The Effect of Using Polar System in Structuring the Training Load on Delaying Muscle Fatigue in Football Players

*Dr/ Ahmed Amin Ahmed EL-Shafee

Introduction:

Modern football has become more professional and competitive through coping with advancement and modern technological means used in improving the competency of the training process, hence developing the players' abilities and increasing their technical, physical, psychological and intellectual levels.

The process of structuring the training load is the basic process that underlies the success in achieving training goals. When this process is successful, it leads to physiological adaptation, thus raising the athlete's level. However, if it fails, the required level is not attained if the training load is less than the athlete's level. Also, if the training load is higher than the athlete's ability, it leads to negative effects of the training load, not only in terms of sporting results, but also in terms of the athlete's health (Abdel Fattah, 1997: 63).

The heart rate variability is an objective criterion that indicates the intensity of the load imposed on the player during physical exertion. It is also one of the best means used in structuring the training load (Abdel Khaliq, 1999: 64; Al-Hazzaa, 2009: 380).

Benson and Connolly (2003) emphasized that understanding the heart rate variability and learning to measure it with modern reliable devices ensures achieving good results when implementing the training programs designed scientifically and for each athlete individually. The use of these devices to measure heart rate variability does not involve the coach's guessing and discretion, and makes them able to control the training load components easily and objectively (Benson & Connolly, 2003: 18).

* Assistant Professor, Department of Teaching Methods, Training, and Sport Kinesiology, Faculty of Physical Education, El-Sadat City University.

In the Arab and Gulf environments, most football coaches rely on their own discretion in structuring the training loads by controlling the relationships between the training load components (intensity, volume, and rest). Consequently, the individual differences among players are not taken into account. Moreover, the lack of accuracy in determining the time when player reach adaptation with the intensity of the training load, the active rest intervals, and the poor ability to estimate the relationship between the training loads and the requirements of the various players' positions.

Accordingly, the negative impact of the lack of accuracy in structuring the training loads appears in the poor general training condition of the players, which accelerates the occurrence of muscle fatigue, especially in the final part of the daily training sessions or the halves of the match. Signs of the players' inability to exert more physical effort, a decline in the coordination level of skills, an increase in the errors of the technical performance of simple skills, as well as muscle injuries occur as a result (Abdel Fattah & Shaalan, 1999: 242; Ahmed, 1999: 177). This is consistent with the other studies which found that the experimental groups that used modern technologies in structuring the training load showed an improvement in the training condition, an increase in the physical and technical performance, and delay in muscle fatigue in the samples in these studies (Bujnovsky et al., 2015; Cheatham , Kolber & Ernst, 2015; Drenowatz, Grieve & DeMello (2015); Nakamura et al., 2015; Ravé & Fortrat, 2016).

Polar system is one of the modern means used in structuring the training loads. It works by recording the heart rate variability, and allows the coach to accurately and directly follow up the training load level of each player separately in order to ensure that all players reach a high level of actual adaptation to the training load intensity and avoid muscle fatigue. Additionally, this system offers the coach the ability to intervene easily during the training process to change the training load components, either to increase or decrease

the load intensity in light of the individual differences in the players' abilities and responses.

The aforementioned review shows that it is important for coaches to use modern technologies in structuring the training load as a determinant of the effectiveness of implementing training programs and developing the players' abilities. Furthermore, the preparation period for the sporting season is important in making the players ready and making them reach an ideal level of adaptation with the training load intensity, so that delaying muscle fatigue is ensured throughout the training sessions and the beginning period of the sporting season competitions. The researcher seeks to identify the effect of using Polar system in structuring the training load on delaying muscle fatigue in football players.

Research Objectives:

This study seeks to identify the effect of using Polar System in structuring the training load on delaying muscle fatigue in football players.

Research Hypotheses:

1- Statistically significant differences exist between the Means of the control group's pre-test and post-test measurements in the footballers' muscle fatigue indicators, in favor of the post-test measurements.

2- Statistically significant differences exist between the Means of the experimental group's pre-test and post-test measurements in the footballers' muscle fatigue indicators, in favor of the post-test measurements.

3- Statistically significant differences exist between the Means of the control and experimental groups' post-test measurements in the footballers' muscle fatigue indicators, in favor of the experimental group.

4- There are differences between the change rates in the post-test measurements Means of the control group and the experimental group in the footballers' muscle fatigue indicators, in favor of the experimental group.

Research Terms:

1- Polar system: is one of the technological systems that "allow direct and real-time monitoring of several

individuals at the same time." Data are transmitted wirelessly between Polar belts on the players' chests and the monitoring device connected to a monitor showing the heart rate variability of up to 10 players in the same time (**Schönfelder** et al., 2011).

2- Muscle fatigue: is the inability of the player to continue training at a certain intensity, as the working muscles cannot sustain working (Heshmat & Shalaby, 2003: 15).

Research Procedures:

A. Research Method

The researcher applied the experimental method as it is suitable for the nature of the current research, using a pre-test/post-test design on two groups: a control group and an experimental group.

B. Participants:

The research sample was purposively selected from young footballers under 19 years of age at Al-Ahly sporting club in Jeddah, Saudi Arabia, who are registered with the Arab Saudi Football Association for the 2015/16 sporting season. The core research sample was composed of 30 footballers assigned to two groups:

- An experimental group: consisted of 15 players. Polar system was used in structuring the training loads of the team's general training (exercises) content during the preparation of the 2015/16 sporting season.
- A control group: consisted of 15 players. The traditional method was used in structuring the training loads of the team's general training (exercises) content during the preparation period of the 2015/16sporting season.

The researcher excluded the five goalkeepers, as it was difficult for them to wear Polar belt during their workouts. Additionally, five players from the same team and not included in the core sample were used to conduct the exploratory study.

Normality of the core sample's data:

The researcher checked the normality of the core sample's data that consisted 30 footballers in terms of the growth variables (age, height, and weight) and the training years, as shown in table 1, Appendix 1/A.

C. Used equipments, tools, and devices:

1. A Restameter to measure height.

2. A scale to measure weight.
3. Polar System (http://support.polar.com/za/support/team2pro), and its users' manual is shown in Appendix 2.
4. Data entry and measurements forms, Appendix 3.

D. Determining the footballers' muscle fatigue indicators:

The researcher relied on the agreement of several references and scientific studies (Radwan, 1998; Abdel Fattah, 1999; Abdel Fattah, Rifaat & Helmy, 2000; Fouad, 2003; Fathy & El-Daly, 2006; Hossam Eddin & Fathy, 2006) on the following indicators that point out the beginning of muscle fatigue in footballers:

1-Electromyography (EMG):

The researcher selected the (basic) working leg muscles in the direction of the physical and skills performance in football (Appendix 4), by reviewing previous scientific studies and references (Abdel Fattah & Hassanein, 1997; Abdel Fattah & Shaalan, 1999; Heshmat & Shalaby, 2003; Rahnama et al., 2003; Rahnama, Lees & Bambaecichi, 2007; Metaxas et al., 2014). He also used a TeleMyo DTS device (https://www.fisaude.eu/files/clinical-DTS-Manual-de-Usuario.pdf) to measure some variables of the electromyography of these muscles. The TeleMyo DTS users' manual is provided in Appendix 5.

The electromyographer was tuned to co-work with the physical efficiency measuring device, by recording the measurements of the following variables:

- Total work area (Microvolt/sec UVS)
- Mean Power Frequency (MPF) (HZ)
- Fatigue indicator (HZ)

1. Physical Efficiency:

A MetaLyzer 3B device (https://www.procarebv.nl/.../Cortex-Metalyzer-3B_-Handleiding.pdf), its users' manual is provided in Appendix 6, was used to measure the physical efficiency variables in the research sample, by setting it to operate according to the appropriate load for conducting the test.

A Bruce Protocol (https://en.wikipedia.org/wiki/Bruce_protocol), shown in Appendix 7, was selected (El-Beik, Abu Zeid, & Khalil,

2009: 141), as the volume and intensity of its implementation on MetaLyzer 3B are suitable to the nature of the football training load. The following variables were measured:

- Heart rate variability (before and after exertion)(beat/minute)
- Anaerobic threshold (minute)
- Oxygen uptake (VO_2)(liter/minute)
- CO_2 production (VCO_2)(liter/minute)

2. Blood lactate

An Accutrend Plus device (https://beta-static.fishersci.com/.../roche-accutrend-plus-users-manual), its users' manual is provided in Appendix 8, was used to measure blood lactate as follows:

- Measurement before performance (mmol/kg)
- Measurement immediately after performance during recovery on the treadmill (mmol/kg)
- Measurement 15 minutes after performance (mmol/kg)
- Measurement 30 minutes after performance (mmol/kg)

E. Exploratory Studies:

The exploratory study was conducted on 12 July 2015 with the exploratory sample. The exploratory study revealed the following results:

- The proposed venue for conducting the pre-test and post-test measurements of the control and experimental groups is suitable (Fizik Center for healthy body, physical therapy and sports rehabilitation, Jeddah Governorate, Saudi Arabia). The center has the most recent devices used in measuring indicators of muscle fatigue in football players.
- The assistants – Appendix 9 – understand the research idea and goal, and the mechanisms of administering the pre-test and post-test measurements. They were also trained on how to record the measurement results.
- Checking the validity of and testing the tools and devices used in the research.
- Identifying the difficulties that may face the researcher and his assistance, the potential errors that could occur during the measuring process so that they can be avoided in the main study.

Implementing the research plan:

The research plan was implemented under the supervision of the researcher and his assistants. Uniformity of the pre-test and post-test conditions was taken into account. The implementation

plan included the following steps:

Pre-test measurements:

The control and experimental groups' pre-test measurements of muscle fatigue indicators under research in footballers under 19 were conducted on 21-24 July 2015. It included conducting pre-test measurements then repeating the measurement for seven players (four players from the control group and three from the experimental group), because they could not complete the physical efficiency test (Bruce Protocol) due to some MetaLyzer-mask-related respiration difficulties during doing the test. The measurements of these players were repeated after having an adequate rest interval to recover (two days). The researcher also calculated the significance of differences(equivalence) between the pre-test of the experimental and control groups in the indicators under research, as shown in table 2 (Appendix 1/B).

1. Applying the main research experiment:

The experimental and control groups were subjected to the same content (exercises) of the team's general training program during the preparation period for the 2015/16 sporting season from 25 July to 1 October 2015, for a 10-week period, receiving 6 daily training modules per week.

The researcher and his assistants structured the training loads of the general training program of the research sample (the control group and the experimental group) as follows:

- The experimental group: Polar System was used in structuring the training loads.
- The control group: the traditional method was used in structuring the training loads.

Appendix 10 shows the outline of team's general training program, which was applied to the two groups.

2. Post-test measurements:

The post-test measurements of the control and experimental groups in the muscle fatigue indicators under research of footballers under 19, from 2-5 October 2015. The post-test measurement procedures included repeating the measurement for one player from the control group, and another player from the experimental group because they could not complete the physical efficiency test for the

same reason of repeating the pre-test measurement. The measurements of these players were repeated after giving them an adequate rest interval for recovery (two days).

F. Statistical Treatment:

The SPSS software was used for data processing. The following statistical methods: Mean, Standard Deviation, Median, Skewness coefficient, T test, change rates in percentage. The researcher considered a statistical significance of 0.05 acceptable.

Results and Discussion:

A. Results and discussion of the first hypothesis:

Table (3)

Significance of differences between the Means of the control group's pre-test and post-test measurements in the footballers' muscle fatigue indicators N=15

Muscle Fatigue indicators			Measurement unit	Pre-test measurement		Post-test measurement		Calculated t value
				M	SD±	M	SD±	
Electromyo-graphy	Total work area		UVS	33225	972.81	29662	960.84	*18.24
	Mean Power Frequency		HZ	556	25.13	493	23.97	*12.70
	Fatigue indicator			824	52.59	670	49.61	*14.91
Physical Efficiency	Heart Rate variability	Before exertion	Beat/minute	68.43	1.82	65.94	1.76	*6.88
		After exertion		195.96	2.50	188.62	2.34	*15.00
	Anaerobic threshold		Minute	15.90	1.37	17.69	1.25	*6.76
	Oxygen intake		Liter/minute	32.18	3.14	35.55	2.80	*5.61
	CO2 production		Liter/minute	3.19	0.52	3.50	0.41	*3.28
Lactic concentration in the blood	Before performance		Mmol/kg	1.94	0.60	1.73	0.49	*1.90
	Immediately after performance			9.79	0.56	8.90	0.48	*8.45
	15 minutes after performance			8.87	0.52	8.48	0.45	*3.97
	30 minutes after performance			8.12	0.55	7.85	0.46	*2.64

*** tabular t value at statistical significance 14, p level 0.05 = 1.761**

Table (3) shows statistically significant differences at p level of 0.05 between the means of the control group's pre-test and post-test measurements in the footballers' muscle fatigue indicators, in favor of the post-test measurements.

The researcher attributes the significance in these differences to the fact that the contents of the general training program was appropriate with the abilities of the players (in the research sample). Additionally, the researcher took the scientific basics of forming the load circuits

during the preparation period into account. Moreover, he took into consideration the relationship between structuring the training load (intensity, volume, and rest) in correspondence with the ability of the control group players. The program was accurately implemented, and the players attended regularly and performed the exercises throughout the program implementation period (10 weeks) which was sufficient to make differences between Means of the control group's pre-test and post-test measurements in muscle fatigue indicators of the research participants (footballers under 19 years of age), in favor of the post-test measurements.

This is consistent with the studies by Benson and Connolly (2003), Fathy and El-Daly (2006), and Cheatham et al. (2015), that found an effect of the scientifically planned training programs on delaying fatigue in athletes. The aforementioned discussion shows that the first hypothesis is supported.

B. Results and discussion of the second hypothesis:

Table (4)
Significance of differences between the Means of the experimental group's pre-test and post-test measurements in the footballers' muscle fatigue indicators N=15

Muscle Fatigue indicators			Measurement unit	Pre-test measurement		Post-test measurement		Calculated t value
				M	SD±	M	SD±	
Electromyo-graphy	Total work area		UVS	33437	950.26	26449	920.65	*36.97
	Mean Power Frequency		HZ	551	24.74	433	20.42	*25.75
	Fatigue indicator			832	50.35	520	47.26	*31.63
Physical Efficiency	Heart Rate variability	Before exertion	Beat/minute	68.35	1.73	63.50	1.60	*14.41
		After exertion		196.23	2.41	180.94	2.16	*33.07
	Anaerobic threshold		Minute	16.02	1.23	19.70	1.08	*15.73
	Oxygen intake		Liter/minute	32.45	2.97	39.26	2.77	*11.75
	CO2 production		Liter/minute	3.26	0.41	3.84	0.36	*7.44
Lactic concentration in the blood	Before performance		Mmol/kg	1.91	0.57	1.53	0.45	*3.66
	Immediately after performance			9.86	0.52	8.01	0.40	*19.74
	15 minutes after performance			8.82	0.49	7.92	0.42	*9.76
	30 minutes after performance			8.05	0.51	7.48	0.39	*6.21

* tabular t value at statistical significance 14, p level 0.05 = 1.761

Table (4) demonstrates statistically significant differences, at p level of 0.05, between the means of the

experimental group's pre-test and post-test measurements in the footballers' muscle fatigue indicators, in favor of the post-test measurements.

The researcher attributes these significant differences to the fact that the training loads were structured using the Polar System, which works by heart rate variability information, throughout the daily training modules of the general program (a total of 60 modules).

By using Polar System, the individual differences in players' abilities were taken into consideration by determining the workouts intensity and volume and rest intervals for each player separately in light of the heart rate readings that appear to the coach on the Polar System monitor outside the field. This in turn contributed in the players' adaptation with the training loads, which also influenced the development of the players' training condition. Thus, the statistically significant differences appeared in favor of the post-test measurements.

The heart rate variability is an important indicator for both the coach and the player, as it gives an indication about the player's condition in terms of the effort exerted during the training module. Thus the training load can be structured and distributed on a scientific basis in terms of intensity, volume, and rest (Abdel Fattah, 1997: 42; El-Besaty, 1997: 44).

This is consistent with the studies of Benson and Connolly (2003), Bujnovsky et al. (2015), Cheatham .S, Kolber .M and Ernst (2015), Drenowatz et al. (2015), Nakamura et al. (2015), Ravé and Fortrat (2016) which pointed out that using Polar system in structuring the training loads of various sporting activities leads to positive results. Thus, the second hypothesis is supported.

C. Results and Discussion of the third and fourth hypotheses:

Table (5)

Significance of differences between the Means of post-test measurements of the control and experimental groups in the footballers' muscle fatigue indicators N1=N2=15

Muscle Fatigue indicators			Measurement unit	Control Group		Experimental group		Calculated t value	Change rate (%)
				M	SD±	M	SD±		
Electromyography	Total work area		UVS	29662	960.84	26449	920.65	*16.90	10.83%
	Mean Power Frequency		HZ	493	23.97	433	20.42	*13.34	12.17%
	Fatigue indicator			670	49.61	520	47.26	*15.32	22.39%
Physical Efficiency	Heart Rate variability	Before exertion	Beat/minute	65.94	1.76	63.50	1.60	*7.18	3.70%
		After exertion		188.62	2.34	180.94	2.16	*16.88	4.07%
	Anaerobic threshold		Minute	17.69	1.25	19.70	1.08	*8.52	11.36%
	Oxygen intake		Liter/minute	35.55	2.80	39.26	2.77	*6.59	10.44%
	CO2 production		Liter/minute	3.50	0.41	3.84	0.36	*4.36	9.71%
Lactic concentration in the blood	Before performance		Mmol/kg	1.73	0.49	1.53	0.45	*2.10	11.56%
	Immediately after performance			8.90	0.48	8.01	0.40	*9.97	10.00%
	15 minutes after performance			8.48	0.45	7.92	0.42	*6.37	6.60%
	30 minutes after performance			7.85	0.46	7.48	0.39	*4.29	4.71%

*** tabular t value at statistical significance 28, p level 0.05 = 1.701**

Table (5) shows statistically significant differences at p level of 0.05 between the post-test measurements of the control group and the experimental group in the footballers' muscle fatigue indicators, in favor of the experimental group's post-test measurements.

The researcher attributes these significant differences to the fact that the success of the training program relies to a great extent on the coach's ability to control and structure the training loads of these programs in order to ensure that the players reach a high level of adaptation with the exerted effort. This was achieved by using Polar System in structuring the experimental group's training loads. As a result, the experimental group outperformed the control group which relied on structuring the training loads by controlling the relationship between structuring the training load (intensity, volume, and rest) in the measurements of muscle fatigue indicators.

This is consistent with the studies by Zhang et al. (1991), Benson and Connolly (2003), Bujnovsky et al. (2015), Cheatham .S, Kolber .M and Ernst (2015),

Drenowatz et al. (2015), Nakamura et al. (2015), Ravé and Fortrat (2016), which pointed out that all sports training theories sought to delay fatigue, thus the possibility to sustain the performance of the sporting effort efficiently throughout the duration of the competition. Delaying the occurrence of muscle fatigue is a criterion for measuring the success of structuring training programs, especially in competitions that has long duration. Muscle fatigue itself cannot be measured, however. But indicators that express its occurrence can be measured. Moreover, the players who used Polar System outperformed their counterparts who used traditional methods for structuring the training loads of various sporting activities.

Table 5 also shows the differences between the change rates of the control and experimental groups' post-test measurements in footballers' muscle fatigue indicators, which came in favor the experimental group's post-test measurements.

This reveals that muscle fatigue indicators happened more quickly in the control group compared to the experimental group, which emphasized the effectiveness of Polar system in structuring the training load compared to the traditional method that relies on structuring the training load by controlling the relationship between intensity, volume and rest. The aforementioned discussion demonstrates that the third and fourth hypotheses are supported.

Conclusions:

In light of the research objectives and hypotheses, the used method, and the results of the statistical analysis, the researcher reached the following conclusions:

1. There are statistically significant differences at p level of 0.05 between the Means of the control group's pre-test and post-test measurements in the footballers' muscle fatigue indicators, in favor of the post-test measurements.

2. There are statistically significant differences at p level of 0.05 between the Means of the experimental group's pre-test and post-test measurements in the footballers' muscle fatigue

indicators, in favor of the post-test measurements.

3. There are statistically significant differences at p level of 0.05 between the Means of the of the control and experimental groups' post-test measurements in the footballers' muscle fatigue indicators, in favor of the experimental group's post-test measurements.

4. There are differences in the change rates of the Means of the control and experimental groups' post-test measurements in footballers' muscle fatigue indicators in favor of the experimental group's measurements.

Recommendations:

Under the limitations of the used procedures and the results that were reached, the researcher makes the following recommendations:

1. Coaches should be guided about the importance of using modern technologies in structuring the training loads (Polar system) as they provide an actual indicator of how the training is reflected in the development of the players' training condition and delaying muscle fatigue indicators.

2. Measuring electromyography, physical efficiency, and blood lactate is important as they are indicators of muscle fatigue levels in footballers before and after the beginning of the sporting season, in order to help in forming the suitable training load circuits and ensure the development of the players' training condition.

3. Studies that address structuring the training loads in football using Polar system should be applied during the competition period, and the transitional period of the sporting season.

4. Similar studies about other sports and different age groups should be conducted.

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