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Mckenna Cornett
2018

COLUMBUS STATE UNIVERSITY

THE CARDIOVASCULAR DEMANDS OF DIVISION I SIDELINE CHEERLEADERS DURING TRAINING AND FOOTBALL GAMES

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BY
MCKENNA CORNETT

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THE CARDIOVASCULAR DEMANDS OF DIVISION I SIDELINE CHEERLEADERS DURING TRAINING AND FOOTBALL GAMES

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ABSTRACT

The purpose of this study was to evaluate the autonomic balance and cardiovascular demands of collegiate sideline cheerleaders between practice and game settings, and throughout four quarters of a football game; and to evaluate the physical fitness of collegiate Division I cheerleaders. Eleven cheerleaders volunteered to participate (age; 18.9±0.8y, height; 163.2±4.3cm, and body mass; 64.9±8.7kg). Basic physical fitness was assessed by evaluating blood pressure, resting heart rate, grip strength, and body composition. Physiological data (maximal heart rate [HR], average HR, physiological intensity, physiological load, maximal activity, and average activity) were collected at four practices and four games using a Zephyr Bioharness HR monitor. Prior to each practice and game, a 15-minute heart rate variability (HRV) reading was taken in the seated position. There was a significantly higher LF/HF ratio prior to game than prior to practice ($p<0.01$). Average HR was significantly higher during game than practice ($p<0.01$). Average activity level was significantly higher during game than in practice ($p<0.01$), while maximal activity level was significantly higher in practice than during game ($p<0.01$). More time was spent in the moderate and vigorous intensity heart rate zones during games than during practice ($p<0.05$). Average HR, physiological intensity, and physiological load were significantly higher in Q1 and Q2 than Q3 and Q4 ($p<0.01$). Maximal HR was significantly higher in Q1 than Q3 and Q4 ($p<0.01$). The present study demonstrates higher HR and intensities and a shift toward sympathetic activity in games than during practice in Division I cheerleaders, therefore implementing more high-intensity exercise sessions during practice may be beneficial to mimic a game-like situation.

KEYWORDS: Cheerleaders, Heart Rate Variability, Intensity, Fitness

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LIST OF ABBREVIATIONS

NCAA	National Collegiate Athletic Association
HR	Heart Rate
HRV	Heart Rate Variability
SNS	Sympathetic Nervous System
PNS	Parasympathetic Nervous System
ANS	Autonomic Nervous System
%BF	Body Fat Percentage
FFM	Fat Free Mass
FM	Fat Mass
BM	Body Mass
SDNN	Standard Deviation of N-N Intervals
RMSSD	Root Mean of Successive Squared Differences
LF	Low Frequency
HF	High Frequency
ACSM	American College of Sports Medicine
VMU	Velocity Magnitude Units
G1,2,3,4	Game 1, 2, 3, 4
Q1,2,3,4	Quarter 1, 2, 3, 4
WGBT	Wet Globe Ball Temperature
TA	Air Temperature
TG	Globe Temperature

CHAPTER 1: REVIEW OF LITERATURE

1.1 Introduction

College cheerleading has evolved from strictly-sideline "pep-club" nature to an athletic and competitive sport. In the 1990's, an upsurge in competitive cheerleading occurred, resulting in increased complexity of skills and competitiveness across the sport (14). Most institutions consider sideline cheerleaders student-athletes because the sport requires enormous athletic abilities on the sideline during game-day (24). Sideline cheerleaders are commonly misconstrued as less athletic than other competitive athletes because they do not perform in competitions against other teams, however the physiological demands and coordination of cheerleaders argues otherwise. Many college teams are highly selective, participate in practices year-round, and attend specialized camps to learn material and skills to perform on the sideline (36). Many Division I cheerleading teams cheer for football, basketball, gymnastics, and volleyball, make community appearances, and compete at national, unsanctioned competitions. Although cheerleaders on the sideline are not competing against others during game-day, the athletes still perform complex pyramids, tosses, stunts, and tumbling to entertain the crowd and promote school spirit for the duration of the game. Because literature regarding the physiological and cardiovascular demands of cheerleaders is non-existent, the purpose of this review is to evaluate heart rate variability, heart rate distribution, intensity, and physiological load of other anaerobic sports.

1.2 Athlete Characteristics

Limited research has assessed the physiological fitness and demands required to effectively perform cheerleading skills. Thomas et al. (2004) evaluated fitness in NCAA Division I collegiate cheerleaders who regularly performed on the sideline and competed at national cheerleading competitions. Collegiate cheerleaders have a high level of musculoskeletal and cardiorespiratory fitness, and also have similar body composition as other competitive Division I female athletes (36). Cheerleading is similar to the sport of dance, both performing choreographed routines that vary in length and include an array of technical skills. Female collegiate dancers have demonstrated significant improvements in anaerobic power, body mass, body composition, and fatigue index over the course of a dance season (3). The physical demands of a collegiate dance season spanning the length of a year, improved overall fitness of these athletes. In addition, gymnastics is also a sport like cheerleading, favoring smaller stature, compact athletes. Body composition variables have been compared in NCAA female athletes from several sports including basketball, lacrosse, rowing, soccer, volleyball and gymnastics. NCAA gymnasts had significantly lower body mass, body height, body fat percentage and fat mass across the 6 aforementioned sports (8). The smaller stature of these athletes is important due to the biomechanical load acquired from complex acrobatic tumbling skills (8).

Cheerleaders and gymnasts perform complex aerial skills that require proper technique, exercise training, and a vast amount of muscle awareness and power. However, few studies have observed training adaptations in cheerleaders. Division I NCAA gymnasts have demonstrated increases in peak power output over the course of a competitive season (approximately 1 year), and longitudinally throughout 3 total seasons (9). Additionally, acrosport is a type of gymnastics which also involves aerial stunt sequences and muscular power, while also resembling the static and dynamic stunt sequences performed in cheerleading. Base and top athletes typically differ in body composition and physiological demand. Bases are more robust because they are responsible for bearing the weight and tossing the tops for static and dynamic movements. Tops are smaller and more flexible with muscular control. Acrosport athletes have demonstrated a significantly higher heart rate (HR) during training than during rest or recovery across positions, and tops had greater levels of exertion compared to bases when working on the execution of individual elements. HR was also higher overall when performing dynamic skills such as tosses in comparison with static skills such as stunts containing still poses (17). Cardiovascular demand differs between each position during a training session in acrosport athletes, thus such findings may be denoted in cheerleaders. Literature has little evaluation the physiological profile of sideline collegiate cheerleaders as a representation of fitness and/or training adaptations that may occur during a season. Furthermore, acute and chronic adaptations to exercise and performance may be unique in collegiate cheerleaders compared to other sports.

1.3 Heart Rate Variability

Heart rate variability (HRV) is a common mechanism used to examine the autonomic nervous system's (ANS) effect on the rhythm of the heart. Autonomic neural regulation is responsible for controlling the heart rate at rest and in response to extrinsic factors such as anxiety, excitement, training adaptations, or exercise, resulting in variability between consecutive heart-beats. The ANS is a balance between parasympathetic (PNS) and sympathetic (SNS) nervous system activity. An increased input from the PNS results in decreased heart rate (HR) due to the release of acetylcholine onto the sinoatrial node. This action decreases the firing of pacemaker cells in the heart. The increase in PNS tone usually results in response to trauma, internal organ stimuli, or exercise training (1). Contrariwise, an increase in the SNS activity results in adrenal gland activation. This action causes epinephrine to be released, increasing the rapid firing of pacemaker cells and ultimately increasing HR (1).

The behavior of HR is perceptible using beat-to-beat analysis, and is indicative of complex interactions between physiological systems. Optimal levels of HRV reflect healthy heart-brain physiological interactions and integral self-regulatory mechanisms (19). The ANS has a pivotal role in regulating cardiovascular functioning along with respiratory sinus arrhythmia in response to physical, environmental, and mental factors (2). Healthy HRV is represented by input from both the PNS and SNS, with the vagal effects predominately active (31). Some variability in HR is healthy, and is an indication of respiratory sinus arrhythmia. Too little variation in HR can be indicative of parasympathetic withdrawal, increasing the input from the SNS (31).

HRV has become a widely used technique in athletic populations to examine the sympathovagal tone of the heart. HRV ease of measurements and interpretations give a good indication of the physiological and psychological components that may alter cardiovascular events (18). Cardiovascular autonomic regulation is important in sporting populations and can be evaluated using HRV to determine training adaptations, performance, overtraining, and recovery (6). HRV has not yet been used to evaluate the ANS balance in any cheerleading population. HRV measurement in cheerleaders will be discussed further in a later section.

1.4 Measurement of Heart Rate Variability

HRV is measured to examine the changes in workload or environmental stimuli, and multiple metrics within HRV measurements are representative of the physiological processes involved in changing HR. HRV metrics can be broken into time domain and frequency domain brackets. Time domain metrics quantify the variability of the heart by measuring the interval of time between consecutive heart beats (30). Time domain measurements include RR, SDNN, RMSSD, and pNN50. RR represents time between successive heart beats. With increased PNS activity, RR intervals increase while SNS activity decreases RR intervals. The standard deviation of NN interval (SDNN) measures normal sinus beats and can be altered by the SNS and the PNS. The pNN50% is the percentage of NN-intervals that differ from each other by more than 50ms and is an indicator of PNS activity. The root mean square of successive RR interval differences (RMSSD) measures the variance between beats and reflect the parasympathetic HR modulation (30). RMSSD is highly correlated with high frequency power, which reflects respiratory sinus arrhythmia, and increased RMSSD can be associated with increased exercise training. With increased training, the volume load on the heart increases which also stimulates an increase in end diastolic volume (EDV). The increase in EDV leads to an increase in stroke volume, allowing the heart to more efficiently pump blood by ultimately decreasing HR. This phenomenon is explained by the Fick Equation, which demonstrates stroke volume and HR are inversely related and are the components that make up cardiac output (40). The decrease in HR can be attributed to the increase in parasympathetic modulation, which is consequently reflected in increased vagal-related HRV parameters (29). Each of the time-domain parameters are adjusted using a natural logarithm transformation to ensure normal distribution since HRV parameters are variable between individuals and normal values are not defined.

Frequency domain measurements are used to determine the individual contribution of the PNS and SNS by filtering signals into different bands using a fast fourier transformation (16). Time domain parameters are sampled on a second-to-second basis. The transformation processes the seconds to a frequency in hertz (Hz) to determine how much activity takes place in a range or frequency band. The very low frequency (VLF) band (0.0033-0.04 Hz) is influenced by the SNS as a response to stress or physical activity. The low frequency (LF) band refers to variation of the R-R interval changes between 0.04 and 0.15 Hz and is thought to be influenced by the SNS and PNS; however, the SNS typically does not produce rhythms above 0.1 Hz. The high frequency (HF) band (0.15-0.40 Hz) reflects vagal tone, representing parasympathetic activity, however lower HF power is an indicator of stress or anxiety. The LF/HF ratio is used to determine the balance of the ANS. A low LF/HF ratio indicates parasympathetic dominance, whereas a high LF/HF ratio indicates sympathetic dominance or parasympathetic withdrawal (30).

Though HRV has become a useful mechanism to determine ANS input on cardiac function, measurements of HRV can also be misleading or inaccurate. Environmental factors and distractions have the potential to disturb homeostasis, thus causing 'noise' in HRV readings. Interpretations of only a single day HRV reading or short-term HRV reading have also shown discrepancies in HRV (23). Other discrepancies in measuring HRV include using several different indices to asses ANS balance. Some of the indices used to assess the ANS are influenced by outside factors such as breathing rate, which could influence the HRV measurement (23). Breathing at a slower rate may slow down the cardiac cycle, therefore increasing HRV, whereas breathing more quickly may speed up the cardiac cycle and decrease HRV. Environmental stressors related to cheerleading include performing in front of a crowd or interacting with people before and after games, which could be a potential source of anxiety and is likely different from practice environments in most team sports. Measuring HRV in athletes could be useful to determine the influence of added stressors on ANS balance and performance.

1.5 Heart Rate Variability as a Marker of Training and Performance

HRV has been measured in a variety of athletes to examine vagal tone as a marker of training and performance. HRV has been measured in gymnastics, a sport much like cheerleading in which the essence of routines is based solely on performance. Gymnasts were evaluated days prior to competition, the day of competition, and after the competition. Authors were interested in whether competition induced anxiety or stress to the athlete which would affect alter ANS balance. HRV analysis confirmed leading up to a competition and during intense training, sympathetic markers are exemplified as a result of either overtraining or external stimuli from competition or performance pressure (28). In volleyball players, a significant decline in HF was observed immediately prior to competitive matches, indicating a reduced response from the PNS and increased response from the SNS. Autonomic balance was also compared with performance indicators. Successful skills, such as serving and receiving the volleyball, were inversely related with HR and LF/HF ratio indicating an increase in performance errors with increased SNS activity (4).

Additionally, HRV has been measured to compare different types of sports to determine if the nature of the sport has an influence on autonomic balance. In a study comparing field hockey players, skydivers, and endurance runners, skydivers had lower HRV markers and an elevated LF/HF ratio, indicating increased SNS activity. Because skydiving is an intense sport, sympathetic dominance could be from an adrenaline rush or similar phenomena.

Endurance runners had a higher parasympathetic input because they have increased vagal tone which comes from being aerobically trained, also commonly resulting in sinus bradycardia (13). Sinus bradycardia occurs because stroke volume and heart rate are inversely related to keep cardiac output consistent. The heart increases stroke volume, decreasing HR to pump blood more efficiently. In a study on recreational endurance runners, SDNN and RMSSD both increased significantly after 28-weeks of a high-intensity training intervention, as well as the high frequency power (HFP), indicating there was a positive training adaptation endurance training (39). Chronic training adaptations involve a lower resting HR and increased stroke volume. The lower overall HR in aerobically trained athletes results in an increased RR interval, RMSSD, and HF, indicating an increase in HRV (5).

These sources are important to examine the differences between sports, especially looking at anaerobically dominant sports. Cheerleading at a Division I football game in front of thousands of fans is intense, and the pressure to eliminate error is high especially when performing stunts, tumbling, and difficult tosses. The pressure to adequately perform is capable of increasing pre-game and in-game stress because the athlete's image is related to performance, and outside judgement by teammates, coaches, and spectators is a potentially stress-inducing phenomenon (25).

1.6 Practice vs. Game-Day

Athletes may experience an anticipatory response to exercise, causing an elevation in cortisol. Sports competition has shown to elicit an anxiety/arousal like state due to the uncertainty of the outcome of the meet. Expectations from coaches, players, and spectators can also alter the athlete's mood prior to the competition and play a psychological component, resulting in an anticipatory response (26). Players have found to exert themselves less during practice than in a game-like situation due to the decreased pressure to perform. HR trends and time spent in high intensity zones have been evaluated in a variety of athletes to determine if training is adequately preparing athletes for game-day. Time spent in high intensity HR zones, mean HR and peak HR were significantly higher in games compared with practice in elite soccer players. This suggests that at higher intensities, HR is higher because athletes are performing near maximal exertion. Approximately 55% of the game was spent in the designated high-intensity zone, whereas only 11% of the training sessions were spent in the high-intensity zone. Because the athletes performed at near maximal intensities for longer durations during games, training at higher intensities could be beneficial to mimic game like situations (22). Similarly, in professional women's ice hockey players, average time spent above 90% of HR_{max} was significantly greater in games than in practices. Working HR during games was significantly higher than working HR during practice due to increased levels of arousal and pressure to perform at maximal effort (33). Though the sports differ in physical demands, the cardiovascular response is similar in each of the sports and may be consistent with various sports including sideline cheerleading. Because cheerleaders do not train in front of a crowd, their efforts are expected to be significantly lower during practice.

1.7 Within-Game Cardiovascular Demands

Within a game, players have demonstrated increased exertion at higher intensities, which has the potential to lead to fatigue, injury, and mental errors. Changes in HR, intensity, and load have been evaluated across various sports to determine if differences/trends can be observed throughout quarters or halves of competitive games. HR differences between halves were examined in elite soccer players. The average HR and maximum HR were greater in the first half compared to the second half during games. In the second half of soccer games, there was a significant difference in time spent in the >95% HR_{max} intensity zone. The decline in HR in the second half could be due to athletes becoming tired, ultimately reducing their effort along with

HR (22). Similarly, in basketball players, higher HR values were recorded in the first half. Average HR and time spent in intensity zones were not statistically different between the first and second halves of the basketball games. Players maintained a HR 85% of their HR_{max} or higher 74.3% of the total game time (38). Conversely, in amateur basketball players, no significant differences in HR were observed between quarters. However, HR was impacted greatly by the scoreboard, suggesting the athletes may have physically exerted themselves more, or there may have been a mental component causing an adrenaline rush, and leading to an increased HR. HR was the highest when the team was winning by 2-possessions during both the first and second quarters, and when the team was losing by 2-possessions during the last quarter (10).

These articles are important to examine the difference in HR throughout the duration of a full game. Soccer is an aerobic sport, whereas basketball is primarily an anaerobic sport. Though the sports utilize different energy systems, HR trends were consistent throughout the literature. This indicates that throughout the duration of a game, higher HR values may be observed in the first quarter/half than in the second quarter/half and could be attributed to fatigue or improper training.

1.8 Conclusion

The literature reviewed examined heart rate variability in anaerobic sports, differences between practice and games in HR activity, and differences between periods or quarters of other sports in HR activity. Measuring HR has become one of the most common mechanisms in research because it is non-invasive and simple. With the technology of the modern HR monitors, several different physiological characteristics can be measured to evaluate physical activity.

Resting HRV is a method that gives good indication of input from the ANS, which should reflect whether or not athletes have stimuli from environmental stressors or vagal influence. Distribution of HR is important to determine both the physiological load and intensity the athletes are performing at and is helpful to develop a training regimen for each specific sport. Examining time spent at different intensities allows coaches to implement a training plan to mimic the physiological demands required for a game. Research has yet to evaluate the cardiovascular and physiological demands of collegiate cheerleading on the sidelines during a football game.

CHAPTER 2: THE CARDIOVASCULAR DEMANDS OF DIVISION I SIDELINE CHEERLEADERS DURING TRAINING AND FOOTBALL GAMES

2.1 Introduction

Since the 1990's, college cheerleading has evolved from a strictly "pep-club" nature to a complex and competitive sport (14). Most schools consider collegiate cheerleaders student athletes even though cheerleading has yet to be deemed a sport by the National Collegiate Athletic Association (NCAA). Many college teams are highly selective, participate in practices year-round, and attend specialized camps to learn material and skills to perform on the sideline (36). Many Division I cheerleading teams cheer for football, basketball, gymnastics, and volleyball, make community appearances, and compete at national, unsanctioned competitions. Although cheerleaders on the sideline are not competing against others during game-day, the athletes still perform complex pyramids, tosses, stunts, and tumbling to entertain the crowd and promote school spirit for the duration of games, requiring enormous athletic abilities (24).

Due to the nature of the game-day atmosphere, where the main goal for sideline cheerleaders is to pump up the crowd, cheerleaders may experience greater cardiovascular demand at greater intensities compared to practice conditions. To evaluate cardiovascular demands of cheerleading at practice or on the sideline at a game, heart rate (HR) monitoring can be used (10, 22). Defining different zones based on a percentage of the individuals HR maximum (HR_{max}) and evaluating the time spent in the zones is a simple way to quantify physiological intensity and load during any given training session (22). HR monitoring can also be used to evaluate the changes in physiological intensity and load throughout the four quarters of a football game. Measuring workload throughout the duration of a game is important to observe the rate of fatigue. As fatigue increases, performance errors are likely to become more prevalent. Due to the complexity and nature of the skills performed, simple mistakes often lead to injury (32). Examining HR during a game setting can aid in developing a proper training regimen to reduce the risk of injury (15).

The driving factors for changing heart rate and includes the sympathetic (SNS) and the parasympathetic (PNS) branches of the autonomic nervous system (ANS) (1). Extrinsic factors such as exercise are responsible for increasing SNS drive, therefore increasing the heart rate and reducing vagal tone (1, 25). HRV is an indirect measurement of SNS and PNS balance. Resting HRV has been measured prior to competition and games in a variety of elite athletes to determine the ANS balance in response to stress and as a marker of training adaptations (4, 13, 27). Measuring resting HRV is a simple, non-invasive method used to evaluate the underlying cardiovascular responses triggered by stressful situations, such as performing on the sidelines of a football game.

Current literature regarding cheerleaders is limited to the argument of whether cheerleading is a sport, injury status, and eating disorders of cheerleaders. Previous research has found cheerleaders have a high level of physical fitness and have similar physiological attributes as other competitive Division I female athletes (36). No existing research has examined the physiological responses that may be triggered by performing in front of large crowds of people or physiological mechanisms to determine training adaptations. In addition, examining time spent at different intensities allows coaches to implement a training plan to mimic the physiological demands required for a game (22). As cheerleading continues to grow in popularity, understanding the physiological demands of the sport are necessary. Therefore, the purpose of this study was to 1) evaluate the autonomic balance and cardiovascular demands of collegiate sideline cheerleaders between a practice setting and a game setting, and throughout four quarters of a football game; and 2) evaluate the physical fitness of collegiate Division I cheerleaders.

2.2 Methods

Participants

Eleven Division I collegiate female cheerleaders were invited to participate in this study. Participants free from any chronic cardiovascular diseases, who were not taking any medications that will alter HR, and who answered “no” to all questions on the Physical Activity Readiness Questionnaire were included in this study. Participants were informed of the commitment and procedure of the study and signed an informed consent. The study was approved by the Institutional Review Board of the university as well as the Athletic Department Chair prior to any data collection.

Study Protocol

Prior to the study, participants baseline characteristics such as height (m), body mass (kg), body composition (%BF), resting HR (bpm) blood pressure (mmHg) and handgrip strength (kg) were collected at the end of the first observed practice. At the pre-screening, participants were sized for the Zephyr HR monitor Bioharness (Bioharness 3.0, Zephyr Technologies, Annapolis, MD) and were assigned a Bioharness, which stayed consistent throughout the duration of the study. Data was collected at four practices, which took place on Wednesday at 9:00am, at the university in the designated practice facility. Data was also collected at four home-games in the university’s football stadium. During practices and games, there was no interference by researchers and the study was strictly observational.

Anthropometrics

Height was measured using a standometer, and recorded in centimeters (cm). Body mass (BM) was measured using a calibrated scale (PD100; Detecto, Webb City, MO) and was recorded to the nearest 0.01 kilogram (kg). Body composition measurements including percent body fat (%BF), fat free mass (FFM), fat mass (FM), and total body mass (BM) were measured using bioelectrical impedance analysis (Tanita TBF-300; Tanita Corporation of America, Arlington Heights, IL). Resting HR was taken manually in beats per minute (bpm) and blood pressure (mmHg) was taken using an OMRON 7-series blood pressure monitor (Omron Corporation, Kyoto, Japan). A handgrip dynamometer was used to determine handgrip strength. Participants were instructed to hold the dynamometer in their dominant hand and squeeze as hard as possible 3 times, and the highest of the 3-measurements was recorded in kilograms.

Resting Heart Rate Variability

Athletes participating in the study were asked to arrive to practices and games 30-minutes prior to the original meeting time for the HRV data collection. Upon arrival, participants put on the HR monitor and data was recorded in the seated position in a quiet room with minimal distractions for 15-minutes (13). HR data were stored and downloaded from the BioHarness for further analysis using Kubios software (University of Eastern Finland, Kuopio, Finland) (34). The following HRV measurements of time domain parameters were taken: SDNN (standard deviation of all NN intervals), and the RMSSD (square root of the mean squared differences of successive NN intervals). Additionally, frequency domain measurements included LF (low frequency) which indicates SNS activity, HF (high frequency) which indicates PNS activity, and the LF/HF ratio which determines ANS balance.

Physiological Variables During Game and Practice

Ambient air temperature, globe temperature, wet ball globe temperature, and percent humidity were collected using a Deluxe WBGT Heat Index Monitor (Taiwan, Republic of China). Physiological intensity and load were examined in practice vs. game and between each of the four quarters of the football game. During practice and games, each athlete continued to wear the Zephyr Bioharness. A detailed script for each of the four practice and game-day sessions was kept and used to provide a second-by-second analysis using the Zephyr OmniSense Software. The average HR and the highest HR reached either during practice or a game (HR_{peak}) were recorded. HR_{max} was defined as each individual's maximum and was determined using the age-predicted maximum HR equation ($220\text{-age} = HR_{max}$) (35). HR_{max} was used to calculate the physiological intensity on a scale of 0 to 10, with 0 representing rest (50% HR_{max}) and 10 representing maximal exertion (100% HR_{max}). The OmniSense Analysis program calculates the physiological intensity as a percentage of each participant's stored HR_{max} as an indirect measurement of cardiac output during the session. From the physiological intensity the OmniSense Analysis program calculates the physiological load, which is a representation of the overall physiological workload of a session. Lastly, raw HR data (sampled at 1Hz) was divided into intensity zones based on each individuals HR_{peak} according to the ACSM guidelines: $\leq$56%, 57-63%, 64-76%, 77-95%, $\geq$96% (22). Total time in each zone was quantified to determine time spent at physiological intensities during games and training sessions (22, 24). Maximal and average activity level were calculated using the OmniSense Software and were used as an indicator of mechanical activity during practices and games. Activity level was recorded in velocity magnitude units (VMU) with the walking equivalent activity being greater than 0.2 VMU, and the running equivalent activity being greater than 0.8 VMU.

Statistical Analysis

Data analysis was performed using SPSS version 22.0 (IBM Corp, Chicago, IL). Descriptive characteristics of the sample were analyzed and reported in mean ± standard deviation (SD). Paired t-tests were used to examine the average differences in main outcomes (HRV, training intensity and load) between practice and game-day settings. A repeated measures analysis of variance (RM-ANOVA) was used to assess changes in time in HR zones, intensity, and load between each of the 4-quarters (Q1, Q2, Q3, Q4) in a football game. A one-way ANOVA was used to assess differences in environment between the 4-games. If HRV variables were not normally distributed, a natural logarithm transformation was applied. Statistical significance was set at $p<0.05$.

2.3 Results

Fitness Profile

Participant characteristics are described in Table 1. All athletes participated in cheerleading for an average of 8.0±4.7years (y). Six of the cheerleaders were participating in their first year, two were in their second year, and three were in their third year of collegiate cheerleading. Positionally, back-spots (n=3) were significantly taller than flyers (n=3) (161.0±1.7cm, $p<0.01$) and bases (n=5) (161.2±3.4cm, $p=0.01$). No other differences were observed in fitness by position ($p>0.05$).

Table 1. Participant Characteristics (mean ± SD).

Variable	n=11
Age (y)	18.9 ± 0.8
Cheer Experience (y)	8.0 ± 4.7
Height (cm)	163.2 ± 4.3
Body Mass (kg)	64.9 ± 8.7
Body Fat (%)	24.5 ± 5.6
Lean Mass (kg)	47.6 ± 6.2
Fat Mass (kg)	16.3 ± 5.8
Systolic BP (mmHg)	119 ± 6
Diastolic BP (mmHg)	76 ± 6
Resting HR (bpm)	75 ± 7
Handgrip (kg)	38.5 ±4.8

Comparison between Practice and Game

All observed practices took place indoors at 9:00am on Wednesdays in the practice arena. The mean practice duration was 121±9minutes (min) and the mean wet globe ball temperature (WGBT) was 66.4±0.2°F. All observed games took place at 2:00pm on Saturday in the university's football stadium. Athletes were required to meet a minimum of 3 hours prior to the 2:00pm kick-off time for pregame run-through with the band, stretching/warm-ups, and various pregame activities (tailgate walk-throughs, homecoming festivities, and etc.). Panther walk was the final event leading up to the game where the cheerleaders performed cheers and band dances amongst a crowd and made a walkway from the bus to the stadium for the football players to enter the stadium. This period was defined as pre-game.

The mean game duration was 139±14 min and average quarter duration was 35.0±2.5 min. Game 1 (G1) mean WGBT across the four quarters was 84.4±3.9°F, Game 2 (G2) was 82.9±5.0 °F, Game 3 (G3) was 58.5±1.8°F, and Game 4 (G4) was 63.5±4.2°F. WGBT was significantly warmer during G1 and G2 than during G3 and G4 ($p<0.05$). Ambient air temperatures were significantly warmer in G1 (97.6±2.2°F) and G2 (93.3±6.3°F) than G3 (63.9±1.3°F, $p<0.01$) and G4 (68.9±2.5°F, $p<0.01$). Globe temperature for G3 (71.2±4.3°F) were significantly cooler than G1 (113.6±12.9°F, $p<0.01$), G2 (112.2±16.8°F, $p<0.01$), and G4 (98.8±16.6°F, $p=0.03$). Humidity percentage was significantly higher in G3 (52.3±1.8%) than G1 (35.1±2.8%, $p<0.01$) and G4 (31.9±5.2%, $p<0.01$). Humidity percentage was significantly higher in G2 (42.3±8.7%) than G4 (31.9±5.2%, $p=0.04$).

All values for practice and game resting HRV and physiological variables are listed below in Table 2. There was a significantly higher LF/HF ratio prior to game than prior to practice (1.19±0.53 vs. 0.91±0.54, $p=0.0003$). Athletes had a significantly higher average HR during game than in practice (132±14bpm vs. 124±11bpm, $p=0.01$). Average activity level was significantly higher during game than in practice ($p<0.01$) while maximal activity level was significantly higher in practice than during game ($p=0.03$). Physiological load, or cumulative cardiovascular effort, was significantly higher during practice than during game ($p<0.01$).

Table 2. Practice vs. game resting HRV and physiological variables.

Variable	Practice	Game	P-value
HRV Variables			
Mean RR (ms)	851.9±103.5	841.4±61.8	0.64
lnSDNN	4.0±0.3	4.0±0.3	0.98
lnRMSSD	4.2±0.4	4.2±0.3	0.84
lnVLF	-3.3±0.1	-3.3±0.1	0.72
lnLF	-2.4±0.2	-2.2±0.5	0.23
lnHF	-1.3±0.1	-1.0±0.9	0.43
LF/HF Ratio (%)	0.9±0.5	1.2±0.5	<0.001
Physiological Variables			
Average HR (bpm)	124±11	132±14	0.01
Maximal HR (bpm)	184±18	180±16	0.19
Average Activity	0.13±0.02	0.18±0.07	<0.01
Maximal Activity	2.8±2.9	2.4±2.2	0.036
Physiological Intensity	3.1±0.9	3.5±1.2	0.068
Physiological Load	300.4±97.5	114.8±41.4	<0.01

SDNN, standard deviation of all NN intervals; RMSSD, square root of the mean squared differences of successive NN intervals; VLF, very low frequency; LF, low frequency; HF, high frequency

Average HR for categories of intensity were as follows: very low intensity (≤56%HR_{max}) ≤110±6bpm, low intensity (57-63%HR_{max}) 111±6bpm to 123±6bpm, moderate intensity (64-76%HR_{max}) 124±6bpm to 148±7bpm, vigorous intensity (77-95%HR_{max}) 149±7bpm to 186±9bpm, and maximal intensity (≥96%HR_{max}) ≥187±9bpm. The amount of time spent in HR intensity zones is displayed in Figure 1. The amount of time spent in the very low intensity zone was significantly higher during practice than game (31% vs. 14%, $p<0.01$). Cheerleaders spent more time in the moderate intensity (42% vs. 30%, $p<0.01$) and vigorous intensity (23% vs. 15%, $p=0.03$) zones during games compared to practices. There were no significant differences in time spent in the low or maximal intensity zones ($p>0.05$).

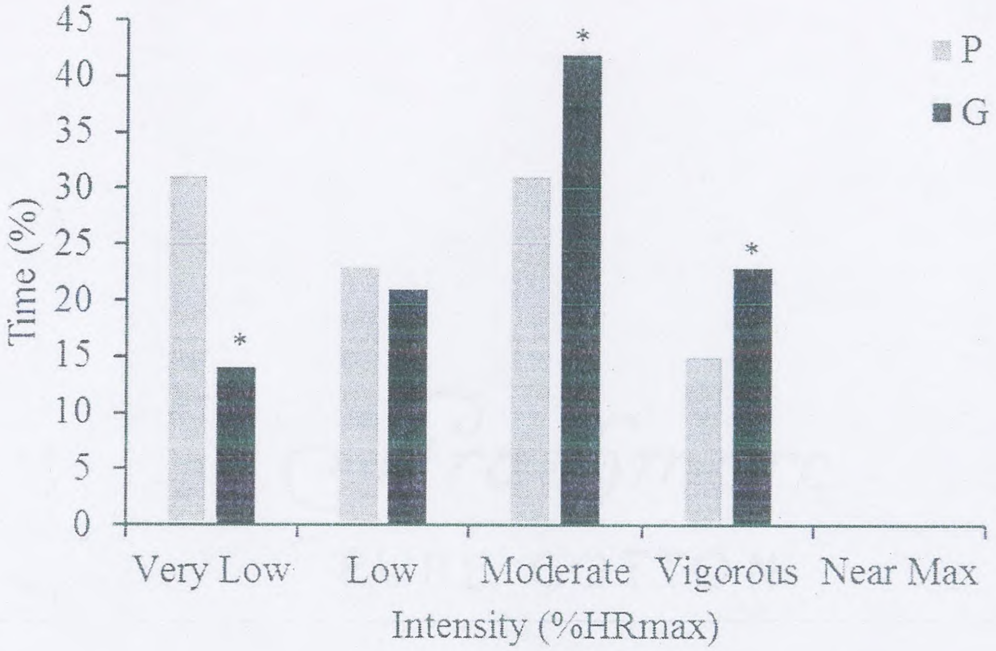

Figure 1. Percentage of time spent in HR zones. P, practice; G, game; Near Max, near predicted maximal HR. *Significantly different between groups (*p*<0.01).

Within Game Comparisons

Differences in the physiological variables among each of the 4-quarters of the football game are represented in Table 3. Both Q1 (143±12bpm) and Q2 (136±16bpm) had significantly higher average HR than Q3 (124±14bpm, *p*<0.01) and Q4 (124±13bpm, *p*<0.01). Maximal HR was significantly higher in Q1 than Q3 and Q4 (*p*<0.01). In addition, maximal HR was significantly higher in Q2 than Q4 (*p*=0.02). Physiological intensity was significantly higher in Q1 and Q2 than in Q3 (*p*<0.01) and Q4 (*p*<0.01). Physiological load was also significantly higher in Q1 and Q2 than in Q3 (*p*<0.01) and Q4 (*p*<0.01). From the detailed itinerary, the number of stunts per quarter was recorded and used to determine no trends were observed in the amount of complex skills performed per quarter. On average, 1 stunt was performed in Q1, 3 stunts were performed in Q2, 2 stunts were performed in Q3, and 3 stunts were performed in Q4.

Table 3. Physiological variables throughout the four-quarters of the football games.

Variable	Q1	Q2	Q3	Q4
Average HR (bpm)	143±12	136±16	124±14[a]	124±13[b]
Maximal HR (bpm)	178±16	170±16	162±16[a]	160±15[c]
Average Activity	0.17±0.04	0.15±0.03	0.17±0.07	0.18±0.11
Maximal Activity	2.3±2.6	2.4±2.8	2.4±1.9	2.4±2.5
Physiological Intensity	4.6±1.5	3.9±1.5	2.8±1.3[a]	2.7±1.1[b]
Physiological Load	132.0±50.9	131.6±75.0	106.0±53.3[a]	89.6±35.6[b]

[a]Q3 significantly different from Q1 and Q2, $p<0.01$. [b]Q4 significantly different from Q1 and Q2, $p<0.01$. [c]Q4 significantly different Q2, $p=0.04$.

2.4 Discussion

This study is the first to examine fitness characteristics and cardiovascular demands of collegiate cheerleaders during a live game environment. This study revealed significant discrepancies between the cardiovascular demands during practice versus game. Resting HRV indicated a shift toward SNS activity prior to games, suggesting that performing in front of a crowd can elicit a stress response. Average HR was significantly higher during games, and the amount of time spent in higher-intensity zones was significantly greater than practice. Average HR, physiological intensity, and physiological load decreased significantly throughout the four quarters of the football game, indicating the athletes may have experienced a decline in extrinsic motivation or may have become fatigued.

Cheerleaders, like gymnasts, typically have a smaller build to facilitate somersaults and rotations during tumbling passes (11), however back-spots are usually taller because they are required to reach the flyer during stunts. No significant differences were observed between bases, flyers, and back-spots in body composition (LBM, FFM, BF%) or handgrip strength. In a similar study examining the fitness status of collegiate cheerleaders, the average body fat percentage for females was reported as ~15% (36), whereas the present study found an average of ~24%. Such a large discrepancy could be due to the use of males and females in a co-ed team unlike the present study which just used a female team. Generally, co-ed stunts require smaller female flyers because they are paired to one male while all-girl teams have three females to support one flyer. With the participants extensive cheerleading experience and homogenous body composition, it is possible the female athletes of this study were versatile positionally, and therefore no differences were seen between positions. Average handgrip strength of the cheerleaders was consistent with findings in collegiate female basketball players (37). This study demonstrated that Division I collegiate cheerleaders have similar body composition and physical fitness to other collegiate athletes and athletes with a similar realm of practice.

Practices took place indoors, where temperature and humidity were kept consistent throughout the duration of the study. Games took place outdoors on a turf field in the months of September and October. Direct sunlight on the cheerleaders during G1 and G2 in combination with a warmer ambient air temperature was reflected in the significantly greater WGBT. G3 saw a large decrease in ambient air temperature compared to G2, probably due to rain with overcast environment, causing an increased humidity and significantly lower WGBT. G4 was also overcast with cooler ambient air temperatures, also causing WGBT to be significantly lower. Therefore, cardiovascular demand may have been altered between G1/G2 and G3/G4. Increased body temperature, or hyperthermia, may result in vasoconstriction. Vasoconstriction reduces visceral blood flow which can negatively affect performance by limiting heat dissipation and in turn reducing the ability to maintain intensity and duration of exercise (12). However, this study found no game to game differences in cardiovascular outcomes, suggesting the increased temperature did not elicit a HR response.

The downward trend in RR intervals from practice to game also confirms the withdrawal from the PNS prior to games. RMSSD is highly correlated with HF power, and increased RMSSD can be associated with increased fitness. In a study looking at short-term HRV in healthy adults, RMSSD values were lower than the RMSSD measured in cheerleaders (21). Similarly, RMSSD values were also consistent compared to other collegiate athletes, suggesting cheerleaders have a similar level of physical training as other collegiate athletes (7). Thus, cheerleaders have an increased resting vagal tone, which could be a marker of exercise training adaptations. Resting HRV in cheerleaders did not demonstrate the athletes were desensitized to the game phenomena, which could be because the athletes cheer very few games per year. Resting HRV appeared to be different in practices compared to games as shown by an increase in LF/HF ratio. Cheerleaders exhibited greater SNS activity prior to games compared to practices. Lower HF power is used as an indicator of stress or anxiety (30). The decreased HF values observed during the game are also an indicator of greater SNS activity in comparison with practice. Sartor et al. (2016) demonstrated induced anxiety and stress prior to a competition altered ANS balance and increased SNS activity in gymnasts (28). In volleyball players, previous research has demonstrated a decrease in HF power prior to competitive matches, indicating a withdrawal in PNS activity (4). The greater SNS input can be triggered by an increased pressure to perform on game day because the athletes are executing complex skills in front of a large crowd, which may cause an increase in epinephrine and norepinephrine, leading to an adrenaline-like response. This could also be a direct result of a mentality shift from practice to game-day, which may vary among different sports. Grant and Rensberg (2008) evaluated resting HRV between different sports including skydivers, field hockey players and endurance runners. Unlike cheerleading, endurance runners demonstrated higher HF due to an increased parasympathetic tone. The increased parasympathetic tone could be from aerobic training, also commonly resulting in sinus bradycardia. Sinus bradycardia occurs because stroke volume and heart rate are inversely related to keep cardiac output consistent. Skydivers, however, had an elevated LF/HF ratio, indicating increased SNS activity due to the intensity and nature of the sport (13). Similarly, cheerleading at a Division I football game may induce greater SNS activity because the pressure to eliminate error and the intensity of a game-day environment is high, especially when performing stunts, tumbling, and difficult tosses.

Athletes may exert themselves more during games than in practice which was reflected in a higher average HR and activity level in games in comparison with practices. During games, the athletes are required to continually move – showing spirit, doing stunts/tumbling, and performing band-dances – in order to elicit a response from the spectators. In a study on women's ice hockey players, HR during games was significantly greater than HR during practice due to increased level of arousal and pressure to perform at maximal effort (33). Though the sports differ in physical demands, the cardiovascular response observed in ice hockey athletes is similar to sideline cheerleader's constant movement. In addition, practices have more sedentary time for athletes to learn or practice skills, resulting in a lower average HR. However, learning and perfecting skills requires repetition, which could lead to significantly higher maximal activity and physiological load during practice. Load represents the workout difficulty; therefore, practices may have been more physically demanding due to the acquisition of new skills to perform on the sideline during game-day. The performance of the skills on the sideline may have elicited a more intense environment, which can be explained by the elevated HR. Increasing the intensity of practices may better prepare the athletes for performing for the duration of the game.

As previously mentioned, more practice time is spent learning and perfecting technique of skills, which requires a large amount of time performing less physically demanding activity This may explain why 31% of practice was spent in the very low intensity HR zone. In contrast, games require constant physical activity including a wide array of low and high intensity activities. This would explain why a significantly greater portion of the game was spent in moderate and vigorous intensity HR zones. These results are consistent with a study performed on soccer players, in which 55% of games were spent in high-intensity zones and only 11% of training sessions were spent in high-intensity zones (22). Based on the current study, cheerleaders may not be adequately prepared for games, and practicing at higher intensities could be beneficial to prepare athletes for game-like situations.

Practicing at higher intensities could also help to prepare athletes for the long duration of the game. Average HR, intensity, and load were all significantly higher in Q1 and Q2 than Q3 and Q4. This could be due to the athletes fatiguing. Ohlssen et al., (2015) demonstrated elite soccer players HR decreased the second half of the soccer game due to a reduction in effort accompanied by fatigue (22). With increased fatigue, HR is predicted to also increase (20); however, as fatigue increases throughout the quarters of the game, the athletes may also become less motivated to perform at an optimal level and more complacent by performing fewer, simpler cheers. There were no trends observed in the number of skills performed on the sideline throughout the game, however the complexity of the skills was not taken into consideration. The lack of extrinsic motivation could possibly be a result of the outcomes of the game as well. Gavalda et al. (2018) found HR of basketball players was impacted by the game outcome (points scored) rather than any differences between quarters. HR was the highest when the team was winning in the first and second quarter, but lower when the team was losing in the fourth quarter (10). Therefore, the scoring and game outcome may have impacted the overall effort of the cheerleaders. Activity level was the same between quarters, which would be anticipated since the athletes are confined to a small space on the sideline.

Strengths and Limitations

All cheerleaders who volunteered to participate in this study were healthy young adults with a wide variety of cheerleading experience. One limitation of the study was the small sample size, due to the small sideline cheerleader population studied. A larger sample size may have reflected significant differences positionally between body composition or strength.

Each of the practice and game times stayed consistent throughout the duration of the study. Each practice differed drastically in the skills and amount of skills practiced, and no strict practice itinerary was followed. This study was observational, so the researchers were not able to intervene. However, the observational approach is advantageous because researchers can assess real-life situations and make practical applications to the population of interest.

Game environment could not be controlled during the study; therefore, the temperature could have impacted results. There was a discrepancy between practice and game duration, which could have altered results. It is difficult to generalize these results to all college cheerleading programs because each university has traditional components to practice and game environments which may lead to different results.

2.5 Conclusion

The purpose of this study was to examine physical fitness in Division I collegiate cheerleaders and evaluate the autonomic balance and cardiovascular demands of collegiate sideline cheerleaders between a practice setting and a game setting, and throughout four quarters of a football game. This study has demonstrated that average HR was higher during game than practice, and average HR trended downward throughout the four quarters of the game. Athletes spent a greater amount of the game in higher intensity HR zones, therefore it may be important to implement higher intensity exercise into training to mimic game-like environments.

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APPENDICES

COLUMBUS STATE
UNIVERSITY

INSTITUTIONAL REVIEW BOARD

Informed Consent Form

You are being asked to participate in a research project conducted by McKenna Cornett, a student in the Health, Physical Education and Exercise Science Department at Columbus State University. This project will be supervised by an exercise science faculty member, Kate Early.

I. **Purpose:**

The purpose of this project is to examine physical fitness in Division I cheerleaders and observe the cardiovascular demands during practice and game-day settings. As cheerleading has grown in popularity, little research has been conducted on the physical demands of the sport and the stress cheerleaders experience. In addition, cheerleaders may experience different physical demands in practice compared to game settings, which may increase their risk of injury.

II. **Procedures:**

If you chose to complete this consent form after all of your questions have been answered, you may be randomly selected to participate in this study. After selection, a pre-screening will take place to determine age, height, weight, resting heart rate and blood pressure. Body composition will be taken using a Tanita scale to determine body fat percentage. Strength will be measured using a hand-grip dynamometer as an indicator of strength. You will be sized for a heart rate monitor and assigned a number that will stay consistent for the duration of the study. You will attend normal practices and games; however, you will be asked to arrive 15-minute earlier than the set time to collect data. Upon arrival, you will place the Zephyr heart rate monitor on and you will be asked to lay as still as possible in a quiet room for the entire 15-minutes. After the 15 minutes, you will practice and perform at games as normal while wearing the heart rate monitor. Data will only be collected at 4 practices and 4 home games, and after each session the heart rate monitors will be taken back up by the researcher.

III. **Possible Risks or Discomforts:**

Minimal risks and discomfort should be experienced during this study, as it is simply an observational study and there will be no interference by the researcher. There may be possible discomfort wearing the heart rate strap. If discomfort occurs, the strap can be repositioned.

IV. **Potential Benefits:**

Researchers will gain knowledge about the physiological demands of cheerleading on the sidelines at a game. The information will be useful in designing training programs that will mimic the game-day intensity to ensure athletes are adequately trained, which should also reduce the risk of injury on the sideline.

V. **Costs and Compensation:**

There is no compensation for participating in this study.

VI. **Confidentiality:**

Any information that could potentially identify you will be coded with a randomized number that only the researcher will have access to. Your coded information will be kept for publication purposes without any information that could possibly identify you.

VII. **Withdrawal:**

Your participation in this research study is voluntary. You may withdraw from the study at any time, and your withdrawal will not involve penalty or loss of benefits.

For additional information about this research project, you may contact the Principal Investigator, McKenna Cornett at (478)213-7922 or cornett_mckenna@columbusstate.edu. If you have questions about your rights as a research participant, you may contact Columbus State University Institutional Review Board at irb@columbusstate.edu.

I have read this informed consent form. If I had any questions, they have been answered. By signing this form, I agree to participate in this research project.

____ ____________________

Signature of Participant Date

THE CARDIOVASCULAR DEMANDS OF DIVISION I SIDELINE CHEERLEADERS DURING TRAINING AND FOOTBALL GAMES

A thesis submitted to the College of Education and Health Professions in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

DEPARTMENT OF KINESIOLOGY AND HEALTH SCIENCES

by

McKenna N. Cornett

2018

Kate D Early 12/7/18

Dr. Kate Early, Chair Date

12-07-2018

Dr. Clayton Nicks, Member Date

12-7-18

Dr. Brian Tyo, Member Date