TRAINING IN HIGH ALTITUDE ENVIRONMENTS AND ITS INFLUENCE ON THE CHANGES IN SELECTED PHYSIOLOGICAL INDICATORS OF A SLOVAK REPUBLIC REPRESENTATIVE IN WALKING

Ivan Čillík, Martin Pupiš

Faculty of Humanities, Matej Bel University, Banská Bystrica, Slovak Republic

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Middle and high altitude preparation is a longterm part of the preparation of our Slovak race walking representatives. Martin Pupiš is one of those athletes whose regularly makes use of this system. In our paper we report his preparation at four high altitude camps, in preparation phases in the years 1998/99–2001/02. The period of the year when the camps took place were very similar. Also the duration was from 26 days to 36 days. The average amount of racewalking and running was, for one day, approximately the same during all four camps. The proportion of race walking in kilometres increased from 70% to 80%. The proportion of walking zones changed depending on the current specialisation with the highest number of km in tempo endurance. The reaction to high altitude preparation was very good, when in analysed blood components – hematocrit, haemoglobin, erythrocytes, and a medium quantity of erythrocytes we recorded positive changes, and only in leucocytes was there a decrease.

Keywords: High altitude surroundings, high altitude preparation, race walking, physiological indicators.

INTRODUCTION

A long process in the discovery of the influences of hypoxia on the organism of sportspeople preceded the utililization of high altitude preparation in preparation for sporting activity. Initial information in this area is connected with mountain touring, hiking and mountaineering. The most significant progress in this research into high altitude environments started in the 1960s shortly after the International Olympic Committee (IOC) decided to host the nineteenth Olympic Games (OG) in Mexico City, where the stadium is at an altitude of 2240 m above sea-level (a. s. l.). Even before the OG in Mexico City the first three, and later an additional high altitude training centre, were built. Since that time the utilization of a new form of preparation, the so-called hypoxic preparation, has started. The hypoxic preparation is characterised by a significantly lower atmospheric pressure and a substantially lower value of partial oxygen pressure. Hollman (1994) stated that already initial research had confirmed assumptions about acute reactions to higher altitudes and about chronic adaptation to physical work.

Later there were found longterm, prevalently positive influences of hypoxic preparation on the organisms of sportsmen. In sports practice the preparation for competition in the mountains, or in usual conditions, has used the following distribution of altitude grades:
low mountains – from 600 to 1200 m above sea-level, middle mountains – from 1200 to 2500 m above sea-level, high mountains – higher than 2500 m above sea-level (Suslov, Gippenrejter, & Cholodov, 1999).

As Hamar (1995) states, a very important factor is the determination of optimal training stay altitude. An enormous altitude may restrict the training load to the extent that the training could be finally insufficient and lead not towards improvement but towards deterioration of efficiency. Training in a hypoxic environment is a supplementary method to develop endurance abilities and this can apply only to those who have reached a sufficient level of VO_2max more than 65ml.kg.min^{-1} (Štulrajter, 1999; Kujaník & Štulrajter et al., 2001).

For the utilisation of high altitude preparation it is necessary to know the dependence between air-circulation and partial pressure from the sea-level. Suslov, Gippenrejter and Cholodov (1999) state changes in density of air, evaporation, air pressure and partial oxygen pressure with growing elevation. The above mentioned authors also follow two other additional important factors linked with preparation in high altitude environments – decreased temperature (in individual centres it is different) and the higher intensity of sun radiation with a growing elevation.

It is inevitable to know and respect the data about phase acclimatisation, as Bahchevanov (1994) states. Just as important are the facts about changes in circulation and respiration systems during adaptation and acclimatisation, as stated by Jungmann (1962) a long time ago. Knowing the conditions of specific adaptation for the preparation at Štrbské Pleso lake centre is

of particular importance for our sportspeople, using as they do often this centre for their preparation (Broďáni, 2002).

Luža, Klvaňa and Vilímová (2002) have recommended the use of high altitude training not only for the development of aerobic, but also of anaerobic endurance.

Referring to the circumstances that the high mountain centres with appropriate climatic conditions are divided amongst different continents, we have to take into account the movement of time as the distance movement causing biorythmic breaks (Jančoková, 2000).

High altitude preparation has become, in recent years, a part of top athletes' preparation for endurance events and in athletic pedestrianism as well. For walkers, who regularly prepare in a hypoxic environment it is essential to carry out systematic controls of the training process before, during and after preparation in high altitude environments. This is consistent with the fact that the reactions of organisms to a training load are very different from those which are usually observed in lowlands. In general, these reactions depend on the period of acclimatisation which the competitor allows him or herself. Obviously the time needed for global acclimatisation varies according to the individual and is not the same for every sportsperson. According to Kisiel (2000) total acclimatisation is different for everybody according to the place of high altitude training, the atmospheric conditions, the level of preparedness for global training and on the number of high altitude training preparations undergone as well as on other factors. Therefore it is necessary to remember the necessity of taking into account individual factors in the determination of the training load.

Based on this, training camps are anticipated in the altitude of 1000–1300 m, with the aim of avoiding the unfavourable influences of acclimatisation in high altitude preparations in the altitude of 1800–2500 m (Bichon, 1990; Kisiel, 1997). One important factor which influences high altitude training is the evaluation of the physiological reaction of the organism to its stay in the mountains and to its performance.

Kisiel (2000), the trainer of the Olympic winner and World Championship winner in walking Robert Korzeniowski, recommends that we carry out a thorough checkup everyday, including measurement of blood pressure and heart pulse, measurement of body weight with the use of a sport tester at every training session as well as the measurement of lactate acid values in the blood. Before every high altitude training camp and after every return to the lowlands walkers undergo a medical investigation, which includes the analysis of blood composition and endurance abilities measurement. During their stay in the mountains they monitor their blood composition – after the completion of the adaptation period. In addition to this, they evaluate consequently the walkers' walking technique by the frequent recording of the training in the field.

Gradually, the sportspeople began (instead of high altitude training) to utilize artificial facilities which simulate a high altitude environment, e.g. hypoxic chambers, hypoxic halls and hypoxic tents. As these facilities are very expensive, hypoxic preparation in the mountains is always realistic. They have begun to use the system of preparation "live high – train low".

The Slovak walker representatives have long utilised hypoxic training in their preparations. The competitors under the leadership of the trainer Benčík have a well-elaborated system of hypoxic preparation, which they have successfully applied together with the monitoring of functional status and physiological indicators. The aim of our paper is to make monitoring of the training in the hypoxic environment, and its influence on selected physiological indicators, representative of the Slovak Republic in athletic walking during a four-year period.

METHODS

Martin Pupiš (M. P.) – born on 19 October 1978, height 175 cm, weight 61 kg, was the monitored competitor. In 1997 he was awarded the bronze medal at the European Junior Championships in 10 km walking. His middle altitude preparation at 1343 m in Štrbské Pleso lake began in winter 1997. Over eighteen months he, several times, repeated his preparation in Štrbské Pleso lake and then in 1998 prepared himself at an altitude of 1900 m a.s.l. in the Austrian Alps. Only in 1999 he first prepared himself at an altitude above 2000 m a.s.l. We have observed in this paper the preparation of the competitor in four-year training cycles (YTC) 1998/99 – 2001/02. He attended in every year of the monitored years one high altitude training camp, anticipated by preparation in lower mountains (TABLE 1). Trainee M. P. was during the monitoring period a member of the Military sports club Dukla in Banská Bystrica and his trainer was Juraj Benčík.

From the selected physiological indicators were discovered blood components affecting oxygen binding – hematokrit, hemoglobin, erythrocytes and a medium volume of erythrocytes and leucocytes. The collection of blood was always taken during the second week after his return from training camp. The Spiroergometric Laboratories investigation was carried out in the same week and under the same conditions.

TABLE 1
Survey of the high altitude camps and middle altitude camps which were used

Year training cycle (YTC)	Camp in the middle altitude mountains	High altitude camp
1998/1999	15. 10.–5. 11. Š. Pleso (22 days) 27. 1.–7. 2. Š. Pleso (12 days)	14. 2.–14. 3. Toluca (Mexico) (29 days) 2640 m above sea-level
1999/2000	7.–14. 1. Malinô Brdo (8 days)	24. 1.–28. 2. Cochabamba, La Paz (Bolivia) (36 days) 2600–3600 m above sea-level
2000/2001	2.–20. 12. Š. Pleso (19 days)	2.–27. 2. Toluca (Mexico) (26 days) 2640 m a.s.l.
2001/2002	–	2. 2.–4. 3. Toluca (Mexico) (31 days) 2640 m. a.s.l.

We evaluated the training load during high altitude training camps in the following specific training indicators (STI):

1 – running (km)
2 – walking at speed to 4:05 km.min^{-1} (km)
3 – walking at speed 4:05–4:39 km.min^{-1} (km) – specific pace in 20 km
4 – walking at speed 4:40–5:22 km.min^{-1} (km) – specific pace in 50 km
5 – walking at speed 5:22–6:22 km.min^{-1} (km)
6 – walking at speed over 6:22 km.min^{-1} (km)
7 – walking total (km)
8 – running and walking total (km)

RESULTS

Trainee M. P. attended high altitude training camps in preparation periods within single YTC in similar periods with a different duration varying from 26 to 36 days. All training camps were adequately long in order to have sufficient effect on the organism of the sportsperson. The volume of training in kilometers in running went down on average in one day, as did the share of the overall volume of the absolved kilometres (Fig. 1, TABLE 2).

This trend is right if the share of walking is increased with the increased efficiency of the competitor in walking. His or her share of walking in total volume formed 80% in the last year. We consider this stressed 80% in accordance with Moc (1976) as adequate for walkers in the top class. Total volume in running and walking is on average in one day almost the same during all four observed training camps (21–22 km). The total absolved volume varies according to the number of days in the camp.

Fig. 1
Percentage proportion of running and special training zones (race walking) during high altitude camps in successive years

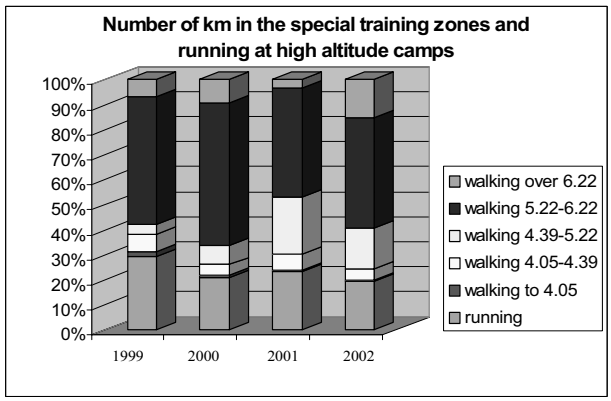


TABLE 2
Proportion of race walking zones (%) and part of race walking km in round numbers of km at high altitude camps

YTC/Training zones	2	3	4	5	6	7
1998/99	3.0	9.7	5.8	71.6	9.9	70.8
1999/00	1.3	5.6	9.5	71.9	11.7	79.4
2000/01	0.9	8.0	29.6	56.9	4.46	76.8
2001/02	0.9	5.5	20.3	54.5	18.8	80.9

Explications: 2 – race walking at speed under 4:05 km.min^{-1} (km), 3 – race walking at speed 4:05–4:39 km.min^{-1} (km) – specific pace at the 20 km, 4 – race walking at speed 4:40–5:22 km.min^{-1} (km) – specific pace at the 50 km, 5 – race walking at speed 5:22–6:22 km.min^{-1} (km), 6 – race walking at speed over 6:22 km.min^{-1} (km), 7 – race walking km from all zones (km), 8 – number of running and race walking km together (km)

High altitude preparation was the most intense in the first year, because from the observed training camps the trainee M. P. absolved the highest volume of kilometers in the highest speed walking zone. The share of walking in the highest speed zone within the total volume of walking was the highest in the training camp in 1999 (Fig. 1, TABLE 2). We explain this by the fact that in 1999 he specialised in walking 20 km and next year (2000) he has begun to specialise in 50 km walking.

The change of specialisation from YTC 1999/2000 in 50 km also caused a change in volume and in the share of absolved walking training indicators.

The camp in the year 2001 was the shortest one, but the most specialised in performance at 50 km. It was characterised by a very low portion in the fastest and the slowest zone. In essence he developed only tempo endurance, a special tempo, and tempo speed (special training zones 5, 4 and 3). Although the camp had the shortest duration, he did the highest number of km at the special rate of 50 km (special training zone 4) of

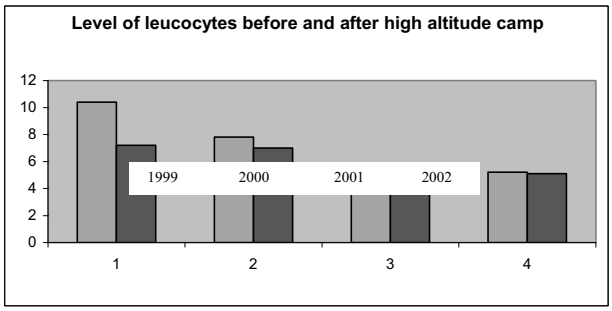
all the analysed camps. During the training camp in the year 2001 he did on average per day the highest number of km – 22.42 km (TABLE 2). This trend has been shown to be right, because M. P. in the season 2001 broke his personal record on 50 km, and also this system of preparation helped him to improve his performance at 20 km. During 3 weeks he improved his personal record at 20 km.

It turned out that an important influence on his growing tendency to improve in both events has been training in the special tempo zone at 50 km. M. P. was able to train in this zone in endurance training sessions at up to 40 km at a significantly stronger load of the circulatory system than in the lowland. M. P. similar to for example, Mráze's, Blažek's and Korčok's records after 3 parts of his high altitude preparation. There was a subjective improvement in his feelings during training sessions in the hypoxic surroundings, and there was also some objective growth in his performance, because in the following season he improved his personal bests in both walking events.

No increase in the intensity in high altitude surroundings was shown for the year 2002. M. P. did, in comparison with the camp a year before, a lower number of km in the special tempo at 50 km (special training zone 4), but also tempo speed (special training zone 3) and tempo endurance (special training zone 5 – Fig. 1, TABLE 2). A high number of km in the slowest zone (STZ-6) was, for a sportsman of top performance, unsuitable. Compared to two previous camps there was also a small decline in the average number of km per day. In that season he fell behind his own personal records in race walking at 50 and 20 km.

The analysed athlete had good proportions of blood components. The value of hematocrit was regularly more than 45%, which is the amount approaching the upper limit of reference values (the reference spread is 39–49%). Also, he was regularly tested on hydration at BODYSTATE, where the water content was at the level of 66%. His reactions to the preparation in the high altitude conditions was very good in all blood components he observed an increase (Fig. 3, TABLE 3). The only component in which he recorded a decrease at all three camps was leucocytes (Fig. 2, TABLE 3), but this phenomenon is not unusual, because in this period (when the organism is in the state of the highest sports performance) the proportion of leucocytes often decreases. It was because of this that the athlete in this period tended to sustain more injuries or diseases, because leucocytes create part of the immune system. This phenomenon also manifested itself at M. P. in the form of little problems with the skeletal and muscular system, and with influenza.

Fig. 2
Comparison of number of leucocytes before and after high altitude camps

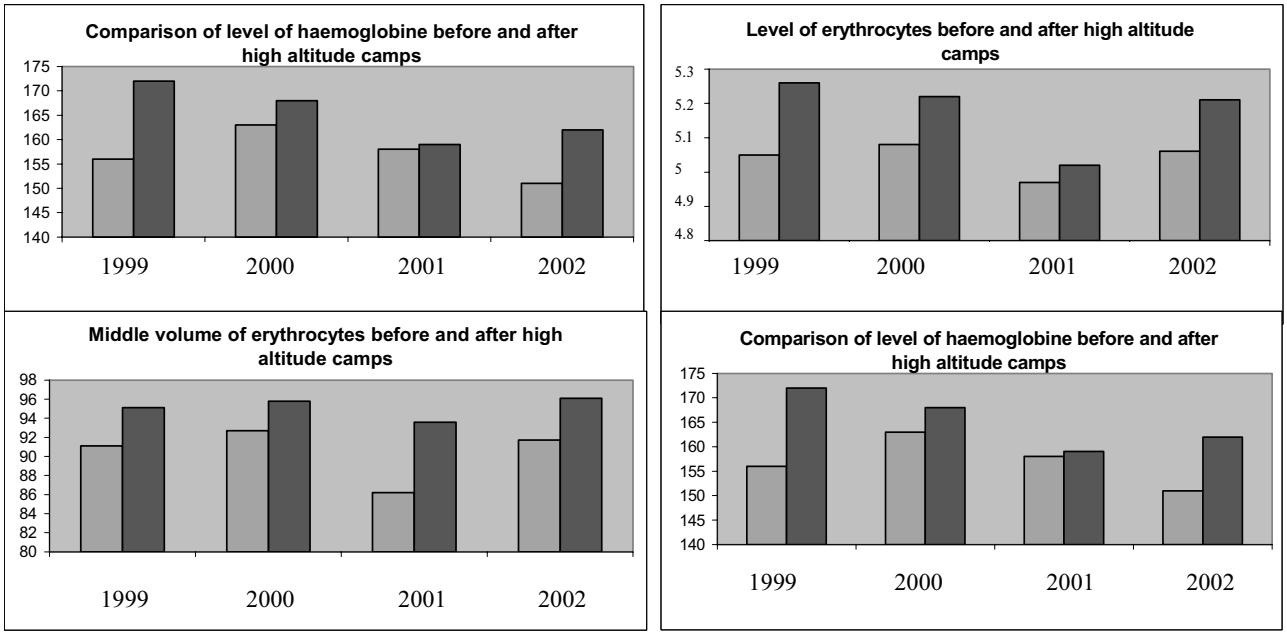


After the first two camps the proportion of hematocrit in his blood was 50%, and also the level of haemoglobin was at 170 $g.l^{-1}$, when haemoglobine too was at a level approximating the upper limit of reference values (140–180 $g.l^{-1}$– TABLE 2). Both these values are at a high level, nearly at the required level, when they approximate the upper limit of reference values, therefore the physiological possibilities of the organism. A conspicuous increase was evident too in the case of the remaining components, except the afore – mentioned leucocytes. The increase of hematocrit was 0.4–4.0%, on average more than 2.5%. The increase of haemoglobin was 1–16 $g.l^{-1}$, on the average 8 $g.l^{-1}$. It has been proven that, during hypoxicy preparation, there is usually a general increase of capacity of blood in the organism. The absolute increase is higher. It also shows an increase of erythrocytes of over 3.1–7.4 $g.l^{-1}$, which is on an average 4.725 $g.l^{-1}$. All these values are at a very good level and approaching the top levels which can be achieved by natural means. As we can see (Fig. 3) before the last high altitude camp (in the year 2002) entry values were lower than in previous years. The reason is that M. P. prepared in Australia (at sea-level), but not in the natural hypoxic surrounding as previously. It showed negatively in the whole structure of the blood from the view of its transport capacity. Also, in this case, after high altitude preparation there was a marked increase in blood components, which shares the transport of O_2 in the organism. Due to these values there is a marked growth in the utilization of oxygen in the organism during sports activity. It results also in an increase in endurance ability. All these facts were shown too on M. P. with regard to the increase of aerobic capacity of the organism, when after middle altitude preparation came an increase of the VO_2max at 11.9 $ml.min^{-1}.kg^{-1}$. After following the high altitude camp for more than 7.3 $ml.min^{-1}.kg^{-1}$. This fact too shows a bilateral linkage between quantitative increase of blood components and the increase of aerobic capacity of the organism. It also manifests iteself in actual sports performance, because a race walker takes a minimum of 90% of his track in the aerobic regime (Brandejský, Kratochvíl, Lapka, & Piták, 2001).

TABLE 3
Results of blood tests before and after high altitude camps

	12.2. 1999/ 17.3. 1999	18.1. 2000/ 3.3. 2000	9.1. 2001/ 14.3. 2001	16.1. 2002/ 11.3. 2002	Reference zones
Haemoglobin- Hmgl ($g.l^{-1}$)	156 / 172	163 / 168	158 / 159	151 / 162	140–180
Hematocrit - Htc (%)	46.0 / 50.0	47.1 / 50.0	45.7 / 46.1	42.8 / 45.6	39–49
Middle volume of erythrocytes - SOEry ($g.l^{-1}$)	91.1 / 95.1	92.7 / 95.8	86.2 / 93.6	91.7 / 96.1	81–100
Erythrocytes - Ery (pl^{-1})	5.05 / 5.26	5.08 / 5.22	4.97 / 5.02	5.06 / 5.21	4.3–5.3
Leukocytes- Leuko (nl^{-1})	10.4 / 7.2	7.8 / 7.0	4.6 / 4.8	5.2 / 5.1	4–9

Fig. 3
Comparison of blood components before and after high altitude camps



CONCLUSION

All high altitude camps were ranked right in the period of special preparation, always after preparation in middle altitude mountains (1000–1300 m above sea-level). A duration of 26–36 days of camps was sufficient. It brought the required effect. The authors claimed that the minimal length of stay in the hypoxic surroundings must be 14–18 days, which was in all cases kept.

The total number of kilometres at the special rate depends on the number of days at high altitude camps. The number of kilometres of race walking and running on average per day was approximately at the same level for all 4 camps. With the growth of age and increasing performance, the total number of km went up from 70% to 80%, which is in accordance with methodological recomendations.

The proportion of individual walking indicators has been changed also in the dependence on change of the specialization with the predominance of tempo rate and special rate, which showed that an important influence on the increasing performance at both tracks was training in the zone of special rate at 50 km.

The reaction of M. P. to high altitude preparation was very good, when in all analysed blood components, except leucocytes, important positive changes were recorded. An absolute increase in blood components was more marked, because under the influence of a hypoxic environment, not only does the capacity of blood components grow, which contributes its share to the transport of the oxygen in the organism (hematocrit, haemoglobin, erythrocytes, a medium amount of erythrocytes), but also there is a general increase in the capacity of the blood in the organism, under the influence of the increase in the capacity of blood plasmas.

The camp in the year 2001 has been considered from the point of view of the training indicators as best done, which reflected directly on the performance of M. P. But the most marked increases were only recorded in the middle erythrocytes and leukocytes. In M. P. we recorded, after the 3rd part of high altitude preparation in the year 2001, a subjective improvement of feelings

during training in the hypoxic surroundings. Generally we valued the influence of hypoxia on the organism of the analysed sportsman as positive.

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TRÉNINK VE VYSOKOHORSKÉM PROSTŘEDÍ A JEHO VLIV NA ZMĚNY VE VYBRANÝCH FYZIOLOGICKÝCH UKAZATELÍCH REPREZENTANTŮ SLOVENSKÉ REPUBLIKY V ZÁVODNÍ CHŮZI

(Souhrn anglického textu)

Příprava ve střední a vysoké nadmořské výšce je dlouhodobou součástí přípravy slovenských reprezentantů v závodní chůzi. Martin Pupiš je jedním z těch atletů, kteří pravidelně využívají tento systém. V tomto příspěvku popisujeme jeho přípravu ve čtyřech vysokohorských kempech v přípravných fázích v letech 1998/1999–2001/2002. Části roku, ve kterých se kempy odehrávaly, byly velmi podobné. Doba trvání byla rovněž stejná od 26 do 36 dnů. Průměrné množství závodní chůze a běhu bylo v rámci jednoho dne přibližně stejné během všech čtyř kempů. Poměr závodní chůze v kilometrech se zvýšil ze 70% na 80%. Podíl oblastí pro chůzi se měnil v závislosti na aktuální specializaci s nejvyšším počtem kilometrů ve vytrvalosti tempa. Reakce na přípravu ve vyšší nadmořské výšce byla velmi dobrá; když jsme analyzovali krevní složky – hematokrit, hemoglobin, erytocyty, střední množství erytocytů – zaznamenali jsme pozitivní změny; pouze u leukocytů nastal pokles.

Klíčová slova: vysokohorské prostředí, příprava ve vysoké nadmořské výšce, závodní chůze, fyziologické ukazatele.

Doc. PaedDr. Ivan Čillík, CSc.

Matej Bel University
Faculty of Humanities
Tajovského 40
974 01 Banská Bystrica
Slovak Republic

Education and previous work experience

Comenius University, Bratislava –1984, Postgraduate Study High School of Pedagogy,

Comenius University, Bratislava – 1994, Faculty of Physical Education and Sport, CSc. in Physical Education,

Matej Bel University, Banská Bystrica – 2001, Faculty of Humanities, Associated Professor in Sport Education,

Since October 1981 – Slovakia, Banská Bystrica, Matej Bel University: Teacher (Assistant Professor, Associated Professor),

Since October 2001 – Poland, Bydgoszcz, University Bydgoszcz (Akademia Bydgoska): External Associated Professor,

April 1991 to September 1992, September 2002 to February 2004 – Slovakia, Banská Bystrica, Matej Bel University: Head of the Department of Physical Education and Sport,

Since March 2004 – Slovakia, Banská Bystrica, Matej Bel University: Vice-Dean of Faculty of Humanities.

First-line publication

Čillík, I. (2000). *Pedagogical assessment of multi-annual sport preparation in the 400 meters womens' run.* Banská Bystrica: FHV UMB.