KINEMATICS ANALYSES OF SPORTS WALKING ON TREADMILL AT DIFFERENT BELT INCLINATIONS

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Abstract
Objective of this research represents detailed reveal of sports walking technique, demonstrated on treadmill at different angles of belt inclination, on the part of subject who overwhelmed the walking technique through the course on Faculty of sports and physical education in Niš and isn't actively involved in training process, as well as subject who overwhelmed the walking technique through the long standing training process, still is actively engaged in this athletic discipline and at this moment is a member of athletic team of Serbia. Problem of research represents possible impact of belt inclination, on values of analyzed kinematics variables (velocity and acceleration). Main aims of this research were to establish, if there exist statistically important differences in values of kinematics variables, upon occasion of different angles of belt inclination and to establish, if different angles of belt inclination have statistically important influence on values of analyzed kinematics variables. At this research, technique of competitive sports walking was recorded by using digital video camera „SAMSUNG VP-D371", and video was mistreated by using software "HUMAN", for kinematics 2D video analyses. Based on results of t test, the conclusion is that statistically important differences in values of kinematics variables, at subjects, upon occasion of different angles of belt inclination, don't exist, and that statistically important influence of belt inclination on values of analyzed kinematics variables doesn't exist. The importance of research lays in capability of clear and strict interpretation of derived data, which will point out on differences in levels of mastered technique, which is the base in achieving top results.

Key words: *sports walking, kinematics, inclination, differences, influence.*

Introduction

Basic meaning of walking
Walking is natural aspect of men's locomotion, whereby moments, phases and period, which characterize movement integrally, are succeeded. It is cyclic locomotor's activity which is characterized by constant contact with ground surface, no matter if it is about ordinarily or sports walking. According to definition of IAAF (International amateur athletic federation): "a sports walking is advancement by stride without interception of contact with ground". With each stride, walker's leg which moves first, must touch the ground before the second detaches the ground. While the feet is on the ground, leg must be outstretched, i.e. leg mustn't be flexed in the knee joint, at least for a moment, support leg is extended in the vertical phase (Tončev, 1991). Unit of walking represents one cycle, made of two connected strides. The support leg must be extended for at least one moment, when it is in vertical position. In the movements of one and other leg, it could be distinct period of reluctance or backing up (when leg touches the ground) and period of swing (when leg freely makes stride forward).

In regard to fact that the period of reluctance by one or the other leg is temporally longer in comparison to swing period, appears so-called period of biped reluctance, when the both feet are in the same time on the ground. Thereafter, one cycle of walking is made of two monopod periods and two biped reluctances. Movements of arms at walking, mostly, contribute in maintain of balance, and in some cases in augmentation of locomotion's velocity. Upon occasion of walking, arms are flexed in the elbow joints and are moving (oscillate) from shoulder forward-inward (approximately till the middle point of trunk) and backward (approximately behind the hip joint), while hand are relaxed all the time. Top sports walkers keep their arms relatively low, i.e., they don't raise them aloft during the swings forward and backward. Fingers of upper extremities are all the time relaxed. During walking, head is in the prolongation if spine, and the trunk is in the upright position, or little inclined forward. Larger inclination forward provokes, in the phase of forward reluctance, flexion of leg and appearance of running, i.e., perturbation of competitive walking, where from effluents notification signal and disqualification on the part of main arbiter.

Aspiration must be deep and rhythmic, accomplished with complete expiration and in accordance to certain number of strides. Inspiration and expiration are usually made of four stride (Bubanj, R. and Branković, 1997). Sports walker develops greater velocity, in comparison to customary walker. Sports walking is in effect, more explosive and faster version of normal walking. Sports walking is often placed in the same category with the races of endurance, especially races on 10000 m till marathon. Although it is physiologically accurate, yet it isn't absolutely right, since in that case the meaning of technique is marginal. Although sports walking has many resemblances with normal walking, great improvement of technique is needed, to achieve velocity of 15 km/h (Tončev, 1991).

Kinematics methods of research

Methods for establishing of effects of sports locomotion show apace rising trend. New technologic possibilities enable detached and accurate access in the backbone of structure of locomotion, based on which it is possible to estimate the efficiency of sports technique, make correction of technique and amelioration of energetic efficiency, in aim of optimalization and rationalization of motor structure of locomotion. In training process, analyses of sports activities are performed, in aim of establishing structural, biomechanical and functional characteristics (Bubanj i Branković, 1997). Principle of kinematics methods of research alludes objectively notation of changing of body's position in place and time and establishing of changes of velocity and acceleration.

Kinematics motion analyses of geometric bodies with shape and volume, and doesn't concern about tangibility of those bodies, but is rigidly concern about time intervals, in which certain measurements are made (Bubanj, R., 1997). Irrespective, that at calculation of translator and angular parameters weigh the same principles, it should be stated that translator change of position, velocity and acceleration relate to movement of particle or material point of rigid body. On the other hand, angular displacement, velocity and acceleration are the same, for all lines of rigid body. Therefore, mentioned parameters, relate to rigid body in its entirety. Also, it should be mentioned, that particle, i.e. material point doesn't express angular parameters, because of its marginal mass (Bubanj, S., Bubanj, R. i Stanković, 2008).

Biomechanical analyses of sports walking

Stick-figure 1 (pos. 1) shows that walker is in the moment of verticale in monopod position, with centre of gravity (CG) above the support leg, and swing leg is flexed in all three joints, at swing forward (pos. 2). By extension in hock and due to inertia, body moves forward. In the moment when feet of support leg, after extension, still touches ground by distal part of fingers, swing leg, by the end of extension in knee joint forward, is placed gently over the heel on the ground (mostly over external arc of feet), so the walker is in the biped position, and CG is in the lowest position (pos. 3, 4 and 5). Yet in next moment walker proceed in monopod position, on leg placed forward (pos. 6, 7 and 8).

Figure 1. Cycle – two strides marked through positions 1 - 13.

After rebound of feet from the ground, leg of this lower extremity raises up in the air, under the influence of inertia-reactive forces, which appear as a result of movement forward of walker and leg downward-forward upon occasion of relaxation of muscles flexors of leg. By continuation of movement, swing leg starts to lower and at the end of movement becomes again support (pos. 9,10,11,12 and 13). In the period of monopod backing up (moment of vertical) CG is in the highest position, and the lowest is in the biped backing up. Position of trunk should be almost vertical.

It was establish that vertical aberrances are in the range of 1.5° - 3°. During walking, it is necessary to avoid lateral excursion of CG related to direction of movement. They appear as a consequence of feet placements on two parallels lines (figure 2, pos. 1). To avoid it, walkers try to place their feet with fingers oriented forward and internal part of feet arc directly along the straight line (pos. 2). By way of exception, in accordance to individual characteristics of walker, feet are placed slightly converted outward or inward (pos. 3 and 4).

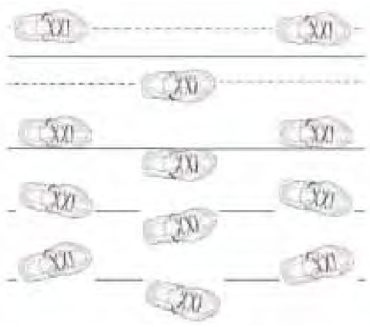

Figure 2. Different styles of sports walking technique

Figure 3. Regular technique of sports walking implies that CG is moving according to imagined straight line

Upon occasion of sports walking, important vertical fluctuation and lateral displacements of CG should be avoided, therewith that movement is translator and equally by reason of economically consumption of energy (figure 3). With augmentation of walking velocity, usually the stride length and frequency augment also. Essential is to walk naturally, without larger exertion, with optimal usage of stride's length and frequency, according to individual characteristics of walker. Velocity during sports walking is higher 2.5 times, in comparison to normal walking and reaches 200 strides per minute. Stride length at sports walking is 1.05-1.20 m and is longer for 20-30 cm in comparison to normal walking. In specification formula of dimensions important for achievement the stride elongation, the most important is displacement of pelvis around vertical and sagital axis (figure 4 and 5).

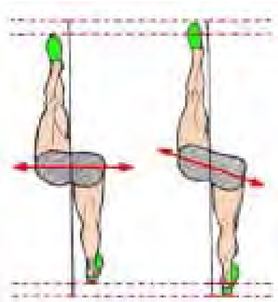

Figure 4. Fluctuation of pelvis axis previewed in horizontal plane during sports walking in aim of stride elongation

Duration of biped position is several times shorter in comparison to monopod, and basically depend of locomotion velocity. Augmentation of locomotion velocity leads to simultaneous abatement in duration of monopod and biped phase. For instance, at relatively low velocity of walker's locomotion (2.6 m/s or 2 min 34 s on 400 m), time of biped phase is 0.06 s, at augmentation of velocity reduces till 0.01 s, and in some cases till 0.005 seconds.

Figure 5. Fluctuation of spine, pelvis and shoulder axis previewed in frontal plane during sports walking

Aim and problem

Main aim of this research was to establish, if there exist statistically important differences in values of kinematics variables, during sports walking on treadmill, upon occasion of different angles of belt inclination and to establish, and problem was to establish if different angles of belt inclination have statistically important influence on values o analized kinematics variables.

Methods of research

Sample of subjects and variables

In this research technique of sports walking demonstrated subject Bojana Eraković, who overwhelmed optimal technique of sports walking through the course on Faculty of sports and physical education in Niš and isn't actively involved in sports walking training process, as well as second subject who is actively engaged in this athletic discipline more than 5 years, he is a member A.C. „Akademski" from Niš, also student of Faculty of sports and physical education in Niš, and at this moment he is a member of athletic team of Serbia, Vladimir Savanović. The sample of variables relates to kinematics parametres velocity and acceleration of referent points of upper right extremity (wrist V, elbow V, shoulder V, wrist A, elbow A, shoulder A) and lower right extremity (ankle V, knee V, hip V, ankle A, knee A, hip A).

Measuring instruments for estimation of sports walking technique and organization of measurement

At this research, technique of competitive sports walking was recorded by using digital video camera „SAMSUNG VP-D371“, and video was mistreated by using software “HUMAN”, for kinematics 2D video analyses. Sports technique was recorded in the Centre for multidisciplinary researches within Faculty of sports and physical education in Niš. Technique of sports walking was recorded by using one camera in the sagital plane. Upon occasion of recording the technique of sports walking, the most important was to align video camera and make it stableness. Height of object glass was equivalent to a height of CG, of recorded system. Points, between which locomotion was demonstrated, were defined. Based on those points cadre was determined and made necessarily zoom, because of distance of camera in regard to recorded system. Subjects acceded to research dressed in sports clothes, which enabled easy visibility of referent points of their bodies, which later were object of digitalization. After short warming and preparation for research, by walking on treadmill, it was determined maximal velocity of locomotion, and concerning by fact, that this value at subject, who overwhelmed the technique by course on Faculty of sports and physical education in Niš (8 km/h), was minor in comparison to active and top sports walker (17 km/h), thereafter during research, subjects walked by velocity of 8 km/h. At first, technique of sports walking was performed by belt inclination of 0 degree and by belt velocity of 8 km/h, and afterwards, the whole procedure of research was repeated under the same conditions, with an exception of belt inclination which was 10 degree.

Methods of data derivation

After several recorded and analyzed techniques of sports walking, record with most effective technique was chosen, for further analyse. Thereafter, record was misterated, which considers constitution of referent points on 6 model system, so-called digitalization. Digitalization request cognition of refent poins of human body and ability of handling with software „HUMAN“, which enables to show video record, frame and translatory and angular kinematics parameters. On the end of digitalization, in the data bank of software „HUMAN“, ratio was imported. Ratio was determined and recorded after recording of actual sports technique. Afterwards, values of basic kinematics variables were calculated. All results were graphically displayed and interpreted. As a main methods of data derivation in this research, in use were, t test with aim to establish differences of velocity and acceleration of referent points, upon occasion of different belt inclination and correlation analyses with aim to establish character of coherence between velocity and acceleration of referent points and belt inclination (Petković, 2000).

As a supplementary method in this research, in use was descriptive method, wherewith were interpreted informations about basic kinematics variables of demonstrated technique of sports walking.

Results

Stick-figure 1. Cycle and cumulative model of two strides at subject Bojana Eraković

For technique of sports walking at subject Bojana Eraković, in the condition of belt inclination of 0o, it is characteristic, that analyzed cycle i.e., two strides lasted 0.72 s, and that record was divided on 18 frames, i.e., that pasted time between contiguous frames was 0.04s. In the condition of belt inclination of 10o, analyzed cycle i.e., two strides lasted 0.76 s, and that record was divided on 19 frames, i.e., that pasted time between frames was 0.04s. Subject Bojana Eraković, during walking in duration of one minute, in the condition of belt inclination of 0o, made 81 cycles, i.e., 162 strides, while for the same time, in the condition of belt inclination of 10o, she made 84 cycles, i.e., 168 strides. The length of analyzed cycle in the condition of belt inclination of 0o was 1.12m, while in the condition of belt inclination of 10o, the length was slightly minor, i.e., 1.11m. For technique of sports walking at subject Vladimir Savanović, in the condition of belt inclination of 0o and 10o, it is characteristic, that analyzed cycle i.e., two strides lasted 0.76 s, and that record was divided on 19 frames, i.e., that pasted time between contiguous frames was 0.04s. Subject Vladimir Savanović, during walking in duration of one minute, in the condition of belt inclination of 0o, made 78 cycles, i.e., 156 strides, while for the same time, in the condition of belt inclination of 10o, he made 79 cycles, i.e., 158 strides. The length of analyzed cycle in the condition of belt inclination of 0o, was 1.02m, while in the condition of belt inclination of 10o, the length was slightly minor, i.e., 0.99m.

Stick-figure 2. Cycle and cumulative model of two strides at subject Vladimir Savanović

Table 1. Results of t test wherewith were tested differences of velocity and acceleration upon occasion of belt inclination of 0o and 10o at subject Bojana Eraković

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
hip V	-0.220	37	0.830742376	-0.00934211	0.043398019
knee V	-0.290	37	0.771087290	-0.06000000	0.204711920
ankle V	-0.020	37	0.980725191	-0.00684211	0.281294788
wrist V	-0.730	37	0.471507571	-0.14342105	0.197146456
elbow V	-0.790	37	0.432775725	-0.13789474	0.173867871
shoulder V	-0.780	37	0.441315321	-0.02731579	0.035094733
hip A	0.498	37	0.621610642	0.83421053	1.675986265
knee A	1.373	37	0.178034620	5.27631579	3.843072011
ankle A	0.496	37	0.623048389	2.62631579	5.298359450
wrist A	0.188	37	0.852153545	0.39473684	2.103252062
elbow A	-0.580	37	0.566963746	-1.68421053	2.915355253
shoulder A	1.955	37	0.058196131	2.16842105	1.109291582

Table 2. Results of t test wherewith were tested differences of velocity and acceleration upon occasion of belt inclination of 0o and 10o at subject Vladimir Savanović

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
hip V	0.03	38	0.972908	0.0030	0.087755
knee V	-1.12	38	0.270507	-0.1985	0.177520
ankle V	0.13	38	0.894014	0.0350	0.260957
wrist V	0.46	38	0.646392	0.1050	0.227049
elbow V	-0.12	38	0.903832	-0.0250	0.205538
shoulder V	-1.53	38	0.133084	-0.1370	0.089255
hip A	0.28	38	0.778342	0.6500	2.292867
knee A	-0.96	38	0.340935	-3.7500	3.888360
ankle A	0.56	38	0.581066	2.6500	4.761067
wrist A	0.97	38	0.340296	4.1000	4.245586
elbow A	1.36	38	0.183177	4.2500	3.134758
shoulder A	-1.29	38	0.204598	-4.1000	3.176517

Table 3. Correlation of belt inclination and velocity and acceleration at subject Bojana Eraković

	hip V	knee V	ankle V	wrist V	elbow V	shoulder V	hip A	knee A	ankle A	wrist A	elbow A	shoulder A
R	0.04	0.05	0.00	0.12	0.13	0.13	0.08	-0.22	0.08	-0.03	0.09	0.31
Sig.	0.83	0.77	0.98	0.47	0.43	0.44	0.62	0.18	0.62	0.85	0.57	0.06
N	40	40	40	40	40	40	40	40	40	40	40	40

Table 4. Correlation of belt inclination and velocity and acceleration at subject Vladimir Savanović

	hip V	knee V	ankle V	wrist V	elbow V	shoulder V	hip A	knee A	ankle A	wrist A	elbow A	shoulder A
R	-0.01	0.18	-0.02	-0.07	0.02	0.24	-0.05	0.15	-0.09	-0.15	-0.21	0.20
Sig.	0.97	0.27	0.89	0.65	0.90	0.13	0.78	0.34	0.58	0.34	0.18	0.20
N	40	40	40	40	40	40	40	40	40	40	40	40

Discussion and conclusion

Based on results of t test (table 1), at subject Bojana Eraković, it is obvious that all values of velocity as value of acceleration of elbow joint, were greater in the condition of belt inclination of 10o in comparision to inclination of 0o. However, statistically important difference exists only at acceleration of shoulder joint (value should be taken with precaution, as it is on boundary of importance, i.e., p= 0.058). Based on results of t test (table 2), at subject Vladimir Savanović, it is obvious that values of velocity and acceleration of hip joint, ankle and wrist and acceleration of elbow joint were greater in the condition of belt inclination of 0o in comparison to inclination of 10o. However, statistically important differences don't exist. Based on results of correlative analyses (table 3 and 4), it is obvious that statistically important correlations between velocity and acceleration of referent points and belt inclination don't exist. Strides frequency during one minute at both subjects increased with increase of belt inclination, which is in accordance to results of research conducted by Swanson & Caldwell, 2000. On the other hand, in research conducted by Werrner et al., 2007, authors determined that strides frequency decreased, and that strides length increased, upon occasion of increase of belt inclination.

Also, at research conducted by Nelson et al., 1972, authors determined, that with increase of belt velocity and inclination, strides frequency decreased, and strides length increased. Based on conducted research, conclusion intrudes, that obtained results of subjects are obtained in the moments, while subjects still didn't feel important fatigue. Although both subjects moved with the same velocity (8 km/h), for subject Vladimir Savanović, that value was far be low his maximal walking velocity (17 km/h), while for subject Bojana Eraković that was her established maximal walking velocity. Although, based on values of kinematics variables, fatigue couldn't be anticipated, values of pulse at subject Bojana Eraković, after demonstrated technique, upon occasion of inclination of 10o, pointed out on first indices of fatigue, which would have, if demonstration lasted, negative effects on values of kinematics variables. Value of pulse, at subject Vladimir Savanović, after demonstrated techniques, pointed out, that he is in training process. Results of research conducted by Kivi et al., 2002, points out, that for more detailed kinematics analyses it should be necessarily, to submit subject at maximal established velocity (in this case, 17 km/h for subject Vladimir Savanović). By observation of stick-figures of Vladimir Savanović, it is obvious, that his position on treadmill is „dragged" forward, and impression is that he didn't make maximal stride.

Minor strides lenght, as minor strides frequency at subject Vladimir Savanović in comparision to subject Bojana Eraković, point out on his insecurity upon occasion of walking on treadmill. That isn't surprise, because, his comlete training process, is administered on athletic track and in nature. Otherwise, both subjects demonstrated very good technique of sports walking, which is obvious by analyzing kinograms.

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KINEMATIČKA ANALIZA SPORTSKOG HODANJA PRI RAZLIČITIM KUTOVIMA NAGIBA POKRETNOG SAGA

Sažetak

Predmet ovog istraživanja predstavlja detaljan prikaz tehnike sportskog hodanja, demonstrirane na tredmil stazi pri različitim kutovima nagiba staze, a od strane ispitanika koji je tehnikom hodanja ovladao putem nastave na Fakultetu sporta i fizičkog vaspitanja u Nišu i ne bavi se aktivno ovom atletskom disciplinom, kao i ispitanika koji je tehniku sportskog hodanja savladao dugogodišnjim trenažnim procesom, još uvek se aktivno bavi ovom atletskom disciplinom i u ovom trenutku je član atletske reprezentacije Srbije. Problem istraživanja predstavlja mogućnost utjecaja nagiba tredmil staze, na vrijednosti analiziranih kinematičkih varijabli (brzine i ubrzanja). Glavni ciljevi ovog istraživanja bili su utvrđivanje postojanja statistički značajnih razlike u vrijednostima kinematičkih varijabli pri izvođenju tehnike sportskog hodanja na tredmil stazi, a kod različitih kutova nagiba staze i utvrđivanje utječe li nagib staze na istraživane kinematičke varijable, prilikom sportskog hodanja. Tehnika sportskog hodanja snimljena je korištenjem digitalne video kamere „SAMSUNG VP-D371", a za obradu video snimaka korišten je softver „HUMAN", za kinematičku 2D analizu. Na temelju t-testa, može se zaključiti da ne postoji statistički značajna razlika u vrijednostima ispitivanih kinematičkih varijabli, kod ispitanika, pri različitim kutovima nagiba tredmil staze i da ne postoji statistički značajan utjecaj nagiba tredmil staze na vrijednosti ispitivanih kinematičkih varijabli. Značaj istraživanja ogleda se u mogućnosti jasne i egzaktne interpretacije dobivenih rezultata, koji ukazuju na razlike u razinama ovladane tehnike, koja je temelj u ostvarenju vrhunskih rezultata.

Ključne riječi: *sportsko hodanje, kinematika, nagib, razlike, utjecaj*

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