Biomechanical and Biochemical Analysis of some Variables associated with Fatigue for sprinter and runner

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Abstract:

the purpose of this study was identifying the biomechanical and biochemical variables related to muscle fatigue for athletics of different running. Twelve athlete participate in this study (age=19.2 ± 0.8 y; height=179.4 ± 2.9 cm; mass=68.9.2 ± 10.9 kg). All subjects signed an informed consent document before the experiment. Each player performed two trials of a continuous vertical jump for 60s (VJ) with a day of rest between each trial. Bertec force plate (500Hz) was used to collect vertical ground reaction force and (Megawin ME 6000 wireless system, Mega Electronics Ltd., Finland) was used for electromyography analysis. Quadriceps Rectusfemoris (RF), vastuslateralis (VL), vastus medialis (VM) biceps femoris (BF) Gastrocnemius muscle - lateral part (GL) Gastrocnemius muscle - medial part (GM) Tibialis anterior muscle (TA) and Soleus muscle (S) were selected for EMG analysis. Root mean square (RMS) used to rectify the signal and the Area under signal was calculated for each muscle to determine the percent of contribution to the performance (work/loading). Jumping height increases due to the increase of strength in short running runners with decreased rate noted for other running. Although the mechanical performance is very similar and muscle contribution percentages are very close, there are significant differences between the three groups of running on physiological fatigue enzymes.

Keywords: Muscle Fatigue, lactate, Creatine kinase, Peak Force, Vertical Jump

Introduction:

The high-performance levels, athletic achievements and world records in all sports depend mainly on proper planning of training. As the primary objective of sports training is to enable athletes to reach highest possible

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performance levels, several scientific theories appeared to explain facts and find solutions that help to improve athletic performance levels.

Running events are the most important events in athletics. There is a three type of running (short – middle – long). Each type requires specific physical and physiological characteristics. But all Events are associated with fatigue manifested as a decrease in the functional ability of the athlete (3).

Fatigue is a multi-facade complex physiological phenomenon that appears during training so that the athlete can benefit from training loads. Because training loads that fail to make the athlete reaches fatigue cannot induce positive changes in biological adaptation which in turn is the major factor in improving the training condition and achieving optimum performance. Fatigue is physiological changes in the human body (3) (4). Many factors is leading to fatigue during maximal training intensities include, Lack of blood glucose, Lack of muscle glycogen (after 2 or more hours), Lack of triglyceride, Dehydration (lack of water) and High Temperature (7)

Accordingly, and through review of related literature, the researchers found out that training loads induce biomechanical and biological changes including changes in the muscle activity. These changes induce physiological gaps in the muscle that lead to fatigue. This phenomenon varies according to the type of race and other biochemical changes including concentrations of lactic acid (LA), Creatine Phosphokinase (CPK) and Lactic Dehydrogenase (LDH). These factors are closely related to fatigue, led the researchers to perform this study to identify the effects of training loads (Bosco Test) on some biomechanical and biochemical variables associated with fatigue in runners of various running (short – middle – long) that can be used in controlling training loads and directing training process. Creatine Phosphokinase (CPK): also, known as Creatine Kinase (CK) wich is a blood serum enzyme with a category as indicated in (10). Lactate Dehydrogenase (LDH) is a blood serum enzyme with a category as indicated in (20). It is one of the enzymes of oxidative/reduction category the measurement unit of these parameters it International Unit (IU) which defined The quantity of the enzyme required for transforming one micromole of the substratum into a product in one minute under optimum interaction conditions (13) (20)

The purpose of this study is to identifying the biomechanical and biochemical variables associated with fatigue in runners of various running (short – middle – long).

Methods:

Twelve athlete participate in this study (age=19.2 ± 0.8 y; height=179.4 ± 2.9 cm; mass=68.2 ± 10.9 kg). All subjects signed an informed consent document before the experiment. Each player performed two trials of a continuous vertical jump for the 60s (VJ) with a day of rest between each trial. Bertec force plate (500Hz) was used to collect vertical ground reaction force and (Megawin ME 6000 wireless system, Mega Electronics Ltd., Finland) was used for electromyography analysis. Quadriceps Rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM) biceps femoris (BF) Gastrocnemius muscle - lateral part (GL) Gastrocnemius muscle - medial part (GM) Tibialis anterior muscle (TA) and Soleus muscle (S) were selected for EMG analysis. Root mean square (RMS) used to rectify the signal and the Area under signal was calculated for each muscle to determine the percent of contribution on the performance (work/loading). The Biochemical variables: Creatine Phosphokinase (CPK), Lactate Dehydrogenase (LDH) and Lactic Acid (LA). These variables were measured through blood analysis. Blood samples (3 cm3) were taken from cubital vein with a sterile plastic syringe (3mm)

Statistical analyses:

Descriptive statistics (Mean and stander deviation), one way ANOVA and LSD test. IBM SPSS 21 software used for the statistical analysis.

Results and Discussion:

Table (1)

Means and SD for biomechanical variables of vertical jump in (60s)

Variables	Groups	Mean	SD

Number of Jumps (N)	Short	41.50	0.58
	Middle	44.50	0.58
	Long	45.50	6.35
Peak Force (N)	Short	1648.70	38.46
	Middle	1077.72	63.31
	Long	1300.94	166.73
Time to Peak Force (s)	Short	0.53	0.08
	Middle	0.61	0.03
	Long	0.66	0.13
Jump Height (m)	Short	0.27	0.02
	Middle	0.22	0.02
	Long	0.20	0.05

Table (1) shows means and SD for biomechanical variables of vertical jump in (60s) obtained on a force platform

Table (2)
One-Way ANOVA between different running groups on variables of vertical jump in (60s)

Variables	F	Sig
Number of Jumps	1.268	0.327
Peak Force	29.849*	0.000
Time to Peak Force	2.179	0.169،
Jump Height	5.523*	0.027

Table (2) shows the results of one-way ANOVA between different running groups on variables of vertical jump in (60s). There are significant differences between the three groups on max peak force at a push in each jump and jumping height. To identify the direction of differences between the three groups, the researchers performed LSD analysis.

Table (3)
LSD Test between different running groups on variables of vertical jump in (60)

Variables			Means difference
Peak Force	Short	Middle	570.98*
		Long	347.76*
	Middle	Short	-570.98*
		Long	-223.22*
	Long	Short	-347.76*
		Middle	223.22*
Jump Height	Short	Middle	0.05*
		Long	0.07*
	Middle	Short	-0.05*
		Long	0.01
	Long	Short	-0.07*
		Middle	-0.015

Table (3) shows significant differences between short running group and the other two groups (middle – long) on the maximum peak force at a push in each jump for short running group. The researchers think that this is due to the type of training programs directed to the short running group (explosive power via anaerobic energy system). Makes the athletes generates the highest possible amount of force in the least possible duration. As it shown in the table (2) showing means and standard deviations of max peak force at a push in each jump for the three groups. Furthermore, short running training depends on repetition on training intensities from 90% to 100%. Also, there are statistically significant differences between long running and middle running groups for long running. Because the training program of long-distance runner is a combined between middle and long-distance training program. Which makes a long distance runners more superior in max peak force at a push in each jump. As it relates to reaching max force table (2). For the number of jumps as the least number was recorded with the short running group while the highest number has been registered for the long-running group. Therefore there is a consistency with the type of effort in addition to the increase of duration and exerting the larger amount of force.

There were significant differences between short running group and the other two groups (middle – long) on jumping height for short running group while no statistically significant differences appeared between the middle and long running groups on the same variable. This may result from the higher force and lower duration that gave the short running group the advantage of altitude for the center of mass. This is very clear during competition as the runner touches the ground with the front portion of his/her foot with decreased duration of pivoting and increased generation of force to maintain the stride length with high frequency. This is consistent with Mero et al. (1986) and Docks (1999) (15) (17).

The explosive power of runners results from a low resistance, high velocity, and small duration. The lack of significant differences between middle and long running groups may be due to the similarities of performance in both distances according to stride length and power production.

Billaut & Bishop (2009), Young (2005) and Mero et al. (1992) agreed that understanding biomechanical factors influencing running are of major significance due to its significant role in improving performance level. Several factors are affecting running distance including reaction time – technique – muscular activity and power production – neural elements – stride frequency (6) (16) (27)

Table (4)
mean and standard deviation for biochemical variables after performance

Variables	Race	Mean	SD
CPK (U/L)	Short	276.35	94.97
	Middle	192.70	53.23
	Long	125.25	39.32
LDH (IU/L	Short	367.85	49.59
	Middle	317.80	7.39
	Long	460.60	67.43
LA (mg/dl)	Short	57.75	4.56
	Middle	52.35	3.29
	Long	33.40	4.62

Table (4) showed mean and standard deviation for biochemical variables after the performance.

Table (5)
One-Way ANOVA between running groups of biochemical variables

	F	Significance
CPK	5.131*	0.033
LDH	8.921*	0.007
LA	37.049*	0.000

Table (5) indicated statistically significant differences between the three groups on all biochemical variables (LA – LDH – COK) as F value was significant on P≤0.05 and 0.01.

Table (6)
LAD between the three groups on biochemical variables

Variables			Mean difference
CPK	Short	Middle	83.65
		Long	151.10*
	Middle	Short	-83.65
		Long	67.45
	Long	Short	-151.10*
		Middle	-67.45
LDH	Short	Middle	50.05
		Long	-92.75*
	Middle	Short	-50.05
		Long	-142.80*
	Long	Short	92.75*
		Middle	142.80*
LA	Short	Middle	5.40
		Long	24.35*
	Middle	Short	-5.40
		Long	18.95*
	Long	Short	-24.35*
		Middle	-18.95*

Table (6) indicated statistically significant differences between the three distances on all biochemical variables. CPK differences appeared between short and long running for long running while LDH differences appeared between the three distance for long running. Also, LA differences emerged between the three distance for long running. There were no differences between short and middle distance on all variables.

The explanation of this is due to the nature of each race as short distance depends on the max force in the least duration. and this is Activates muscles to produce max force and induces fatigue. The oxygenic debt of short distance is higher compared to middle and long distance due to the dependence on phosphate anaerobic energy. This increases CPK concentrations in blood. This enzyme is a characteristic of sprinters as they need higher anaerobic power with high tolerance of biochemical byproducts resulting from the performance. This increases energy resources in the muscle and therefore enhances the release of enzymes working on this system for power. The increase of CPK concentrations in sprinters is the result of high levels, intensities and influence of speed training compared to endurance training. This adds greater training boredom over muscles due to anaerobic metabolism and its resultants. This increases CPK concentrations for longer durations after performance due to muscular metabolism and recovering from metabolic wastes. This is consistent with Sherwood (2001), Foss & Keteyian (1998) and Paul et al. (1998) in that CPK induces specific reactions for the anaerobic production of ATP through ATP-PC system, and this interprets its increase in sprinters compared to endurance runners (24) (9) (8).

Sprinters are characterized by fast muscular contractions that depend fundamentally on anaerobic energy system. ATP is the response for active contraction demands. It is formed after CP dichotomy. CPK works as a catalyst in this process. This is consistent with Viru & Viru (2000), Foss & Keteyian

(1998) and Paul et al. (1998) in that fast contractions depend on phosphate system as a primary source of energy, and this increases the CK activity levels in muscles (26) (9) (18).

Middle distance depends on anaerobic glucose as a source of energy which in turn increases LDH concentrations. Functional characteristics of this enzyme during training appear with the accumulation of metabolic byproducts. Therefore, its role increases during continuous training with high intensities. Due to the variance of muscle fibers in lactate tolerance according to its functional and structural characteristics and type of race, CPK and LDH levels vary in their response to training. The increase of MLDH in fast twitch fibers increases its ability to associate with Pyruvic Acid which in turn increases the concentrations of lactic acid and speeds up fatigue during training. This is consistent with Viru & Viru (2000) in that fast contractions depend on phosphagen system as a dominant source of energy, and this increases CK levels in muscles (26).

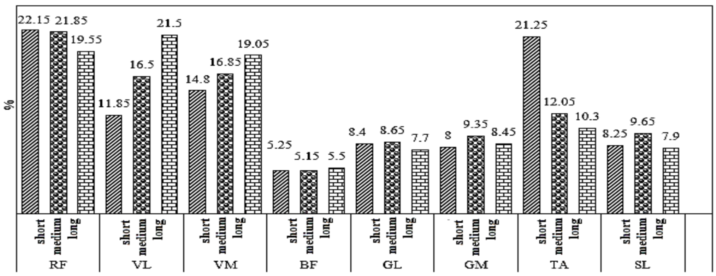
Abd El-Fattah, A. (2003), Sherwood (2001) and Viru & Viru (2000) indicated that CPK activates biochemical reactions specific to producing ATP anaerobically through the phosphagen system to fulfill the energy demands of high-intensity training for shorter periods of time (2) (24) (26).

Robergs & Roberts (2000) and Foss & Keteyian (1998) indicated that LDH activates reactions transforming pyruvate into lactate to produce ATP through anaerobic glycolysis to provide energy demands required for continuous high-intensity training for relatively longer periods (22) (9).

There is a clear relation between some training load variables and CK activity. Karamizark S, et al. (1994) indicated that training intensity and duration are of mutual influence with CK concentrations and the increase of LDH activity during high-intensity training depends on the duration of training load (11). Atwell, A, et al. (1991) indicated that continuous training with high-intensity loads for (60) seconds produces high concentrations of serum LDH immediately after the performance (5).

Martine & Coe (1997), Powers & Howley (1997) and McArdle et al (1996) indicated that the increase of M-LDH in fast-twitch fibers increases its ability to associate with pyruvic acid which in turn increases the concentrations of serum lactic acid and speeds up fatigue (12) (20) (14).

Staron & Hikida (2000) indicated that measuring enzymes concentration in serum for athletes reflects the effects of training on metabolic variables in cells and the adequacy of recovery durations. This means it works as a good indicator for fatigue and harmful side effects of training on musculoskeletal muscles, the heart, brain tissues and liver functions (25).



(RF): Right Quadriseps Rectus Femoris - (VL): Right Vasrus Lateralis - (VM): Right Vastus Medialis - (BF): Right Biseps Rectus Femoris - (GL): Lateral part of Leg Muscle - (GM): Medial part of Leg Muscle lift and right - (TA): Right Tibial Muscle - (SL): Soleus

Figure (1): Means of muscle contribution in performance (%) using EMG for short, medium and long distance races

Table (7)
One-Way ANOVA between various running groups on muscular contribution percentages using EMG

Muscles	F	Sig
RF (mv)	0.28	0.761
VL (mv)	5.33	0.030*
VM (mv)	10.74	0.004*
BF (mv)	0.60	0.568
GL (mv)	0.73	0.508
GM (mv)	2.10	0.178
TA (mv)	6.23	0.020*
SL(mv)	7.17	0.014*

(RF): Right Quadriceps Rectus Fumoirs - (VL): Right Vastus Lateralis - (VM): Right Vastus Medialis - (BF): Right Biceps Rectus Fumoirs - (GL): Lateral part of Leg Muscle - (GM): Medial part of Leg Muscle lift and right - (TA): Right Tibial Muscle - (SL): Soleus

Table (7) indicated statistically significant differences between four muscles (VL- VM – TA – SL). To identify difference significance, the researchers used LSD test between the three groups.

Table (8)
LSD test for the three groups on muscular contribution percentages using EMG

Variables			Mean Difference (I-J)
VL	Short	Middle	-4.65
		Long	-9.65*
	Middle	Short	4.65
		Long	-5.00
	Long	Short	9.65*
		Middle	5.00
VM	Short	Middle	-2.05
		Long	-4.25*
	Middle	Short	2.05
		Long	-2.20*
	Long	Short	4.25*
		Middle	2.20*
TA	Short	Middle	9.20*
		Long	10.95*
	Middle	Short	-9.20*
		Long	1.75
	Long	Short	-10.95*
		Middle	-1.75
SL	Short	Middle	-1.40*
		Long	0.35
	Middle	Short	1.40*
		Long	1.75*
	Long	Short	-0.35
		Middle	-1.75*

Figure (1) and tables (7) and (8) indicated that contribution percentages of muscles in all distance are very similar as they are the same working muscles that perform the motor task of running. These percentages may vary a little according to variations in technical performance of the three distance according to pivoting form and the amount of push during backward pivoting. These differences are not significant. That is because the test protocol depends on the same prime movers and any differences may be due to land on the force plate or pushing style. Some athletes maintain full extension of joints during pushing, and this increases muscle activity. During the motor performance of running, electromyography of the muscles increases with the running speed. This increase leads to further increase in fatigue. But the testing protocol used in this study did not show any significant increase between the three groups. Fatigue leads to decreasing neural activity rates and neural signal speed, and this affects stride frequency (15) (19) (23).

Conclusions:

According to this research aim, limitations, methods and results, the researchers concluded the following:

- Jumping height increases due to the increase of strength in short running runners with decreased rate noted for other running.
- Although the mechanical performance is very similar and muscle contribution percentages are very close, there are statistically significant differences between the three groups of running on physiological fatigue enzymes.

Recommendations:

According to these conclusions, the researchers recommend the following:

- Results of biomechanical and biochemical measurements of athletes should be used and compared with field tests for each event so as to be used in controlling training loads and designing training programs.

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