European Journal of Sport Sciences
Vol 3 | Issue 2 | May 2024
ISSN 2796-0048

RESEARCH ARTICLE

Effect of COVID-19 on Performance and Recovery of Division I Women's Basketball Players: A Case Study

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ABSTRACT

This report aimed to examine the effects of COVID-19 on athletic performance and recovery in women's basketball players. Twelve participants were included in this case report, with four serving as the test group and eight serving as the control group. All participants wore a Polar GPS unit and a Whoop Strap. The Polar unit was worn during games and practices and used to collect metrics of physical workload. The Whoop strap was worn during daily activities, including periods of sleep, to collect metrics of sleep and recovery. Data were analyzed via descriptive statistics (mean difference ± standard deviations), and T-tests were used to evaluate between-group differences ($p < 0.05$). To further analyze clinical significance, the Smallest Worthwhile Change (SWC) and Cohen's d effect sizes were calculated. The results indicated that COVID-19 had the greatest effect on heart rate and sleep metrics with smaller, yet still clinically meaningful, effects on athletic performance. The results show the multisystem effect of COVID-19 on women's basketball players, including both a physiological and performance decrement during training and less efficient recovery. This was the first study to examine the direct impact of COVID-19 on athletic performance and recovery, and it provides insight into the importance of proper return-to-play considerations.

Submitted: October 13, 2023

Published: May 02, 2024

10.24018/ejsport.2024.3.2.105

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Keywords: Athletes, heart-rate, injury, training-load.

1. Introduction

The relationship between training load and its effect on musculoskeletal injury and physical performance in athletes has garnered significant interest within the sports science community. It is well understood that drastic increases in training load may increase the risk of injury and decrease athletic performance (Borresen & Ian Lambert, 2009; Drew & Finch, 2016; Eckard *et al.*, 2018). Most sports organizations, including the National Collegiate Athletic Association (NCAA), operate under defined phases (e.g., pre-season, competitive season, off-season) within the competitive year. Likewise, athletes' training schedules often vary as per these phases. For example, the pre-season is often highlighted by substantial physical training (high intensity, high frequency, and long duration of training). At the same time, the competitive season includes a combination of structured training and competitive games.

Sports coaches, strength and conditioning coaches, and certified athletic trainers often collaborate to optimize training programs to maximize sports performance and decrease injury. Sports injuries may result from various associations between training patterns and other daily stresses (e.g., disturbed sleep, poor nutrition, illness) and occur when physical demands outweigh the body's ability to recover fully. Recent reviews have substantiated the well-accepted notion that training loads affect athletic performance and risk of injury (Borresen & Ian Lambert, 2009; Drew & Finch, 2016; Eckard *et al.*, 2018). With respect to the periodization of a competitive athletic season, there is often a spike of injuries within the first few weeks (e.g., pre-season), which is largely explained by the drastic increase in training load relative to the previous weeks (Hootman *et al.*, 2007). The notion that prolonged periods of inactivity result in higher injury rates upon commencement of activity has been of particular interest during the COVID-19 pandemic when the normal periodization of the athletic season was disrupted due to individual player quarantine, full-team shutdowns, and subsequent modifications to the competitive schedule.

The effect of a modified schedule structure due to COVID-19 has been well-documented in high-profile sporting leagues such as the National Football League (NFL) and Premier League soccer (Mannino *et al*., 2023; Omari *et al*., 2022; Patetta *et al*., 2021; Volpi *et al*., 2022). In these elite athletes, it was found that the modified COVID-19 season resulted in an increased total injury rate and increased incidence of anterior cruciate ligament (ACL), as well as Achilles and hamstring tendon injuries (Mannino *et al*., 2023; Omari *et al*., 2022; Patetta *et al*., 2021; Volpi *et al*., 2022). In all scenarios, variables associated with an attenuated preseason were considered a causative factor. In the case of the 2020 NFL season, where the pre-season was canceled altogether, there was a 119% increase in ACL tears during the first four games of the season (Omari *et al*., 2022; Patetta *et al*., 2021). This further highlights the increased injury risk that occurs early in the season when athletes are subjected to sudden increases in training load. It emphasizes the importance of coaches, strength and conditioning coaches, and certified athletic trainers to properly implement a gradual return to play period following periods of inactivity. In addition to the increased injury rate and decreased time to first injury, Mannino *et al*. also noted the significantly shorter time between competitive games (Mannino *et al*., 2023). This supports previous research suggesting the impact of a congested fixture period (Dellal *et al*., 2015). In other words, when more competitive games are played in a shorter period to accommodate for a condensed athletic season, there is a negative effect on physical performance and injury rate. Therefore, athletes were particularly susceptible during the COVID-19 athletic seasons as they were subjected to multiple shortcomings, including congested fixtures, an inadequate preseason, and frequent periods of forced shutdown.

In addition to the effect of the modified COVID-19 athletic seasons on injury rates, negative effects on match performance metrics have also been reported (Sekulic *et al*., 2021; Thron *et al*., 2022). While these limited reports largely correlate the degree of impact to the duration of the lockdown, the effects were attributed to inadequate adaptation to sport-specific match demands and a congested competitive match schedule after competition resumed (Thron *et al*., 2022). More specifically, individual metrics, including high-intensity running, total distance, and the total number of high-intensity accelerations and decelerations, were found to be most affected (Sekulic *et al*., 2021). These metrics are critical to an individual's physical performance and team success.

COVID-19 is known to primarily affect the respiratory system and, to a lesser degree, the cardiovascular system. The direct cardiorespiratory effects of the disease, combined with the indirect effects of detraining (caused by quarantine and/or shutdown) on the neuromuscular and musculoskeletal systems, puts an athlete at greater risk for increased injury and decreased performance upon returning to competitive play. The effects of COVID-19 on the cardiorespiratory system have been explored in different populations and, to a lesser degree, specific sports (Cavigli *et al*., 2021; Córdova-Martínez *et al*., 2022; Milovancev *et al*., 2021). A review of the effects of detraining in athletes due to COVID-19 was reported by Cordova-Martinez *et al*., highlighting the effect of COVID-19 on physiological parameters and resulting performance, as well as the return to regular physical activity (Córdova–Martínez *et al*., 2022). Their results portrayed the multisystem physiological effects, including the cardiorespiratory and neuromuscular systems, and their resultant influence on athletic performance. Due to these observed effects, it was emphasized that athletes should be allowed to resume physical training and sports activity progressively. Furthermore, Grazioli *et al*. suggested that COVID-19 quarantine is even more detrimental than traditional off-season detraining on physical conditioning due to the nuances that are inherent in detraining resulting from illness vs. those of a standard off-season (Grazioli *et al*., 2020). This further illustrates the importance of properly phasing in activity and adherence to recommendations to promote a safe return to play.

Quantifying athletes' sleep has been of recent interest to predict overall recovery and has even prompted the NCAA to publish consensus recommendations on the importance of sleep for student-athletes (Kroshus *et al*., 2019). Studies have examined the general sleep patterns of athletes across a competitive season, as well as the impact of sleep on game performance and injury (Power *et al*., 2023; Senbel *et al*., 2022). However, the degree to which COVID-19 impacts sleep and recovery in athletes is not well understood. Since the COVID-19 pandemic began, it has manifested as a rapidly evolving health crisis in which there have been fluctuations in infection rates and resulting social restrictions. Due to its complexity, developing proper recommendations to ensure a safe return to physical activity has been challenging. Nonetheless, general return-to-play guidelines have been developed, including those of specific athletic associations such as the NCAA (Baggish *et al*., 2020; NCAA, 2020a, 2020b; Wilson *et al*., 2020). Sudden cardiac death is the leading cause of sudden death in sports and physical activity, and complications from COVID-19 (e.g., myocarditis) can further predispose an athlete to sudden cardiac death. Furthermore, there have been consistent reports of athletes who pose persistent and residual symptoms weeks to months after the initial infection, further predisposing them to cardiorespiratory complications (Baggish *et al*., 2020). As a result, return-to-play guidelines have focused on screening for potential cardiovascular sequelae following disease infection, including clinical assessment, cardiac screening, and respiratory and biochemistry testing. Specific recommendations for the degree of testing are largely based on the severity of reported symptoms and total recovery time (Baggish *et al*., 2020; Wilson *et al*., 2020). However, while return-to-play recommendations have addressed the direct cardiorespiratory effects of the disease, they have failed to consider the indirect effects of detraining due to periods of shutdown. This study aimed to examine the effects of COVID-19 on athletic performance during training and competition in NCAA Division I women's basketball players. Additionally, we sought to examine the effect of COVID-19 on sleep and recovery in this cohort.

2. Method

2.1. Experimental Approach to the Problem

The dataset that was utilized in this study was part of a larger study where athletic performance and injuries were analyzed via machine learning techniques to develop insights into collegiate women's basketball players during the 2021–2022 NCAA basketball season (Senbel *et al*., 2022). For this case analysis, we aimed to target a condensed testing period when multiple players tested positive for COVID-19 in close proximity to one another (Fig. 1). This method allowed for data uniformity of a homogenous sample and minimized the impact of confounding variables. In addition, it allowed for a direct analysis of the effects of COVID-19 rather than those indirectly occurring simply due to quarantine.

2.2. Subjects

For this case analysis, 12 participants (Age: 21 ± 3 yrs; Height: 174.21 ± 19.27 cm; Body Mass: 73.98 ± 11.52 kg) were chosen for the study cohort to determine the impact of COVID-19 on athletic performance and recovery. Subjects were eligible for this case study if they were members of the University's Women's basketball team and wore the necessary equipment, resulting in the acquisition of complete data during the collection period. All participants signed a consent form prior to data collection, and the study was approved by the University's Institutional Review Board (IRB#170720A). Within this cohort, 4 players served as the test group (COV) as they tested positive for COVID-19, and eight players served as the control group (CON) as they remained healthy during the testing period of interest. The testing period was chosen due to the condensed period in which the COV group tested positive and included the three consecutive game/practice sessions before testing positive for COVID-19 and the three consecutive game/practice sessions after being cleared to return to participation (see Fig. 1). The six-day period encapsulates the illness most optimally, such that a shorter time does not show the true effect of the illness. In comparison, a longer period dilutes the effect of the illness. In addition, this time frame aligns with return-to-play considerations largely based on the severity and duration of symptoms (Baggish *et al*., 2020; Wilson *et al*., 2020).

2.3. Procedure

All participants were given a Polar Team Pro GPS unit (Polar Team Pro, Polar Electro, Kempele, FI) and a Whoop Strap (Whoop, Boston, MA, USA) for the entirety of the study. The Polar unit was worn during all games and practices, and metrics related to physical workload and heart rate were collected. The units were sampled at 10 Hz, and all metrics were calculated using Polar's proprietary collection and analysis software. Data obtained from the Polar units were used to compare physical performance metrics between the COV and CON groups during practices and games.

The Whoop strap was worn during all daily activities, including periods of sleep. Metrics related to resting heart rate, heart rate variability, sleep, and recovery were collected and analyzed using Whoop's proprietary collection software. The Whoop strap has been determined reliable and valid compared to polysomnography in third-party sleep and heart rate testing (Miller *et al*., 2020). Data obtained from

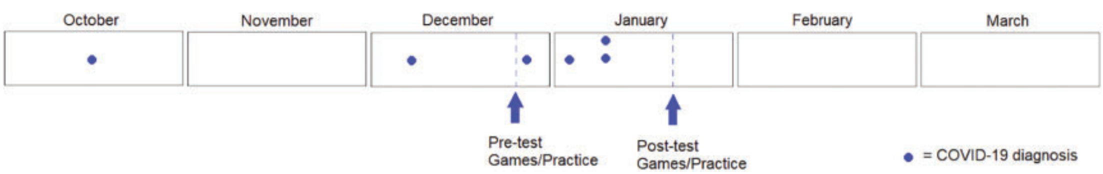

Fig. 1. Timeline of data collection period within the season.

the Whoop strap is individual; therefore, data comparison between COV and CON groups was not applicable. Rather, analysis was performed within the COV group, and metrics were compared during the active COVID-19 period (COV-A) and the healthy period of the same individual (COV-H).

2.4. *Statistical Analysis*

Statistical methods were used to quantify the effect of COVID-19 for each Polar and Whoop metric (Hopkins *et al.*, 2009; Hopkins, 2015). Descriptive statistics are presented as the mean difference (**Δ**) ± standard deviation (SD). T-tests were used to evaluate differences between groups for each metric with significance set at $p \leq 0.05$. Cohen's d effect sizes were calculated to compare the magnitude of the differences between groups and interpreted based on generally accepted magnitude thresholds as trivial ($d < 0.20$), small ($0.20 < d < 0.40$), medium ($0.40 < d < 0.70$), large ($0.10 < d < 1.0$), and very large ($d > 1.0$) (13). In addition, the Smallest Worthwhile Change (SWC) was also calculated. For team sports, the smallest worthwhile change can be calculated as $0.2 \times$ SD (test data) (Bernards *et al.*, 2017). For this study, the SWC was considered the smallest clinical difference, indicating a practically meaningful change for each metric examined.

3. Results

Descriptive data collected by the Polar unit to compare physical performance metrics during training and competition between COV and CON groups are presented in Tables I, II, and III. Descriptive measurements and differences between COV and CON groups for maximum heart rate (HR_{max}), minimum heart rate (HR_{min}), average heart rate (HR_{avg}), overall cardio load, and overall training load are presented in Table I. Statistical significance was observed ($p = 0.05$) for the average heart rate between COV and CON groups. In addition, large effect sizes ($0.70 < d < 1.0$) were observed for all heart rate metrics and load scores except HR_{max} ($d = 0.19$).

Descriptive measurements and differences between COV and CON groups for general running metrics are presented in Table II. No statistically significant results were present for performance

TABLE I: Descriptive Statistics and Differences between COV and CON Groups for Heart Rate Metrics and Training Load

Metric	SWC	COV group Δ Mean (SD)	CON group Δ Mean (SD)	*p*-value	Cohen-*d*	Effect
HR_{max}	0.99	−1.83 (7.53)	−0.35 (7.74)	0.76	0.19	Trivial
HR_{min}	1.53	−5.33 (9.03)	−14.67 (10.28)	0.15	0.94	Large
HR_{avg}	0.75	−6.67 (0.98)	−11.17 (5.42)	0.05*	0.99	Large
Cardio.load	7.06	−4.92 (24.16)	−41.63 (48.17)	0.11	0.87	Large
Training load score	6.54	−12.71 (21.87)	−44.21 (44.52)	0.13	0.81	Large

Note: SWC = smallest worthwhile change; COV = covid group; CON = control group; HRmax = maximum heart rate; HRmin = minimum heart rate; HRavg = average heart rate. *$p \leq 0.05$.

TABLE II: Descriptive Statistics and Differences between COV and CON Groups for a Total Number of Sprints and Running Metrics

Metric	SWC	COV group Δ Mean (SD)	CON group Δ Mean (SD)	*p*-value	Cohen-*d*	Effect
Sprints	2.22	−2.58 (15.54)	−6.31 (17.88)	0.72	0.22	Small
Total distance (m)	67.45	−130.83 (427.56)	−355.21 (893.09)	0.57	0.29	Small
Distance covered in low-intensity running (<10.99 km/h)	50.34	−106.04 (324.21)	−216.46 (587.69)	0.68	0.21	Small
Distance covered in moderate-intensity running (11.00 to14.99 km/h)	18.55	96.00 (87.86)	36.63 (146.80)	0.40	0.45	Moderate
Distance covered in high-intensity running >15.00 km/h)	23.80	−122.88 (212.39)	−174.44 (191.45)	0.70	0.26	Small

Note: SWC = smallest worthwhile change; COV = covid group; CON = control group.

TABLE III: Descriptive Statistics and Differences between COV and CON Groups for Accelerations and Decelerations

Metric	SWC	COV group Δ Mean (SD)	CON group Δ Mean (SD)	*p*-value	Cohen-*d*	Effect
Number of high-intensity decelerations (>1.99 m.sÂ^2)	3.51	1.13 (19.15)	−4.33 (32.22)	0.72	0.19	Trivial
Number of low-intensity decelerations (<1.99 m.sÂ^2)	9.36	−21.17 (93.54)	−48.00 (95.02)	0.66	0.28	Small
Number of low-intensity accelerations (<1.99 m.sÂ)	9.69	-9.63 (104.50)	−33.25 (101.76)	0.72	0.23	Small
Number of high-intensity accelerations (>1.99 m.sÂ^2)	2.76	0.54 (14.90)	−11.10 (26.20)	0.35	0.50	Moderate

Note: SWC = smallest worthwhile change; COV = covid group; CON = control group.

TABLE IV: Descriptive Statistics and Differences between COV-A and COV-H Groups for Recovery Metrics

Metric	SWC	COV-A group Δ Mean (SD)	COV-H group Δ Mean (SD)	*p*-value	Cohen-*d*	Effect
Resting heart rate	0.90	−0.57 (5.83)	−1.00 (3.22)	0.87	0.09	Trivial
Heart rate variability	8.11	15.43 (34.59)	21.50 (50.92)	0.81	0.14	Trivial
Respiratory rate	0.13	−0.64 (1.45)	−0.10 (0.37)	0.37	0.50	Moderate
Hours in bed	0.27	3.61 (0.80)	−0.28 (1.47)	<0.001*	3.36	Very large
Hours of sleep	0.22	2.45 (1.16)	−0.27 (1.33)	<0.001*	2.18	Very large
Awake hours	0.07	1.16 (1.34)	−0.01 (0.27)	0.06	1.17	Very large
Sleep efficiency	0.68	−7.14 (9.15)	−0.33 (2.50)	0.10	0.98	Large
Sleep score	2.42	24.43 (9.38)	0.00 (12.81)	<0.001*	2.21	Very large

Note: SWC = smallest worthwhile change; COV = covid group; CON = control group; *$p \leq 0.05$.

metrics. Small effects ($0.20 < d < 0.40$) were observed for the number of sprints, total distance covered, and distance covered when running at both low and high intensities. A moderate effect ($d = 0.45$) was observed for the distance covered when running at a moderate intensity.

Descriptive measurements and differences between COV and CON groups for accelerations and decelerations are presented in Table III. No statistically significant results were present for these performance metrics. Small effects between COV and CON groups ($d = 0.23$, $d = 0.28$) were observed for low-intensity accelerations and low-intensity decelerations, respectively. A moderate effect ($d = 0.50$) was observed for high-intensity accelerations.

Descriptive data collected by the Whoop strap to compare recovery metrics during activities of daily living and sleep between COV-A and COV-H groups are presented in Table IV. Statistical significance ($p < 0.05$) was observed for hours in bed, hours of sleep, and overall sleep score between the COV-A and COV-H groups. A moderate effect ($d = 0.50$) was observed for respiratory rate between COV-A and COV-H groups. Very large effects ($d > 1.0$) were observed between COV-A and COV-H groups for all sleep metrics, except sleep efficiency, which showed a large ($d = 0.98$) effect.

4. Discussion

This study aimed to examine the effects of COVID-19 on athletic performance and recovery in a cohort of NCAA Division I women's basketball players. The results indicated that COVID-19 had the greatest effect on heart rate and sleep metrics with smaller, yet still clinically meaningful, effects on metrics of athletic performance. Due to the cardiorespiratory and overall recovery deficit exhibited by these athletes, it is critically important to ensure an adequate recovery and acclimatization period to confirm a safe return to play.

The COVID-19 pandemic posed several limitations to athletes competing in organized sports. Collectively, regardless of COVID-19 testing status, athletes were forced to adapt to significant modifications to their normal periodized season, including congested fixtures, frequent periods of shutdown, and inadequate acclimation following periods of shutdown. These limitations posed risks upon return to play due to subsequent detraining effects, including physiological (e.g., cardiorespiratory fitness) and physical (e.g., neuromuscular performance) consequences. These effects were likely heightened in athletes who tested positive for COVID-19, as they were subject to longer periods of shutdown and the negative physiological effects associated with the virus. In this study, our results indicate the most detrimental effects occurred to physiological parameters, including various heart rate metrics during training and competition (Table I) and recovery metrics during periods of inactivity (Table IV).

More specifically, we observed large effect sizes for HR_{min}, HR_{avg}, cardio load, and overall training load during training periods in the COV group vs. CON group (Table I). While previous research has shown the negative effects of cardiorespiratory function due to detraining, data is limited regarding the direct effect of COVID-19 on cardiorespiratory fitness in athletes (Córdova-Martínez *et al*., 2022). One study, which sought to explore the effects of COVID-19 on the cardiorespiratory fitness of volleyball players, found pulmonary function tests to be normal after a battery of tests (Milovancev *et al*., 2021). However, several methodological pitfalls led the authors to conclude that the true effect of COVID-19 could not be assessed; rather, results were simply attributed to a period of detraining. For example, this study did not have comparison data before the period of COVID-19 infection, pulmonary function testing was not done until 3 weeks post-RTP, and a true control group was not used (Milovancev *et al*., 2021). Therefore, compared to a homogeneous control group, we believe our study is the first to show the direct effects of COVID-19 infection on heart rate metrics in athletes immediately upon RTP.

Furthermore, while the effect of sleep and recovery on game performance and injury in athletes has previously been reported, the effect of COVID-19 on these metrics is unknown (Senbel *et al*., 2022). In addition to the aforementioned negative physiological effects during training (Table I), we also found that COVID-19 negatively impacted recovery (Table IV). While only trivial effects were observed for resting heart rate and heart rate variability, very large effects were observed for almost all sleep metrics (Table IV). While this study did not measure the effect on injury and performance, previous research has shown that poor sleep and recovery can decrease game performance and increase injury risk in athletes (Senbel *et al*., 2022). Collectively, this shows that athletes who tested positive for COVID-19 were not only at a physiological deficit when they returned to training but also had a less efficient recovery.

In addition to the novel results showing the effects of COVID-19 on physiological and recovery metrics in athletes, this study also sought to explore the effects on athletic performance. Largely consistent with previous reports, our results showed clinically meaningful deficits in various physical performance metrics (Tables II and III) (Sekulic *et al*., 2021; Thron *et al*., 2022). For example, Sekulic *et al*. demonstrated that physical performance in soccer players significantly decreased in matches following a COVID-19 lockdown compared to pre-lockdown values (Sekulic *et al*., 2021). While metrics varied among playing positions, high-intensity running, distance covered, and the number of accelerations and decelerations were negatively affected. While our study did not compare performance metrics between different playing positions, we found similar effects in running metrics (Table II) and accelerations/decelerations (Table III).

These results were also consistent with a recent review by Thron *et al*., where most parameters of physical match performance were negatively affected after a COVID-19 lockdown in all but one professional soccer league (Thron *et al*., 2022). It is important to note that, unlike the athletes used in the present cohort, the players in these studies did not test positive for COVID-19. Therefore, the results can be attributed to inadequate acclimation to soccer-specific match demands and congested fixtures rather than direct effects from the virus itself (Sekulic *et al*., 2021; Thron *et al*., 2022).

In addition to effects on physical performance, injury risk and incidence have also been reported with mixed results (Krutsch *et al*., 2022; Maestro *et al*., 2022; Seshadri *et al*., 2021; Thron *et al*., 2022). However, only one study has examined the true effect of COVID-19 on injury in competitive athletes, in which a soccer team involving 14 COVID-19 cases and 12 control cases were studied (Maestro *et al*., 2022). It was found that injury incidence in players infected by COVID-19 significantly increased compared to the injury rates that these same players had before the illness. Additionally, the injury incidence was two-fold higher when compared to players who were not infected by COVID-19 during the season, especially during competitive matches (Maestro *et al*., 2022). In the present study, we utilized a targeted subset and abbreviated period of a larger cohort to maximize control of confounding variables for our primary areas of interest. Therefore, the methodology did not align with directly analyzing injury rate, which would have required both a larger sample and a broader period for analysis. Based on our findings that physiological, performance, and recovery metrics were all negatively impacted by COVID-19, we can speculate that injury risk may have been heightened in our athletes. However, it is more important to suggest that return to play for athletes diagnosed with COVID-19 be more conservative than routine protocols for periods of inactivity.

5. Practical Applications

The results of this study show the multisystem effect of COVID-19 on NCAA Division I women's basketball players. Negative effects on heart rate and physical performance metrics were observed during periods of training and competition, with additional effects observed during periods of rest and inactivity. This shows that athletes who tested positive for COVID-19 were not only at a physiological deficit when they returned to training, but they also had a less efficient recovery. This was the first study to examine the direct impact of COVID-19 on athletic performance and recovery, and it provides insight into the importance of proper and more cautious return-to-play considerations for athletes recovering from respiratory illness.

Acknowledgment

The Welch College of Business and Technology and the College of Health Professions at Sacred Heart University funded the purchase of the Whoop straps and Polar heart rate monitors. The authors would also like to thank Srishti Sharma for assisting with initial data analysis and insights and Jui Shah and Emma Patterson for their support with data collection on this project.

Conflict of Interest

The authors have no professional conflicts of interest to disclose, and the results of the present study do not constitute an endorsement of the products used by our research group or the NSCA.

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