

## ❖ SPORT AND PERFORMANCE

### THE EFFECTS OF ANKLE PLANTAR FLEXOR AND KNEE EXTENSOR MUSCLES FATIGUE ON DYNAMIC BALANCE OF THE FEMALE ELDERLY

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#### Abstract

**Objective:** The purpose of this study is to investigate the effects of ankle plantar flexor and knee extensor muscles fatigue on dynamic balance of Tehran female elderly people. The subjects of this study consist of 30 active elderly women with mean age  $68 \pm 3/4$  years.

**Method:** Star Excursion Balance Test (SEBT) applied, for dynamic balance evaluation. Ankle plantar flexor machine and knee extensor muscles machine were used for implementation of fatigue protocol on these muscles respectively; we also used Kin-Com machine for muscles strength evaluation. Sample t test as well as independent t test were applied for statistical analysis ( $p=0/05$ ).

**Discussions and Conclusion:** Comparison of the mean distance of the eight vectors Star Excursion Balance Test (SEBT) before and after implementation of the fatigue protocol, showed a meaningful decrease in each of the eight vectors. We concluded that, despite participation in general fitness programs, the female elderly people experience balance- disturbances.

**Key words:** Fatigue, Dynamic Balance, Elderly

#### INTRODUCTION

As one of the challenging concepts in sensory-motor system (BL, Riemann, JB, Myerse, SM., Lephart, 2002), postural control studies the mutual and complicated relation between the sensory inputs and motor reactions needed for maintenance or alteration of posture (PE., Sullivan, PC., Marcos, 1995). From a practical point of view, balance is divided into three fields of dynamic, semi-dynamic and static (K, Guskiewicz, D., Perrin, 1996), for assessment of which, different methods like Star Excursion Balance Tests (SEBT) (DT., Ochsendorf, CG, Mattacola, BL., Arnold, 2000), Berg Balance Scale (LD, Thorbhr, RD., Newton, 1995), and Tineh t Scale (SL., Whinteny, JLC, People, SP., Cass, 1998) as well as Biodex Machine (S, Colby, R, Hintermeister, M, Torry, R. Steadman, 1999) and Power Plate (J, Yaggie, S. McGregor, 2002) applied. Fatigue is a common phenomenon which appears after exercising and daily activities, and results in disturbances of people's motor performance (J., David, R., Joan, H., Arnold, 2004). Former studies (A. McComas, 1996, K., Miura, Y, Ishibashi, E, Tsuda, Y, Okamura, H, Otsuka, S. Toh, 2004) have divided the causes for muscle fatigue into marginal and central sets; which among the first group we can refer to disturbance in control of muscular webs impels and contraction process itself (A. McComas, 1996), and non-activation of motor neurons by the brain and break of information chain sent from the brain to motor neurons and the muscle as the main central cause of fatigue (K., Miura, Y, Ishibashi, E, Tsuda, Y, Okamura, H, Otsuka, S. Toh, 2004). Aging

and decrease of physical activities may result in disturbance of many physiological performances, namely sensory-motor performance, and may consequently lead to decrease of elderly people's postural control and increase of probability for injuries (M, Beers, R. Borkow, 2000). As a result of postural control decrease, elderly people's safety, decreases while performing daily activities and exercising; this problem might be a reason for later disturbances in elderly societies. Decrease of physical activities along with aging, is followed by worrying alterations in the capacity of some systems of the body, say cardiac system, respiratory system, neural system and muscular-skeletal system, which face most changes (W.R, Frontera, C.N, Meredith, K.P., Reilly, H.G, Knuttgen, W.J. Evans, 1998, MA, Rogers, JM., Hagberg, WH, Martin, AA, Ehsani, JO. Holloszy, 1990). Alterations in neural and muscular-skeletal systems consist of reduction of bone density, muscular atrophy, power decrease and disturbance in neuromuscular control of physical activities. Among cardiac and respiratory system changes, we can refer to the decrease of performance capacity of these systems, which altogether can result in premature fatigue of elderly people in performing daily activities and exercising (W.R, Frontera, C.N, Meredith, K.P., Reilly, H.G, Knuttgen, W.J. Evans, 1998, MA, Rogers, JM., Hagberg, WH, Martin, AA, Ehsani, JO. Holloszy, 1990). Due to the decrease of the time for fatigue attributed to the decrease of physiological systems capacity, and decrease of postural control ability-

resulting from disturbances in neural control of muscle movements- prevalence of the injuries among the elderly people caused by lack of proper postural control, and exhaustion at the end of daily activities and sport competitions- a time when occurrence of fatigue is much more probable- have been reported repeatedly (JA, Balogun, KA, Akindele, J. Nahinlola, 1994). Therefore, researchers have focused on studying and diagnosis of the factors affecting postural control, namely fatigue, among elderly people (P, Gribble, J, Hertel, C, Denegar, W. Buckley 2004, N, Vuillerom, S. Dmetz, 2006). For instance, Gribble et al. (2004) in their study The effects of fatigue and chronic ankle instability on dynamic postural control have, found a meaningful correlation between fatigue and decrease of postural control (P, Gribble, J, Hertel, C, Denegar, W. Buckley 2004). The findings of another research on the effects of calf muscles fatigue on dynamic balance in the elderly people conducted by Vuillerem et al. (2006) confirmed decrease of postural control after the

### RESEARCH METHODOLOGY

The statistical society of this study is composed of active elderly women in Tehran, among whom 30 people with mean age of  $68 \pm 3.4$  years, mean height of  $168 \pm 10.4$  cm and mean weight of  $65 \pm 5.4$  kg, without any injuries in lower parts of body for the last 5 years, were selected for this investigation voluntarily. In this study we used an ankle plantar flexor machine, a knee extensor muscles machine, Star Excursion Balance Test (SEBT), a 5 centimeter adhesive tape, a textile meter, a standard height measuring set, and a digital scale made by Germany. For evaluation of dynamic balance of the subjects we used Star Test, in which eight vectors drawn on the ground with  $45^\circ$  angles in a star form. To implement this test and normalize the data, leg height (length) -that is from anterior upper pelvic to internal ankle- was measured (P, Gribble, J. Hertel, 2003). After receiving essential instructions from the tester, each subject performs this test three times to learn how to do it. Besides, subjects' superior leg is defined prior to the test; so that if it is their right leg, the test be done counterclockwise, and in case of left leg superiority, the test be done clockwise (K, Guskiewicz, D. Perrin, 1996, P. Gribble, 2003). The subject stands on her superior leg at the center of the star and performs the access action without error (errors: leg movement from the center of the star, resting of the other leg at the contact point of the star line, and falling down) in the eight vectors of the star; the tester tells which vector to go. The distance between contact point of the free leg and center of the star recorded as access distance. Each subject does the test on each of the vectors three times. Finally their mean is divided by the leg height (in centimeter), and then multiplied in 100 to obtain the access distance as a percent of the leg height (P, Gribble, J. Hertel, 2003, F, Karl, J. Ian, 2006). For measurement of thigh extensor muscle power we used Kin-Com dynamometer which

implementation of fatigue protocol (N, Vuillerom, S. Dmetz, 2006). In most of the researches on the effects of fatigue on dynamic balance, researchers have studied the effects of fatigue among athletic and non-athletic subjects (DT, Ochsendorf, CG, Mattacola, BL. Arnold, 2000, J, Yaggie, S. McGregor, 2002), and few studies with female elderly subjects have employed isokinetic and isometric fatigue protocols (DT, Ochsendorf, CG, Mattacola, BL. Arnold, 2000, J, Yaggie, S. McGregor, 2002) which are quite obviously different from daily physical activities. Moreover, in the studies so far conducted, the relative contribution of fatigue in various lower parts of the body in decrease of postural control has not been considered. According to this issue and considering the importance of maintenance of elderly people's health, this study aims to investigate the effects of ankle plantar flexor and knee extensor muscles fatigue on dynamic balance of Tehran female elderly people.

is an accurate method for evaluation of muscular power (U. Svantesson, B., Ernstoff, P., Bergh and G., Grimby, 1991). Kin-Com dynamometer helped us to perform various exercises of isometric, constant and slow passive movements, isokinetic and plyometric types. Machine's contraction speed varies between 1 and  $250^\circ$  per second, and its utmost force is 450 pounds (2000n). It is also capable of measurement and evaluation of any muscular parameters (such as: power, strength, entropy, torque, maximum force, correlation of maximum entropy to the body weight, the whole work etc.) in any angle from movement range of the joint precisely together with a diagrams. In the present research we set the machine on  $0$  to  $90^\circ$  angle and maximum input force of 100 N with the speed of 120 m/s. sitting on the machine seat, every subject performed concentric contraction by bending and stretching her knee for  $0$  to  $90^\circ$  with 120 m/s speed and 100 N force. Three contractions performed in three phases. After any phase the subjects rested for 90 seconds till the completion of the three phases. Then the machine showed the power amount of thigh extensor muscles (concentric contraction) via a diagram appeared on its monitor. To measure the power of knee plantar flexion muscles the knee was posited in a  $90^\circ$  angle (the reason for choosing the  $90^\circ$  angle was that according to various studies the maximum power of these muscles is produced in this position), and after contraction of these muscles by the subjects their power was recorded (U. Svantesson, B., Ernstoff, P., Bergh and G., Grimby, 1991). To implement fatigue protocol on knee extensor and ankle plantar muscles, the subject were asked to perform 2 sets of knee extension and ankle plantar flexion respectively on knee extensor machine and ankle plantar flexor machine, each set consisted of 50 movements, with 50% of a repetition maximum (repetition maximum is calculated via the formula:  $1RM = 0.1$  of the lifted weight-  $0.02$  of repetitions, and there was a 4 minute rest between the two sets). Either it was supposed that whenever the subject becomes

incapable of continuing the repetitions, fatigue has happened (4), or after performing the repetitions muscle power was measured by the Kin-Com machine, if the power mount in knee extensor and ankle plantar muscles was less than 20% of the amount obtained prior to the test, it is also considered as sign of fatigue

### THE PROCEDURE

For sample selection, the research plan was explained for the elderly female available in Tehran who had sportive activities, then the volunteers' background studied for injuries in lower parts of body. Those people with sever injuries of lower parts in recent 5 years as well as those who had not optimal conditions for balance test and fatigue protocol were excluded. Afterwards, during a coordination session the test and its performance steps were explained for the subjects. To facilitate performance of the test and implementation of fatigue protocol on two different areas in parallel conditions, the subjects were divided into three groups (of 10 people), and the test conducted during a period of 3 weeks. Subjects' weight and their leg height (that is from interior upper pelvic to internal ankle) were measured, and again after a brief explanation of the procedure the subjects conducted Star Excursion Test. While performing Star test, the value of a Repetition Maximum for knee extension and ankle plantar flexion of the subjects was calculated. Afterwards, the subjects performed a warm up step (5-10 minutes of extension and slow running). The subjects selected by the researcher, stood on the center of the star on their superior leg, and upon his/her call performed access action in the vectors (randomly chosen by the researcher). After the subjects' foot touching the chosen vector, the researcher marked the contact point on the Star, and measured the distance in centimeters. The mean for three performance of the test

(U. Svantesson, B., Ernstoff, P., Bergh and G., Grimby, 1991). For implementation of fatigue protocol in to different areas (knee extensor and ankle plantar muscles) the second trial of test was performed 72 hours after the first one, with as much parallel conditions as possible.

calculated and divided by the leg height of the subjects, and finally multiplied in 100. After that, the subjects stood on knee extensor muscle machine and performed extension action for 50 times, with 50% repletion maximum, which was already calculated and added to the machine resistance. If at the first set the subject was unable to continue the action at any of repetitions, the fatigue protocol would be stopped and the Star test be conducted, but in case of finishing the first set of 50 repetitions without incapability, after a 4 minute rest implementation of the protocol would be started again (all the subjects reached to partial inability while doing the first set of repetitions, and there was no need for performance of the second set). After 72 hours needed for recovery of knee extensor muscles fatigue, and 30 minutes delay (because this time, procedure explanation, 6 times of instructing practices, and also pretest step for Star test, were not needed), again the first 10 people of the sample group attended the test. Like implementation of fatigue protocol on extensor muscles at the first test, this time the subjects performed ankle plantar flexion and after stopping the repetitions, Star test was conducted. During the next weeks, all steps of the test were done on the other two groups in similar conditions. In this study we used sample t test and independent t test for data analysis with  $p= 0.05$ .

## RESULTS

In table 1 the general characteristics of the subjects are shown.

Table 1. General characteristics of the subjects

Variables	The Measured Values
Age(Year)	3.4±70
Height(centimeter)	10.4±168
Length of legs(Centimeter)	6.5±82
Weigh(kg)	5.4±65
Maximal power of knee extension: (kg)	6±43
Maximal power of ankle plantar flexion: (kg)	7±30
Repetition of the movement before inability in knee extension	3±19
Repetition of the movement before inability in ankle plantar flexion	2±21

Table2. Mean (standard deviation) for subjects' access distance in Star test divided by leg height ×100

SEBT Vectors	Test		
	Pretest	After knee extensors fatigue	After ankle plantar flexors fatigue
Anterior	¶1.78 74.42☼	¶42.31 1.60☼	¶1.92 62.55☼
Anterior-	¶2.06	¶52.42	¶1.76

Interior	83.40☀	1.63☀	71.81☀
Anterior-Lateral	☿1.63 71.64☀	☿42.05 1.54☀	☿5.73 60.85☀
Lateral	☿1.65 66.24☀	☿50.45 1.52☀	☿3.38 58.1☀
Posterior-Lateral	☿2.80 83.80☀	☿61.21 1.65☀	☿1.69 64.69☀
Posterior	☿1.08 84.67☀	☿64.72 1.83☀	☿1.88 66.1☀
Posterior-Interior	☿1.76 83.60☀	☿63.30 1.973☀	☿1.60 64.59☀
Interior	☿1.84 88.46☀	☿67.31 2.03☀	☿1.88 76.27☀

☀: Stands for meaningfulness of the difference between access distance before and after implementation of fatigue protocol on knee extensors muscle group.

☿: Stands for meaningfulness of the difference between access distance before and after implementation of fatigue protocol on ankle plantar flexors muscle group.

According to the table 2 and comparison of the obtained distances for the eight vectors of Star test before and after implementation of fatigue protocol on knee extensors and ankle plantar flexors, it can be said that implementation of fatigue protocol on the aforementioned muscle groups results in meaningful decrease of access distance in all eight Star vectors.

### DISCUSSION AND CONCLUSION

The main purpose of this study is a comparative study of the effects of knee extensor and ankle plantar flexor muscles fatigue on dynamic balance of the active elderly female in Tehran. The findings of the study confirmed a meaningful effect of knee extensor and ankle plantar flexor muscles fatigue on dynamic balance of the elderly people, and the difference between the effects of knee extensors on the dynamic balance of the elderly people and that of the ankle plantar flexors. Regarding the decrease of ability for balance control after implementation of fatigue protocol is in accord with the findings of Treleaven et al (2008), Vaillant et al (2008), and Vuillerme et al (2007), who have reported an almost similar decrease of balance control and increase of body fluctuations after the implementation of fatigue protocol (J, Treleaven N, lowchoy R, Darnell B, Panizza D., Brown-Roth well 2008, J, Vaillant N, Barthalais N, Vuillerme, 2008, N, Vuillerme, R., Cuisinier 2008). As the diagram 1 shows, within the subjects' access distance fatigue in knee extensors face more decrease than in ankle plantar flexors in all eight star vectors. Via calculation of the percentage of decrease for the subjects' access distance after the implementation of fatigue protocol, we found out that execution of the program on knee area brings the highest decreases

respectively in following vectors: anterior, anterior-lateral, anterior-interior, posterior-lateral, posterior-interior, interior, posterior and lateral, while implementation of fatigue protocol on ankle area brings the heist decreases respectively in following vectors: posterior-lateral, posterior, posterior-interior, interior, anterior, anterior-lateral, anterior-interior and lateral. In spite of lowness of access distance in lateral vector for each of the tests, in comparison with distance decrease in other vectors, decrease of access distance in this vector after implementation of fatigue protocol on both muscle groups is much less. It is also observed that, the three anterior vectors have the highest decreases after knee fatigue, while for ankle fatigue the highest decreases take place in posterior vectors of access distance. Moreover, the less difference between the percentage access distance decreases after implementation of fatigue protocol on both muscle groups is observed in posterior vector. Comparison of the access distance for the subjects of this study with those of former researches on young subjects, with mean values of 100, 105, 95, 94, 103, 105, 105 and 107 respectively for anterior, anterior-interior, anterior-lateral, lateral, posterior-lateral, posterior, posterior-interior and interior vectors (A., Sarshin, H., Sadeghi, A., Abasi, 2008), verified that ageing results in a meaningful decrease in access distance in all eight vectors of star test, which shows that aging is accompanied by decrease of dynamic balance. This part of the present study findings is in accord with those of Gribble's (2004) research which had reported increase of body fluctuations among the elderly people. It was also observed that, the decrease of access distance for both young and elderly subjects, in three vectors of anterior (25%), anterior-lateral (33%) and

lateral (36%), known as difficult vectors of the star, face more differences than other vectors, and elderly people have much less access distances than the young subjects (A., Phillip Gribble; J., Hertel, C. R. Denegar; W. E. Buckley, 2004). Decrease of dynamic balance by ageing can be attributed to sensory-motor changes developed by ageing, because according to the findings of some researchers, ageing leads to reduction of skin sensitivity, vibratory sensitivity and sensitivity towards pain and heat (K. Guskiewicz, D. Perrin, 1996). Therefore, since balance is dependent not only to the messages received from deep sensory receivers but also to the information prepared by skin receivers, decrease in balance to some extent is related with reduction of sensory-motor abilities of the elderly people (LD, Thorbhr, RD, Newton, 1995). The decrease of elderly people's balance can also be attributed to reduction of the performance of visual and internal ear labyrinth sensory receivers, low flexibility, and power and speed decrease as well as reduction of neural transmission (J, Treleaven, N, lowchoy, R, Darnell, B, Panizza, D. Brown-Roth well, 2008). Regarding the effects of power decrease in the elderly people, in this study we can refer to decrease of knee extensor and ankle plantar flexor muscles power observed in this study compared with the findings of former researches. The decrease of the maximal muscular power in the active elderly people can be attributed to decrease of physical activity accompanied by ageing, or we can claim that at least part of this power decrease is associated with decrease of intensity and volume of elderly people's exercises (DT, Ochsendorf, CG, Mattacola, BL., Arnold, 2000, LS, Aaronsonal, CS, Teel, V, Cassmeyer, GB, Neuberger, L, Palliccathayil, J. Pierce, 1999, J., David, R., Joan, H., Arnold, 2004). After comparing the number of performed repetitions for knee extension and ankle plantar flexion, it was also observed that despite 40% lowness of maximal power of ankle plantar flexor muscles to that of knee extensor muscles, repetitions performed before inability in ankle plantar flexion movements averagely was 22% higher than the number of performed repetitions for knee extension movements, a fact which be related to the type of muscular webs of each of the muscular groups (P., Gribble, 2003, P, Gribble, J. Hertel, 2003). One must note that according to the findings of former researches, motor units of knee extensor muscles are mostly of fast-contraction type, which generate more power than slow-contraction muscles but are not as resistant against fatigue as the slow-contraction muscles (P, Gribble, J, Hertel, C, Denegar, W. Buckley, 2004). The obtained findings in this study, in accordance with the findings of former studies by Vuillerem et al (2008) and Vaillant et al (2008), are indicative of decrease of balance and access distance after implementation of fatigue protocol (J, Vaillant, N, Barthalais, N., Vuillerme, 2008, N, Vuillerme, R., Cuisinier, 2008). The probable reason for the observed decreases can be associated with lack of proper function of muscles and the sensory effects of fatigue. The implementation of fatigue protocol in one area of

the body and on the muscles functioning in one joint, leads to transmission of some messages from sensory receivers to the central neural system, which in turn probably reacts for safety of the aimed muscles, via sending a massage for reduction of their contractive activity (P, Gribble, J, Hertel, C, Denegar, W., Buckley, 2004). Therefore, implementation of fatigue protocol on one muscle group results in reduction of neural transmission speed in afferent and efferent paths leading to the aimed muscle group, which may also contribute to decrease of dynamic balance and access distance of the elderly subjects after implementation of fatigue protocol. So, in short, noting that changes in afferent sensory inputs from a peripheral receptor change muscular-neural control of the lower parts of the body, and also that lower parts muscles fatigue also change the afferent input from muscular receivers, we can consider a combination of these factors as the probable reason explaining the decrease of the body's inability in controlling the lower parts after implementation of fatigue protocol (BL, Riemann, JB, Myerse, SM. Lephart, 2002, DT, Ochsendorf, CG, Mattacola, BL. Arnold, 2000, SL, Whinteny, JLC, People, SP. Cass, 1998). The decrease of access distance after implementation of fatigue protocol on both muscle groups mentioned so far had a meaningful difference so that the decrease in knee extensors was more than that of ankle area (diagram 1). The reason for this issue can probably be attributed to the different roles each of the lower part members of the body play in performing the Star test, because trying to reach the longest access distance in anterior, anterior-interior and anterior-lateral vectors, the body leans backward, and performing this movement needs extensive extrovert activity of knee extensors. Similarly, performing the test in posterior-lateral, posterior-interior and posterior vectors, the subjects need ankle plantar flexion action to reach the longest access distance, and this necessitates intense activity of posterior muscle group of the leg while trying to perform the test in these vectors (L., **Jorunn Helbostad, S., Leirfall, R., Moe-Nilssen and O., Sletvold, 2007, P. A. Gribble, J., Hertel, C.R., Denegar, W. E., Buckley, 2004, N., Pinsault and N., Villierme, 2008**). Based on the findings of the present study, it can be said that decrease in access distance on various vectors of Star test after implementation of fatigue protocol on various muscles of lower parts of the body depends on the function of theses muscles while performing access action before implementation of fatigue protocol, and unlike the findings of Vuillerem and his colleagues (2006), compensatory mechanisms, thought to interfere after implementation of fatigue protocol for maintaining balance, do not interfere in limiting the role of certain muscle group in reaching the longest access distance on various vectors of Star test (N, Vuillerom, S., Dmetz, 2006). As the diagram 1 show, implementation of fatigue protocol on proximal area of lower parts (knee extensors) has had more influence on decrease of the subjects' access distance in Star test, which may probably be explained

as: knee area fatigue just brings change and fall of the function of muscles and afferent nerves of this area. Conversely, implementation of fatigue protocol on distal area of lower parts (ankle plantar flexors) only results in change and fall of the muscles and afferent nerves of ankle. Hence, the decrease of access distance in Star test after fatigue protocol on knee area can be attributed to the high correlation between performance of Star test, almost in all vectors, and proper function of knee extensor muscles (N. F., Horgan, F., Crehan, E., Bartlett, A. M., Grandy, A. R., Moore, C. F., Donegan, M., Curran, 2008, N., Pinsault and N., Villerme, 2008, J., Treleaven N, lowchoy R, Darnell B, Panizza D., Brown-Roth well 2008). Another explanation for this issue may be the precedence of the role of neural afferent of proximal area to the role of neural afferent of distal area in balance control. The results of this study confirm a theory which considers partial fatigue in lower parts muscles (knee extensors and ankle plantar flexors) as the reason for decrease of dynamic balance and increase of probability for injuries among the elderly people caused by falling down.

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## RELIABILITY AND VALIDITY OF A DISCONTINUOUS GRADED EXERCISE TEST ON DANSPRINT® ERGOMETER

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#### Abstract

The aim of this study was to determine the validity and reliability of a graded exercise test on a specific kayak ergometer (Dansprint®) in which certain physiological and technical parameters that can to define kayaking performance were assessed. Fourteen male top-level kayak paddlers (all members of Spanish Kayaking National Team) participated in this investigation. All subjects carried out two ergometric tests (Ergo1 and Ergo2) and one flat water test (FWT) in random order. At anaerobic threshold (AnT) intensity, the results showed acceptable levels of reliability (comparison between data of Ergo1 and Ergo2 tests) in the assessment of velocity ( $r=0.784$ ;  $p=0.004$ ), stroke frequency ( $r=0.976$ ;  $p<0.001$ ), heart rate ( $r=0.964$ ;  $p<0.001$ ), and blood lactic acid concentration ( $r=0.899$ ;  $p<0.001$ ). Validity coefficients showed a strong relationships between Ergo2 and FWT tests in all physiological and technical parameters with the exception of velocity ( $r=0.498$ ;  $p=0.121$ ). It can be concluded that specific ergometry can be used to evaluate and to prescribe training AnT intensities of top-level kayakers attending to parameters such us heart rate, whole blood lactic acid concentration, and stroke frequency. Nevertheless, the training prescription through specific ergometry must be taken cautiously when velocity is the parameter of reference.

**Key words:** kayaking, testing, ergometry.