary to slow progression of the disease (16), the NPIs added social, emotional, and economical stresses in addition to the already deleterious effects of the pandemic (5, 16). After the start of the COVID-19 pandemic, a general decrease in mental health was seen around the world including increased risk of anxiety and depression (5, 11). Stresses stemmed not only from fear of contracting the disease but from financial instability, a lack of resources, and disruption of normal daily activities and routines (5, 7, 15).

The COVID-19 pandemic also brought a decrease in physical activity that could be attributed to the stay-at-home orders that discouraged people from doing activities outside of their homes (22). Reduction in activity has been shown to correlate with decreases in leg muscle mass and aerobic capacity (18). Prolonged immobilization and increased time in sitting have been tied to endothelial dysfunction, which is one of the primary pathophysiological factors for cardiovascular disease (24, 25, 31). While some data exist on the impact of the COVID-19 pandemic, especially associated with mental health in college undergraduate students (19), there is a need for further research examining the effects of a pandemic on the physical and mental health of specific populations, such as graduate students. Even with COVID-19 not being a factor of low physical activity, graduate health care students already have a unique experience that differs from undergraduate students since the learning workload increases while free time decreases, thus leading to potential diminished healthy behaviors and a possible decrease of academic performance (10, 27). Therefore, the purpose of this study is to determine how the COVID-19 pandemic and a graduate program in health sciences (i.e., Doctor of Physical Therapy (DPT) program) impact the health outcomes of students as they progress through the program and different COVID-19 restriction periods.

METHODS

Participants

Using a convenience sample, 18 students enrolled in the DPT class of 2023 at The University of Texas at El Paso (UTEP) were recruited. Exclusion criteria included cardiovascular disease diagnosed by a health care provider and/or any physical injury/limitation that prevented physical activity. A pre-survey was administered to determine if the participant met eligibility requirements. Additionally, participants were asked to refrain from taking over-the-counter analgesics, such as NSAIDs, and nutritional supplements that have antioxidants for at least 12 hours before their testing session. Participants were assigned a subject code unrelated to any personal information. The study was approved by the Institutional Review Board of UTEP, and all individual participants included in the study signed the informed consent before beginning testing. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (23).

Protocol

This study was a longitudinal study following the UTEP DPT class of 2023 cohort through the 2 years of their didactic program. Participants were recruited via an in-class presentation and emails. The first data points were collected between October and November 2020, within 9 months of HRs, where all academic activities were online and hands-on activities were postponed to December 2020. The second data points were collected between June and August of 2021 during MRs, where all lectures were online and all hands-on activities were performed face-to-face. The final data points were collected in April of 2022 during LRs where all academic activities were back to face-to-face format. At each data point, participants were asked to attend one visit at the Clinical Applied Physiology (CAPh) lab. Each visit had 4 stations where participants completed 1) surveys regarding physical activity levels and perceived stress levels, 2) vascular testing via venous occlusion plethysmography (VOP) 3) body composition via Dual-energy X-ray Absorptiometry (DEXA), and 4) cardiorespiratory fitness via maximal aerobic capacity (VO2max) testing.

The following two self-report surveys were administered online to participants via QuestionPro: Perceived Stress Scale 10 (PSS-10) and the International Physical Activity Questionnaire (IPAQ). The PSS-10 is a reliable and valid survey for depression and anxiety (4). The survey has 10 items and each item is scored from 0 to 4 for a maximal total score of 40 (4). Higher scores indicate higher perceived stress. The IPAQ long form is a reliable and valid survey to estimate physical activity (9). The IPAQ is scored using the participant's estimated time spent doing various occupational and recreational physical activities at different intensities. These data are then converted to metabolic equivalent of task (MET) minutes per week. For this survey, sitting is considered 1.0 METs, walking 3.3 METs, moderate activity 4.0 METs, and vigorous activity 8.0 METs (9, 10).

Height (Seca, Hamburg, Germany) and weight (WB-110A Class III, Tanita, Japan) of each participant were taken at the beginning of each visit. VOP (AI6 Arterial Inflow System, D. E. Hokanson, Inc., Bellevue, WA, USA), a measurement of microvascular endothelial function, was assessed on the right arm of all participants as previously described in Adkisson et al. (2). Ten baseline readings were taken followed by an ischemic event. The ischemic event was set to a pressure of 180 mmHg and lasted 5 minutes. After the ischemic event concluded, 10 readings of VOP were taken and the peak slope was selected for peak blood flow. Forearm blood flow was determined and expressed as milliliters per minute per 100 mL of tissue (mL/min per 100 mL tissue) by the slope of the plethysmograph signal.

Body composition was collected via a DEXA (Lunar DPX-NT, GE Lunar Corp., Madison, WI, USA). The DEXA uses low-energy x-rays to obtain quick and reliable body composition data, such as fat tissue mass (32). Each scan exposes the participant to a radiation dose of approximately 0.4 to 0.86 millirem, less than most medical procedures (32). The DEXA machine was calibrated each morning of data collection. Participants were asked to remove any metal, such as piercings, glasses, or watches, from their body, and were asked if there was a chance of pregnancy before testing commenced. The participants were then instructed to lay supine on the DEXA machine and were positioned carefully within the testing field by the investigators to ensure proper measurements of both sides of the body. A total body scan, using the default settings, was taken once for each participant, and each scan took approximately 10-15 minutes to complete.

Cardiorespiratory fitness capacity was obtained with a maximal oxygen consumption (VO2max) test on a cycle ergometer (Corival, Lode, Groningen, Netherlands). The VO2max metabolic cart (TrueOne 2400, Parvomedics Inc., Sandy, UT, USA) was calibrated at the beginning of the day and again at mid-day. Participants were allowed to set the height of the bike seat and were given the option to perform the test with music of their choice in order to promote the best performance possible. Participants were instructed on the graded exercise protocol for the VO2max test, which included increasing resistance levels every 2 minutes. Borg's rate of perceived exertion (RPE) was used to determine the patient's self-reported effort and fatigue during the test. RPE ratings were recorded near the end of each stage. Participants were instructed to make as much effort as they could and were encouraged verbally to continue with the test for as long as possible. Indicators that participants were nearing completion of the test included an RPE of greater than or equal to 17 and a respiratory exchange ratio (RER) of 1.10 (28). However, the participants were also instructed that they were able to terminate the test whenever they needed.

Statistical Analysis

Descriptive statistics, including mean and standard deviations were obtained. Normal distribution for all dependent variables was evaluated by Kolmogorov-Smirnov test. A repeated-measures analysis of variance (RM-ANOVA) with pairwise comparisons (Least Significant Difference-LSD) was utilized. Significance was set prior at an α level of 0.05 and observed power was calculated. The statistical analysis was performed with IBM SPSS Statistics (version 25.0, IBM, Chicago, IL, USA).

RESULTS

Eighteen participants (9M, 9F) initially participated in the baseline data collection, followed by 16 (8M, 8F) during the second visit and 17 (9M, 8F) in the final visit. Attrition was due to failure to meet inclusion criteria and scheduling conflicts. Data were confirmed normally distributed. Demographics for the initial visit are listed in Table 1. Final analysis was performed in 16 (8M, 8F) participants that completed all 3 visits (Table 2).

Table 1. Baseline Characteristics of the Sample.

	Age (years) Mean (SD)	Weight (kg) Mean (SD)	Height (cm) Mean (SD)	BMI (kg/m^2) Mean (SD)
Total (n=18)	24.65 (3.24)	71.56 (13.45)	170.52 (13.09)	24.48 (2.95)
Males (n=9)	23.89 (0.93)	75.26 (12.68)	173.37 (10.02)	24.86 (2.21)
Females (n=9)	25.50 (4.63)	66.71 (12.80)	176.33 (7.22)	23.75 (3.53)

Table 2. Data analysis at different timepoints for all studied variables

n = 16	High Restrictions (HR) Mean (SD)	Moderate Restrictions (MR) Mean (SD)	Low Restrictions (LR) Mean (SD)	RM-ANOVA (p-value)
VO_2max (ml/Kg/min)	36.95 (6.56)	41.66 (8.43)	35.82 (5.85)	0.003
Resting Blood Flow (mL/min/100 mL tissue)	2.15 (0.57)	2.80 (0.86)	2.27 (0.85)	0.078
Peak Blood Flow (mL/min/100 mL tissue)	17.06 (15.33)	25.67 (17.44)	40.84 (10.49)	< 0.001
BMI (kg/m^2)	24.48 (2.95)	24.98 (3.30)	25.42 (3.46)	0.015
Fat Mass (%)	30.32 (6.57)	31.21 (6.72)	30.60 (6.99)	0.510
IPAQ (METs)	1396 (1242)	2510 (1839)	1974 (2268)	0.122
PSS (score)	15.63 (6.78)	17.19 (7.74)	15.44 (8.08)	0.330

VO_2max: Maximal Oxygen Consumption; BMI: Body Mass Index; IPAQ: International Physical Activity Questionnaire; MET: Metabolic Equivalent; PSS: Perceived Stress Scale; RM-ANOVA: Repeated Measures Analysis of Variance

VO_2max (Figure 1) had a significant increase between visit 1 and visit 2 (p=0.013; CI 95: [1.154,8.259]); however, it had a significant decrease between visit 2 and visit 3 (p=0.002; CI 95: [-9.140, -2.010]) to the point there was no difference between visit 1 data point and visit 3 (p=0.421; CI 95: [-4.313,2.575]). RM-ANOVA observed power for VO_2max was 90.1%.

Resting arm blood flow (Figure 2) had a significant increase between visit 1 and visit 2 (p=0.021; CI 95: [0.089,1.206]); however, it had a no significant change between visit 1 and visit 3 (p=1.000; CI 95: [-0.678,0.926]) or visit 2 and visit 3 (p=0.472; CI 95: [-9.140, -2.010]). RM-ANOVA observed power for resting arm blood flow was 50.1%. Peak arm blood flow (Figure 3) had a significant increase between visit 1 and visit 3 (p=0.002; CI 95: [8.892,38.657]) and visit 2 and visit 3 (p=0.005; CI 95: [4.520,25.821]); however, it had a no significant change between visit 1 and visit 2 (p=0.550; CI 95: [-8.009,25.217]). RM-ANOVA observed power for peak arm blood flow was 97.8%.

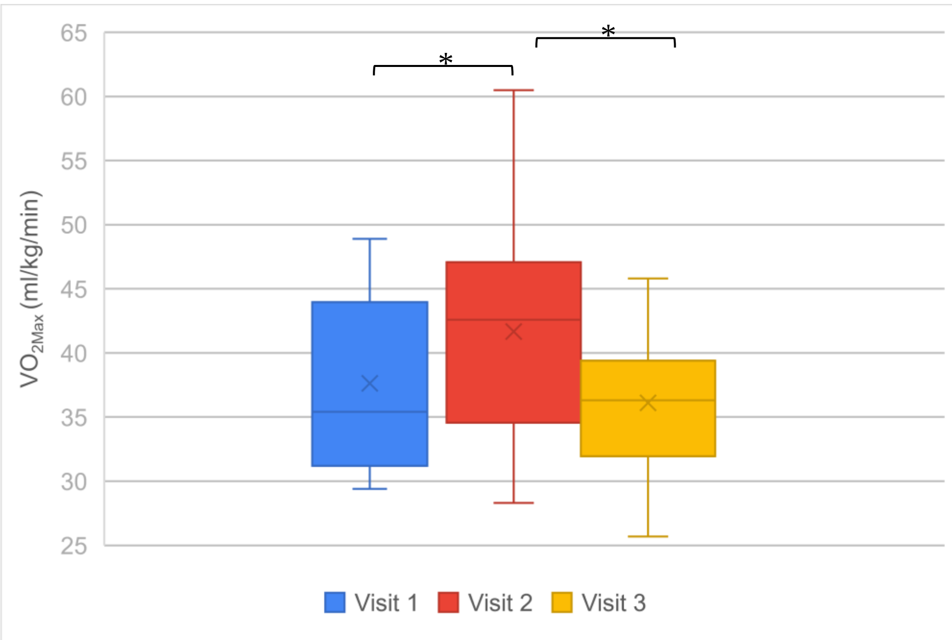

Figure 1. Maximal Oxygen Consumption (VO_2max) in Visits 1,2, and 3 in UTEP DPT Students. *p<0.05 with Visit 2 significantly higher than Visit 1, Visit 3 significantly lower than Visit 2

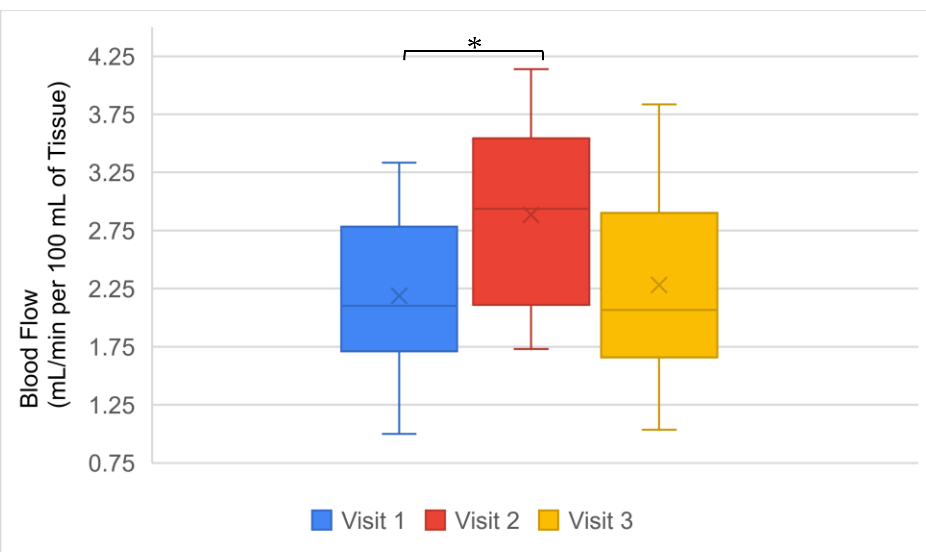

Figure 2. Resting Arm Blood Flow in Visits 1,2, and 3 in UTEP DPT Students. *p<0.05 with Visit 2 significantly higher than Visit 1.

BMI (Figure 4) showed a significant increase from visit 1 to visit 2 (p=0.004; CI 95: [0.354, 1.503]) and from visit 1 to visit 3 (p=0.028; CI 95: [0.115, 1.779]). RM-ANOVA observed power for BMI was 76.0%. There was no significant change in the percentage of fat mass (Figure 5) between any of the visits (p>0.05). RM-ANOVA observed power for percentage fat mass was 15.5%.

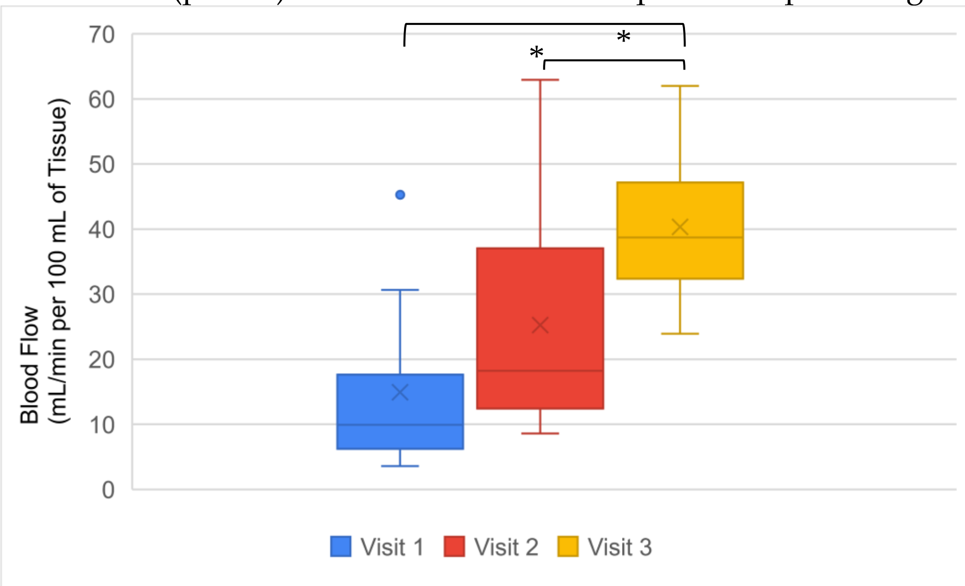

Figure 3. Peak Arm Blood Flow after Ischemic Event in Visits 1,2, and 3 in UTEP DPT Students. *p<0.05 with Visit 3 significantly higher than Visit 1 and Visit 2.

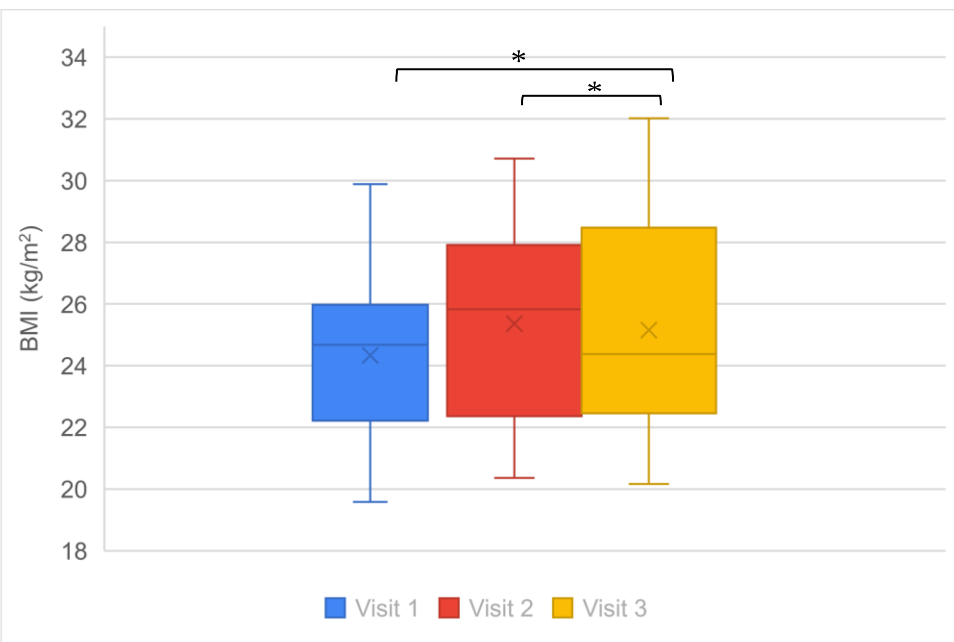

Figure 4. Body Mass Index in Visits 1,2, and 3 in UTEP DPT Students. *p<0.05 with Visit 2 and Visit 3 significantly higher than Visit 1.

DISCUSSION

The purpose of the current study was to determine how the COVID-19 pandemic and a graduate doctoral program impact the health outcomes of students. The results of the current study show improvements from HR to MR in aerobic capacity and resting blood flow and improvements from MR to LR in vascular function. Additionally, a decline was seen from MR to LR in aerobic capacity and BMI. Finally, no significant difference was seen across HR, MR, and LR for perceived stress or fat mass.

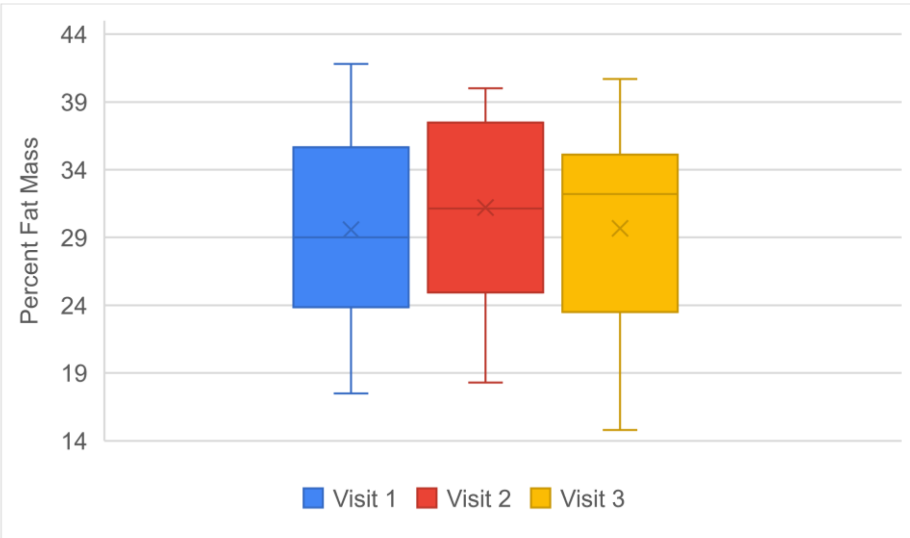

Figure 5. Fat Mass in Visits 1, 2, and 3 in UTEP DPT Students. *p<0.05 with no significant difference seen between visits.

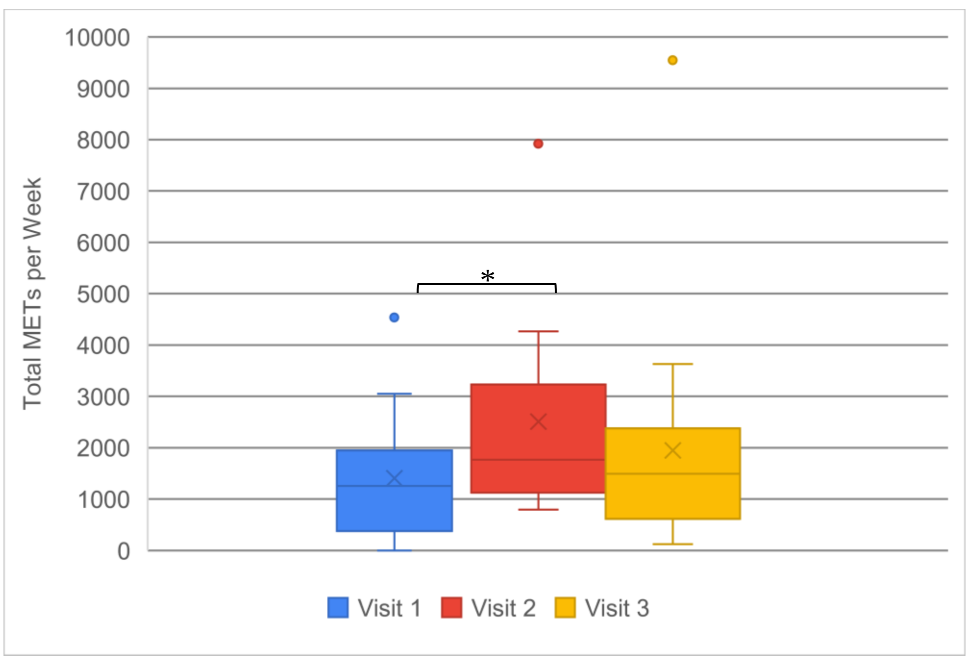

Figure 6. Weekly Metabolic Equivalents of Time According to the International Physical Activity Questionnaire in Visits 1,2, and 3 in UTEP DPT Students. ***p<0.05 with Visit 2 significantly higher than Visit 1**

Because of the COVID-19 restrictions implemented for 9 months before the first visit, we expected that the participants' health outcomes would be at their lowest levels at baseline. as they were navigating both graduate level education as well as a pandemic. We predicted that at MR participants would demonstrate improved results compared to HR; and by LR participants would have statistically better results in most outcomes. This expectation was due to the decrease in restrictions and increase in availability to have in-person social interactions and perform physical activity outside the home. However, the only improvement at LR was in vascular function.

Cardiopulmonary fitness capacity, measured via VO2max, is indicative of cardiovascular health (12) and it might be associated with academic performance (27). Even though there was an expected improvement in VO2max between HR and MR, due to students leaving their home and accessing more recreational areas and fitness centers, there was a decrease in VO2max during LR (Figure 1). Strong et al. (30) looked into the prison population and showed that prolonged isolation affected prisoners' mental and physical health and reduced their desire to be active. In addition, low levels of physical activity can lead to adverse effects including a reduction in VO2max (18, 20). Therefore, the results of the present study align with the hypothesis that increasing freedom can increase physical activity, improving cardiovascular health (12), as an improved in METs from HR to MR (Figure 6) is associated with an increase in VO2max (Figure 1). Moreover, and based on Redondo-Flórez et al. (27), the increase in physical activity observed in MR and LR would have helped with students' academic performance. Interestingly, the decrease in VO2max observed during LRs could be associated with an increase in persons' workload, where students needed to spend more time commuting, studying, and doing less physical activity in a demanding and stressful environment. Unfortunately, the present study was not able to determine this association as data from PSS and IPAQ did not show any changes from MR to LR (Figures 6 and 7, respectively).

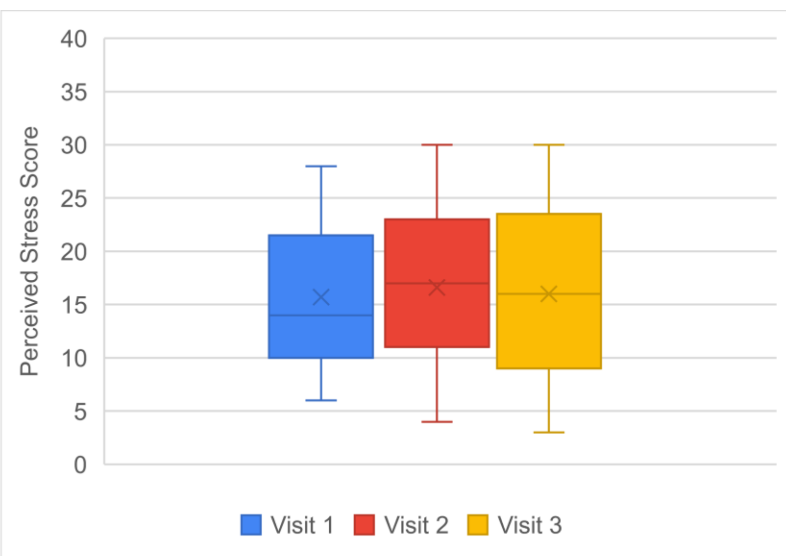

Figure 7. Stress Levels according to the Perceived Stress Scale in Visits 1,2, and 3 in UTEP DPT Students. *p<0.05 with no significant difference seen between visits.

Krogh-Madsen et al. (18) and Woods et al. (34) showed that a decrease in walking time over a short period of time (i.e. 2 weeks) significantly decreases VO2max. These studies could support a lower VO2max during HRs (Figure 1) as students might have been very sedentary during the first months of the pandemic. However, IPAQ might not be sensitive enough to determine small behavioral changes as it is a self-reported measure. For example, there was an increase in total METs from HR to MR and no change between MR and LR (Figure 7). Since IPAQ only categorizes activities into sitting, walking, moderate, and vigorous categories, and does not differentiate between cardiovascular or resistance training, this could explain the discrepancy between physical activity and VO2max seen from MR to LR. The initial improvement in participants' VO2max during the MR period may be attributed to an increase in physical activity, as well as easier access to outdoor cardiovascular activities such as walking, running, hiking, and biking, compared to resistance training activities due to the slow reopening of gyms as restrictions lessened. As restrictions lessened and participants had more opportunities to perform resistance training, participants may have maintained total physical activity while engaging in different types of physical activity not differentiated by the IPAQ.

The present study showed some improvements in resting blood flow and endothelial function associated with less pandemic restrictions (Figures 2 and 3, respectively). These changes were associated with the increase with VO2max, especially from HRs to MRs. Interestingly, endothelial function significantly improved during LRs, but this improvement was not associated to VO2max or increase in physical activity, measured via IPAQ. Prolonged immobilization or sitting can cause endothelial dysfunction (31) and exercise or active behaviors can enhance endothelial function (21). For example, Thosar et al. (31) showed that just 3 hours of seating decreased shear stress in the femoral artery, which elicited a decreased in endothelial function, measured via flow mediated dilation (FMD). In addition, Morishima et al. (21) showed that active behaviors, such as cycling before seating for 3 hours or working standing up, inhibit the endothelial dysfunction (maintained FMD) observed when seating for 3 hours. Therefore, physical activity would increase endothelial shear stress, which would enhance endothelial function (3, 8, 14). However, there is a difference between sitting (or sedentary behavior) and lack of exercise (26). Activities below 1.5 METs are considered detrimental to our health (e.g., sitting without otherwise being active or bed rest). Even the simple act of standing, which generates only 2.0 METs, is beneficial for the endothelial health (21, 26). During HRs, students were mostly seated and confined to their homes engaged in virtual learning with little physical activity. Then, during MRs, physical activity levels increased what could explain the increase in resting blood flow. Finally, once restrictions were lifted, they came back to a more normal schedule where daily walking and less sedentary behaviors were more predominant. This behavior could explain the lack of improvement in VO2max but an increase in endothelial function observed in the present study (Figures 1 and 3, respectively).

Finally, the present study showed some interesting results associated with body composition. Even though there were no changes in fat mass between data points, BMI systematically increased with lesser restrictions (Figures 4 and 5, respectively). This could be due to an increase in muscle mass rather than fat mass as BMI is not very sensitive to changes in muscle mass, especially in young healthy individuals (33).

The present study is not without limitations. First, we were unable to obtain a real baseline measurement as students were able to come back to campus for practical lab sessions during the transition of HR and MR. Some of the changes between HR and MR observed in the present study could have been larger if data had been collected in the middle of HRs, what was unsafe and undoable because of the high contagious nature of the virus and the local restrictions, respectively. Additionally, the study used a small sample size recruited through convenience sampling thereby increasing bias of the results. Another variable that could have played an important role in the current study is nutrition. The original data collection included a food journal; however, participants' compliance was very low. Including the nutritional data would have impacted sample size even more. Finally, scheduling of data collection could have impacted some results as dates were chosen according to the participant's schedule, where weeks with decreased academic workloads were given priority. This might have affected self-report surveys, such as the PSS and IPAQ, as the students' perception of stress and activity may fluctuate with varying school workload.

The results of the present study showed that lesser restrictions during the COVID-19 pandemic could improve cardiopulmonary fitness levels and endothelial function in students of a graduate doctoral health sciences program, regardless of the teaching demands of the program. Moreover, some of the academic activities (e.g., hands on practical labs) might have helped decreasing pandemic sedentary behaviors improving some of the health markers. To determine the effects of graduate doctoral education in health outcomes, future studies may focus on the impact of graduate school alone outside of a pandemic, recruit a larger sample size, include multiple disciplines or schools, test during periods of high academic load, and focus on additional objective measures for weekly physical activity.

REFERENCES

1. Adams C. Timeline: How coronavirus in Texas unfolded since first case one year ago. In: kxan.com editor 2021.

2. Adkisson EJ, Casey DP, Beck DT, Gurovich AN, Martin JS, Braith RW. Central, peripheral and resistance arterial reactivity: Fluctuates during the phases of the menstrual cycle. Exp Biol Med 235(1):111-118, 2010.

3. Amador M, Huerta JA, Garcia MA, Conde DA, Gurovich AN. In vitro exercise-induced endothelial shear stress protects the vascular endothelium. Cardiopulm Phys Ther J 34(2):81-86, 2023.

4. Baik SH, Fox RS, Mills SD, Roesch SC, Sadler GR, Klonoff EA, Malcarne VL. Reliability and validity of the perceived stress scale-10 in Hispanic Americans with English or Spanish language preference. J Health Psychol 24(5):628-639, 2019.

5. Brooks SK, Webster RK, Smith LE, Woodland L, Wessely S, Greenberg N, Rubin GJ. The psychological impact of quarantine and how to reduce it: Rapid review of the evidence. Lancet 395(10227):912-920, 2020.

6. CDC. When you've been fully vaccinated. In: Center for Disease Control and Preventions; 2021.

7. CDC. Covid-19 timeline. In: C Museum editor: Center for Disease Control and Preventions; 2022.

8. Coovert D, Evans LD, Jarrett S, Lima C, Lima N, Gurovich AN. Blood flow patterns during incremental and steady-state aerobic exercise. J Sports Med Phys Fitness 58(10):1537-1543, 2017.
9. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 35(8):1381-1395, 2003.

10. Dabrowska-Galas M, Plinta R, Dabrowska J, Skrzypulec-Plinta V. Physical activity in students of the medical University of Silesia in Poland. Phys Ther 93(3):384-392, 2013.

11. Daly M, Robinson E. Psychological distress and adaptation to the COVID-19 crisis in the united states. J Psychiatric Res 136:603-609, 2021.

12. Fernström M, Fernberg U, Eliason G, Hurtig-Wennlöf A. Aerobic fitness is associated with low cardiovascular disease risk: The impact of lifestyle on early risk factors for atherosclerosis in young healthy swedish individuals–the lifestyle, biomarker, and atherosclerosis study. Vasc Health Risk Manag :91-99, 2017.

13. Guo Y-R, Cao Q-D, Hong Z-S, Tan Y-Y, Chen S-D, Jin H-J, Tan K-S, Wang D-Y, Yan Y. The origin, transmission and clinical therapies on coronavirus disease 2019 (covid-19) outbreak–an update on the status. Mil Med Res 7:1-10, 2020.

14. Gurovich AN, Rodriguez L, Gomez M, Caraveo P, Ochoa L, Morales-Acuna F. Imaging ultrasound assessment of exercise-induced endothelial shear stress of the brachial and carotid arteries. Cardiopulm Phys Ther J 32(1):30-36, 2021.

15. Health C. COVID-19 pandemic timeline fast facts. In: CNN editor2022.

16. Hsiang S, Allen D, Annan-Phan S, Bell K, Bolliger I, Chong T, Druckenmiller H, Huang LY, Hultgren A, Krasovich E. The effect of large-scale anti-contagion policies on the COVID-19 pandemic. Nature 584(7820):262-267, 2020.

17. Khachfe HH, Chahrour M, Sammouri J, Salhab H, Makki BE, Fares M, Salhab HA, Fares MY. An epidemiological study on COVID-19: A rapidly spreading disease. Cureus 12(3):e7313-7319, 2020.

18. Krogh-Madsen R, Thyfault JP, Broholm C, Mortensen OH, Olsen RH, Mounier R, Plomgaard P, van Hall G, Booth FW, Pedersen BK. A 2-wk reduction of ambulatory activity attenuates peripheral insulin sensitivity. J Appl Physiol 108(5):1034-1040, 2010.

19. Lee J, Solomon M, Stead T, Kwon B, Ganti L. Impact of COVID-19 on the mental health of us college students. BMC Psychol 9(1):95, 2021.

20. Lim MA, Pranata R. Sports activities during any pandemic lockdown. Ir J Med Sci 190(1):447-451, 2021.

21. Morishima T, Restaino RM, Walsh LK, Kanaley JA, Padilla J. Prior exercise and standing as strategies to circumvent sitting-induced leg endothelial dysfunction. Clin Sci 131(11):1045-1053, 2017.

22. Mutz M, Gerke M. Sport and exercise in times of self-quarantine: How germans changed their behaviour at the beginning of the COVID-19 pandemic. Int Rev Sociol Sport 56(3):305-316, 2021.

23. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerci Sci 12(1):1-8, 2020.

24. Nosova EV, Yen P, Chong KC, Alley HF, Stock EO, Quinn A, Hellmann J, Conte MS, Owens CD, Spite M. Short-term physical inactivity impairs vascular function. J Surg Res 190(2):672-682, 2014.

25. Peçanha T, Goessler KF, Roschel H, Gualano B. Social isolation during the COVID-19 pandemic can increase physical inactivity and the global burden of cardiovascular disease. Am J Physiol Heart Circ Physiol 318(6):H1441-H1446, 2020.

26. Pinto AJ, Bergouignan A, Dempsey PC, Roschel H, Owen N, Gualano B, Dunstan DW. Physiology of sedentary behavior. Physiol Revi 103(4):2561-2622, 2023.

27. Redondo-Flórez L, Ramos-Campo DJ, Clemente-Suárez VJ. Relationship between physical fitness and academic performance in university students. Int J Environ Res Public Health 19(22):14750, 2022.

28. Riebe J. Clinical exercise testing and interpretation. In: C Brawner and J Ehrman editors. ACSM guidelines for exercise testing and prescription. Philadelphia, PA: Wolters Kluwer; 2018.

29. Shereen MA, Khan S, Kazmi A, Bashir N, Siddique R. Covid-19 infection: Emergence, transmission, and characteristics of human coronaviruses. J Adv Res 24:91-98, 2020.

30. Strong JD, Reiter K, Gonzalez G, Tublitz R, Augustine D, Barragan M, Chesnut K, Dashtgard P, Pifer N, Blair TR. The body in isolation: The physical health impacts of incarceration in solitary confinement. PLoS One 15(10):e0238510, 2020.

31. Thosar SS, Johnson BD, Johnston JD, Wallace JP. Sitting and endothelial dysfunction: The role of shear stress. Med Scin Monit 18(12):RA173, 2012.

32. Ward S, Noland D. Body composiiton. In: D Noland, J A Drisko and L Wagner editors. Integrative and functional medical nutrition therapy: Principles and practices. Netherlands: Springer Nature; 2020.

33. Weir CB, Jan A. Bmi classification percentile and cut off points. In. StatPearls. Treasure Island, FL: StatPearls Publishing; 2023.

34. Woods JA, Hutchinson NT, Powers SK, Roberts WO, Gomez-Cabrera MC, Radak Z, Berkes I, Boros A, Boldogh I, Leeuwenburgh C. The COVID-19 pandemic and physical activity. Sports Med Health Sci 2(2):55-64, 2020.