Journal of Kinesiology and Wellness
A Publication of the Western Society for Kinesiology and Wellness
Volume 12, Number 1, Pages 38-44, 2023
ISSN# 2332-4503

Daily Heart Rate Variability is Higher in Regular Exercisers Versus Matched Non-Exercisers with Similar Chronic Stressor Profiles During the COVID-19 Pandemic

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Abstract
The COVID-19 pandemic increased stress levels and created new health issues amongst individuals of all ages, genders, socioeconomic status, and occupations (da Silveira et al., 2020). The purpose of this research project was to examine differences in acute daily stress using measures of daily morning heart rate (HR), the root mean square of successive differences between normal heartbeats (RMSSD), and a proprietary index of heart rate variability (HRV) compared between matched groups of exercisers and non-exercisers with similar levels of chronic stressors. The sample consisted of 20 adult subjects (10 exercisers, 10-matched non-exercisers), including ten males and ten females with a mean body mass index (BMI) of 26.6±12.87 (females = 27.53±5.34, males = 24.77±3.55). The sample was recruited from the Pueblo, Colorado community and Colorado State University Pueblo and consisted of local community members and faculty, staff, and student body members. The participants recorded their daily morning heart rate at home using a Polar heart rate monitor and the Elite HRV phone application. Chronic stressor load was measured using the Trier Inventory of Chronic Stress (TICS) (2004) at baseline, 3 and 6 weeks. The study occurred during the COVID-19 Pandemic between September 2020 and December 2020. The regular exercise group experienced a significantly lower mean HR ($p < 0.05$), significantly higher mean RMSSD ($p < 0.05$), and mean HRV ($p < 0.05$) than the non-exercisers during the study period, with no significant differences between the groups in mean chronic stressor level as evaluated by the TICS. This research provides further evidence that exercise offers a stress-buffering effect during periods of high chronic stress, such as experienced during the COVID-19 Pandemic.

Keywords: breathing, stress, tolerance, exercise, heart rate, RMSSD

1 Introduction

The COVID-19 pandemic forced an abrupt change to many individuals' routines by increasing responsibilities such as taking precautions for COVID-19 (wearing face masks, using hand sanitizers, etc.) and following stay-at-home orders (taking care of younger family members, participating in work and school online) while also reducing the opportunities to exercise. Hagger et al. (2020) suggested that chronic stressors increased dramatically during the COVID-19 pandemic as an indirect result of such stay-at-home orders and a lack of sense of belonging to social groups, which normally occur naturally because of interactions at work, school, gyms, and while traveling (Hagger et al. 2020). This phenomenon layered one stressor upon another, taxing an individual's ability to buffer stress normally. Consequently, many people's exercise routines were not being practiced regularly as before (Fallon, 2020). Jiménez-Pavón et al. (2020) also recently observed that such a sudden quarantine radically changed the lifestyles of much of the world population and limited their exercise behaviors, such that many people were no longer achieving the recommended physical activity levels necessary to stay healthy and fight off chronic illness. Brand et al. (2020) found that those who did not exercise during the lockdown period from March to May of 2020 had a worse mood than those who exercised during the lockdown period. By contrast, several researchers have also demonstrated that regular exercise resulted in lower stress levels, an increase in positive moods, decreased chronic illness, increased overall well-being and increased immunity during this time frame (Ranasinghe et al.,2020; Jiménez-Pavón et al., 2020). Recently, the ability to measure the HRV of human subjects using Bluetooth-equipped heart rate telemetry has created a new tool for directly measuring acute stress in human subjects during free-living conditions, allowing for a serial examination of their daily acute stress level over time as well (Kim et al., 2018). In addition, Chalmers et al. (2021) found that wearing a smartwatch or a chest strap to detect heart rate and heart rate variability provided accurate results in assessing both resting and stressed states, further validating such an approach. Lastly, da Estrada et al. (2021) found that HRV is an accurate measure of stress if there is a baseline measure and added acute stressors are calculated properly. The stressor load can be evaluated using the Trier Inventory of Chronic Stress (TICS), a questionnaire validated to measure chronic stressor events using self-report. The TICS has been used for over 15 years (Schulz et al., 2011) to evaluate life experiences that may create stressors. The stressors include low-income status, unemployment, and poor housing, and subject scores are based on their subjective judgments towards specific stressors such as noise, poor career prospects, and marriage conflicts, which occur over time. In addition, with excessive demands occurring within individuals' social and occupational daily activities, an increase in chronic stressors can lead to personality trait imbalances and disturbances (Petrowski et al., 2018). The TICS measures chronic stress incorporated within specific psychosocial domains and is a reliable and valid measure of chronic stressors (Petrowski et al., 2018; Schulz et al., 2011). The potential effect of regular exercise on lowering acute stress levels associated with a high chronic stressor load and increasing overall well-being has been previously studied indirectly in cross-sectional approaches examining the associations between workplace stressors, HRV, and physical activity levels (Tonello et al., 2014), suggesting the need to examine these relationships more directly in free-living conditions. Therefore, the purpose of our study was to prospectively measure the differences in matched exercisers and non-exercisers experiencing similar high chronic life stressors during the COVID-19 Pandemic, as measured by the TICS questionnaire, in their daily acute level of stress measured physiologically by daily morning HR, RMSSD, and HRV as a more direct, quasi-experimental approach to the question.

2 Methods

2.1 Participants

A mixed gender sample of 20 (10 males and 10 females) participants, including 10 exercisers (no daily exercise) and 10 matched non-exercisers (at least 30-60 minutes of exercise 5-6 days/week), were recruited from Colorado State University, Pueblo and the general community of Pueblo, Colorado. The participants included students/faculty/staff and adult community members ages 18-65 who were not currently using medications or recreational drugs likely to influence their daily stress response. The participants were classified as exercisers or non-exercisers based on their involvement in an ongoing formal exercise group or lack thereof and matched with non-exercising controls based on age, gender, and living/working conditions as matching variables. Exercise compliance in the exercising group was evaluated using reported exercise participation.

2.2 Procedures

The study was submitted and approved by the Colorado State University, Pueblo Institutional Review Board (CSUP IRB) as a human subject research study. Participants were required to review and sign a human consent form developed in this process. Each participant was issued a Polar 8 heart rate transmitter for the duration of the study and instructed in the daily use of the free Elite HRV© phone application, which was used by the subject to collect daily heart rate (HR) and calculate various heart rate variability related measures including both RMSSD and a proprietary index of HRV created by the Elite HRV company. Participants were asked not to change their daily activities throughout the study. The exercise group was expected to record when they exercised using the Elite HRV application, which downloads the data provided to Elite HRV servers. The principal investigator obtained the data from Elite HRV and saved it as a de-identified file on their password-protected computer.

2.3 Statistical Analyses

Heart rate (HR), the Elite HRV proprietary HRV index (HRV), and the associated root mean square of successive differences between normal heartbeats calculation (RMSSD) data were recorded upon waking each morning daily across 6 weeks. The mean HR, RMSSD, and the HRV index produced by the elite HRV program daily were then averaged across all measures taken over the 6-week study period to calculate each participant's individual mean score for subsequent probability analysis. The TCIS survey was implemented three times: once at the beginning of the data collection period, once at the middle, and once at the end. An average of those three measures was calculated and used as each participant's mean chronic stressor score. The data were analyzed using SPSS V 26 by applying dependent samples t-tests between groups, with participants' mean HR, mean HRV, mean RMSSD, and mean TICS scores serving as dependent variables and using an alpha level of $p < 0.05$. Individual group scores were described by calculating the mean (M), standard deviation (SD), and standard error (SE) by group for each dependent variable. The effect size for each probability test of mean differences was calculated using Cohen's d = (M1 – M2/s2p.). The strength of the effect was determined using the following scheme: Small = 0.2 – 0.49, Medium = 0.5 to 0.79, Large > 0.8.

3 Results

Descriptive measures for the subjects by group may be found in Table 1. Mean ages were not significantly different between groups ($t(19) = 0.09$, $p > 0.05$); however, the BMI was significantly higher in the non-exercising group ($t(19) = 8.75$, $p < 0.05$) than the exercise group.

Table 1: Sample Descriptive Statistics by Group

Group	Age *M*	Age *SD*	BMI *M*	BMI *SD*
Exercise (10)	26.8	14.27	24.21	3.52
Non-Exercise (10)	26.4	12.08	28.1	4.96

Note. BMI: Body Mass Index. Values in parentheses denote sample size.

Exercisers and non-exercisers exhibited no significant differences in chronic stressor levels both within specific domains (below) and overall ($t(19) = 0.127$, $p > 0.05$), as evaluated by the TICS survey tool and further illustrated in Table 2 below.

Mean HRV was significantly higher in the exercisers than the non-exercisers with a large effect size ($t(19) = 1.807$, $p < 0.05$, ES = 0.81, Mex. = 64.02 ± 2.70, Mnonex = 55.54 ± 3.83). Mean RMSSD was significantly higher in the exercisers than the non-exercisers with a large effect size ($t(19) = 1.91$, $p < 0.05$, ES = 2.92, Mex = 31.41±1.27, Mnonex =26.92 ± 1.82). Mean HR was significantly lower in the exercisers than the non-exercisers with a large effect size ($t(19) = 1.82$, $p < 0.05$, ES = 1.21, Mex= 66.11±1.93, Mnonex =76.11 ± 3.15) evaluated by the table above.

4 Discussion

The purpose of our study was to prospectively measure the differences in matched exercisers and non-exercisers experiencing similar high chronic life stressors during the COVID-19 Pandemic, as measured by the TICS questionnaire, in their daily acute level of stress measured physiologically by daily morning HR, RMSSD, and HRV as a more direct, quasi-experimental approach to the question. The first finding in this study that both exercisers and matched non-exercisers groups experienced similar high levels of chronic stressors during the COVID-19 Pandemic is not surprising given that the groups were matched on factors likely to influence chronic stressors. This finding also supports the COVID-19 pandemic scenario as ideal for assessing the daily stress responses to such unusually high stressors as a function of each subject's choice to participate in an ongoing exercise program or not. The second finding, that the self-selected exercisers experienced lower daily stress levels than matched non-exercisers, as measured by HR, HRV, and RMSSD, strongly suggests the possibility that regular exercise favorably impacts the association between high chronic stressors and ongoing daily stress response. While no experimental evidence exists examining this potential effect directly, various researchers have attempted to look at this association less directly. Early studies examining heart rate variability and exercise suggest that chronic HRV is higher, suggesting lower acute stress levels in fitter populations (Braz et al., 2020; Hertzog et al., 2018). Michael et al. (2017) reviewed the existing literature on the acute sympathetic activation created by exer-

Table 2: TICS Domain Comparisons

Domain	Exercisers/Non-Exercisers M	SE	t(19)	p	Cohen's d
Work overload	1.82	.64	0.177	0.819	0.016
Social overload	2.04	.70	0.607	0.524	0.32
Pressure to perform	1.94	.70	0.254	0.171	0.21
Work disconnect	1.82	.63	0.138	0.856	0.10
Excessive demands at work	1.81	.63	0.207	0.795	0.02
Lack of social recognition	1.76	.73	0.125	0.869	0.01
Social tension	1.79	.71	0.031	0.964	0.02
Social isolation	1.82	.62	0.122	0.871	0.02
Chronic worrying	1.83	.63	0.102	0.881	0.02
Overall Chronic Stress Screening Scale	1.78	.72	0.127	0.856	0.08

Note. *t*(df).

Table 3: Results HRV Exercisers and Non-Exercisers

	Exercisers		Non-Exercisers				
Measure	M	SD	M	SD	t(19)	p	Cohen's d
HRV	64.02	2.70	55.54	3.83	1.807	0.05	2.56
RMSSD	31.41	1.27	26.92	1.82	1.91	0.05	0.95
HR	66.11	1.93	76.11	3.15	1.82	0.05	3.83

Note. *t*(df).

cise, as evaluated using HRV, which suggests that HRV is reduced proportionately as exercise intensity increases. This finding illustrates the possible mechanism by which exercise systematically applies a stressor to the autonomic regulation of the nervous system, resulting in reduced stressor reactivity (Boutcher, 2017). In addition, a greater training load also induces a greater sympathetic activation post-exercise, which then resolves more slowly, suggesting the possibility of a dosage-based response, a concept not addressed in this preliminary study. In addition, Schinkoeth et al. (2019) compared exercisers and non-exercisers by having the participants view pictures of others exercising and found that regular exercisers view exercise pictures with a greater HRV response (greater relative parasympathetic activation) than those who were not exercisers suggesting that perceptions around exercise are modified favorably through regular exercise participation as well. Kim et al. (2018) also found that HRV responds to changes in stress levels in various situations and that this response is impacted by an individual's psychological health, suggesting the improvements in psychological health associated with regular exercise might also be a contributing factor in our second finding, as suggested by Brand et al. (2020), who found that those who exercised regularly during the COVID-19 pandemic reported a better mood than those who do not exercise. In addition, Ranasinghe et al. (2020) found that participants who engage in regular physical activity have an increase in their immune response while lowering stress levels, similar to the potential effect of exercise suggested by our results. HRV has also been shown to have a strong positive relationship with aerobic performance. At the same time, chronically low levels of HRV are associated with poor sleep quality, further increasing the effect of chronic stressors in producing acute stress (da Silveira et al., 2020), suggesting a mechanism whereby regular exercise might improve sleep and correspondingly increase parasympathetic activation and HRV. Further illustrating another possible mechanism to explain this interaction, Rominger et al. (2019) found that individuals who exercise regularly can accomplish a more spontaneous way of thinking associated with higher levels of HRV and, in so doing, reduce the onset of stress. These findings suggest that regular exercise may act through a myriad of mechanisms to achieve a reduced stress level and improved health. This study illustrates that this association persists even during a highly stressful global pandemic such as COVID-19.

4.1 Limitations

This study uses a quasi-experimental research design, whereby the groups were formed deliberatively based on pre-existing behaviors and using a matching procedure rather than a randomization procedure. This primary limitation must be recognized in interpreting these findings as an effect of exercise participation on chronic stress reduction. While a matching procedure increases the probability that the grouping variable, exercise participation, is associated with the differences observed in daily stress response, it does not eliminate the potential for a selection bias, differentiating these groups as well. For instance, the exercising group had a significantly lower body mass index than their matched counterparts, which suggests the possibility of a greater predisposition to a lower stressor reactivity or superior nutritional habits in those who choose of their own accord to exercise regularly as possible alternative mechanisms responsible for the observed differences in stress response seen in this study. A second limitation of importance is the relatively small sample size, which might increase the probability of type II error. While the sample size was adequately powerful to produce statistically significant results in most of the variables of interest, the relatively low, yet not below the chosen alpha level, p-value of 0.083 for the work overload domain comparison in the TICS data suggests the possibility that a mechanism influencing the observed differences in daily stress response may also have been differences in work-related stress between the groups if this result is a type II error attributable to inadequate sample size. Consequently, while this study provides evidence that a positive effect of regular exercise on reduced stressor reactivity may exist, it cannot be considered definitive proof of the concept.

5 Conclusion

This study found that chronic exercisers exhibit higher daily HRV levels, suggesting lower acute stress, than matched non-exercisers with similar chronic stressor loads, providing further evidence that regular exercise may reduce stressor reactivity, particularly in periods of high stressor load. Therefore, further, more directed experimental research is justified as it could provide more substantial evidence supporting regular exercise to decrease overall daily stress.

Acknowledgments

We gratefully acknowledge Colorado State University-Pueblo for the SEED grant to help fund this project. Dr. George Dallam for co-authoring, and Jenna McKinley for the data collection.

Conflict of Interest

We have no conflicts of interest to disclose.

Funding Sources

This study was made possible thanks to the SEED Grant from Colorado State University-Pueblo.

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