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Analysis of Heart Rate Training Responses in Division I Collegiate Athletes

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ANALYSIS OF HEART RATE TRAINING RESPONSES

IN DIVISION I COLLEGIATE ATHLETES

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New technology on the effectiveness of external stimuli or training volume continuously develops to assist with enhancing athletic performance. Assessing the physiological responses athletes experience from training is crucial when developing programs to simultaneously optimize performance and improve fitness levels. By combining coaching expertise with scientific technology, coaches can monitor and obtain their athletes' individual objective physiological responses program(s). PURPOSE: To describe the physical training doses through heart rate monitoring of strength and conditioning (S&C) sessions compared to a game in female soccer and basketball collegiate athletes. METHODS: Participants were nine female soccer players [means ± SD, age: 20.5 ± 0.3 yr., height: 172.2 ± 1.3 cm, mass: 66.9 ± 1.7 kg, BMI: 22.6 ± 0.5] and nine female basketball players [means ± SD, age: 20.3 ± 0.3 yr., height: 178.4 ± 2.3 cm, mass: 73.3 ± 3.4 kg, BMI: 22.9 ± 0.8] from a NCAA Division I university. Participants wore a heart rate chest strap monitor during the summer S&C training sessions and pre-season games. Each subject's height, weight, age-predicted max heart rate, and player position were recorded into Polar Team^2 Pro system. After each training session and game, each subjects' data from the transmitter was uploaded for analysis. Data was subsequently analyzed to determine the training load (TL), average calories expended per minute (kcal/min), average heart rate, maximum heart rate, and percent of time spent in each training zone (Z1-Z5) for the selected S&C sessions (T1 and T2) and one pre-season game (T3). RESULTS: One-way ANOVA with repeated measures detected significant differences in women's soccer TL with post hoc comparisons revealing the TL in T3 (239.1 ± 112.4) was higher than T1 (147.1 ± 63.3) and T2 (149.6 ± 36.4) and percent time in Z3 was lower in T3 (13.7 ± 2.7) compared to T1 (22.5 ± 6.5) and T2 (21.7 ± 8.1). One-way ANOVA with repeated measures detected significant differences in women's basketball kcal/min, average heart rate and percent of time spent in Z1-Z5. Post hoc comparisons revealed T3 had the lowest values in both kcal/min (9.7 ± 3.0) and average heart rate (134.6 ± 21.9). T1 had the greatest amount of time spent in Z4 (25.9 ± 10.0) and Z5 (32.8 ± 21.1) and the least amount of time spent in Z1 (13.0 ± 22.1) and Z2 (12.9 ± 9.0). T2 had the highest percent time spent in Z2 (20.3 ± 3.8) and Z3 (20.1 ± 6.3). T3 had the greatest percent time spent in Z1 (44.0 ± 28.9) and the least amount of time spent in Z3 (11.3 ± 6.3) and Z4 (15.2 ± 7.1). CONCLUSION**:** Summer strength and conditioning sessions for soccer produced physiological responses that were relatively similar to the responses experienced in pre-season games. However, summer strength and conditioning sessions for basketball had similar training loads to the pre-season game but it did not replicate the physiological responses in the pre-season games. Heart rate monitoring systems may be useful in helping strength and conditioning coaches and the sport coaches to quantify physiological responses to game and practice sessions in their athletes.

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M.C.C

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CHAPTER I

ANALYSIS OF HEART RATE TRAINING RESPONSES IN DIVISION I COLLEGIATE ATHLETES

Introduction

Athletes who participate at higher levels, such as collegiate or professional, are expected to perform exceptionally with the increased physical demands of the sport. Coaches prescribing a training stimulus should have a goal of optimizing performance and minimizing the potential risks of training (i.e., injury, illness, fatigue, overtraining) (4, 5, 7, 10, 12, 21, 22, 29). Research has found relationships between greater training volumes and performance outcomes as well as higher training intensities and performance outcomes (4, 5, 7, 10, 18, 27). Conversely, exercise training has a dose-response relationship and the highest occurrence of illness and injury occurs when training loads are highest (1, 4, 5, 9, 10, 18, 22, 25).

The three factors that influence training load are frequency, duration and intensity with varying individual differences of optimal training load between players (4-7, 10-12, 15, 22, 29). The current literature also notes that training load should include adequate recovery time to improve performance (4-6, 12, 22, 28). Extensive research has investigated the prescribed external loading and the associated adaptations or physiological responses that occur (1, 2, 4, 5, 8-10, 25, 29). There is limited research analyzing the role of internal training load and game loads on changes in fitness in sports, specifically team sports (1, 2, 4, 5, 10, 12-15, 22, 23, 29). Recent studies attempted to quantify internal loading by analyzing blood lactate concentration, core and muscle temperatures, depletion of muscle glycogen, heart rate, heart rate variability, measurements of oxygen uptake, biochemical/hormonal evaluation through saliva assessments, psychological markers, training impulse (TRIMP), rating of perceived exertion (RPE), and questionnaires/diaries (2, 4, 12, 18, 23). Determining the best method of monitoring is based on many factors to be considered, such as feasibility, cost, time allotment, education and/or experience with the chosen method (if needed), and equipment availability.

Kraemer et al. (2004) found that over the course of an 11-week soccer season overall performance progressively declined, especially towards the later stages of the competitive period. Monitoring training intensity and load might be an essential factor for further improvements and observing recovery rates in elite athletes' training programs. There is currently no gold-standard method to assess training load (external) and physiological responses (internal) (4, 12, 18, 23). The most accurate measurement of physiological responses would be direct oxygen consumption. Several studies have been conducted on individual and/or endurance sports (e.g., cycling, running, triathlon) where a controlled environment and state-of-the-art laboratory equipment was easily accessible (8, 10, 12, 23). However, it is more feasible for contact and intermittent sports to use field-based assessments to determine external and internal volumes of workload in athletes (2, 12, 25). Suggested research concludes that monitoring team sports can be more difficult in comparison to individual sports due to the diverse range of training activities (e.g., general conditioning, resistance training, interval training, and skill-based conditioning) (1, 8, 10, 12, 20, 22). It is found to be even more challenging with collision or contact sports if wearable technology is required (e.g., heart rate monitors, portable VO_2 analyzers) or if assessments are needed in the middle of practices, conditioning or games (e.g., blood lactate concentration samples) (8, 12, 15).

Heart rate monitoring is a commonly used, non-invasive method for measuring exercise intensity. It has been shown to be a valid and reliable measurement tool to assess physiological responses due to heart rate having a linear relationship with oxygen consumption and increasing exercise intensity as well as consistent values with electrocardiograph readings (2, 4, 5, 8, 12, 15, 19). By combining scientific methods via technology (i.e., heart rate monitoring) with coaching expertise, coaches can receive objective feedback from their athletes on the effectiveness of a specific training program. Additional benefits of monitoring athletes are injury prevention, structured individualized training, effectiveness of the training program, and preventing overtraining (1, 4, 7, 12, 15, 20).

The purpose of the study is to describe the physical training doses through heart rate monitoring of strength and condition (S&C) sessions compared to a typical game setting in female soccer and basketball collegiate athletes. The data will summarize each athlete's individual heart rate, accumulated training load, average daily calories expended per minute (kcal/min), and percentage of time expended in specific training zones monitored during strength and condition trainings and pre-season games. The training sessions will be compared to a pre-season game to examine if the physiological responses in strength and conditioning sessions can replicate a game-type setting.

Methods

For the present study, the subjects were from a National Collegiate Athletic Association (NCAA) Division I women's soccer and women's basketball team. The selected training measures were assessed during the off-season summer strength and conditioning (S&C) training sessions and one pre-season game. Each of the strength and conditioning training component (e.g., intensity level, selected exercises, volume of training) varied each day based on the team's associated strength coach's prescribed training program.

Two weeks of practice for each team were selected as representative data based on the weeks with the highest player attendance. Following the selected weeks, players would be included into the data sample if they were present for at least seventy percent of the training sessions. The number of players in the two week sample who were also in the pre-season game would be included in the data analysis. The two week training sessions were compared to the one selected game to determine if strength and conditioning sessions reflect or are similar to a competitive setting. The variables that were analyzed are training load, energy expenditure (kcal/min), average heart rate, maximal heart rate, and average percentage of time spent in each training zone.

Participants: Fourteen female soccer players and ten female basketball players from a NCAA Division I university participated in the study. The data was archived from the university's athletic department's heart rate monitoring system, Polar Team^2 Pro (Polar Electro, Kemple, Finland). However, due to individual player attendance previously mentioned, the sample was reduced to nine female soccer players (n = 9) and nine female basketball players (n = 9). The physical characteristics are presented in

Table 1 and 2. Height, weight and age variables for each subject were measured and/or provided by each team's associated strength coach. Body mass index (BMI) and age-predicted max heart rate (APMHR) were calculated from the provided demographic data. Participants were not asked to perform any other tasks outside of their physical requirements for the sport. The subjects provided written informed consent for their participation in this study using forms that had been reviewed and approved by the Illinois State University Institutional Review Board (Appendix).

Heart Rate Monitoring System: Each player's name, sex, date of birth, height, and weight were entered into the software. The software has designed algorithms to calculate individual estimated heart rate max values. The software provides the following three options to select from for determining individual heart rate zones: max heart rate value, threshold value and heart rate reserve value. The max heart rate value is calculated using the APMHR formula. Threshold value separates the heart rates into anaerobic (upper limit) and aerobic (lower limit) values. Heart rate reserve uses individual heart rate resting values factored into the age-predicted max heart rate. The resting heart rate values were not collected prior to the study, which eliminates the option of using heart rate reserve due to potential inaccuracy. As a result, age-predicted max heart rate was utilized because of its commonality. The software separates heart rate ranges into five different sport training zones as a percentage of APMHR. Zone 1 (Z1) is 50-59%, zone 2 (Z2) is 60-69%, zone 3 (Z3) is 70-79%, zone 4 (Z4) is 80-89%, and zone 5 (Z5) is 90-100%.

Each player was assigned to a numbered chest strap transmitter from the Polar Team[2] Pro system. All strength and conditioning sessions and a single pre-season game were recorded and stored on each individual heart rate transmitter until the data was uploaded, which occurred one to two times per week. The data was uploaded to the Polar Team[2] Pro system and performance was analyzed. Individual heart rate, accumulated training load, daily/weekly energy expenditure, projected rate of recovery, and total duration expended in specific training zones were examined. The participants were only expected to wear their assigned chest strap monitor while performing their sport required trainings. At the end of each week, both strength and conditioning coaches would examine the physiological responses for each individual athlete and determine how to progress the training for the subsequent week.

Training Session Components: The first selected soccer S&C session (T1) consisted primarily focusing on aerobic capacity, which lasted about 75 minutes. Detailed prescription of the training session included the following: 75% effort tempo runs, 1:3 work to rest ratio and a goal heart rate range between 145-165 bpm followed by core and mobility exercises. The T2 session followed the same training as T1 only additional volume was prescribed with a duration of about 90 minutes. T3 was a NCAA pre-season, officiated game that lasted approximately 150 minutes in duration, which included the team's warm-up and cool-down phases.

The first selected basketball S&C session (T1) included 60 minutes of continuous agility stations with 1-2 minute intervals at each station. The T2 session consisted of sled sprints, jumps and lower body weights in about 90-minutes. The T3 was a NCAA pre-season, officiated game that lasted approximately 150 minutes in duration, which included the team's warm-up and cool-down phases.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics Version 20 for windows (SPSS Inc., Chicago, IL) and Microsoft Excel for windows (Microsoft Corp., Seattle, WA). Values are expressed as means and standard deviation (means ± SD). A one-way ANOVA with repeated measures was performed to detect significant differences in the selected variables: training load; energy expenditure (kcal/min); average heart rate; max heart rate; and percent of time spent in zones 1-5. If a significant difference was found in the within-subjects effects, a post-hoc analysis was performed to more closely investigate significant differences between the variables. An alpha level of 0.05 was used for significance testing.

Results

The characteristics of the participants are presented in Table 1 and Table 2. The subjects consisted of 9 female soccer players and 9 female basketball players from collegiate Division I university. Table 3 and Table 4 display the comparisons between all the physiological variables measured during three different events: strength and conditioning session one (T1), strength and conditioning session two (T2) and pre-season game (T3) for female soccer and basketball players, respectively.

One-way ANOVA with follow-up post hoc tests found differences within subjects in training load and percent time spent in Z3 between all three events in the soccer players (Table 3). Soccer mean training loads were higher in the T3 in comparison to T1 and T2. No statistical significant difference was observed between T1 and T2. There were no statistical differences between kcal/min, average heart rate, max heart rate, and percent time spent in Z1, Z2, Z4, and Z5 between all three events. However, the T3 of time spent in Z3 was found statistically lower than both T1 and T2 strength and conditioning sessions, but T1 and T2 did not differ statistically.

One-way ANOVA with follow-up post hoc tests found differences within subjects in average kcal/min, average heart rate achieved, and percentage of time spent in zones 1-5 between all three events in the basketball players (Table 4). There were no statistical differences observed within subjects in training load and max heart rate achieved between T1, T2 and T3, respectively.

There were statistically higher values of energy expenditure during T1 than T2 and the T3, but T2 had a higher value than T3. The average heart rate achieved was higher in T1 and T2 in comparison to T3. However, T1 and T2 were not statistically different. There was a greater percentage of time in spent Z1 during the T3 in comparison to T1 and T2, but T1 and T2 did not differ statistically. The percentage of time spent in Z2 was highest in T2 in comparison to both T1 and T3, but no statistical differences between were observed between T1 and T3. The percentage of time spent in Z3 was highest in T2 in comparison to T3, but not statistically different from T1. The lowest time spent in Z4 was during T3 in comparison to T1 and T2, but there were no statistical differences observed between T1 and T2. The percentage of time spent in Z5 was highest in T1 in comparison to T2 and T3, but no statistical differences were observed between T2 and T3.

Discussion

This investigation described the physical training doses through heart rate monitoring of S&C sessions compared to a game setting in female soccer and basketball collegiate athletes. The current study compared S&C sessions to game situations to determine if coaches could strategically apply volume of training (external load) that would resemble the physiological responses (internal load) to a game setting based on the sports metabolic requirements. It is commonly accepted that the benefits of exercise are maximized when the training stimuli are similar to competitive demands (28). There is currently no best method to measure and quantify internal loading in athletes (4, 12, 18, 23), especially in team sports, in order to assess the effectiveness of a training program (1, 2, 4, 6, 10, 12-15, 22, 23, 25, 29). There have been numerous of attempts to observe and quantify the loading in order to determine the relationship between training and games. However, the methods that are permitted in competition to determine physiological stresses that are associated with game play are limited (8). Much of the current literature focuses primarily on sport practices, which can include strength and conditioning, and some competitive games.

It has been identified that soccer performance is dependent on aerobic endurance, frequent high-intensity actions, speed, agility, strength and power (17, 28). From a metabolic perspective, soccer utilizes highly on the phosphagen system with moderate anaerobic glycolysis and aerobic glycolysis (2, 3, 16). In relation to training zones for this study, it would be expected that the players would spend majority of the time in Z3-Z5. However, the involvement of metabolic pathways is highly dependent on age, sex, sport position, and playing time (2).

The current study found that the soccer S&C sessions did provide an accurate reflection of a game setting. The ANOVA revealed only training load and Z3 means were statistically different. The TL was lower in both T1 (147.1 ± 63.3) and T2 (149.6 ± 36.4) in comparison to the T3 (239.1 ± 112.4), while Z3 was higher in both T1 (22.5 ± 6.5) and

T2 (21.7 ± 8.1) compared to the T3 (13.7 ± 2.7). The training load discrepancy could be explained by two of the three variables (intensity and duration) that influence training load (4-7, 10-12, 15, 22, 29). Intensity could have been influenced by some of the players included in the sample were seated longer due to less playing time. Additionally, intensity would affect the training load results based on player position. For example, a goalkeeper would spend more time in Z1 than any other position while a midfielder would have greater time spent in higher intensities (Z3-Z5). All of the athletes performed the same S&C workout with the same intensity, but during a game the performance varies substantially making each player's intensity vary by position. Duration is another factor that influences the accumulated training load. A S&C session lasts roughly 90 minutes compared to a 150 minute game setting. There were no significant differences in training load between T1 and T2 even though T2 had a higher volume. To balance the increased volume in T2, the intensity was decreased.

Both T1 and T2 occurred during the summer training sessions, which is directly prior to the initial start of pre-season. Gabbett and Domrow (2007) results suggested that increasing training load during pre-season training phase can also increase the odds of injury in collision sport athletes. Further, previous studies have shown that injuries in collision sports occur most often during sport trainings in pre-season prep with non-body contact (i.e., running and training) (10, 28). Thus, the decreased training load during S&C sessions may be beneficial to performance and injury prevention regardless of the loading not being reflective of a game.

Drust, Reilly, and Cable (2000) attempted to devise a laboratory-based protocol that could replicate the work rates observed during soccer game play. The authors analyzed responses in soccer-specific intermittent (high-intensity) exercise and a continuous steady-rate exercise to see if physiological variables (i.e., oxygen consumption, heart rate, rectal temperature and sweat production rate) were reflective of game settings. High-intensity interval training has been reported to elicit greater improvements in both aerobic and anaerobic capacity compared to continuous training (28). Drust, Reilly, and Cable (2000) concluded that the prescribed intermittent exercise's minute ventilation was similarly associated to a 45-minute soccer game. These findings indicate the significance of prescribing interval training to S&C sessions for soccer players by reason of the similar responses to game-like settings. It has also been reported that a combination of HIIT, small-sided games and repeated sprint ability training can be used to improve aerobic and anaerobic capabilities within soccer players (28).

Basketball has been characterized as predominantly an intermittent, high intensity sport. From a metabolic perspective, basketball relies highly on the phosphagen system with moderate to high utilization of the anaerobic glycolysis (3). Relative to training loads, it would be expected that the players would spend the majority of the time in Z4-Z5 with sufficient recovery time in Z1. Researchers have summarized that basketball performance is dependent on a player's anaerobic ability, aerobic fitness to improve performance, and maximal aerobic power (VO_2max) to improve recovery from anaerobic efforts during competition (26). Similar to soccer and team sports in general, the contribution of energy production pathways is highly dependent on age, sex, sport position, and playing time (2, 26).

The present study found no statistical differences in accumulated training load and max heart rate achieved between all three events for the basketball players. The one-way ANOVA with repeated measures revealed statistical differences in kcal/min, average heart rate and percent of time performed in every training zone (Z1-Z5). Both S&C training sessions (T1 and T2) had higher average energy expenditure per minute than the game (T3) with T1 having the highest value (15.4 ± 3.6). The T1 training involved continuous agility stations that could result in higher kcal/min value due to the nonstop movement in comparison to a game-setting that is intermittent with high intensity bouts followed by a brief recovery period. T3 also had the lowest average heart rate (134.6 ± 21.9) out of all three events. Similarly to kcal/min, the S&C sessions had more continuous movement instead of intermittent activity, which explains the lower average heart rate in T3.

There were mixed results in the relation to percent of time spent in each training zone. It is expected that due to the nature of a game setting, alternating of high intensity bursts and recovery periods, T3 would have the greatest times spent in lower zones (Z1) and higher zones (Z4 and Z5). The current results show that T3 did have the greatest time spent in Z1 (44.0 ± 28.9), but the greatest time spent in Z4 and Z5 was during T1 training (25.9 ± 10.0, 32. 8 ± 21.1). During a S&C training session, there is more continuous movement in order to achieve enough volume and loading to improve performance in a shorter time frame (90 minute in S&C training versus 150 minutes in a game). It seems logical that a S&C session would be performed in all five training zones, which would not ideally reflect an intermittent basketball game that focuses predominantly in the lower and higher zones. Therefore, it is up to the coach to decide how to program the strength and conditioning workouts to best resemble a game setting as well as improving physical fitness.

Scanlan, Dascombe, Reaburn, and Dalbo (2013) analyzed the physiological and activity demands experienced by Australian female basketball players during competition. Their results were similar to the present study's findings with team's average heart rate during the total time of the game at around 136 ± 6 bpm. However, the authors reported that their physiological data was somewhat lower than that reported at the current time of the study for national and international female competition. The lower results might have resulted from the players not being able to maintain higher work intensities across games compared to other higher-level or greater fitness level players due to earlier fatigue onset and a reduced ability to recover from high-intensity bouts (24). The authors analyzed the data for each individual position, which makes the study a better representation of female basketball players in comparison to the current study's method of averaging the team as a whole.

There are some limitations that must be considered. Firstly, there are numerous external factors that can affect heart rate such as environmental conditions, state of training, player position, current fitness levels, and medications (2, 4, 7, 20, 21, 23-25). It should be noted that the training days selected were performed either in the morning when the environmental factors would be less influential (e.g., sunlight, humidity, temperature) or in a controlled indoor environment. Secondly, there are variations in heart rate responses up to 6.5% (± 6 bpm) (2, 4, 12, 23, 25). This could potentially explain the very low and high values some of the athlete's heart rates. Another reason for the extremely low and high values could be the loss of the chest transmitter connection.

Finally, much of the current research has been conducted on endurance athletes with limiting research in team and ball sports (6, 10, 16, 23-25, 29). It is important to consider that team-sport athletes require a high level of aerobic fitness to generate and maintain power output during repeated high-intensity efforts and to recover, which differs greatly from endurance athletes testing in controlled environments (26). Further research should be conducted using larger sample sizes, a greater variety of sports and analyzing individual sport positions.

Conclusion

Sport coaches have a desire to enhance athlete performance through the application of training programs with the intentions of increasing physical fitness levels. There have been several methodologies proposed to gauge exercise intensity and quantify internal loading, but there is still no gold-standard method. It is important that coaches are able to accurately gauge the intensity of sport drills and training to appropriate implement optimal training parameters and periodization strategies (20). It can be concluded from this study that soccer strength and conditioning sessions do provide an accurate representation of a game setting. However, basketball strength and conditioning sessions do not provide an accurate reflection of a game setting. This could be explained by the nature of the sport being more anaerobic and intermittent in comparison to soccer. The limited time available during S&C sessions compared to a game requires the coaches to prescribe continuous training to receive the same training effect. Heart rate monitoring is an effective tool that objectively would be able to provide important physiological responses in the athletes. Therefore, heart rate monitoring systems may be beneficial in assisting helping strength and conditioning coaches and the sport coaches to quantify physiological responses to game and practice sessions in their athletes.

Practical Application

Coaches must select the best monitoring assessment tool based on a variety of factors such as feasibility, convenience, cost, and equipment availability. Heart rate monitoring is a cost-effective and feasible assessment tool that can be used to quickly retrieve physiological information on the coach's athletes. Unlike other methodologies like blood lactate and oxygen consumption, heart rate monitoring eliminates the issue of interfering with the player's routine in order to analyze the most accurate responses. By using heart rate monitoring systems, coaches are able to see how well their prescribed training goals meet the actual athlete's physiological responses. Subsequently, the coaches then have the ability to adjust training volumes to reflect game settings to optimize performance as well as individualize programs based on each athlete's current fitness levels.

TABLE 1. Descriptive Characteristics of the Soccer Players (n = 9, mean ± SD)

Variable[a]	Value[a]	Range
Age (years)	20.5 ± 0.3	19 - 22
Height (cm)	172.2 ± 1.3	167.6 - 175.3
Body mass (kg)	66.9 ± 1.7	57.4 - 74.1
BMI	22.6 ± 0.5	19.8 - 24.1
APMHR	199.4 ± 0.3	198 - 201

[a] Values are means ± standard deviations

TABLE 2. Descriptive Characteristics of the Basketball Players (n = 9, mean ± SD)

Variable[a]	Value[a]	Range
Age (year)s	20.3 ± 0.3	19 - 22
Height (cm)	178.4 ± 2.3	170.2 - 193
Body mass (kg)	73.3 ± 3.4	54.6 - 89.5
BMI	22.9 ± 0.8	18.2 - 25.7
APMHR	199.7 ± 0.3	198 - 201

[a] Values are means ± standard deviations

TABLE 3. Mean Comparison of Soccer Player's Physiological Variables

Variable	T1 (n=9)[a]	T2 (n=9)[a]	T3 (n=9)[a]
Training Load (AU)	147.1 ± 63.3	149.6 ± 36.4	239.1 ± 112.4*
Energy Expenditure (kcal/min)	10.3 ± 3.4	9.8 ± 2.3	8.8 ± 2.8
Average Heart Rate (bpm)	143.6 ± 21.4	136.9 ± 19.2	133.8 ± 16.8
Max Heart Rate (bpm)	192.3 ± 11.2	188.1 ± 2.5	195.7 ± 24.3
Percent in Z1 (%)	23.6 ± 24.7	24.2 ± 18.4	40.3 ± 17.6
Percent in Z2 (%)	19.9 ± 6.9	20.0 ± 7.0	17.9 ± 6.5
Percent in Z3 (%)	22.5 ± 6.5	21.7 ± 8.1	13.7 ± 2.7*
Percent in Z4 (%)	17.0 ± 9.9	22.2 ± 6.7	15.0 ± 6.7
Percent in Z5 (%)	17.1 ± 14.7	11.8 ± 6.5	13.1 ± 12.2

[a]Values are means ± standard deviations

***Significantly different at p < .05

TABLE 4. Mean Comparison of Basketball Player's Physiological Variables

Variable	T1 (n=9)[a]	T2 (n=9)[a]	T3 (n=9)[a]
Training Load (AU)	159.4 ± 60.6	172.3 ± 28.8	239.6 ± 125.7
Energy Expenditure (kcal/min)	15.4 ± 3.6*	11.2 ± 1.9*	9.7 ± 3.0*
Average Heart Rate (bpm)	159.4 ± 21.1	148.0 ± 7.4	134.6 ± 21.9*
Max Heart Rate (bpm)	201.8 ± 15.8	199.8 ± 17.2	197.3 ± 13.8
Percent in Z1 (%)	13.0 ± 22.1	19.5 ± 10.6	44.0 ± 28.9*
Percent in Z2 (%)	12.9 ± 9.0	20.3 ± 3.8*	13.4 ± 5.7
Percent in Z3 (%)	15.5 ± 8.0	20.1 ± 6.3*	11.3 ± 6.3
Percent in Z4 (%)	25.9 ± 10.0	23.9 ± 9.0	15.2 ± 7.1*
Percent in Z5 (%)	32.8 ± 21.1*	16.1 ± 9.4	16.1 ± 12.2

[a]Values are means ± standard deviations

***Significantly different at $p < .05$

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CHAPTER II

EXTENDED LITERATURE REVIEW

Introduction

Sport coaches have an objective to optimize their athlete's performance through implementing strategic training programs with the expectations of increasing physical fitness levels. The prescribed training required to achieve advanced performance and fitness levels is vastly dependent on the coach's personal experience and expertise (4). Research has shown increasing training loads will elicit overall enhancement in performance (2, 4, 5, 9, 18, 20, 23, 27). The physical, external demands placed on the body will force the body to adapt to the new heightened stimulus by which increases internal, physiological responses. The quantification of the outcome measurements (e.g., volume of load lifted, distance traveled) from external stimuli is referred to as external training load (6, 10, 11, 24, 26). The physiological training adaptations, both positive and negative, that occur as a result of the external stimuli or training load is referred to as the internal training load (6, 10, 11, 24, 26).

There is currently no gold-standard method in assessing the internal training load (4, 11, 18, 24); however, the current literature presents numerous of techniques that have been utilized in an attempt to quantify internal training load in endurance athletes, individual sport athletes, team sport athletes, and ball sport athletes. The techniques that have been performed are separated into directly measured variables and indirect or self-perceived variables (24).

Gauging Exercise Intensity: Directly Measured Variables

Oxygen consumption (VO_2) has been known to be a major contributor when assessing one's fitness level. Some factors can affect VO_2 such as level of physical activity, age and disease (4). VO_2 represents the metabolic rate which is directly proportional to training intensity (18). Specifically, VO_2 and exercise work rate have a linear relationship, making it a valid measurement tool for assessing exercise intensity (4, 14,). VO_2 should be expressed in relative terms in comparison to absolute when discussing exercise intensities (4). Research has generally accepted the linear increase during steady-state exercise but there have been inconsistent results in supramaximal and interval exercise bouts (4). Xu and Rhodes (1999) found that performing below lactate threshold has produced exponential increases in VO_2, but exceeding above lactate threshold VO_2 becomes more complex. Further, Hopkins (1998) indicates that measurements of oxygen consumption only provide information on the intensity of steady-state exercise, which can be less appropriate in quantifying training load for intermittent team sports such as soccer and basketball.

The nature of measuring and analyzing oxygen consumption requires the use of a metabolic cart in a laboratory setting for accurate measurements (7, 14, 16). This involves the athlete to breathe into a special sensor device that allows the inspired and expired air to be collected and analyzed through the corresponding software. This method can be unrealistic for athletes who must execute practice drills or perform in competitions outside of a laboratory-based environment (e.g., soccer, basketball, volleyball). The advancement in technology has allowed portable oxygen analyzers to be available to eliminate the requirement of being in a lab setting (2, 14, 16). However, the portable analyzer still does not solve the issue with collision sports (2).

Little research has directly examined oxygen consumption during games since the collection of data would cause interference (2, 7). Some attempts have been in soccer to replicate activity in laboratory environments of both soccer-specific field tests and intermittent high intensity bouts alternating with static recovery (2, 7, 16, 20). Drust, Reilly, and Cable (2000) developed laboratory-based intermittent protocols that would represent match-play work rates. The aim of the study was to analyze each subject's physiological response and compare the soccer-specific drills to steady-rate exercise performed at the same average speed. The results were successful and showed no significant differences in physiological responses between the soccer-specific drills and steady-rate exercise. Some limitations described by the authors included the inability to perform game skills (e.g., kicking, heading, tackling), elimination of utility motions (e.g., backwards and sideways walking/jogging), and less frequent activity changes (7). Further research is needed to test game skills, which may require higher oxygen demands (7, 16, 20).

The assessment of blood lactate concentration in athletes has grown in interest to evaluate exercise intensity. The concept of analyzing blood lactate concentrations (BLC) is providing the estimation of anaerobic glycolysis metabolism (14, 21). Moderate intensity exercise produces a steady state value in lactate, while higher intensity activities produce an increase in blood lactate (4, 14, 22). The point at which the body achieves a maximal, steady-state workload in blood lactate levels is referred to as anaerobic or lactic threshold (around 4 mmol·L) (4, 14). Assessing lactate levels during exercise or athletic sport practices requires either retrieval of blood from either finger pricking or earlobe puncture (4, 14, 21, 25). Following the collection, the samples are either placed into a portable analyzer or a calibrated machine lactate analyzer.

Scanlan, Dascombe, Reaburn, and Dalbo (2012) investigated the competition physiological and activity demands experienced by Australian female basketball players over the course of eight matches. Heart rate and blood lactate concentration (BLC) were the two variables assessed to examine the physiological responses while time motion analysis (TMA) examined the activity demands. All of the participants wore heart rate monitors throughout all eight competitive matches that synced up to the corresponding computer software. BLC included blood drawn from the earlobe in a capillary tube exclusively during substitutions and between each quarter. No samples were taken during time-outs. TMA was set up for each game using a frame-by-frame manual tracking system to be analyzed post-game. The authors analyzed all of the following through the TMA technology: standing/walking, jogging, running, sprinting, low shuffling, high shuffling, dribbling, jumping, and upper-body movements. Collected heart rate data was then corresponded to the TMA to identify match stoppages and team substitutions in order to calculate true heart rate responses for live and total match time (25).

Overall, Scanlan et al. (2012) found that player activity demands were similar throughout match periods. Specifically, they found that approximately 39% of the time players were at low intensity and about 52%, 5% and 4% at moderate intensity, high intensity, and dribbling, respectively. These results show that high intermittent demands as well as both anaerobic and aerobic metabolic pathways are utilized during competition. Matthew and Delextrat (2009) found similar results in their study using the same physiological (i.e., heart rate) and activity (i.e., TMA) testing variables.

The physiological assessment of BLC provides beneficial information to team sports that include both aerobic and anaerobic activity. However, there are limitations when using BLC as measurement for exercise intensity. BLC sampling is very invasive and is extremely difficult to collect during matches, which explains the limited research of lactate levels during game play for team sports (2, 24, 25). There are many factors that can affect the outcomes of lactate sampling such as carbohydrate ingestion, muscle damage, diet, dehydration, previous exercise, mode of exercise, and ambient temperature. (4, 11, 14, 18). If a team decides to perform lactate analyzing tests, a major issue to consider is the potential of false or inaccurate results (25). The professional performing the test is not allowed to interfere with the competitive matches in order to retrieve the samples, which results in taking samples during breaks (2, 21, 25). This procedure may not reflect the overall physical demands due to the collection of blood not being taken during the match plays instantaneously (2, 21, 25). It has been presented as a more appropriate measurement for endurance athletes where controlled environmental conditions are available (4).

Stress exerted on the body during physical training produces biochemical changes. These changes can modify bodily fluids such as blood and saliva (11-13, 17, 22, 24). Analyzing the changes that arise through blood and saliva sampling can provide valuable information to identify biomarkers of work load, recovery, muscle damage, and injury (11-13, 17, 22, 24). Research indicates that measuring salivary levels is a less invasive method to evaluate exercise intensity in comparison to blood lactate concentration (12, 22, 24). Examples of salivary analytes to measure are total protein concentration, alpha-amylase, electrolytes, creatine kinase, lactate, cortisol, testosterone, and catecholamines (11-13, 17, 22, 24).

In particular, cortisol, testosterone, salivary alpha-amylase, and total protein concentration have been shown to be valid and reliable markers in assessing training stress (11-13, 17, 22, 24). Cortisol tends to significantly increase in response to exercise training prior to and during competition (12, 13, 17). Additionally, the relationship of assessing cortisol via blood serum and salivary have a correlation range of r = 0.60-0.97 (12, 17). Sex should also be considered when determining which salivary hormones to assess since cortisol is a more appropriate hormonal biomarker of stress in women due to less influence from the menstrual cycle (12). Genner and Weston (2014) indicate that there has been a lack of strength in correlation when measuring the relationship between workload and salivary cortisol. The process of collecting samples from saliva involves obtaining values at designated time slots (e.g., pre-competition, post competition, pre-practice, post-practice) and immediately freezing the specimen after collection until examination (12, 17, 22). The analysis of the samples requires the use of a saliva/enzyme sampling immunoassay (12, 13, 17, 22).

Kraemer, French, Paxton, Häkkinen, Volek, Sebastianelli, Putukian, Newton, Rubin, Gómez, Vescovi, Ratamess, Fleck, Lynch, and Knuttgen (2004) examined the changes in physical performance and hormonal concentrations over a Big Ten soccer season (11-weeks) in both starters and nonstarters. There was a total of six tests performed (including baseline) that involved a series of performance tests (i.e., isokinetic strength of knee flexors and extensors, isometric strength of knee extensors, maximal vertical jump, and 20 meter sprint), body composition analysis (i.e., 7-site skinfolds) and hormonal concentrations (i.e., cortisol and testosterone) (17).

Over the course of the 11-weeks, the authors found nonstarters had significantly increased in body fat from the first to last test. Isokinetic strength of knee extensors was decreased in both starters and nonstarters. However, sprint speed and vertical jump only decreased in the starters. Possible reasoning could indicate that the starters were under a greater amount of physical stress due to increased playing time over nonstarters (17). Cortisol was elevated significantly in both groups at the first and fourth tests while remaining elevated by the last test. Similarly, testosterone was higher in the both groups but significantly at the third and last tests (17).

The authors concluded that players who tend to start a season with elevated hormones (i.e., cortisol and testosterone) are at a greater risk of diminished performance without appropriate rest and recovery. The catabolic processes that potentially occur throughout a sport season can result in decrements in muscular force, speed, vertical jump height, and strength, regardless of starters or nonstarters. Continuous assessments of testosterone and cortisol levels are a valid method to monitor and observe the stress and catabolic adaptations during training and competition (17). Haneishi, Fry, Moore, Schilling, Li, and Fry (2007) and Hoffman, Kang, Ratamess, and Faigenbaum (2005) found similar results with salivary cortisol in female collegiate soccer players and creatine kinase in intercollegiate football players, respectively.

It is clear that hormonal evaluations are an easy, feasible method to provide information on the physiological responses resulting from physical training. The cost of completing salivary hormone analyses can be time consuming and expensive without the correct equipment (11). Sampling cannot be collected during competition settings in order to avoid interference. Other factors can affect the results from the saliva samples such as conditioning activities, practice schedules, academic demands, psychological stressors, and competition (17). Further research is necessary to determine the reliability and validity of the method in chronic physical activity as well as the influence of psychological stressors (17, 22, 24).

Heart rate is one of the most common methods to assess internal training load and exercise intensity in athletes (4, 11, 24). The assessment of heart rate is a non-invasive method to administer that can monitor and store values with high reliability (2, 19). There is an existing linear relationship between VO_2 and heart rate during steady state exercise (2, 4, 11, 14). Little and Williams (2007) and Drust et al. (2000) have shown that heart rate is a valid measurement in comparison to VO_2 during continuous exercise when the primary objective is to gauge exercise intensity and metabolic expenditure during activity. However, there has been inconsistent research to conclude the validity during intermittent drills in field settings to practice settings attempting to reflect a match (2, 7).

When estimating and prescribing exercise intensity, percent heart rate max (HRmax) is the most popular method utilized (4, 11, 14). Unfortunately, research has shown that HRmax is not a valid method in comparison to the Karvonen formula or heart rate reserve (HRR). HRR takes into consideration individual resting heart rate, age and fitness level (2, 4, 14). Research has concluded that supplementing heart rate with other variables such as blood lactate concentration and RPE improves the validity of the measurement (2, 24).

Wrigley, Drust, Stratton, Scott, and Gregson (2012) investigated the typical weekly training load in elite junior soccer players during a competitive season through heart rate and RPE. The participants included the three following age groups: under 14 years, under 16 years and under 18 years. A maximal Yo-Yo intermittent test was administered to retrieve individual max heart rate in order to use percentage max heart rate for gauging exercise intensity.

The researchers found there was no difference in mean heart rate during matches. However, the weekly periodization varied between age groups, specifically as the age increased there was an increase in intensity (28). It was also observed that the average heart rate in matches were higher than the average heart rate during practices or field training. This indicates that match settings require a higher physiological and physical demand than practice settings (28).

Matthew and Delextrat (2009) investigated the physiological demands and movement patterns in female basketball players. At the time the study was conducted, there was a change in the rules of basketball games by decreasing both the shortening attack time and the time allotted to cross the median line (21). The researchers wanted to examine any potential metabolic responses that could result from the rule change. The participants were nine female basketball players from a top ranking team in the British University Sports Association Premiere League. Prior the initial start of the study, height (m), body mass (kg), and body fat via bioelectrical impedance analysis (BIA) were administered. Subsequently to the anthropometric measurements, the subjects performed a discontinuous incremental treadmill test to determine maximal heart rate, maximal blood lactate concentration, maximal aerobic speed, and lactate threshold (21). During the matches, heart rate, blood lactate concentration and time-motion analysis data were collected.

The authors found differences in physiological responses in comparison to previous studies using the old basketball game rules. Maximal heart rate achieved was higher in this study than the current published literature with the old rules, 89.1% and 84.5% of max heart rate, respectively (3, 21). However, the mean heart rate in the current study was slightly lower than values previously reported. The researchers noted results could have been influenced from confounding variables such as playing standard/level, player's physical fitness, higher recordings of heart rate in players, etc. (21). Another significant finding was the differences in the first and second half of the game with the first half presenting higher values. A potential explanation of the lower heart rates during the second half is more frequent rest periods allowed during the fourth quarter, such as time-outs and free throws (21). Prior to this study, no blood lactate concentration samples were collected in previous research with the old game rules. However, the results from the present study have been reported similar to values seen in elite male Tunisian players and elite female Spanish basketball players (21).

There are some limitations that should be discussed when assessing heart rate responses for quantifying internal training load. Psychological factors (e.g., emotional stress, anxiety, and adrenaline) can influence the heart rate responses to display high values (2, 21, 24). The following factors can also pose as a threat to retrieving accurate results if not controlled: altitude, humidity, environmental conditions, state of training, duration of exercise, player position, hydration status, altitude, nutrition, hormonal variations, high tensile strain, diurnal changes, and medications (2, 4, 11, 20, 21, 24-26). Furthermore, it is not a valid method to estimate overtraining in athletes due to a variation in heart rate responses up to 6.5% ($\pm$ 6bpm) as well as during discontinuous high intensity training (2, 4, 11, 24, 26). It can be concluded that heart rate monitoring improves its validity when supplemented with other physiological assessments, which the most commonly used methods are blood lactate concentration and RPE (2, 4, 24).

Gauging Exercise Intensity: Indirect, Self-Perceived Measured Variables

The understanding that athletes can intrinsically monitor the physiological stress their bodies experience during exercise is referred to as rating of perceived exertion (RPE) (4, 11). Athletes have the capability to regulate their training intensity using their own perception of effort (4). Previous research has used this method most often with monitoring heart rate during steady-state exercise and high-intensity interval cycling (4, 11). Additionally, heart rate, lactate and VO_2 responses are strongly correlated with RPE (4, 11, 20). However, inconsistent correlations have been found using heart rate to gauge intensity during short-duration, high-intensity soccer drills (4, 11, 20). There are various methodologies (e.g., Bannister's TRIMP method and Foster's RPE-session) utilized that are derived from RPE to quantify exercise intensity and training loads.

Little & Williams (2007) examined the physiological responses during match games in professional soccer players. The authors selected heart rate and Borg's 6-20 RPE scale as the monitoring tools. Moreover, the data collected would also be used to assess the validity of heart rate in comparison to RPE to measure exercise intensity during various soccer training drills (20). The authors hypothesized that Borg RPE will elicit more accurate overall reflection of exercise intensity during soccer drills while heart rate will underestimate drills that involve near-maximal intensity (4, 20).

The results presented heart rate as a valid method of monitoring training intensity in soccer games with a couple of limitations (20). Heart rate had underestimated the responses seen during shorter, more intense drills, especially in 2 vs. 2 drills. Also, the responses in heart rate were not instantaneous during maximal intensity drills. Contrary, RPE appeared to be an inexpensive, quick, valid indicator for exercise intensity during all the soccer drills tested (20). One limitation mentioned by Little & Williams (2007) was the individuals perceiving the same drills performed differently because of their psychological state. The authors briefly explained the differences in perceived intensity could be a potential sign of overtraining. It can be summarized from this study that heart rate is a valid method of monitoring during when avoiding short-duration and high intensity bouts, but when combined with RPE it may be advantageous (11, 20).

An alternative method to observing RPE alone during training sessions is evaluating session-RPE. Foster, Florhaug, Franklin, Gottschall, Hrovatin, Parker, Doleshal, and Dodge (2001) used male collegiate basketball players to examine the ability of session-RPE to quantify training load during both steady-state and high intensity training based on heart rate as a reference tool. The first part of the study involved each participant to perform a maximal incremental exercise cycling protocol to assess power output, oxygen uptake, and peak VO_2 values. At the end of each stage, blood lactate was measured in order to calculate both individual anaerobic threshold (IAT) and recovery blood lactate concentrations. Following the maximal cycling test, all the subjects performed the eight different exercise bouts selected at random that incorporated three variations in steady-state durations (i.e., 30-, 60- and 90-minutes) at each individual's 90% IAT power output and five interval, 30-minute bouts with variations in magnitude (power output) and interval duration (8). Throughout all eight exercise bouts heart rate was measured and based on percentages of heart rate peak, while blood lactate samples and RPE were obtained at rest and at every 10-minute interval. Subsequently, an exercise score was calculated by multiplying the duration of each bout by the corresponding session-RPE. A second exercise score was calculated by multiplying the accumulated duration in each heart rate zone by a multiplier for each zone (i.e., 50-60% = 1; 60-70% = 2, 70-80% = 3, 80-90% = 4; and 90-100% = 5).

The second part of the study performed an Astrand protocol incremental treadmill test until volitional fatigue (8). Ventilatory and respiratory responses were assessed by the changes in slopes of the VCO_2 versus VO_2 and VE versus VCO_2 relationships. Additionally, heart rate was examined using radiotelemetry. The subjects were expected to wear the heart rate monitors during basketball practice sessions and/or competitive matches based on the coach's preference. Heart rate responses were downloaded to a corresponding software and analyzed using the summated heart rate zones approach as in part 1 of the study (8). Thirty-minutes after every session, the subject used the RPE method to rate the overall difficulty of that particular training session to calculate the session-RPE value similarly as in part 1 of the study.

The authors found a strong correlation between session-RPE and the pre-determined heart rate zones during the practice and/or match settings. This conclusion supports that both calculated session-RPE methods used in this study can be utilized to evaluate training sessions (8). The overall similarity between objective (heart rate zones) and subjective (RPE values) methods of monitoring training during various types of exercise suggests that session-RPE method may be appropriate over a wide assortment of exercise sessions. Moreover, the authors conclude that the calculated session-RPE method is a simple and useful assessment tool to quantify the training load during non-steady state exercise, high intensity training, and team sport practice and matches (8).

Other studies (1, 4, 9, 11, 18, 23, 26, 28) conducted using the combination of heart rate responses and RPE have also confirmed that it is a valid method to estimate training loads through a wide variety of individual sports, team sports, and general exercise. Bannister's TRIMP method is a popular method used to assess exercise intensity and training load with a correlation range between r = 0.50-0.77 in soccer players (15). The Borg 6-20 scale has been shown to be a valid measurement tool for exercise intensity, but only moderately strong correlations with other physiological variables such as heart rate (r = 0.62), blood lactate concentration (r = 0.57), percent VO_2max (r = 0.64), VO_2 (r = 0.63), VE (r = 0.61), and respiratory rate (r = 0.72) (1, 4). In relation to resistance training, further research is necessary in order to conclude RPE as a valid assessment tool to gauge intensity and training load (4, 18).

The use of questionnaires is one of the simplest methods to retrieve subjective information on training load, exercise intensity, injuries, illnesses, and physical and physiological well-being (4, 11, 24). Methodology requires the athlete to recall the executed physical tasks during the past week, month or even years (4, 11). Questionnaire assessments are feasible because they are easy to administer, cost-effective, does not interfere with training, and has the ability to test large populations (4). It is essential to note the importance of ensuring the athletes to record data immediately following the training in order to avoid information escaping one's memory (4, 14).

Subjective measures can also have disadvantages. As mentioned previously, memory recall is essential and can be the greatest contributor to inaccurate results (4). Borresen and Lambert (2009) mentions another study that investigated the relationship between what athletes perceive they perform in training and what they actually perform. The authors found that twenty-four percent of the participants over-estimated the training duration while seventeen percent underestimated. Reliability of the subjective data decreases as the duration between the performed activity and the recording of data increases (4).

Moreover, there are factors that must be considered when designing questionnaires to avoid "questionnaire fatigue" such as frequency of administration, time taken to answer provided questions, sensitivity of the questionnaire, response type (e.g., written answers, multiple choice), time of day when questionnaire is administered, and amount of time necessary to provide appropriate feedback (4, 11). Other factors that can influence the circumstances of the athlete taking the questionnaire are motivational, psychological, and physical effects of the individual. To summarize, when determining to use questionnaires/diaries as an assessment tool, it should be considered to also incorporate measurement of physiological variables to assess training prescription (4, 11, 24).

Summary

There is currently no gold-standard method to assess training load (external) and physiological responses (internal) (4, 11, 18, 24). Research continues the investigation in determining the most valid and reliable physiological variables to assess in order to retrieve accurate information on internal training load. There have been numerous attempts to quantify the relationship of external and internal loading through the use of laboratory equipment (e.g., metabolic carts), portable devices (e.g., heart rate monitors) and individual subjective information (e.g., RPE). To determine the best monitoring assessment tool, one must consider a variety of factors such as feasibility, convenience, cost, time availability, education and/or experience with the selected method (if needed), and equipment accessibility. Subsequently, the coach can optimize their athlete's performance by developing individualized programs to implement into training regimens based on each athlete's current fitness levels and physiological responses. From the coaches' perspective, the most feasible and frequently used monitoring measurements are HR, HRV, and RPE, which are frequently used in combination with the duration of the training session (24). Further research is necessary in order to determine a conclusive statement on the assessment of the physiological responses and adaptations of daily training loads in all sport-types (e.g., endurance, individual, team, and ball sports).

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APPENDIX

CONSENT FORM

Data Use for Research Purposes:

The analysis of an athlete's physical responses during team practices/games and during scheduled strength and conditioning sessions is not only important for performance development but it's also important in assessing the health and wellbeing of the athlete. The goal of this research study is to analyze the heart rate training responses in Division I Collegiate Athletes. Your heart rate activity previously recorded during prior team practices and games and during your previously scheduled strength and conditioning sessions will be examined. Specifically, your training heart rate, accumulated heart rate training load, total time in heart rate intensity zones, recovery rate against total training load, and weekly caloric expenditure will be examined. The data that will be used for this project will come from the archived/stored data that has been previously recorded in the Polar Heart Rate Team2 Software System.

What Additional Expectations Are There For Your Participation?

Nothing more, other than providing your consent. We are not asking you to do anything additional than what you have already done during previous team practices and strength conditioning sessions. If you agree to allow your data to be used, we only need you to sign this informed consent form and return it back to us.

Risks & Benefits:

Risks. There are no risks associated with your involvement in this study given that the data being examined is archived/stored data within the Polar Team2 Heart Rate Monitoring System. Your information will be completely confidential. In other words, your name will not appear anywhere on the results produced from this research and only the principal investigators will have access to the data.

Benefits. There are no direct benefits to you in having your data included for research purposes. However, your information will help to better understand the athlete's physical responses during team practices and games and during scheduled strength and conditioning sessions. As a result a clearer picture of sports performance development and also a better understanding of how to assess the health and wellbeing of the athlete will be attained.

Voluntary Participation & Confidentiality:

Participation. Your participation in this study is completely voluntary and done so at your own choosing/desire. If you decide to have your data included for research purposes, sign/return this form and your data will be included in this research project. If you decide NOT to have your data included for research purposes, DO NOT sign/return this form and the data will be left out of the research project. Additionally, it is important for you to know that the strength and conditioning coaches/staff and the your team's sport coach will not be informed as to if you do or do not agree to participate in this study.

Confidentiality. Your information will be handled confidentially. Your name will not appear in any of the publications/presentations that result from your involvement with this research project. All data will be kept in a locked file within the principal investigator's office.

Who to contact if you have questions about the use of data for research purposes:

Dr. Dale D. Brown at (309) 438-7547 or Maria Canino at (708) 253-7983 within the School of KNR at Illinois State University, Normal, IL 61790-5120.

Who to contact if you have questions about your rights in the study:

Additional questions can be directed to the ISU Research Ethics & Compliance Office at (309) 438-2529. The Research Ethics & Compliance Office can also answer questions about your rights as a participant.

If you agree to allow your data to be included in the research study described above, please sign and date this form, and return the form to the principal investigators.

Name (please print)

Signature

Date