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Preliminary Research of Kinetic and Time Characteristics of Gait

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Abstract

Purpose of the study is to assess plantar kinetic characteristics of adults over 18 while walking. Walking variability is both a biomechanical and an orthopedic problem. Individual techniques may influence the economy of movement or cause problems with the support or locomotive systems. The quality of walking is influenced by foot architecture and biomechanical properties of an individual as well as other factor such as body weight, muscle fatigue, the location of the body center etc.

The aim of the study is to set basic representative dynamic parameters of walking which can affect walking effectiveness and economy.

With the help of PEDAR mobile device, 31 adults (26 – 60 years old) were observed while walking. Selected kinetic parameters of walking have been observed. We focused on time characteristics of the walking cycle and plantar pressure while the foot contacts the floor as average and maximal plantar pressure, contact time and plantar pressure during active and passive parts of the step, area of foot contact during step. Body weight, height, and age of tested persons were recorded and BMI calculated. Laterality of lower limbs was found out through test. The physical activity assessment of the participants with a focus on utilizing walking was carried out through a questionnaire. Wilcoxon test, analysis of variance and factor analysis for statistic evaluation was used.

Factor analysis revealed that the selected strength, time and area variables (n=28) which characterize the activity of the plant are possible to be reduced down to four representative parameters. In a heterogeneous group regarding age, body proportions and BMI a logical significant differences appeared for mean and maximum plantar pressure during regular walk when we divided all participants into groups with optimum weight and overweight according to BMI below or over 25 respectively. Mean value of plantar pressure during the whole course of contact was 0.8 times the body weight for both groups divided according to BMI, maximum pressure reached 1.1 times the body weight in the

group with index over 25; and 1.2 times the body weight in the group with lower BMI. We found differences between right and left foot maximal plantar pressure for all group during the step (p = 0,004) and for maximal pressure between both foots during active part of step (p = 0,002), but laterality was not significant for this variable (Wilcoxon test, p=0.35). Any significant differences ($p<0.05$) regarding time characteristics of step were not found.

For further research, it is necessary to adjust the range of observed parameters. We found difference of plantar load between right and left but the follow-up survey is necessary.

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Introduction

The development of motor stereotypes of humans is very long. The way to bipedal gait starts in the period of one of the earliest hominids *Sahelanthropus (6 million years ago)*, however, only Homo erectus (1.9 million years ago) became fully bipedal as his pelvis and femur were similar to the pelvis and femur of modern man and thus enabled him to cover longer distances by walking. Standing on both legs became a great advantage while walking on earth, developing skills and other motor activities; on the other hand erected bipedal gait can have a number of side effects on health which arise from this posture (Vařeka, 2009 etc.). Walking is one of significant motor activities which enabled humans to get new experience, to enhance their learning and it also made it possible to develop new activities. Thus, it has become part and parcel of physical load. Since the 1950s, modern humans have gradually started to neglect the need of physical activity. If we take physical load manifested by a human in the early 20th century as 100 %, then at the end of the century the load was 1 % (Frollis, 1988). At present, up to 70 % of the inhabitants of advanced countries suffer from motor insufficiency as a result of a sedentary way of life (Dobrý, 2007). Decreasing the level of physical fitness as well as decreasing the time spent by active moving in the inhabitants' leisure time have a secondary effect on work capacity, work performance and, most of all, health (Blair, 1989, 2001, Pangrazi, 1996, Blahutková, 2005, Dobrý, 2008). The share of walking in total motor activity remains still big and walking is most often reported as usual motor activity which is used by more than 75 % of population of the Czech Republic during the week. Frömel (2005, 2006) states that the average time that teenagers spent by walking per day is 50-80 minutes. Neuls (2007) found out that the average time in adult population of the Czech Republic is about 60-80 minutes and this amount of time being also influenced by environmental factors. If compared with other advanced countries, the Czech Republic is still a country of walkers; e.g. in the USA, Berkey (2003) found out only 24 minutes of walking per day and only for 15-30 % of adults in the USA walking presents the most often used motor activity (McArdle, 1986). Still, walking is considered significant by elderly people to maintain optimum functions (Wert, 2009).

Research in the area of health and motor activity of humans increases the amount of knowledge about walking and its kinetic and kinematic characteristics. Great individual variability in gait has been proved which is based on the quality of the locomotive and support systems, the quality of controlling and regulatory mechanisms and on motor activity in childhood and youth. Gait variability is an issue both biomechanical and orthopaedic. Studies have been carried out to describe some variables which contribute to the gait variability mainly from the point of view of age or illness (Brach, 2008). According to Gabell, Nayak (1984), the characteristics of gait such as length, the duration of a step represent the automatic stepping mechanisms of gait (i.e. pattern generator for gait) and gait width and the duration of double-support posture represent the checking of balance. Therefore, worsened activity of such controlling mechanisms increases gait variability. Scientists who study the differences in gait of different adult age categories have proved a number of changes in elder population such as decrease in velocity (Hageman, 1986, Waters, 1988, Winter, 1990, Ostrosky, 1994, Perry, 2010), smaller extension in hip and knee joints, smaller range during dorsal leg flexing (Winter, 1990, Ostrosky, 1994, Kerrigan, 2001, McGibbon, 2004), decrease in stride length, changes in stride width or reductions in performance during the take-off stage of a stride (Blake, 1989, Ostrosky, 1994, McGibbon, 2003). Further increase in gait variability has been proved with the influence of diseases such as Parkinson or Alzheimer diseases (Hausdorff, 1997, 2000, Schaafsma, 2003, Sheridan, 2003), peripheral neuropathy (Richardson, 2004) etc.

Gait technique and its quality is affected by foot architecture, anthropometric and biomechanical properties of an individual and other factors such as body weight, muscle fatigue, the location of the center of gravity of the body etc. Individual gait technique affects movement economy or causes problems with the support or locomotive systems. The range of normality of gait motor pattern determination is a matter of selecting appropriate criteria for evaluating its quality with respect to the uniqueness of every individual. At present, it is possible to make use of a number of modern technologies and methodologies which help to examine and solve this topic (e.g. Ayyappa, 1997a, 1997b, Kirtley, 2006, Zvonař, 2009, Perry, 2010).

Our preliminary research attempts to find out about the basic characteristics of selected force, time and overall indicators of gait in ordinary population of the Czech Republic with respect to age and laterality of lower extremities.

Methods

We have carried out a preliminary descriptive study. The research group was composed of random selection of adult population of both men and women of the Czech Republic at the average age of 43.8 (SD 9.9) within the range of 26-57 years of age, weight 70.9 (SD 12.1), BMI 23.7 (SD 3.1) (n=31, 11 men, 20 women). Laboratory research has been carried out in standard condition. Vertical ground reaction force of the sole during stance was recorded using Pedar mobile system (by Novel Company, Munich, Germany) by means of two pressure insoles (in the form of shoe insoles) which contain 99 pressure sensors evenly distributed over the whole insole. The record has been taken with 100 Hz frequency using special software by the Novel Company. The insoles were calibrated using calibration equipment of the Pedar device. The forces created during gait have been recorded for 12-15 strides, out of which six were used for assessment (three for each foot).

Eleven representatives factors were chosen: Maximal force (F_{max}), maximal force during absorption stage of stance (F_{abs}, phase of Loading Response [LR] and MidStance [MSt]), maximal force during active stage of stance (F_{act}, phase of Terminal Stance [TSt] and Preswing [PSw]), mean force during stance (F_m), mean force during absorption stage of stance (F_{mabs}), mean force during active stage of stance (F_{mact}), time of total stance (t), time of active stage of stance (t_{act}), time of absorption stage of stance (t_{abs}), area of maximal plantar contact area during stance (A_{max}), area of plantar contact during F_{max} (A_{act}). Multiple body weight (mBW) was used to compare ground force reactions among different persons. Laterality of the lower extremities was being found out with a test according to Ruisel's methodology (1976) – backward decline from an elevated platform. Further, body weight, height, age and BMI of the observed persons were taken.

Statistics
Wilcox test, variance analysis and Pearson product-moment correlation coefficient were used to assess the results. The statistical level of significance was set at ά = 0,05.

Results

Force Characteristics of Gait
In the introductory part of the results we compare the magnitude of force which is applied by feet on the surface during stance. Throughout the entire group, differences were found between the right and left feet for F_{max} by 3.6 % (p=0.005), similarly for the difference between left and right feet in the active stage of stance by 3.8 % (p=0.002).

Table 1. Force characteristics of investigate group (average of both foot)

Group		F_{max} (N)	F_{act} (N)	F_{aps} (N)	F_m (N)	F_{mact} (N)	F_{maps} (N)
Whole	Mean	783	779	684	551	562	529
	SD	138	139	111	85	103	81
	mBW	1,1	1,1	1	0,8	0,8	0,8
<25 BMI	Mean	751	749	647	525	536	503
	SD	131	130	112	77	92	81
	mBW	1,15	1,15	1	0,8	0,8	0,8
25< BMI	Mean	841	833	750	599	608	578
	SD	129	135	70	76	104	51
	mBW	1,1	1,1	1	0,8	0,8	0,75

When recalculating maximal vertical ground reaction forces into mBW, these values reached 1.1x for the right foot and 1.15x for the left one. No differences in any force indicator were found in the volume of force on planta in mBW during stance between the right and left feet. Changes were within the range of 1-4 %. Mean difference between the values of F_{max} during absorption and active stages for both feet was 12.2 % (p=0.000), the difference for the left foot reached 11.4 % (p=0,004), and for the right one 13.1 % (p=0.014).
For mBW no differences between left and right feet were found for F_m during the whole course of stance, or for its active and absorption stage either. Here,

the values for the right foot reached 0.75 and 0.8 mBW for the left one respectively.

After dividing probands by their BMI into two groups (below 25 and over 25), statistical differences were found for both F_{max} and F_m between the groups both during the whole stance and during its individual stages. The values were logically higher in groups with higher BMI. For F_{max}, the mBW coefficient manifested very similar force appliance in both groups during the whole stance as well as during individual stages. The differences were not significant. The same way any significant differences between both BMI groups were not found for F_m in mBW coefficient.

Significant relations were logically found only between absolute values of force parameters and weight or BMI (R= - 0.6 to -0.85) because force results have been influenced by the weight of observed probands. The relationship between age and force characteristics of stance were at a low level of dependence both for F_m and F_{max} (R = - 0.20 to - 0.35). Still lower were correlation relationships for age and force values expressed by the mBW coefficient (R = - 0.019 to – 0.09).

Time Characteristics of Gait

The duration of stance was very similar in all groups (Table 2), no statistically significant differences were found. The time parameters results make it obvious that the active stage of stance was statistically longer than absorption stage (p=0.000) in all groups. Likewise, the time ratio during both stages of stance was similar in all groups, without significant differences. No significant relationship between time characteristics and age or BMI was found within the observed group.

Table 2 Time characteristics of gait

Group		Absorption stage (s)	Active stage (s)	Total time of stance (s)	Rate of Act/Aps	Active phase (%)
Whole	me an	0,31	0,41	0,72	1,39	56,9
	SD	0,05	0,08	0,07	0,39	6,7
BMI <25	me an	0,30	0,41	0,71	1,37	57,8
	SD	0,03	0,06	0,06	0,30	4,7
BMI 25<	me an	0,31	0,42	0,73	1,40	57,5
	SD	0,05	0,08	0,07	0,43	7,5

Laterality of Lower Extremities

The examination of the laterality of lower extremities showed that 67 % of persons prefer the right leg while 32 % prefer the left one. No significant relationship to the observed force or time parameters which characterize gait variability was found. During examination, it was found that none of the persons had any health problems of the locomotive system which could affect the results.

Area of contact

The area of contact between loaded sole and the surface during stance was significantly different for the right and left feet at its maximal value (p=0.05).

Table 3. Contact area of sole during the stance

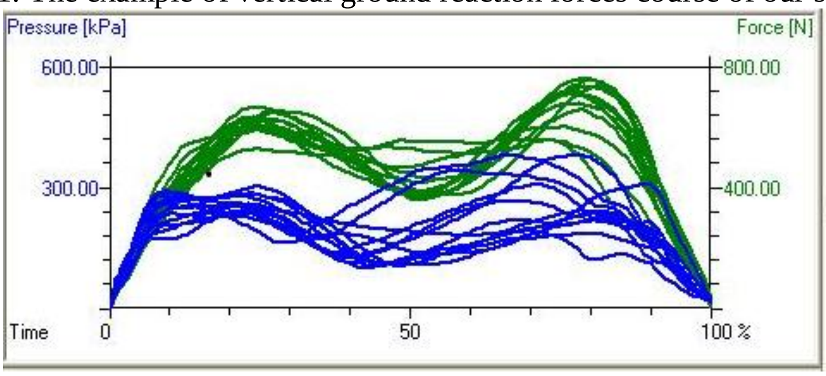
Group		A_{max} (cm2)	A_{act} (cm2)
Whole	mean	128	103
	SD	48	11
BMI <25	mean	129	99
	SD	58	9
BMI 25<	mean	127	110
	SD	12	13

Differences were found between groups divided along BMI during active stage for both the left (p=0.007) and the right (p=0.029) foot. The contact area at the moment of F_{mact} was 80.5 % out of the maximum sole surface (p=0.000) in the whole group. In the group with lower BMI, this area was 76,7 %, which was a significant difference to the maximum area (p=0.000). In the group with BMI over 25, the difference was found to be smaller: only 15.4 % (p=0.006). The difference between the groups in the size of the sole contact area at the moment of creating maximal ground reaction force was 10 % (p=0.004).

Discussion

This paper of our preliminary descriptive study is mainly aimed at the magnitude of ground reaction force and time characteristics of stance during gait of Czech adult population. Observed persons varied in age and weight to a great extent, which well represents typical Czech population. As magnitude of foot load varies during gait with many variables such as position of COP, centre of body, weight, limb position, the stage of stance, velocity of gait etc. For the observed persons, typical ground force reaction with two peaks and one decline (see Figure 1) was confirmed during individually natural gait.

Figure 1. The example of vertical ground reaction forces course of our subjects



The peaks represent two important stage of stance: the first being the absorption stage, the other one propulsive stage of stance. The majority of the observed persons performed typical procedure of force loading during stance with significant differences between the peaks and decline between them whereas they did not depend on gait velocity. Our group performed natural gait at the speed between 3.0 and 4.2 kph. Thus, our results are not in compliance with for instance the findings made by Perry (2010), Ayyappa (1997) etc. who state that the differences between peaks and decline are more significant during faster gait while they are only very little significant during slow gait, or plató appears. If compared with the results of other studies which state balanced values of the magnitude of ground reaction force for both the first and the second peak (Ayyappa, 1997, Kirtley, 2006, Perry, 2010), in average, our group manifested lower values of maximal ground reaction forced at the first peak, during the absorption stage of stance. The magnitude of relative force applied on the surface was at the level of mean body weight (1x mBW) at the first peak (LR); at the second climax in, the values were at a level (1.1-1.15 mBW) similar to other studies. For instance Perry (2010) presents values at both peaks at the level of 110 % of BW, Kirtley (2006) for the first peak 117 %, for the second one 109 %. Our values which are lower at the first peak than in other studies are difficult to explain only from the point of view of kinetics, without a kinematic view which will be employed in the following assessment. The most of our walkers (24) realized stance with higher vertical ground reaction forces during second (active) stage, only 7 persons showed higher forces during the absorption stage. Smaller differences in the magnitude of relative ground reaction force (mBW) were found also between groups divided according to BMI (over 15, below 25) during propulsive stage. They imply more active appliance of lower extremities in the final stage of stance during creating motor force in individuals with lower BMI. These differences were not significant.

No relationships between relative indicators of ground reaction force on planta and age (in mBW) were found in the observed persons so we can believe, in compliance with other authors (Crowinshield, 1978, Hagmann, 1986, Bunch, 2008, Perry, 2010, etc.) that until approximately the age of 60, these indicators are relatively stable.

The analysis of selected time characteristics revealed similar values for all groups, differences between groups were not significant. The active stage was always significantly longer than the initial (absorption) stage and in all groups, it took approximately 57 % of the whole stance. We suppose that longer duration of the second stage of stance is caused by generating required motor force in order to maintain gait velocity. The first stage during which velocity declines must be carried out fast so as the decline in velocity is as small as possible thus increasing movement efficiency. Likewise, for time characteristics of stance, no significant differences were found in dependence on age, weight or BMI. It is obvious that at the active age period, even though the age range from 26 to 57 is quite wide, time characteristics change only to a very small extent just like kinetic characteristics. According to other studies, more significant changes start only at the age over 60 (Kirtley, 2006, Perry, 2010).

Any influence of laterality on the observed force and time variables was not found. In laterally balanced activities, like locomotion, laterality is not manifested unlike in different structured motor activities such as sprints, quick changes of direction, throws, jumps, etc. which are performed in shorter time intervals and with a bigger force generated by the lower extremities and which focus on using a certain extremity or side of the body.

Maximum plantar contact area with the surface during stance was similar in both groups. The size of the area in active stage during generating greatest ground reaction force was significantly lower than maximum contact area of sole due to natural mechanics of foot movement during gradual heel lifting. The differences were interesting mainly when comparing the groups divided according to BMI. Probands with lower BMI used significantly smaller surface of planta for support at the moment of creating maximal ground reaction force in active stage than probands in the other group, even though the maximum contact area of sole was similar in both groups. We suppose that this can be related to higher relative weight of the probands with higher BMI.

Conclusions

This study is limited in the number of participants as well as in the age range. The aim was to carry out a pilot study to find out about our possibilities to monitor sufficient number of persons in individual decades from the age of 18 within nationwide research.

In compliance with other studies, in our group of probands, we have not found significant differences in force and time characteristics in relation to age.

The influence of laterality of lower extremities on gait characteristics has not been confirmed.

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References

Ayyappa, R. (1997). ´Normal Human Locomotion, Part 1: Basic Concepts and Terminology.´ *Journal of Prosthetics and Orthotics* 9(1): 10.

Ayyappa, R. (1997). ´Normal Human Locomotion, Part 2: Basic Ground-Reaction Force and Muscle Activity.´ *Journal of Prosthetics and Orthotics* 9(2): 49-57.

Berkey, C. S. et.al. (2003). ´One-year changes in activity and inactivity among 10 to 15year old bioys and girls: Relationship to change in Mody Mass Index.´ *Pediatrics* 111: 592- 600.

Blahutková, M. & Řehulka, E. & Dvořáková, Š. (2005). *Movement and mental health*. Brno: Paido. [in Czech]

Blair, S. N. (1985). ´Relationship between exercise or physical activity and other health behaviors.´ *Public Health Reports,* 100:172–180.

Blair, S. N.& Clark, D. B.& Cureton, K. J. (1989). ´Exercise and fitness in childhood: Implications for a lifetime of health.´ In C. V. Gisolfi & D. L. Lamb (Eds.), *Perspectives in exercise science and sports medicine, Vol 2 . Youth, exercise and sport* (s. 401–430). Indianapolis: Benchmark Press.

Blair, S. N. et.al. (1989). ´Physical fitness and all-cause mortality: A prospective study of healthy men and women.´ *Journal of the American Medical Association* 262(17):2395-2401.

Blair, C. N.& Dunn, A. L.& Marcus, B. A.& Carpenter, R. A.& Jaret, P. (2001). *Active living every day.* Champaign, Human Kinetic.

Blanke, D. J., Hageman, P. A. (1989). ´Comparison of gait of young men and elderly men.´ *Physical Terapy* 69:144–148.

Brach, J. S. & Studenski. S. & Perera, S & et al. (2008). ´Stance time and step width variability have unique contributing impairments in older persons.´ *Gait Posture* 27:431–439.

Crowinshield, R.D.& Brand, R.A.& Johnson,R.C. (1978). The effects of walking velocity and age on hip kinematics and kinetics.´ *Clinical Orthopaedics* 132: 140-144.

Dobrý, L. (2008). ´Knowledge about health benefits of physical activity of youth.´ *Tělesná Výchova Mládeže a Sport* 74(1):12-18. [in Czech]

Frollis, V. V. (1988). *Ageing, life extending.* Leningrad, Nauka. {in Russia]

Frömel, K. (2005). *Physical activity in life of men.* Olomouc, FTK UP, 68 s.

Frömel, K.& Nykodým, J. et.al. (2006). ´Intensity and volume from 15 to 69 years of Czech population.´ *Česká kinantropologie,* 1(10): 13 - 29.[in Czech]

Gabell, A. & Nayak, U. S. L. (1984). The effect of age and variability in gait.´ *Journal of Gerontology*. 39:662–6.

Hayafune, N. et.al. (1999). ´Pressure and force distribution characteristics under the normal foot during the push-off physe in gait.´ *The Foot,* 9: 88-92.

Hageman. P. A. & Blanke, D. J. (1986). ´Comparison of gait of young women and elderly women.´ *Physical Terapy* 66:1382–1387.

Hausdorff J.M, Mitchell S.L, Firtion R, Peng C.K, Cudkowicz M.E, Wei J.Y, et al. (1997). ´Altered fractal dynamics of gait: reduced stride-interval correlations with aging and Huntington's disease.´ *Journal of Applied Physiology* 82:262–9.

Hausdorff, J. M. & Lertratanakul, A. & Cudkowicz, M. E. & Peterson, A. L, & Kaliton, D. & Goldberger, A. L. (2000). ´Dynamic markers of altered gait rhythm in amyotrophic lateral sclerosis. *Journal of Applied Physiology* 88:2045–53.

Kerrigan, D. C. & Lee L. W. & Collins J. J. et al.(2001). ´Reduced hip extension during walking: healthy elderly and fallers versus young adults.´ *Archives of Physical Medicine and Rehabilitation* 82:26–30.

Kohl, III, H.W. & Hobbs, K. E. (1998). ´Development of physical activity behaviors among children and adolescents.´ *Pediatrics* 1001:549-554

Kirtley, Ch. (2006). Clinical gait Analysis. Theory and Practise. Elswier Limited, Philadelphia.

McArdle, W. D. & Katch, F. I. & Katch V.L.(1986). *Exercise Physiology*. 2nd ed. Philadelphia, PA: Lea & Febiger.

McGibbon. C. A. & Krebs, D.,E. (2004). ´Discriminating age and disability effects in locomotion: neuromuscular adaptations in musculoskeletal pathology.´ *Journal of Applied Physiology* 96:149–160

McGibbon, C.,A. (2003). Toward a better understanding of gait changes with age and disablement: neuromuscular adaptation´. *Exercise Sport Science Review* 31:102–108.

Neuls, F. & Frömel, K. (2007). Selected correaltions of physical aktivity of Czech girl. *Česká kinanatropologie* 11(4):21-32. [in Czech]

Ostrosky, K.M. & VanSwearingen, J. M. & Burdett R. G. & Gee Z. A. (1994). ´Comparison of gait characteristics in young and old subjects.´*Physical Terapy* 74:637–644; discuss. 644–646.

Pangrazi, R. P. & Corbin, C. B. & Welk, G. J. (1996). ´Physical activity for children and youth.´ *Journal of Physical Education and Recreational Dance* 67(4):38-43.

Perry J. (1992) *Gait analysis; normal and pathological function*. Thorofare, N.J.: Slack

Schaafsma, J. D. & Giladi, N.& Balash, Y. & Bartels, A. L. & Gurevich, T. & Hausdorff, J. M. (2003). ´Gait dynamics in Parkinson's disease: relationship to Parkinsonian features, falls, and response to levadopa.´ *Journal of Neurology Science* 212:47–53.

Sheridan, P.L & Solomont, J. M. & Kowall, N. & Hausdorff, J. M. (2003). ´Influence of executive function on locomotor function: divided attention increases gait variability in alzheimer's disease.´ *Journal of American Geriatric Society* 51:1633–7.

Richardson, J. K. & Theis, S. B. & DeMott, T. K. & Ashton-Miller J. A. (2004). ´A comparison of gait characteristics between older women with and without peripheral neuropathy in standard and challenging environments.´ *Journal of American Geriatric Society* 52:1532–7.

Thompson, D. et.al. (1993). ´Vertical forces and plantar pressures in selected aerobic movements versus walking. *Journal of American Podiatric Medical Association,* 83(9),504-508.

VanZant, R. et.al. (2001). ´Symetry of plantar pressures and vertical forces in healthy subjects during walking.´ *Journal of American Podiatric Medical Association* 91(7) 337-342.

Waters, R. L. & Lunsford, B. R. & Perry, J. & Byrd, R. (1988). ´Energy-speed relationship of walking: standard tables. *Journal of Orthopaedic Research* 6:215–222.

Wert, D. M, & VanSwearingen, J. (2009). ´Energy cost of walking contributes to physical fiction in older adults.´ In: *American Geriatrics Society Annual Conference. Annual Scientific Meeting Abstract Book* Vol 57(4). Chicago, IL: Wiley-Blackwell.

Winter, D. A. & Patla, A.E. & Frank, J.S.& Walt, S. E.(1990). ´Biomechanical walking pattern changes in the fit and healthy elderly.´ *Physical Terapy* 70:340–347.

Vařeka, I.& Vařeková, R. (2009). *Kinesiology of foot.* 1.vyd. Olomouc.

Zvonař, M. & Lutonská, K. (2009). ´The analysis of plantar pressure distribution with the help of EMED desk. In. *Sport a kvalita života 2009*. 1. vyd. Brno: FSpS MU. [in Czech]