EFFECTS OF THE APPLICATION OF INERTIAL LOADS ON THE MORPHOLOGICAL PERFORMANCES IN THE STAGE OF RUNNING DEVELOPMENT AT MAXIMAUM SPEED

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Abstract
The objectives of this study were: a) the training, application additional inertial burdens caused by changes in the kinematics and dynamic performance running at maximum speed, b) to identify the effects of such training on inter-relation kinematics and morphological performance. The sample consisted of respondents were students of the Faculty of Sport and Physical Education in Belgrade sorted into three groups depending on the running speed: 1 (K) - control group without additional burden (N = 7); 2(E - R) - experimental group with the load their hands (N = 7); 3(E - N) - experimental group with the load their legs (N = 7). It is realized with initial and final measurement of morphological variables and kinematics variables when they were running at maximum speed on the track 30 m long to the acceleration phase (0.5 - 25m). During six weeks training practice was performed 3 times a week, it was progressively more difficult and increasing the scope of work after every two weeks. The results indicate the existence of a significant correlation between running speed in the initial measurement of all morphological variables in all three groups. In Group 3 (E - N) running speed, which has been dropped comparing to the initial measurement, the final measurement is not significantly correlated with the morphological variables. Variable frequency and step length significantly correlate with morphological characteristics, and the additional burden affect the decline of their relationship with morphological characteristics. It is not entirely clear whether the experimental factors caused the loss of correlation links, or that the reason of sample was inhomogeneous (morphological and / or motor mismatch) or both.

Key words: *speed run, inertial load, morphological performance*

INTRODUCTION

In the experiments that have been analyzing the impact on inertial application of burden on morphological characteristics of the respondents found that it is possible morphological adaptations of muscle structure (Bosco et *al.,* 1986) as well as additional burden affect on the muscular system**,** increasing mechanical and physiological strain (Baum et *al.,* 2003). When running treadmill with the additional workload was found bigger leg muscle activity, and thus expressed their greater power, but the work without additional burden (Ewans et *al.,* 1983). Adaptation of the organism in these conditions is neuron-genetic and myo-genetic nature**,** and is conducted in two phases (Bosco et al., 1983; Bosco et *al.,* 1984; Bosco et *al.,* 1986; Rusko, H. & C. Bosco, 1987). Current observations indicate that the improvement of specific muscle properties can reach, after practicing with the additional load, only those variables that are stimulated during exercise (Rao et *al.,* 2009); if some variable is not specifically treated by training, no changes will be given only in response to exercise with additional load (Bosco et *al.,* 1986). The moderate intensity of running without the additional burden engage the slow muscle fibers (Rusko, H. & C. Bosco 1987) while the fast muscle fibers, recruited when the reach anaerobic threshold. Therefore, the anaerobic threshold *(ANP)* is attainable by increasing the mechanical and physiological stress, which can be achieved by applying additional load. In this way the lower level of intensity in exercise affects the increased mobilization glycol fast muscle fibers, but when the exercise without any additional burden. Ropret (Ropret, 1998) in his research points to a different intensity of the relationship of the morphological characteristics of the kinematics of running at maximum speed and in relation to the running phase, the location and size of the additional load. Correlation between morphologic characteristics of *running speed*, relative to the size and location of additional load, exist only in cases when the application weight is 1.2-1.8 kg. Significant correlation of morphological characteristics with the *frequency steps* in relation to the size and location of additional load was determined in the load on the hands of 0.44 kg and 0.66 kg. The load *on the legs* of 0.6 kg and 1.2 kg there is a significant correlation between frequency steps and some morphological variables. Also shown is the correlation between morphological variables (body weight, height, non fat component, the length of the feet) and *length of steps in* relation to the size and location of additional load on the hands, (0.22 kg, 0.44 kg and 0.66 kg), as the load on the legs, too. This relationship is significant in terms of running with all the loads in both phases. In this connection the intensity decreases with increasing load. Juhas (Juhas, 2001) in his research indicates the existence of a significant correlation between frequency steps to the length of the legs and the length of step with the length of the legs. Detected running speed and the correlation with body height, relative mass of fat tissue, absolute muscle mass and muscle-fat is ratio of components. The aim of this study was that, in the specific training to the implementation of additional inertial load, cause changes in the kinematics and dynamic performance running at maximum speed, as well as to identify the effects of training with inertial load on inter relation kinematics and morphological performance.

METHOD

Participants

Participants in this study consisted of students of the Faculty of Sport and Physical Education in Belgrade *(Table 1).* The current population is defined sample of male students (n = 21). Students were at the time of execution of research were healthy and without injuries of the loco motor apparatus. In relation to the initial sprint time of respondents were classified into three groups depending on the running speed: 1 (K) - control group without additional load (N= 7); 2 (E - R) - experimental group with the load on the hands (N = 7), 3 (E - N) - experimental group with the load on the legs (N = 7).

Table 1. Means and standard deviations of aged, body height, body mass and run 50m for all three groups

Variables	1 (K)	2 (E-R)	3 (E-N)
	Means ± SD	Means ± SD	Means ± SD
Aged (years)	20.3±1.1	20.9±1.14	20.7±1.1
Body height (cm)	174.3±10.0	179.8±13.2	177.8±8.38
Body mass (kg)	66.36±10.7	73.5±10.6	70.14±8.9
Run 30m (s)	4.63±0.55	4.71±0.62	4.65±0.49

Terms of measurements and variables

Anthropometrical measurements were made by the International Biology Program (IBP). Basic morphological variables *were: body height (Tv), body mass (Tm), the length of the legs (Dn), diameter of the hand (Diru), diameter of the elbow (Dila), knee diameter (Diko), diameter of foot (Dist), volume up elbow (Onl), volume forearm (Opl), volume up hock (Onk), leg volume (Opk), thickness of skin folds of the upper arm (Dknnd), thickness of skin folds of the forearm (Dknpl), thickness of skin folds of the breast (Dkngr), thickness of skin folds of stomach (Dkntr), thickness of skin folds up hock (Dknnk) thickness of skin folds fore knee (Dknpk)*.

Derived morphological variables were: *the absolute value of the muscular components of body composition (M),* the *relative weight of muscle tissue (M%),* the *absolute value of the fatty components of body composition (D),* the *relative mass of fat tissue (D%), non fat component of body mass (lean -body mass) - (LBM) and muscle-fat ratio of components (muscle to fat ratio) - (MFR).* They are calculated according to the modified method Mateigke (Jovic et *al.,* 1982), with the relative value of the fat components of the estimated indirect method, using "bio-impedance system" (Biological ohm meter, BES200Z).

Variable *running speed (BT), the average length of steps (DK)* and *step frequency (FK)* were measured using photo cell system GW20 supported application software (GateWayMenager). The average length of steps *(DK)* is calculated by dividing the distance between the first and last foot contact with a number of steps. *Frequency steps (FK)* is calculated by dividing the running speed to the length steps.

Performed an experiment with parallel groups where the effects of experimental factors (inertial load) were on two levels. In order to increase the moment of inertia of the legs and hands in practice procedure is applied additional load in the form of cuffs with tiles, fixed to the hock and the wrist. In line with previous research and achieved results (Ropret, 1998; Stegman, 1981) was applied to load of 1.8kg for which is considered to be changes in average torque inertia segments by 50%. The investigation included initial and final measurement of all variables. Both measurements were realized in two days and initial measurement (pre-test), one day before the application of training procedures, and the final two days after the training procedure. Measurement of dynamic and kinematics variables is realized when running at maximum speed on the track 30 meters. Each candidate has run twice and for the final processing we used the better result (less total time).

Each athlete is getting ready stretching before active speed training. During six week training exercise was performed 3 times a week, and it was progressively more difficult, because the volume of work increased after every two weeks. In the first two weeks of each candidate is performing a series of five repetitions of his specific training regime. During the third and fourth week of training load is increased to two series of five repetitions of their specific training. Last two weeks the intensity was increased to three series of five repetitions for each group. One series consisted of five repetitions and run the maximum speed 30 m from half high start, with 2-3 minutes rest between each run, with 8 -10 min recovery between each series.

Acquisition of experimental results

The data processing applied to descriptive statistics. From the comparative statistical indicators to determine the relation between the morphological and kinematics variables was determined application partial correlation (Pearson Product-Moment correlation) matrix. The level of significance of $p < 0.05$ was applied to determine significant difference between pre test and post test for each group.

All data were analyzed using statistical software application STATISTICS 5.0.

RESULTS

Descriptive statistics for the morphological characteristics of respondents to the initial and final measurements for all three groups is shown in Table 2.

Table 2 Average values of morphological variables at initial and finale measurement for all three groups

Var.	Initial			Final		
	1 (K)	2 (E-R)	3 (E-N)	1 (K)	2 (E-R)	3 (E-N)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
TV (cm)	174.26±10.02	179.82±13.17	177.77±8.38	174.26±10.02	179.82±13.17	177.77±8.38
TM (kg)	66.36±10.74	73.50±10.65	70.14±8.90	65.79±10.87	71.74±11.86	69.08±8.93
DN (cm)	97.43±7.09	102.93±7.15	99.82±6.35	97.43±7.09	102.93±7.15	99.82±6.35
M(kg)	32.84±7.09	37.42±7.54	34.46±6.33	32.61±7.14	37.31±7.59	34.22±6.52
M %	49.12±2.83	50.55±3.53	48.84±3.89	48.86±2.88	50.39±3.58	48.61±3.94
D(kg)	11.24±2.96	10.04±3.07	9.70±1.68	10.12±3.10	9.15±2.22	9.16±1.66
D %	17.00±5.39	14.39±5.81	14.76±4.32	15.25±5.36	12.93±4.64	13.36±3.48
LBM(kg)	55.12±12.21	63.46±12.09	60.44±9.43	55.67±12.63	62.59±13.31	59.92±9.55
MFR	3.16±1.18	4.11±1.52	3.67±0.92	3.61±1.59	4.39±1.59	3.87±1.06

Correlations of morphological and kinematics variables in the development stage of maximal running speed in the initial and final tests for the control group (K) are shown in Table 3.

Table 3 Correlations of morphological and kinematics variables in the initial and final for the control group 1(K)

Var.	Initial			Final		
	BT	DK	FK	BT	DK	FK
TV	0.67*	0.67*	-0.65*	0.61*	0.35*	-0.62*
TM	0.74*	0.46*	0.14	0.67*	0.43*	0.23
DN	0.58*	0.79*	-0.77*	0.53*	0.32	-0.74*
M	0.76*	0.47*	-0.44*	0.71*	0.44*	-0.54*
M %	0.68*	0.35*	0.21	0.67*	0.33	-0.47*
D	-0.58*	-0.22	-0.25	-0.54*	-0.24	-0.27
D %	-0.76*	-0.35*	-0.27	-0.70*	-0.33	-0.34
LBM	0.79*	0.46*	-0.44*	0.71*	0.43*	-0.43*
MFR	0.79*	0.49*	-0.47*	0.73*	0.37*	-0.49*

* Coefficients are significant - $p < 0.05$.

On the basis of results from *Table 3* relating to the initial measurement, it can be noticed that the speed of running all the morphological variables showed a positive correlation except for variables of absolute and relative fatty components of body composition, which correlate but negative. The step length is positively correlated body height, weight, leg length, absolute and relative muscular component, non fat component of body mass and muscle-fat ratio of components, and a negative relative fat component. The frequency steps negatively correlated body height, leg length, the absolute muscle component, non fat component of body mass and muscle-fat ratio of components. On the basis of results from *Table 3* relating to the final measurement, it can be noticed that the speed of running all the morphological variables showed *a positive* correlation except for variables of absolute and relative fatty components of body composition, whose correlation was significant and negative. The length of step height is positively correlated body mass, absolute muscular component, non fat component of body mass and muscle-fat ratio of components. The frequency steps negatively correlated body height, leg length, absolute and relative muscular component, and non fat component of body mass and muscle-fat ratio of components.

Correlations of morphological and kinematics variables in the development stage of maximal running speed in the initial and final measurements for the experimental group (ER) are shown in Table 4.

Based on the results from *Table 4* relating to the initial measurement, it can be noticed that the speed of running all the morphological variables showed *a positive* correlation except for variables of absolute and relative fatty components of body composition, which correlate significantly, but negatively. The step length *is positively correlated* body height and leg length. The frequency steps *negatively* correlate body height, length of steps, and the absolute muscle mass. Based on the results from *Table 4* relating to the final measurement, one can notice the existence of significant correlation between some morphological variables with running speed. The running speed all morphological variables showed *a positive* correlation except for variables of absolute and relative fatty components of body composition, which correlate significantly, but negative. The step length *is positively* correlated absolute muscular component. The steps frequency has no significant correlation.

Table 4 Correlations of morphological and kinematics variables in the initial and final for the control group 2(E-R)

Var.	Initial			Final		
	BT	DK	FK	BT	DK	FK
TV	0.77*	0.65*	-0.61*	0.77*	0.41	0.50
TM	0.74*	0.33	0.30	0.70*	0.44	0.40
DN	0.68*	0.65*	-0.64*	0.68*	0.34	0.45
M	0.78*	0.38	-0.65*	0.74*	0.62*	0.31
M %	0.79*	0.42	0.26	0.77*	0.59	0.36
D	-0.72*	-0.31	-0.32	-0.71*	-0.25	-0.54
D %	-0.89*	-0.38	-0.40	-0.84*	-0.36	-0.60
LBM	0.84*	0.37	0.35	0.74*	0.43	0.45
MFR	0.85*	0.56	0.19	0.77*	0.50	0.42

* Coefficients are significant - $p< 0.05$.

Table 5 Correlations of morphological and kinematics variables in the initial and final for the control group 3(E-N)

Var.	Initial			Final		
	BT	DK	FK	BT	DK	FK
TV	0.75*	0.72*	-0.71*	0.04	-0.44	0.44
TM	0.63*	0.26	0.02	0.29	-0.24	0.43
DN	0.73*	0.84*	-0.68*	-0.09	-0.53	0.44
M	0.78*	0.23	0.09	0.43	-0.25	0.52
M %	0.66*	0.05	0.25	0.49	-0.11	0.42
D	-0.54*	0.06	-0.31	-0.50	0.26	-0.52
D %	-0.58*	-0.12	-0.18	-0.56	0.28	-0.59
LBM	0.56*	0.24	0.07	0.36	-0.26	0.49
MFR	0.73*	0.15	0.69*	0.61*	-0.34	0.68*

* Coefficients are significant - $p< 0.05$.

Correlations of morphological and kinematics variables in the development stage of maximal running speed in the initial and final measurements for the experimental group (EN) are shown in Table 5. Based on the results from *Table 5* that related to the initial measurement, it can be noticed that the speed of running all the morphological variables showed *a positive* correlation except for variables of absolute and relative fatty components of body composition, which correlate significantly, but negatively. The step length *is positively correlated* body height and leg length. The frequency steps *negatively* correlate body height and leg length, and a positive relationship between muscle fatty components. Based on the results from *Table 5* that affect the final measurement, it can be noticed that the running speed shows *a positive* correlation ratio of muscle-fat components. The length of the steps has no significant correlation. The step frequency *is positively* correlated relationship between muscle-fat components.

DISCUSSION

When viewing the results of descriptive statistics for the morphological variables of the sample can be concluded that all three groups of respondents have an average body height of 174.26 ± 179.82 ± 10.02 cm until 13.17 cm, which corresponds to an average of our student population. The same applies to percentage of muscle tissue (from 48.84 ± 3.89 % to 50.55% ± 3.53). It is noticeable that all three groups in the study are *(MFR)* of 3.61 ± 1.59 to 4.39 ± 1.59, which indicates that the respondents for the fat-and muscle-sports morphological type. In order to identify the effects of training with inertial load on inter relation of kinematics and morphological performance running at maximum speed, and explication of adaptive process, calculate the correlation of morphological and kinematics variables in running both phases (acceleration and maximum speed) at the initial and final measurements for all three groups . Based on the results can be noticed the existence of significant correlation between running speed and the initial and final measurement of all morphological variables for the control (K) and (E - R), since a large number of correlation and connection with the frequency and length of steps. Frequently, if the morphological characteristics do not show correlation with any of these characteristics, then the speed is not correlated, because they are mutually exclusive. It is particularly evident and significant, but negative correlation between running speed with the body fat component. Of course, the variables show a negative correlation and absolute *(D)* and relative fatty component *(% D),* reasonable for initial and final measurements. Efficacy of locomotion is complex which is moving faster. It is inversely proportional to the volume and weight of the body, a good part of the fat. Negative impact of inertia force and resistance, which the body is providing depending on the amount of inactive mass, is known.

If it is approximately over 20% of body mass, then its impact on inertial capabilities is significantly pronounced. Thus, there is an undeniable negative impact of fat on all regions of the body on the efficiency of locomotion. The extremely heavy person, whose mass is determined among other things, greater amounts of fat, achieved weaker results in the motor activity of maximal running speed. Subcutaneous fat acts as a ballast weight, because it reduces the relative strength, i.e. relationship between developed force and body mass, which is essential for successful sprint race.

Significant correlations between morphological variables and running speed are noticeable on the initial measurement in the experimental group (E - N). However, it is particularly interesting that the group was carrying the load on the legs (E - N) running speed, which is normally dropped compared to the initial measurement; the final measure is not correlated significantly. The decline rate is expected (Jaric et *al.,*), but can not claim with certainty that this is a consequence of the adequacy of the load or duration of experimental treatments. So, appears even greater loss of correlation links, but the group (E - R). Thus, the body height *(TV),* mass *(M),* length of legs *(DN),* absolute *(M),* relative muscle component *(%M)* and muscle-fat ratio *(MFR)* which correlates with running speed in the initial measurement, not correlation after the experimental treatment. It is not entirely clear whether the experimental factors caused the loss of correlation or connection that the reason non homogeneous sample, or both. Variable length steps *(DK)* significantly correlated with the morphological characteristics (Juhas, 2001; Ropret, 1998; Van der Welt, W.H., & C.H. Wyndham, 1973) especially with the longitudinal *(TV, DN),* body mass *(TM)* and the muscle component *(M)* in all three groups at initial measurement. However, the experimental group who wore additional load of a correlation function is lost. For example, the length of steps *(DK)* is significantly correlate length legs *(DN)* of the initial measurement of the group (E - R), while the association had lost the final measurement. In (E - N) on the initial measurement, there was a significant correlation with the length of the legs *(DN).* However, the final measurement, the correlation, as with all morphologic variables is missing, which is again probably attributable to experimental factors action. Variable frequency steps *(FK)* on the initial measurement, often significantly, but negatively correlated with the length of the legs *(DN),* which agrees with the results of few studies they got (Juhas, 2001; Ropret, 1998; Van der Welt, W.H., & C.H. Wyndham, 1973) with body height *(TV)* and absolute muscle component *(M).* However, noticeable are that frequency of reciprocal steps and the length of steps, in groups that are practiced with the additional load, do not show morphological variables with no correlation. It can be assumed that the absence of significant correlation at the final measurement in both groups was trained with the load, a consequence of the impact of experimental factors.

CONCLUSIONS

In this paper, the experimental factor caused by changes in the kinematics and dynamic performance running at maximum speed to the observed variables determines adaptive processes. It is noticeable that these new processes influenced inter relation of morphological and kinematics performance. Based on the results can be noticed the existence of significant correlation between running speed and the initial and final measurement of all morphological variables for the control (K) and (E - R).

In the group that was carrying the load on the legs (E - N) running speed, which is normally dropped compared to the initial measurement; the final measurement is not significantly correlated with the morphological variables.

So, appears even greater loss of correlation links, but the group (E - R). It is not entirely clear whether the experimental factors caused the loss of correlation or connection that the reason non homogeneous sample (morphological and / or motor mismatch) or both. It is noticeable that the length of steps *(DK)* significantly correlated with the morphological characteristics, especially with the longitudinal *(TV, DN),* body mass *(TM)* and the muscle component *(M)* in all three groups, and that the groups that practiced with the load occurring loss of correlation links.

Additionally, the load affects the frequency correlation with the morphological characteristics of steps by the intensity of the connection is lost with increasing load. Considering that all the negative correlation can be concluded that as muscle mass and longitudinal dimensionality higher - frequency step is smaller.

It can be concluded that applying the additional load comes to violations of significant correlations between kinematics and morphological characteristics that exist in terms of running applications without the additional load. Given that these correlations depend on the homogeneity of the sample in this study, where the sample is not uniform in relation to morphological characteristics, applied additional load, appear some vague correlation. Respondents with greater height and body mass in a particular advantage when carrying extra load, because it is for them proportionally less and causes less torque of inertia. This means that the additional load affects different subjects with different morphological characteristics. Therefore, when explaining the effects of the treatment applied training, it is necessary to pay attention to morphological and motor characteristics of the sample, as determined and [Cavanagh, P. & K.R. Williams, 1982; Cavanagh, P.R. & R. Kram, 1989). Thus, for example, the control (K) and experimental (E - R) group is evidently differ in body weight, leg length and body height (Table 1). The study applied an additional load not comply with the mass of the body segments of each of the respondents, and were probably caused by a different adaptation in each of the respondents.

The above facts indicate the need for individualization of the size of the load in relation to the aforementioned characteristics. Of course, this also applies to the level of motor abilities, and above all power and strength. This would be realized in future research, the principle of individuality and allows homogenization of the sample in relation to set criteria, especially the moment of inertia. People higher level body with longer legs, greater body mass and mass of the leg with higher moment of inertia, usually have a step higher length. Such, different and conflicting conclusions have yet another argument in favor of the fact that speed is the result of the individual, the optimal combination of length and step frequency, depending on the constitutional characteristics. Morphological differences between patients must be accurately identified and balanced samples, to ensure that the obtained differences in the mobility expression arise precisely due to the experimental factors.

Relations and correlations between kinematics variables of sprint, and especially the frequency and length of steps and morphological characteristics of elite sprinters can be used as criteria by which athletes of lower rank may be compared to determine how to spend time in training, and to raise frequency of steps and/or increase the length of the steps.

EFEKTI PRIMENE INERCIONIH OPTEREĆENJA NA MORFOLOŠKE PERFORMANSE U FAZI RAZVOJA TRČANJA MAKSIMALNOM BRZINOM

Originalni naučni rad

Sažetak

Ciljevi ove studije su bili: a) da se treningom, sa primenom dodatnog inercionog opterećenja, izazovu promene u kinematičkim i dinamičkim performansama trčanja maksimalnom brzinom; b) da se identifikuju efekti ovakvog treninga na interrelacije kinematičkih i morfoloških performansi. Uzorak ispitanika su sačinjavali studenti Fakulteta sporta i fizičkog vaspitanja u Beogradu razvrstani u tri grupe u zavisnosti od brzine trčanja: 1(K) – kontrolna grupa bez dodatnih opterećenja (N=7); 2(E-R) – eksperimentalna grupa sa opterećenjem na rukama (N=7); 3(E-N) – eksperimentalna grupa sa opterećenjem na nogama (N=7). Realizovano je inicijalno i finalno merenje morfoloških varijabli, kao i kinematičkih varijabli pri trčanju maksimalnom brzinom na stazi od 30 m i to u fazi ubrzanja (0.5 - 25m). Za vreme šestonedeljnog treninga vežbanje je izvođeno 3 puta sedmično, bilo je progresivno sve teže, a obim rada se povećavao nakon svake dve sedmice. Dobijeni rezultati ukazuju na postojanje značajne povezanosti brzine trčanja u inicijalnom merenju sa svim morfološkim varijablama u sve tri grupe. Kod grupe 3(E-N) brzina trčanja, koja je opala u odnosu na inicijalno merenje, u finalnom merenju ne korelira značajno sa morfološkim varijablama. Varijable frekvencija i dužina koraka značajno koreliraju sa morfološkim karakteristikama, a dodatno opterećenje utiče na opadanje njihove povezanosti sa morfološkim karakteristikama. Nije potpuno jasno da li je eksperimentalni faktor prouzrokovao gubljenje korelacionih veza, ili je tome razlog nehomogenost uzorka (morfološka i/ili motorička neusklađenost) ili i jedno i drugo.

Key words: *brzina trčanja, inerciona opterećenja, morfološke performanse*

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