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Individual variation in physiological training load during a division III soccer season

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ABSTRACT

This study was performed to evaluate the effect of soccer training during a DIII soccer season on the physiological response of training load. Training load was assessed by tracking individual player heart rates during all training sessions and games. Training load was scaled for each player throughout the season and average responses were characterized for individual positions.

INTRODUCTION

In recent years, many elite athletic programs have shifted towards a more scientific approach in designing and monitoring their training programs. This trend has been slow to spread to athletics at the collegiate level, and even slower to division III programs. This disparity is due, in large part, to insufficient resources. Following the donation of a training monitoring system on behalf of Dr. Tyler Bosch from the University of Minnesota Educational Technology Innovations, the Saint John's University men's varsity soccer team became one of the first known DIII athletic programs to engage in daily heart rate monitoring.

Training load can be divided into two categories: external or internal. External training load expresses the work an athlete completed, regardless of any individual characteristics (Wallace, 2009). In soccer, this would be the same volume of work physical output performed by each member of the team during a training session. Conversely, internal training load reflects the physiological load imparted on the individual level; so, each member of the team would have a different internal load at the end of a team training session. A combination of both external and internal training load is suggested for the most accurate assessment of an athlete's level of fatigue.

Monitoring heart rate is one of the most commonly used methods of assessing athletes' training load. (Borresen, 2008). Evaluation, and subsequent modification, of training load is one of the most effective methods of athletic performance improvement (Halson, 2014). Variation in external and internal training load has been related to changes physical fitness performance, and as such, training load quantification has been implemented widely in elite soccer programs (Los Arcos, 2017).

By altering variables such as frequency, duration, and intensity, fatigue can be increased or decreased to fit the goals of particular training sessions. This management of fatigue is essential not only for optimizing competition performance and determining if athletes are adapting to training programs, but also for reducing athletes' proneness to injury and illness (Thorpe, 2017).

Periodization refers to the intentional variation of training with the aim to optimize competitive performance. Team periodization strategies have been relatively unexplored, but it is thought that varying the degree of training is more specific to the individual than the team (Gamble, 2006). In soccer, group exercises can have vastly different training demands between individuals due to the different physical components required of each position; a significant difference in work rate has been found between players of different positions in professional soccer (Di Salvo, 2006). Even further, external training loads have the potential to produce different internal loads in each player simply due to individual variation (Jaspers, 2017). These variations (positional and individual) can make it difficult to optimize individual training load prescriptions.

So, within a single team, there can be a large amount of variation in external and internal training load between individuals (Manzi, 2009). This variation increases when a team has a consistent group of 11 starting players, leaving the rest of the team not exposed to the heightened training load of a competitive match (Los Arcos, 2015). Competitive matches have been shown to be the most physically demanding session of a typical in-season week resulting in the greatest training load; this suggests that training load differences between starters and non-starters can be attributed to competitive matches (Kraemer, 2004).

Therefore, the aim of this study was to determine the effect of team training on the physiological effect of individual training load over the course of a DIII soccer season.

METHODS

Participants

Twenty (age 18 – 22) DIII soccer players from Saint John's University agreed to participate in this study. Within this group, there were 8 center midfielders (CM), 2 central attacking players (T), 6 wide attacking players (W), and 4 central defenders (CB). All athletes were members of the men's varsity soccer team during the 2016 season.

The players trained an average of 6 days a week throughout the season. There was an average of 2 training sessions between each competitive match. Training sessions consisted mainly of a warmup exercise, technical-tactical skill development, and small-sided games.

Experimental design

The players were each assigned a heart rate monitor that was worn on a chest strap during every training session and competitive match. Live heart rate data was recorded every 5 seconds (Polar Team System, Polar Electro Oy, Kempele, Finland) and loaded on a PC Polar Team software.

During each training session, the data was segmented and noted with each drill name and type. The same procedure was followed for competitive matches marking the beginning and each of each half. At the end of each recording, the data set was exported and saved as an electronic spreadsheet (Excel, Microsoft Corporation, USA).

Data Analysis

Statistical analysis was performed using RStudio (RStudio, Inc., Boston, MA). The main test used to determine statistical significance analysis of variance (ANOVA) using a p value of 0.05 for significance. A Tukey's test was also used in conjunction with the ANOVA.

RESULTS

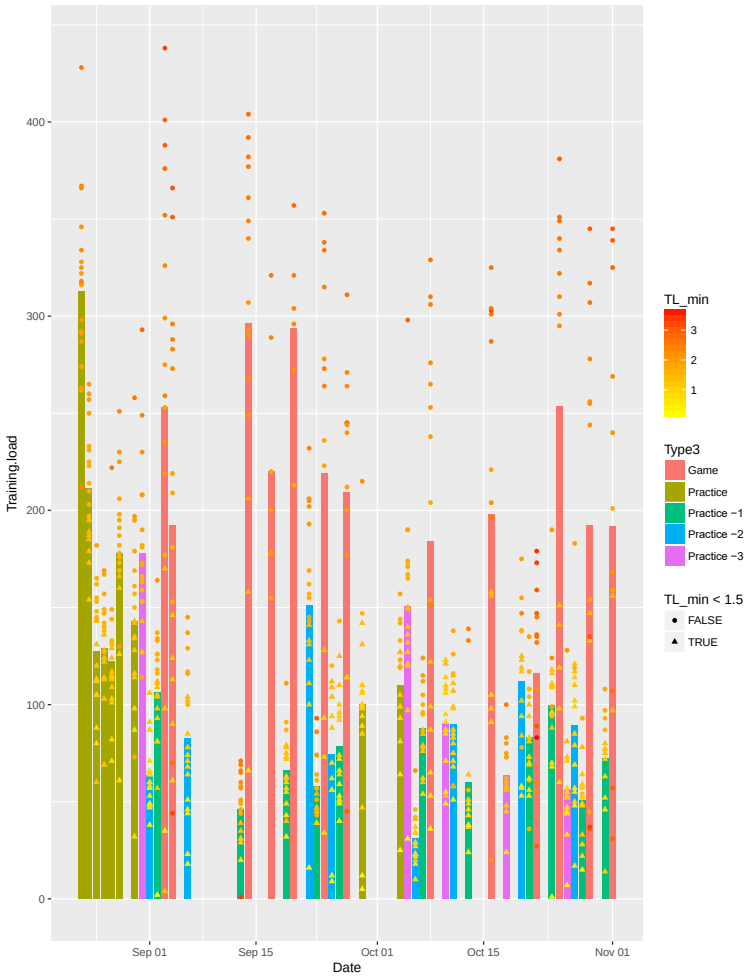

Figure 1: Average volume (TL) during training sessions arranged by date and session type. Each data point corresponds to an individual athlete's average volume (TL) completed on that day.

Table 1: Average volume (TL) during training sessions for individual players by session type arranged into statistically significant groups

	Statistically Signifcant			*Statistically Signifcant*											
Player	**Game**			**Practice -1**			**Practice -2**			**Practice -3**			**Practice**		
	Average TL	**Std. Dev.**	**Group**	**Average TL**	**Std. Dev.**	**Group**	**Average TL**	**Std. Dev.**	**Group**	**Average TL**	**Std. Dev.**	**Group**	**Average TL**	**Std. Dev.**	**Group**
Rocky Harmon (CM)	324.5	62.7	a	73.4	30.5	ab	98.3	39.3	a	142.3	60.3	a	182.8	78.1	a
Justin DuQue (CB)	290.2	95	ab	77.5	20.7	ab	72.3	47.8	a	100.5	78.1	a	130.3	81.5	a
Dylan Lehrer (CB)	289.8	101.2	ab	63.3	26	ab	63.6	35.7	a	112	55.1	a	146.6	38.1	a
Ryley Sullivan (CB)	278.1	57.9	abc	70.9	25.2	ab	84.6	48.7	a	124.5	59.7	a	165	65.1	a
Nick Van Marter (CM)	266.4	129.9	abc	75.8	33.1	ab	47	25.2	a	96.3	73.7	a	147.8	76.2	a
Jose Cabrera (CM)	266	70.2	abc	71.2	29.6	ab	90.3	47	a	156.5	9.2	a	147.8	59.6	a
Uriel Cordoba (CM)	226.2	111.8	abcd	63.6	24.8	ab	74.5	46.9	a	108	47.4	a	145.6	94.9	a
Zack Boerjan (W)	218.8	62.7	abcde	47.3	24	b	76	32.8	a	87.8	48.9	a	146.2	86.6	a
Daniel Bruckbauer (W)	217.7	62.7	abcde	60.8	38	ab	71.4	22.6	a	112	21.2	a	135.8	84	a
Tyler Street (CM)	199.6	83.3	abcde	49.4	33.7	b	69	28.4	a	113.4	112.4	a	158.2	74.1	a
Sam Newman (W)	198.6	55.5	bcde	67.7	23	ab	96.3	38.1	a	95.4	47.8	a	163.7	64	a
Nic Kramer (W)	166.6	65.8	cde	83.5	48.5	ab	97.1	47	a	143	71.6	a	176.2	66	a
Rene Cabrera (CB)	161	95.3	cde	69.9	37.1	ab	89	42.8	a	102.5	54.9	a	153.1	80	a
Thomas Bell (CM)	161	178.2	cde	73.3	27.6	ab	72.4	29.5	a	114.4	46.4	a	159.2	40.6	a
Andrew Weiler (CM)	140.6	83.5	cde	82.5	21.3	ab	105	57.9	a	116.8	70.3	a	169	82.4	a
Zach Wright (W)	112.6	73	de	71	26.5	ab	53.3	26.7	a	87.4	53.8	a	160.1	79.8	a
Ben Becker (T)	94.9	43.2	e	75.8	24.6	ab	114.2	67.2	a	131.8	38.8	a	147.6	105.4	a
Ben Thompson (T)	62	37.4	e	108.4	26.8	a	135.7	67.5	a	165.7	72.3	a	221.1	106.3	a
Joel Baeza (W)	61	NA	e	111	35.1	a	103.7	62.8	a	146.6	91.9	a	179.7	50.9	a
Jerry Havens (CM)	17.5	19.1	e	100.4	28	a	118.7	50.5	a	107.3	60.9	a	178	62.5	a
Number of Groups			6			3			1			1			1

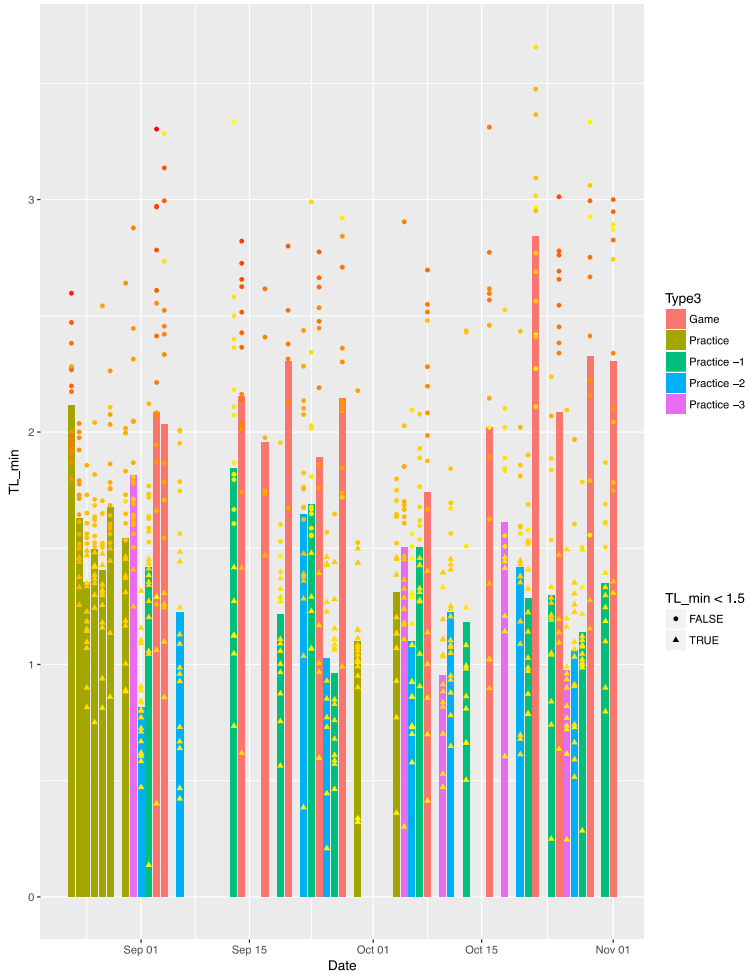

Figure 2: Average intensity (TL/Min) during training sessions arranged by date and session type. Each data point corresponds to an individual athlete's average intensity (TL/Min) completed on that day.

Table 2: Average intensity (TL/Min) during training sessions for individual players by session type arranged into statistically significant groups

	Statistically Signifcant			*Statistically Signifcant*			*Statistically Signifcant*						*Statistically Signifcant*		
Player	**Game**			**Practice -1**			**Practice -2**			**Practice -3**			**Practice**		
	Average TL/Min	**Std. Dev.**	**Group**	**Average TL/Min**	**Std. Dev.**	**Group**	**Average TL/Min**	**Std. Dev.**	**Group**	**Average TL/Min**	**Std. Dev.**	**Group**	**Average TL/Min**	**Std. Dev.**	**Group**
Rocky Harmon (CM)	2.8	2.4	a	1.3	0.2	bcd	1.4	0.4	abcd	1.5	0.4	a	1.7	0.3	ab
Dylan Lehrer (CB)	2.7	2	a	1	0.2	cd	0.8	0.3	cd	1.4	0.6	a	1.5	0.4	ab
Ben Thompson (T)	2.5	0.9	ab	1.8	0.5	ab	1.7	0.5	a	1.9	0.7	a	2.2	0.4	a
Justin DuQue (CB)	2.5	1	ab	1.5	0.4	abcd	1.2	0.5	abcd	1.1	0.7	a	1.3	0.5	b
Ryley Sullivan (CB)	2.4	2.2	ab	1.2	0.2	bcd	1.1	0.4	abcd	1.3	0.5	a	1.5	0.4	ab
Nick Van Marter (CM)	2.3	0.7	ab	1.3	0.4	bcd	0.7	0.2	d	1.1	0.5	a	1.5	0.4	ab
Uriel Cordoba (CM)	2.3	0.6	ab	1.2	0.4	bcd	1	0.4	abcd	1.3	0.3	a	1.4	0.5	b
Tyler Street (CM)	2.2	1.1	ab	1.1	0.9	cd	0.9	0.3	abcd	1.3	1	a	1.4	0.3	b
Jose Cabrera (CM)	2.2	1.3	ab	13	0.4	bcd	1.3	0.3	abcd	1.5	0.1	a	1.4	0.3	b
Rene Cabrera (CB)	2.2	0.6	ab	1.3	0.5	bcd	1.2	0.4	abcd	1.3	0.3	a	1.4	0.5	b
Jerry Havens (CM)	2.1	1.3	ab	1.9	0.4	ab	1.6	0.5	ab	1.6	0.4	a	1.6	0.4	ab
Zack Boerjan (W)	2	1.3	ab	0.9	0.3	d	1.1	0.3	abcd	1.3	0.4	a	1.3	0.4	b
Andrew Weiler (CM)	2	0.9	ab	1.5	0.6	abcd	1.2	0.5	abcd	1.5	0.6	a	1.5	0.4	ab
Daniel Bruckbauer (W)	1.9	1.1	ab	1	0.4	cd	0.9	0.2	abcd	1.5	0.5	a	1.3	0.5	b
Sam Newman (W)	1.7	1.2	b	1.2	0.4	bcd	1.3	0.3	abcd	1.1	0.3	a	1.5	0.3	ab
Ben Becker (T)	1.7	0.4	b	1.6	0.3	abcd	1.5	0.6	abc	1.8	0.3	a	1.5	0.6	ab
Nic Kramer (W)	1.7	1	b	1.6	0.3	abc	1.4	0.4	abcd	1.8	0.8	a	1.6	0.3	ab
Zach Wright (W)	1.7	0.6	b	1.2	0.4	bcd	0.9	0.3	bcd	1.1	0.5	a	1.5	0.4	b
Thomas Bell (CM)	1.5	0.4	b	1.4	0.4	abcd	1.3	0.4	abcd	1.5	0.2	a	1.5	0.3	ab
Joel Baeza (W)	0.9	1.3	b	2.1	0.5	a	1.4	0.6	abcd	1.8	0.7	a	1.7	0.3	ab
Number of Groups			3			6			5			1			3

DISCUSSION

Conclusions

There were two major conclusions drawn from the results of statistical significance tests. The first is that individual variation had a statistically significant effect on the volume of work performed during "Game" and "Practice -1". Secondly, individual variation had a statistically significant effect on the intensity of work performed during "Game", "Practice -1", "Practice -2", and "Practice".

Discussion

The statistically significant individual variance in volume of work performed during "Game" can be correlated with game minutes played; the players with the highest volumes were the athletes that played the most in that game. As expected, variance in volume the day before a game is relatively inversely related to game minutes played - this relationship is intentional to rest starting players the day before a game. The rest of the training sessions (practices more than one day before a game) had no statistically significant differences in volume of work performed showing that practice plans are prescribing an equal volume of work to all individuals.

In terms of training load per minute, individual variation in intensity of work performed during games can also be correlated with game minutes played. More so than volume of training, intensity patterns are greatly dependent on the athlete's status as a starter or a non-starter (Anderson, 2016). The exceptions to this trend can be explained by fitness level of the individual or individual physiological differences. Intensity levels for training sessions the day before a game mirrors the inverse relationship seen in volume of work, but with greater variation. As explained earlier, during all other training sessions beyond one day before the game, each athlete is performing the same volume of work; the variation in intensity on these days does not seem to be caused by positional differences, but rather individual fitness level or physiological differences. It is impossible to determine to cause of this variation without further information.

When comparing volume and intensity as indicators of athlete output and performance, intensity can be used as a much more effective marker than volume (Castagna, 2013). This is most applicable during pre-season training where the intent is to develop and improve aerobic fitness (Impellizzeri, 2006). However, these high-intensity training sessions are correlated with increased bodily strain and help to explain the higher incidence of training injuries during a precompetitive training period (Owen, 2015). The best way to prescribe appropriate training loads without increasing risk of injury appears to be live monitoring of heart rate variability to ensure players do no exceed their optimal training load (Coutts, 2009).

Recommendations

Based on the results of this study, I have developed two recommendations for the Saint John's University soccer program. The first involves training load (volume) during the practice session preceding a competitive game. In order to more firmly ensure starting players are not overworking themselves, a training load threshold should be established for each player based on anticipated playing time in the next day's game. This volume can be monitored live during the training session, and players can be removed from practice once they have hit their volume threshold. This recommendation will help to ensure that players with more game minutes are getting in a low-volume, high-intensity training session before a game.

The second recommendation I am making involves training load per minute (intensity). It has been shown that games are consistently the highest intensity session of the week; during elite soccer matches, the average intensity rests in the range of 80-9% of maximal heart rate (Castagna, 2011). There is also typically a lighter practice session the day before a game and a rest day following the game. So, the players beyond the top twelve to thirteen with the most playing time are missing out on that high-intensity game and also taking three days of "rest" in a row. This has the potential to result in detraining throughout the season, negating any conditioning work built during the off season. In order to combat this, I am recommending that players with limited gam minutes participate in an alternate training session the day after the game. The ideal training session would reach the average intensity of yesterday's game and stimulate match-like movements and performance. A small-sided game would be a great option for this alternate workout as it reaches a similar HR response as full matches and requires athletes to repeat high-intensity actions (Alexandre, 2012).

Limitations

This study was performed with a small sample size (n=20) and used only one season of heart rate data. In addition, the participants were athletes in a DIII program and the literature on soccer physiology and training periodization overwhelming comes from professional or elite programs; caution should be used when drawing connections between these two levels and structures of play.

We were also unable to export the heart rate data in segmented portions to more closely analyze games by halves and training sessions by drill type. Players wore their heart rate monitors for the entirety of a game, including times they were off the playing field. This potentially created skewed variation on game days.

Areas for Future Study

Since this was the first year of data analysis using the SJU soccer data, there is a lot of room for improvement and areas for further study. After speaking with the head coach about his expectations of the applicability of the team's heart rate data, I was able to determine a few possible areas that would be of use to explore.

One of the most basic ways to improve upon this research would be to implement a method for athletes to self-report various variables that could help to explain variation in training load responses. Learning more about the athletes' diet, sleep, or stress could provide more insight and better explain how their bodies are responding to a given external training load rather than attributing variation to individual fitness level or physiological differences.

The team will be implementing a new up-tempo, high-pressure playing style beginning with the 2018 season. This will include more numerous and more frequent substitutions; not many individuals will be playing for longer than 20 minutes at a time. Based on this change, should the recommendations for a low-volume, high-intensity practice the day before a game change?

Since the intensity in training sessions the day before the game had significant variance, it was difficult to determine how those changes were impacting game day performance. It would be

useful to compare the average intensity of the training session preceding a game with the individual performance and outcome of each game throughout the season.

As mentioned in the limitations of this study, professional soccer schedules differ greatly from DIII schedules. Most notably professional leagues usually play one game per week on Saturdays; DIII programs play multiple games throughout the week and oftentimes, play games on two days back to back. This occurs most often during NCAA playoffs-the most important games of the season. This raises the question of whether or not the team should train differently the day before two games are played on two days in a row.

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