UNIVERSITY OF PÉCS

Biological and Sportbiological Doctoral School

Changes of the composition of human saliva and blood after exercise

PhD Thesis

Éva Tékus

Supervisor

Dr. Márta Wilhelm

PhD

PÉCS, 2016

1. Introduction

In the modern molecular biological studiesseveral body fluids were analysed investigatingphysiologicalprocesses in the human body, to diagnose diseases or to monitor the effets of physical activity.In the present investigation we examined the qualitative and quantitative composition of both body fluids (saliva, blood) after exercise.

Nowadays many publications have reported exercise-induced changes in saliva composition after one bout of exercise. Chicharro and collegues (1998) reported that physical activity modifies the amount of some salivary immunoglobulins, proteins, electrolytes, hormones and lactate.

Since salivary lactate (SL) is a useful molecule to measure the effectiveness of training, its changes has been longinvestigated in blood samples. During physical activity blood lactate (BL) concentration is elevated, then it gradually decreases post-exercise (Zagatto et al., 2004).First Mendez and his collegues (1976) found significant correlation between SL and BL concentration, in an other research also high correlation was reported in BL and SL content following a 30 km race (Santos et al.., 2006). SL level was found significantly lower, than BL concentration measured at the same time, it wasonly 15% of the BL concentration (Segura et al., 1996). Among athletes significant relationship was found between the peak SL and BL level after 400 m run (Ohkuwa et al., 1995). Based on previous studiesa time difference between peak SL and BL concentration was suggested but more investigations are needed to determine theunderlaying mechanism. SL level appears potentially delayed compared to BL samples (Santos et al., 2006; Reer et al., 2009).

Physical activity strongly influences the composition of the blood (Sanchis-Gomar and Lippi, 2014). The biological characteristics of marker molecules, the type of training, the intensity and duration, the time of the recovery after exercise all influence when and how much of the extracellular biomarkers appear in the blood (Lippi et al., 2008).

Based on Sanchis-Gomar and Lippi's (2014) research, the three most important changes in the human body influencing the composition of blood caused by physical activity are: reduction in plasma volume, increased basal metabolism and microdamage in organs and organ systems (mainly in striated muscle). In the present dissertation we investigated the exercise induced muscle damages and their biomarkers in blood. Unaccustomed, high-intensity exercise or eccentric training can induce microinjuries in striated muscle (Friden et al., 1983; McKune et al., 2012). These microdamages summated might lead to major injuries, like tendon injuries, hamstring tear (Brockett et al., 2001) or long lasting sport injuries. Reactive oxygen species produced during physical activity and oxidative stress can cause further damages, inflammation in the muscle and other tissues (Brancaccio et al., 2010). The inflammation has an important role in the repair and regeneration of the damaged muscle tissue (Clarkson and Hubal, 2002).

McKune et al. (2012) described that the most important indirect indicators of exercise induced muscle damage (EIMD) are the reduction of torque, decreased range of motion, the swelling in muscle, the delayed onset of muscle soreness (DOMS) and biomarkers in body fluids.

Numerous markers are found in the blood following microinjuries of the muscle such as structural proteins (like myosin heavy chain; Sorichter et al., 2001), enzyme activity (creatine kinase - CK; Stäubli et al., 1985; lactate dehydrogenase; Munjal et al., 1983), myoglobin (Munjal et al., 1983; Speranza et al., 2007), aspartate amino transferase (Van der Meulen et al., 1991; Lippi et al., 2008) and have been used to monitor EIMD. Nowadays microinjuries have indirectly been investigated with newer, more specific blood markers. These marker molecules are skeletal troponin I (s-troponin-I; Sorichter et al., 1997), fast skeletal troponin I (fs- troponin-i; Chapman et al., 2013) and α-actin (Martinez-Amat et al., 2005). Few indirect markers possess high sensitivity and specificity in estimation of EIMD, so it is important to identify molecules for accurate monitoring.

Our knowledge is limited to orosomucoid and gelsolin molecules and their relationship to physical activity. Earlier Poortmans and Haralambie (1979) found that after a 100 km run serum orosomucoid level (AGP) was significantly higher compared to the resting level for 24 h.

In a bicycle ergometer test, the untrained controls' plasma gelsolin level (GSN) decreased, while in athletes it increased 30 minutes after exercise, suggesting that endurance exercise changes the expression of gelsolin in striated muscle (Yu et al., 2013). Our knowledge is limited to the aforementioned molecules (GSN, AGP) in EIMD.

The effects of regular training are the occurance of many adaptational changes in the human body affecting the function of all organs whith varying degrees. Only some of the possible adaptation processes are presented. Regular physical activity leads to changes in body composition (decreased fat mass, increased muscle mass; Malina, 2007), improvements in spirometrical parameters (higher tidal volume and vitalcapacity; Adegoke and Arogundade, 2002), more effective cardiovascular function (decreased heart rate in rest, higher maximal heart rate; Katch et al., 2011; enlargement of the left ventricular volume and it's wall thickening, Fagard et al., 1984) and changes in regulation (augmented parasympathetic activity, decreased sympathetic effect). Heart rate variability and R-R variability analysis is used investigating the effects of the autonomic nevous system in heart fuction (Sayers, 1973). The most important parameters of R-R variability are the high frequency component (HF; shows the effect of the vagus nerve; Perini and Veicsteinas, 2003), the low frequency component (LF; caused by the sympathetic and the vagal nerve innervation) and very low frequency component (VLF) that is the consequence of peripheral vasomotor control.The resting LF/HF ratio is approximately 1, this ratio elevates at the start of physical activity (decreased parasympathetic activity, augmented sympathetic regulation), while after activity this value

decreases again as atypical consequence of resting parasympathetic predominance (Apor et al., 2009).

2. Aims of the study

According to previous data we defined the following aims:

1. Nowadays many researches examine the changes and the relationship between SL and BL level during exercise, mainly among athletes (Santos et al., 2006; Reer et al., 2009; Zagatto et al., 2004). SL concentrations measured post-exercise are less known, only one study investigated the effect of two training conditions and compared the lactate level of body fluids, but the immediate changes of SL have not been studied yet few minutes after exercise (Ohkuwa et al., 1995). The first aim of our study was to investigate the changes of BL and SL after maximum intensity exercise among athletes, recreational athletes and non-athletes.

2. Numerous studies are known describing the factors influencing BL level (Borresen and Lambert, 2008), however the parameters affecting the SL concentration are less known, especially in the post-exercise period. Therefore, the second aim of the study was to investigate the physiological and biochemical parameters influencing quantitative changes of SL and BL.

3. In elite sports it is an important research area to examine the EIMD caused by eccentric training, since microinjuries might lead to serious muscle tears, although these also can cause hypertrophy in muscles (Brockett et al., 2001). Numerous blood molecules have been used to study micro injuries indirectly, but most of them are not only found in skeletal muscles and the sensitivity of the mentioned markers is often low (McKune et al., 2012). In previous researches difference was shown in EIMD markers between athletes and non-athletes after training (Vincent and Vincent, 1997; Brancaccio et al., 2007; Karamizrak et al., 1994). The aim of the study was to measure the plasma concentration of two novel molecules (GSN, AGP) and other indirect EIMD markers 24 h after eccentric exercise, and to analyze the concentration difference of the two molecules between athlete and non-athlete subjects.

4. In addition to blood markers of microinjuries (CK, myoglobin, lactate dehydrogenase, troponin – I, actin etc.) induced by eccentric training, there are other indirect markers (torque deficit, DOMS, swelling, reduction in range of motion) widely used investigating microdamages (McKune et al., 2012). In the present study our aim was to investigate the correlation between blood markers (GSN, AGP) and other conventional EIMD markers.

3. Materials and methods

Analysis of the blood and salivary lactate

During our preliminary measurements physical education students were recruited in athletes group (SCS, n=13) but they did not participate in any elite competitive sports. Later on participants were divided into a group of endurance athletes (middle- and long-distance runners, ÁCS; n=8) and non-athletes subjects (KCS; n=8) as a control group were measured in the studied sample. In KCS subjects have not been involved in any regular training for years.

During the preliminary study measurements of SCS were perfomed. Based on the obtained data the number of the measured physiological parameters was increased to further delineate the causes of the previous results. The protocols used were the same as later on, only the total body water and R-R variability were new parameters collected.

Later the study protocol began with antropometric parameters (height, weight, body mass index - BMI, body composition; Tanita BC-420 MA, Tokyo, Japan) measured, then R-R variability and resting heart rate (HR) was registered with a HR monitor (RS-800, Polar Electro, Kempele, Finland). HR monitoring was conducted according to Baynard's method (2004). In addition, lung function measurements were taken with a spirometer (SpiroDoc Inc. MIR, Rome, Italy).

After collection saliva samples were centrifuged (4000 rpm, 10 min) and stored at –20 °C until further measurements. Blood samples were taken from fingertips at the same time as saliva collected and BL was determined with a portable lactate analyzer (Lactate Scout, SensLab, Leipzig, Germany) immediately after collection.

Then each subject performed a maximal Astrand treadmill test (Astrand and Ryhming, 1954) during and 5 min after the exercise test R-R variability and HR data were registered. During the treadmill protocol heart function of subjects was continuously monitored with the aid of a 12-lead electrocardiograph (ECG CARDIOVIT AT-60, Schiller Medical, Wissembourg, France), each case sports practitioner assisted the exercise protocol.

Whole saliva samples were collected before and 1, 4, 8, 12, 15, 20 min after the exercise test, as well as BL level was measured again. After centrifugation salivary samples were stored at –20 °C, then spectrophotometric analyses (Hitachi U-2000 spectrophotometer, Hitachi, Japan; Phypers and Pierce, 2006) were applied to measure lactate content in saliva.

Analysis of muscle damage with plasma actin, gelsolin and orosomucoid level

Physical education students were recruited in SCS (n=12) but they did not participate in any competitive sports. In KCS subjects (n=6) have not been involved in regular training for years.

First antropometric parameters (height, weight, BMI, body fat percent, fat mass, muscle mass; Tanita BC-420 MA, Tokyo, Japan) were measured.

Later venous blood samples were collected during rest. Samples were centrifuged. Laemmli buffer (Tris-HCl pH 6.8; β-mercaptoethanol, Sodium dodecyl sulfate - SDS -, glycerol) was added 1: 5 to plasma one part of the supernatant, and after boiling samples were stored frozen at -70 °C. The other part of the supernatant was immediately used for measurements without freezing.

After a warm-up all subjects performed 6 sets of 15 repetitions maximal eccentric quadriceps contractions with the dominant limb on Multicont II isokinetic device (Multicont II, Mediagnost, Budapest and Mechatronic Ltd., Hungary) and between sets one minute rest was provided. The contractions were executed between 20° and 80° knee angles, at 60°/s constant angular velocity (Váczi et al., 2009).Before the training subjects performed three maximal isometric contractions with the trained quadriceps at 70° knee angle to measure the maximal isometric torque. During the exercise HR changes were registered with RS-800 HR monitor (Polar Electro, Kempele, Finland).

Pre- (baseline), immediately (0 h), 1 h, 6 h, and 24 h post-exercise venous blood samples were taken. After sampling the plasma aliquots were stored at - 70°C. Plasma concentrations of actin, GSN and AGP were determined with Western blot technique with enhanced chemiluminescence detection. The blots were photographed in a G:BOX Chemi XX6 gel documentation system (Syngene) and quantified with its densitometric software.

At each sampling timepoint BL levels were assessed (Lactate Scout Analyzer, EKG Senslab, Germany), and for CK activity measurement an automated clinical chemistry analyzer (Cobas Integra 400 Plus, Roche Diagnostics, Hungary) was used.

The subjective intensity of soreness was estimated using a visual analog soreness scale (0 without pain to 10 with intolerable pain) at baseline and at 24 h (Bobbert et al., 1986), furthermore maximal voluntary contraction torque was measured.

Statistical analysis in the two measurements

The normality of data was analyzed with Kolmogorov-Smirnov test. If normally distributed values were found, differences between the two groups were computed with one-way analysis of variance (ANOVA). If normally distributed values were not found, non-parametric Man-Whitney U-test was applied to investigate muscle soreness of the two groups. The changes of plasma parameters in time among the two groups were compared with two-way (group x time) factorial ANOVA. One-way repeated measures ANOVA tests were used with Bonferroni post-hoc analyses to investigate the differences among the five measurement timepoints. To determine correlations results of measurements were analyzed with Pearson test. Values are reported as mean ± standard error of mean (SEM). The level of significance was adopted at $p < 0.05$.

4. Results

Analysis of blood and salivary lactate

Based on pretest experiences, methods of later measurements were supplemented with total body water assessment and more scheduled water consumption of the subjects. During the preliminary tests all participants belonged to the SCS group. Based on the mean somatometric and body composition data, the studied population was homogenous; there are no significant differences in the measured antropometric parameters.

After the exercise two SL peaks were detected in each athlete subject. They were divided into two subgroups on the basis of SL curves. In the first subgroup (n = 5) subjects had a lactate peak at 1 min and in the second subgroup (n = 3) the peak was later, at 4 min. A second lactate peak was found in both subgroups and it also differed in the first subgroup at 8 min after the test, in the second subgroup at 12 min after the test). Later the SL level decreased and this decrease was faster in the second subgroup than in first one. The profile of BL concentrations and curves were the same in both subgroups during measurements. There was only one significant difference among physiological parameters between SL subgroups, namely forced exspiratory volume in one second (FEV1).

Later the anthropometric results of ÁCS, KCS were compared. We found significant differences between the groups only in body fat percentage and training volume. ÁCS group has lower body fat mass, while training volume of this group was higher.

In this study concentration of BL and SL were measured before and after an Astrand treadmill protocol used as vita maxima load. As after the preliminary test two lactate peaks were detected in each athlete subject in saliva after the exercise. Subjects of ÁCS were divided into two groups on the basis of SL curves (in the first group at 1 min and 8 min after the test; in the second group at 4 min and 12 min after the test). In controls (KCS) we found high individual variability in lactate profile of SL, ÁCS-like pattern was not found.

The BL concentration measured was the highest 1 min after exercise then it gradually decreased in both groups. After the exercise test lower BL was detected among athletes, although they spent more time on the treadmill. The last BL level of ÁCS was closer to the resting value than in KCS. We found significant positive correlation between BL and SL in all subjects after maximum intensity exercise, but correlation is weaker in controls.

Nearly significant ($p<0.069$) difference was found in LF parameters between the two subgroups of ÁCS and post-exercise LF/HF ratio was also higher after the exercise. ÁCS significantly differed from KCS in spirometric and circulatory parameters, as well as changes in sympathetic-parasympathetic balance before, during and after the Astrand test. Several correlations

were found between the measured parameters (e.g between SL levels and total body water, between maximal HR during exercise and SL levels, between mean R-R interval and SL levels).

Analysis of muscle damage with plasma actin, gelsolin and orosomucoid levels

The investigation started with antropometric measurements, body composition of two training groups (SCS, KCS) were compared. There were significant differences between body fat percent and fat mass of the two groups and both parameters were higher in KCS. As it was expected, weekly training volume was significantly higher in the trained group (SCS).

Significant difference ($p=0.037$) was found between the two groups in the baseline MVC torque. Subjects of SCS had higher MVC torque during the measurements. The value of total work performed during the exercise was significantly higher in KCS, although maximal heart rate of this group was nearly the same. The BL level did not differ between groups during the test protocols, but maximal value of BL was significantly higher than all other BL level in both groups.

The intensity of muscle soreness did not show differences, but the muscle soreness at 24h post-exercise was significantly elevated compared to the baseline value in all subjects.

Plasma concentrations of actin, GSN, AGP and CK enzyme activity were measured at baseline, immediately, 1 h, 6 h, and 24 h post-exercise. There was no significant group-by-time interaction in plasma actin, GSN, AGP and CK levels, suggesting that changes in time were similar in the two groups (SCS, KCS). However, we found significant time main effect for the aforementioned blood markers (GSN, AGP, CK), suggesting that they changed significantly over time regardless of the training status.

Plasma actin levels did not show substantial differences between groups throughout the study period. The post-hoc analyses revealed that actin level was elevated significantly from 0 h to 1 h and other post-exercise measured GSN levels did not differ signifficantly from the baseline value.

According to the results of post-hoc analyses the minimal GSN value post-exercise (MIN) significantly differed from the resting GSN concentration.

AGP level of each subjects increased after training. There were significant differences between maximal AGP levels post-exercise (MAX) and the baseline value, as well as between 1 h, 6 h post-exercise and MAX.

CK activity continuously increased post-exercise and peaked at 24 h. The post-hoc analyses revealed significant differences between the baseline and 24 h post-exercise CK levels.

For the Pearson correlation test, the trained (SCS) and untrained groups (KCS) were combined. Relationships among plasma actin, GSN, AGP and conventional muscle damage markers (muscle soreness score, CK, torque deficit) obtained at each time points and the MIN and MAX

values were also considered investigating the relation of the measured parameters to each other. The most important relationships are highlighted. CK levelat 6 h post-exercise significantly correlated with GSN level at immediately, 6 h, 24 h post-exercise and MIN. High correlation was found between the intensity of muscle soreness at 24 h post-exercise and MIN GSN. Muscle soreness differences at the two timepoints correlated with GSN MIN and AGP level at 24 h post-exercise. According to Pearson correlation analysis no relationship was found between plasma actin and GSN concentrations at any time points. The resting level of GSN correlated with AGP immediately after and 1 h post-exercise. The total quadriceps mechanical work correlated with GSN level at 6 h and 24 h post-exercise and MIN.

5. Discussion

Regular physical activity can influence normal physiological functions of the human body which can be detected at the level of the organs and at molecular level in body fluids. Some physiological adaptations of the organ systems are well-known and discussed in this dissertation also.

Trained participants of our studies had more optimal body composition, lower body fat percentage and BMI, as well as higher total body water. During spirometric measurements they had higher FEV1 and 25-75 values referring to more efficient functions of the respiratory muscles. The adaptation of the autonomic nervous system and cardiovascular system cause lower heart rate during exercise, faster HR recovery and significantly higher RR variability in athletes. As it was expected better physiological parameters, higher total work and physical performance were measured in moderately and highly trained groups oppositely to sedentary subjects.

As it was previously described plasma CK enzyme activity and AGP level increased one day after eccentric exercise. Presumably both molecules had a relationship with EIMD and the following inflammatory processes induced by eccentric exercise.

However, several new results are obtained during our investigations and they are summarized in the following points:

1. According to our results SL level measured after maximal treadmill test significantly differs in athlete and non-athlete groups. Two lactate peaks were detected in each athlete subject in saliva after the test protocol, while in controls we have found high individual variability in lactate profile, without any regular changes in SL. Physiological differences between athletes and sedentary controls can cause different SL responses in both groups. According to our findings, these can be defined primarily as physiological changes, namely adaptation of the nervous system and circulatory system to exercise, and altered hydration status.

2. We described a time delay between BL and SL levels and two lactate peaks were observed in saliva after maximal exercise. These curves were different in endurance athletes and non-athletes.

On the basis of SL curves endurance athletes were divided into two groups. In the first group subjects had a lactate peak at 1 min after exercise and the second peak at 8 mins after the test. In the second group each lactate peak occurred 3 mins later. A difference was detected in R-R variability values between the two groups. In the second athlete group data were obtained from HR analyses. Our study shows that in the rest period, and also in the end of the recovery period RR is smaller, indicating that indeed high sympathetic tone slows saliva secretion and lactate appearance in saliva. Higher sympathetic tone has a strong influence in performance during competition. Before sport competition too high sympathetic tone can be beneficial or disadvantageous also. SL measurement in the preparatory period could be a useful tool testing physical and psychological efficiency of trainings in athletes.

3. We identified some physiological parameters which alter SL level after maximal exercise. The most important ones are total body water, maximal heart rate, number of heart beats and R-R variability measured during exercise.

4. In opposite to other researches, we did not find relationships between trained and untrained groups neither in plasma markers of microinjuries nor other EIMD indicators (CK, DOMS, torque deficit). In previous studies the baseline strength profile of trained and untrained groups were more higher than in our study, while the strength difference between the measured groups were similar to our subject's. We proposed that changes in EIMD markers after eccentric exercise depend on the training status of subjects and the level of physiological adaptations to exercise.

5. 24 h after the eccentric exercise, plasma GSN level was decreased while actin concentration remained unchanged. There was no relationship between the quantity of actin and GSN, however other EIMD markers (CK, intensity of muscle soreness) correlated with GSN levels after exercise. Supposedly plasma GSN levels are influenced by the level of physical activity and EIMD, changes of plasma GSN in healthy subjects are not actin-dependent.

6. References

Adegoke OA, Arogundade O. (2002) The effect of chronic exercise on lung function and basal metabolic rate in some Nigerian athletes. *Afr J Biomed Res* 5: 9-11.

Apor P, Petrekanich M, Számadó J. (2009) Heart rate variability analysis in sports. *Orv Hetil* 150(18): 847-853.

Astrand PO, Ryhming I. (1954) A nomogram for calculation of aerobic capacity (physical fitness) from pulse rates during submaximal work. *J Appl Physiol* 7: 218-222.

Bobbert MF, Hollander AP, Huijing PA. (1986) Factors in delayed onset muscle soreness of man. *Med Sci Sports Exerc* 18: 75-81.

Borresen J, Lambert MI. (2008) Quantifying training load: a comparison of subjective and objective methods. *Int J Sports Physiol Perform* 3: 16–30.

Brancaccio P, Maffulli N, Limongelli FM. (2007) Creatine kinase monitoring in sport medicine. *Br Med Bul* 81,82: 209–230.

Brancaccio P, Lippi G, Maffulli N. (2010) Biochemical markers of muscular damage. *Clin Chem Lab Med* 48(6): 757-767.

Brockett CL, Morgan DL, Proske U. (2001) Human hamstring muscles adapt to eccentric exercise by changing optimum length. *Med Sci Sports Exerc* 33: 783-790.

Chapman DW, Simpson JA, Iscoe S, Robins T, Nosaka K. (2013) Changes in serum fast and slow skeletal troponin I concentration following maximal eccentric contractions. *J Sci Med Sport* 16(1): 82-85.

Chicharro JL, Lucía A, Pérez M, Vaquero AF, Urena R. (1998) Saliva Composition and Exercise. *Sports Med* 26(1): 17-27.

Clarkson PM, Hubal MJ. (2002) Exercise-induced muscle damage in humans. *Am J Phys Med Rehabil* 81(11 Suppl): S52-69.

Fagard R, Aubert A, Staessen J, Eynde EV, Vanhees L, Amery A. (1984) Cardiac structure and function in cyclists and runners: comparative echocardiographic study. *Br Heart J* 52(2): 124-129.

Friden J, Sjostrom M, Ekblom B. (1983) Myofibrillar damage folowing intense eccentric exercise in man. *Int J Sports Med* 4: 170-176.

Karamizrak SO, Ergen E, Tore IR, Akgun N. (1994) Changes in serum creatine kinase, lactate dehydrogenase and aldolase activities following supramaximal exercise in athletes. *J Sports Med Phys Fitness* 34: 141–146.

Katch VL, McArdle WD, Katch FI. (2011) *Essentials of exercise physiology.* Lippincott Williams & Wilkins, a Wolters Kluwer business; Philadelphia, USA

Lippi G, Schena F, Montagnana M, Salvagno GL, Guidi GC. (2008) Influence of acute physical exercise on emerging muscular biomarkers. *Clin Chem Lab Med* 46: 1313-1318.

Malina RM (2007) Body composition in athletes: assessment and estimated fatness. *Clin Sports Med* 26(1): 37-68.

Martinez-Amat A, Boulaiz H, Prados J, Marchal J, Puche PP, Caba O, Rodriguez-Serrano F, Aranega A. (2005) Release of α-actin into serum after skeletal muscle damage. *Br J Sports Med* 39: 830-834.

McKune AJ, Semple SJ, Peters-Futre EM. (2012) Acute exercise-induced muscle injury. *Biol Sport* 29: 3-10.

Mendez J, Franklin B, Kollias J. (1976) Relationship of blood and saliva lactate and pyruvate concentrations. *Biomedicine* 25: 313-314.

Munjal DD, McFadden JA, Matrix PA, Coffman KD, Cattaneo SM. (1983) Changes in serum myoglobin, total creatine kinase, lactate dehydrogenase and creatine kinase MB levels in runners. *Clin Biochem* 16(3): 195-199.

Ohkuwa T, Itoh H, Yamazaki Y, Sato Y. (1995) Salivary and blood lactate after supramaximal exercise in sprinters and long-distance runners. *Scand J Med Sci Sports* 5: 285–290.

Perini R, Veicsteinas A. (2003) Heart rate variability and autonomic activity at rest and during exercise in various physiological conditions. *Eur J Appl Physiol* 90: 317-325.

Phypers B, Pierce JMT. (2006) Lactate physiology in health and disease. *Contin Educ Anaesth Crit Care Pain* 6(3): 128-132.

Poortmans JR, Haralambie G. (1979) Biochemical changes in a 100 km run: proteins in serum and urine. *Eur J Appl Physiol* 40: 245–254.

Reer R, Semerak P, Ziegler M, Schmidt T, Loppow D, von Duvillard SP, Braumann KM. (2009) Comparison of blood vs saliva lactate measurements resulting from lactate minimum vs constant load tests. *Med Sci Sports Exerc* 41: 258.

Rundle A. (2005) Molecular epidemiology of physical activity and cancer. *Cancer Epidemiol Biomarkers Prev* 14(1): 227-236.

Sanchis-Gomar F, Lippi G. (2014) Physical activity- an important preanalytical variable. *Biochem Med (Zagreb)* 24(1): 68-79.

Santos RVT, Almeida ALR, Caperuto EC, Martins JrE., Costa Rosa LFBP. (2006) Effects of a 30-km race upon salivary lactate correlation with blood lactate. *Comp Biochem Phys* 145: 114–117.

Sampson DL, Broadbent JA, Parker AW, Upton Z, Parker TJ. (2014) Urinary biomarkers of physical activity: candidates and clinical utility. *Expert Rev Proteomics* 11(1): 91-106.

Sayers B. (1973) Analysis of heart rate variability. *Ergonomics* 16: 17-32.

Segura R, Javierre C, Ventura JLL, Lizarraga MA, Campos B, Garrido E. (1996) A new approach to the assessment of anaerobic metabolism: measurement of lactate in saliva. *Br J Sports Med* 30: 305–309.

Sorichter S, Mair J, Koller A, Gebert W, Rama D, Calzolari C, Artner-Dworzak E, Puschendorf B. (1997) Skeletal troponin I as a marker of exercise-induced muscle damage. *J Appl Physiol* 83(4): 1076–1082.

Sorichter S, Mair J, Koller A, Müller E, Kremser C, Judmaier W, Haid C, Calzolari C, Puschendorf B. (2001) Creatine kinase, myosin heavy chains and magnetic resonance imaging after eccentric exercise. *J Sports Sci* 19(9): 687-691.

Speranza L, Grilli A, Patruno A, Franceschelli S, Felzani G, Pesce M, Vinciguerra I, De Lutiis MA, Felaco M. (2007) Plasmatic markers of muscular stress in isokinetic exercise. *J Biol Regul Homeost Agents,* 21(1-2): 21-29.

Stäubli M, Roessler B, Köchli HP, Peheim E, Straub PW. (1985) Creatine kinase and creatine kinase MB in endurance runners and in patients with myocardial infarction. *Eur J Appl Physiol* 54(1): 40-45.

Váczi M, Costa A, Rácz L, Tihanyi J. (2009) Effects of consecutive eccentric training at different range of motion on muscle damage and recovery. *Acta Physiol Hung* 96(4): 459–468.

Van der Meulen JH, Kuipers H, Drukker J. (1991) Relationship between exercise-induced muscle damage and enzyme release in rats. *J Appl Physiol* 71(3): 999-1004.

Vincent HK, Vincent KR. (1997) The effect of training status on the serum creatine kinase response, soreness and muscle function following resistance exercise. *Int J Sports Med* 18: 431-437.

Yu CC, Zendzian-Piotrowska M, Charmas M, Dlugolecka B, Baranowski M, Górski J, Bucki R. (2013) Change in blood gelsolin concentration in response to physical exercise. *Biol Sport* 30: 169-172.

Zagatto AM, Papoti M, Caputo F, de Castro Mendes O, Denada BS, Baldissera V, Gobatto CA. (2004) Comparison between the use of saliva and blood for the minimum lactate determination in arm ergometer and cycle ergometer in table tennis players. *Rev Bras Med Esporte* 10: 481-486.

Publications

I. Publications related to the thesis

Tékus É. Plasma actin, gelsolin and orosomucoid levels after eccentric exercise. *J Hum Kinet* **Under review. IF: 1,029**

Tékus É, Kaj M, Szabó E, Szénási NL, Kerepesi I, Figler M, Gábriel R, Wilhelm M. (2012) Comparison of blood and saliva lactate level after maximum intensity exercise. *Acta Biol Hung* 63(Suppl 1.): 89-98. **IF: 0,593**

Kaj M, **Tékus É**, Juhász I, Stomp K, Wilhelm M. (2015) Changes in physical fitness of Hungarian college students in the last fifteen years. *Acta Biol Hung* 66(3): 270-281. **IF:0,589**

Vaczi M, **Tekus E**, Kaj M, Koszegi T, Ambrus M, Tollar J, Atlasz T, Szabadfi K, Karsai I. (2013) Changes in metabolic and muscle damage indicators following a single bout of jump training on stair versus at level. *Acta Physiol Hung* 100(4): 445-456. **IF: 0,882**

Tékus É, Kaj M, Kerepesi I, Wilhelm M. (2012) Különböző edzettségű csoportok maximális terhelést követő nyál- és vér tejsavszintjének vizsgálata = Analysis of blood and salivary lactate concentration of groups with different fitness level after maximal intensity exercise. *Egészség-Akadémia* 3(2):147-153.

II. Conference abstracts related to the thesis

Tékus É, Horváth-Szalai Z, Ludány A, Kőszegi T, Wilhelm M. (2015) Edzés hatására létrejövő mikrosérülések és a plazma aktin, gelszolin, orozomukoid koncentrációja. *XII. Országos Sporttudományi Kongresszus.* Eger, Magyarország

Tékus É, Váczi M, Horváth-Szalai Z, Ludány A, Kőszegi T, Wilhelm M. (2014) Plasma actin, gelsolin levels and exercise induced skeletal muscle damage. *Compass to health: 1st International Conference on Leisure, Recreation and Tourism Conference*. Harkány, Magyarország

Tekus E, Vaczi M, Cselko A, Pinter G, Koszegi T, Wilhelm M. (2014) The effect of exercise on blood plasma markers of skeletal muscle injuries. *Joint meeting of the Federation of European Physiological Societies (FEPS) and the Hungarian Physiological Society*. Budapest, Magyarország

Tékus É, Váczi M, Cselkó A, Pintér G, Kaj M, Figler M, Kőszegi T, Wilhelm M. (2013) A gelszolin mennyiségének vizsgálata excentrikus terhelést követően. *A Magyar Élettani, Farmakológiai és Mikrocirkulációs Társaságok 2013. évi közös Tudományos Kongresszusa.* Budapest, Magyarország

Tékus É, Váczi M, Cselkó A, Pintér G, Kaj M, Kőszegi T, Wilhelm M. (2013) Edzés indukálta mikrosérülések vizsgálata vérplazma markerek segítségével. *Fiatal Sporttudósok I. Országos Konferenciája.* Szombathely, Magyarország

Tekus E, Kaj M, Szabo E, Szenasi NL, Kerepesi I, Figler M, Gabriel R, Wilhelm M. (2012) The effect of the sympathetic nervous system and dehydration on salivary lactate concentration. *1st International Doctoral Workshop on Natural Sciences*. Pécs, Magyarország

Tékus É. (2012) Salivary lactate influencing factors: effects of the sympathetic nervous system and dehydration during physical activity. *20th International Congress on Sports Sciences for Students.* Budapest, Magyarország

Tékus É, Kaj M, Fodróczy E, Kerepesi I, Wilhelm M. (2011) A tejsavszint változása vér- és nyálmintákban terhelést követően. *Magyar Farmakológiai, Anatómus, Mikrocirkulációs és Élettani (FAMÉ) társaságok 2011. évi közös tudományos konferenciája.* Pécs, Magyarország

III. Other publications

Váczi M., **Tékus É.**, Atlasz T., Cselkó ., Pintér G., Balatincz D., Kaj M., Wilhelm M. (2016) Ballroom dancing is more intensive for the female partners due to their unique hold technique. Physiology International **Accepted. IF: 0,814**

Tékus É. (2015) Modern eljárások a diagnosztikában: Mutasd meg a nyálad, megmondom ki vagy! *Élet és tudomány* 70(27): 841-843.

Németh J, Schulteisz N, **Tékus É**, Wilhelm M. (2014) Szociális otthonban élő idősek egészséggel kapcsolatos fittsége. *Népegészségügy* 92(1): 26-34.

Cselkó A, László Z, **Tékus É**, Wilhelm M. (2013) Anthropometric and cardiovascular characteristics of young elite male handball players according to playing positions. *Exercise and Quality of Life. Journal of Science in Sports* 5(1): 31-41.

Kaj M, Németh J, **Tékus É**, Wilhelm M (2013) Physique, body composition and physical fitness of Finish, Hungarian and American adolescents. *Exercise and Quality of Life. Journal of Science in Sports* 5(1): 19-29.

Bobály V, **Tékus É**, Kaj M, Váczi M. (2013) Testösszetétel, erő, egyensúly és hajlékonyság vizsgálata modern- és néptáncos nőknél. *Tánctudományi közlemények: a magyar Táncművészei Főiskola tudományos folyóirata* 5(1): 18-26.

Tékus É, Szanka K, Kaj M, Atlasz T, Wilhelm M. (2013) Az elhízás hatása falvakban és városban élő 11-15 éves tanulók testösszetételére, fizikai teljesítőképességére és alapvető élettani paramétereire. *Magyar Sporttudományi Szemle* 14(56): 37.

Pintér G, **Tékus É**, Kaj M, Váczi M, Wilhelm M, ifj. Gallyas F. (2012) A B-alanin és a rendszeres edzés együttes hatásának vizsgálata dohányzó- és nem dohányzó személyeken = Examination of the combined Effect of B-alanine and Regular Exercise with Smoking and Non-Smoking Subjects. *Egészség Akadémia* 3(3): 185-193.

IV. Other conference abstracts

Cselkó A, **Tékus É**, Szabó E, Schuth G, Kőszegi T, Wilhelm M. (2015) 8 hetes edzés hatása prepubertás korú kézilabdázók teljesítményére és hormonális állapotára. *XII. Országos Sporttudományi Kongresszus.* Eger, Magyarország

Szabó E, Szénási NL, Gazdag Z, Heckel Z, Váczi M, Wilhelm M, **Tékus É.** (2015) Antioxidáns folyamatok vizsgálata időskorban. *XII. Országos Sporttudományi Kongresszus*. Eger, Magyarország

Cselkó A, **Tékus É**, Váczi M, Schuth G, Kőszegi T, Pintér G, Wilhelm M. (2014) Hormonal changes among prepubertal female handball players after aerobic training. *Compass to health: 1st International Conference on Leisure, Recreation and Tourism Conference*. Harkány, Magyarország

Vaczi M, **Tekus E**, Atlasz T, Cselko A, Pinter G, Balatincz D, Kaj M, Wilhelm M. (2014) Ballroom Dancing: Recreation or Performance Sport? *Compass to health: 1st International Conference on Leisure, Recreation and Tourism Conference*. Harkány, Magyarország

Ambrus M, Falvay P, **Tékus E**, Atlasz T, Cselko A, Pinter G, Wilhelm M, Vaczi M. (2014) Stair-Climb Exercise Training For The Development Of Cardiovascular and Muscular Fitness In Overweigth Women. *Compass to health: 1st International Conference on Leisure, Recreation and Tourism Conference*. Harkány, Magyarország

Heckel Z, Atlasz T, **Tékus É**, Kőszegi T, Laczkó J, Váczi M. (2014) Mikrosérülés markerek és adaptáció monitorozása egy kéthetes erőfejlesztő mikrociklusban idős és fiatal embereknél.*XI. Országos Sporttudományi Kongresszus.* Debrecen, Magyarország

Cselko A, **Tekus E**, Vaczi M, Schuth G, Koszegi T, Wilhelm M. (2014) The effect of aerobic training on performance and hormonal changes among prepubertal female handball players.*Joint meeting of the Federation of European Physiological Societies (FEPS) and the Hungarian Physiological Society*. Budapest, Magyarország

Cselkó A, **Tékus É**, Schuth G, Wilhelm M. (2013) Utánpótláskorú leány kézilabdázók állóképességének változása edzés és spontán fejlődés hatására. *43. Mozgásbiológiai konferencia.* Budapest, Magyarország

Cselkó A, **Tékus É**, Schuth G, Váczi M, Wilhelm M. (2013) Antropometriai és spiroergometriai jellemzők vizsgálata utánpótláskorú leány kézilabdázóknál. *Fiatal Sporttudósok I. Országos Konferenciája.* Szombathely, Magyarország.

Pintér G, **Tékus É**, Kaj M, Váczi M, Hegyhát-Végvári Á, Wilhelm M, Ifj. Gallyas F. (2013) Enzimaktivitás és fizikális paraméterváltozások, dohányzó és nem dohányzó fiatalokon, béta-alanin kiegészítést követően. *Fiatal Sporttudósok I. Országos Konferenciája.* Szombathely, Magyarország.

Pintér G, **Tékus É**, Kaj M, Váczi M, Wilhelm M, Ifj. Gallyas F. (2013) Dohányzó és nem dohányzó fiatalok terhelésélettani paraméterváltozásai β-alanin kiegészítést követően. *A Magyar Élettani, Farmakológiai és Mikrocirkulációs Társaságok 2013. évi közös Tudományos Kongresszusa.* Budapest, Magyarország

Wilhelm M, Kaj M, **Tékus É**, Németh J, Schulteisz N, Szanka K, Berki T. (2013) Az idősek egészséggel kapcsolatos fittsége Magyarországon. *A Magyar Élettani, Farmakológiai és Mikrocirkulációs Társaságok 2013. évi közös Tudományos Kongresszusa.* Budapest, Magyarország

Kaj M, **Tekus E**, Juhasz I, Stomp K, Wilhelm M. (2012) Immobility Stress - How has the health-related fitness status changed in the Hungarian young adults in the last decades? *1st International Doctoral Workshop on Natural Sciences*. Pécs, Magyarország

Pintér G, **Tékus É**, Kaj M, Váczi M, Wilhelm M, Jr Gallyas F. (2012) The effect of β-Alanine in smoker and non-smoker university students. *János Szentágothai Memorial Conference and Student Competition.* Pécs, Magyarország

Váczi M, **Tékus É**, Kaj M, Kőszegi T, Ambrus M, Tollár J, Atlasz T, Karsai I, Szabadfi K. (2012) Mikrosérülést jelző és metabolikus markerek akut változása intenzív lépcsőedzés után. *IX. Országos Sporttudományi Kongresszus*. Szeged, Magyarország

Wilhelm M, **Tekus E,** Kaj M, Schulteisz N, Krucso J. (2011) The health and fitness of Hungarian females between the age of 20 and 65 years. *2nd International Scientific Conference Exercise and Quality of Life.* Novi Sad, Szerbia

Váczi M, **Tékus É**, Kaj M, Kőszegi T, Ambrus M, Tollár J, Atlasz T, Karsai I, Szabadfi K. (2011) Nagy intenzitású lépcsőn végrehajtott edzés akut izommechanikai és élettani hatása. *Magyar Farmakológiai Anatómus Mikrocurkulációs Élettani Társaságok Közös Tudományos Konferenciája.* Pécs, Magyarország

Atlasz T, **Tekus E**, Krucso J, Balasko M, Soos S, Forro Z, Szabadfi K, Wilhelm M. (2010) Comparison of healthy adult and COPD female population in Hungary by spirometric analysis. *15th Annual Congress of the European College of Sport Science*. Antalya, Törökország

Kállai V, Vecsei Zs, **Tékus É**, Wilhelm M. (2010) Thalamic Mast Cell Number and their Distribution in Female Rats. *IBRO International Workshop*. Pécs, Magyarország

V. Book chapters

Tékus É. (2015) Antropometriai mérések. In: Tékus É, Meszler B, Váczi M.: Motorikus képességek mérése. (ebook) Pécs, *Pécsi Tudományegyetem TTK* (ISBN:978-963-642-650-7)

Tékus É. (2015) Az állóképesség mérése. In: Tékus É, Meszler B, Váczi M.: Motorikus képességek mérése. (ebook) Pécs, *Pécsi Tudományegyetem TTK* (ISBN:978-963-642-650-7)

Tékus É. (2015) Az ízületi mozgékonyság mérése. In: Tékus É, Meszler B, Váczi M.: Motorikus képességek mérése. (ebook) Pécs, *Pécsi Tudományegyetem TTK* (ISBN:978-963-642-650-7)

Tékus É. (2015) A légzés sejtszintű alapjai. In: Józsa R, Atlasz T, Tékus É, Wilhelm M.: A terhelésélettan alapjai I. (ebook) Pécs, *PTE TTK Sporttudományi és Testnevelési Intézet* (ISBN:978-963-642-815-0)

Cumulative impact faktor: 2,878
Impact factor of publications related to the thesis: 2,064
Total citations: 7
Cited by others: 7