Zbigniew STANIAK
Department of Research Instruments Construction, Institute of Sport, Warsaw
Krzysztof BUŚKO
Department of Biometry, Josef Pilsudski Academy of Physical Education, Warsaw,
Department of Biomechanics, Institute of Sport, Warsaw
Bohdan KARPIŁOWSKI
Department of Research Instruments Construction, Institute of Sport, Warsaw
Zdzisław NOSARZEWSKI
Department of Research Instruments Construction, Institute of Sport, Warsaw
Konrad WITEK
Department of Biochemistry, Institute of Sport, Warsaw

ANALYZE OF VERTICAL ACCELERATION OF THE BODY MASS CENTER DURING RUNNING ON TREADMILL

Summary. The work presents analyze of vertical acceleration curve of the body mass center (VACM characteristic) obtained by eleven athletes during on treadmill running with gradual rise velocity. The measurements are made by uniaxial accelerometer placed in loins part of trunk near the center of body mass. The chosen value of characteristics was calculated for every single run with applied velocity of treadmill. The velocity of treadmill of every run was significantly correlated to mean values of VACM characteristics calculated for all subjects. For every athletes analyzed mean values of characteristics calculated separately for left and right steps were significantly different.

1. INTRODUCTION

Technological advanced dynamometric equipment and video systems are applied for qualitative and quantitative assessment of human movement kinematics. Measurements by those methods are expensive and time-consuming and often inconvenient to use in daily sports practice or rehabilitation.

Multi-channels and portable measurement systems based on accelerometer technology are applied for measure changes of acceleration of chosen segments (limbs) of body during running or gait [3, 4]. Loins back part of the spine is the most stable part of body during running or walking and is located near the body mass center. The segment of the body transfers interactions between the lower limbs, trunk and upper limbs [1, 2, 5]. That segment of the body is optimal to use for single channel accelerometer measurement systems and analyze of motion of runner.

The aim of the study was to attempt the evaluate whether a characteristic of vertical acceleration of curve of the body mass center is useful for qualitative and quantitative assessment of running.

2. MATERIAL AND METHOD

The study was conducted on 4 female and 7 male athletes of modern pentathlon. Characteristic of group (mean±SD): age 22.3±7.31 years, body mass 66.8±8.70 kg, height 1.75±0.071 m. The measurements are made by uniaxial accelerometer placed on loins, back part of the trunk close of the spine near the body mass center. The device are stabilized to the trunk by elastic belt placed over hip plate. (fig. 1). The accelerometer was made with Analog Devices integrated circuit with nominal range of acceleration ±5 g. Range of frequency from 0 to 4 kHz. Maximal relative error of measure track was estimated on 5%. Acceleration data were sampled with 1 kHz frequency and filtered by 300 Hz digital low pass filter.

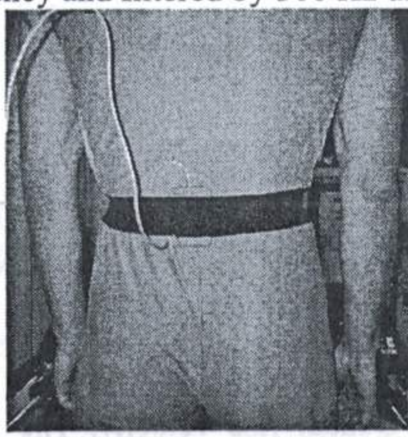

Fig. 1. View of athlete with attached measure equipment

The measures were made during running effort with gradual rise speed on treadmill. Every athlete ran five times over four and half minutes every effort with one minutes of pause between. Applied speeds (v_b) of treadmill were 12, 13.5, 15, 16.5 and 18 km/h.

Special software for measurement controls and calculate characteristic of vertical acceleration curve of body mass center for mean step of running (named in text below VACM characteristic) was work out.

The significance of differences between averages was confronted using the Student t-test. The order of dependence among measured values was estimated on the basis of Pearson's correlation coefficients. All calculations were done using the Statistica ™ v 5.5 programme (StatSoft, Inc. USA).

3. RESULTS

The VACM characteristics are calculated separately for left and right limb as well as for mean step for both limbs (MEAN STEP). The maximal value of acceleration (a_{max}), minimal value of acceleration (a_{min}), integrated accelerations value (C_p) over contact period (t_p), integrated accelerations value (C_l) over fly period (t_l), and value of rate of steps (TMP) was analyzed in this study for individual subjects and the group. The rate of steps (TMP) was calculated as inverse of sum of contact period and fly period. Mean values (±SD) of the results are presented in table 1.

Table 1. Mean values (±SD) of the maximal value of acceleration (a_{max}), minimal value of acceleration (a_{min}), integrated accelerations value (C_p), integrated accelerations value (C_l), and value of rate of steps (TMP) and speed of treadmill (v_b) for examined group (n = 11)

v_b [km/h]	a_{max} [m/s^2]	a_{min} [m/s^2]	C_p [m/s]	C_l [m/s]	TMP [k/min]
12.0	21.8 ±3.11	-13.4 ±0.80	16.4 ±0.79	-16.8 ±0.74	166.9 ±3.58
13.5	23.9 ±3.35	-14.1 ±0.85	16.5 ±0.71	-17.1 ±0.67	169.0 ±3.14
15.0	25.4 ±3.64	-14.5 ±0.96	16.1 ±0.70	-16.8 ±0.70	173.0 ±3.24
16.5	26.2+3.99	-15.0 ±1.14	15.4 ±0.84	-16.2 ±0.83	177.3 ±3.52
18.0	27.0±4.41	-15.3 ±1.26	14.3 ±1.10	-15.2 ±1.11	181.9 ±4.67

The coefficients of correlations between speed of run (v_b) and mean values of the maximal value of acceleration (a_{max}), minimal value of acceleration (a_{min}), integrated accelerations value (C_p), integrated accelerations value (C_l), and value of rate of steps (TMP) for examined group were calculated (r = 0.9777, -0.9933, -0.9097, -0.8365, -0.9926, respectively). The coefficients of the Pearson correlations between speed of run (v_b) and mean values of the maximal value of acceleration (a_{max}), minimal value of acceleration (a_{min}), integrated accelerations value (C_p), integrated accelerations value (C_l), and value of rate of steps (TMP) for individual athlete are presented in table 2.

Table 2. The coefficients of correlations between speed of treadmill (v_b) and mean values of the maximal value of acceleration (a_{max}), minimal value of acceleration (a_{min}), integrated accelerations value (C_p), integrated accelerations value (C_l), and value of rate of steps (TMP)

Athlete	a_{max}	a_{min}	C_p	C_l	TMP
BP	0.993*	-0.994*	-0.979*	0.965*	0.993*
GJ	0.945*	-0.984*	-0.872	0.842	0.995*
HM	0.378	-0.720	-0.942*	0.792	0.991*
KL	0.664	-0.698	-0.845	0.737	0.925*
KM	0.967*	-0.909*	-0.982*	0.978*	0.996*
KMi	0.993*	-0.746	-0.840	-0.130	0.997*
KP	-0.278	-0.997*	-0.952*	0.915*	0.903*
MB	0.957*	-0.992*	-0.375	0.324	0.859
ME	0.970*	-0.946*	-0.948*	0.955*	0.995*
SA	0.703	0.530	-0.618	0.512	0.960*
SM	0.981*	-0.963*	-0.831	0.747	0.981*

* - $p<0,05$

Analyzed VACM characteristics calculated separately for left and right steps were significantly different ($p<0.05$) for every athlete (fig. 2.). The body height and body mass of subjects were not significantly correlated with every analyzed mean values of VACM characteristic in every run. The figure 3 presents how the VACM characteristics of one chosen athlete (SA) change by speed treadmill. The figure 4 presents the VACM characteristics of chosen athletes obtained et the same speed equal to 16.5 km/h.

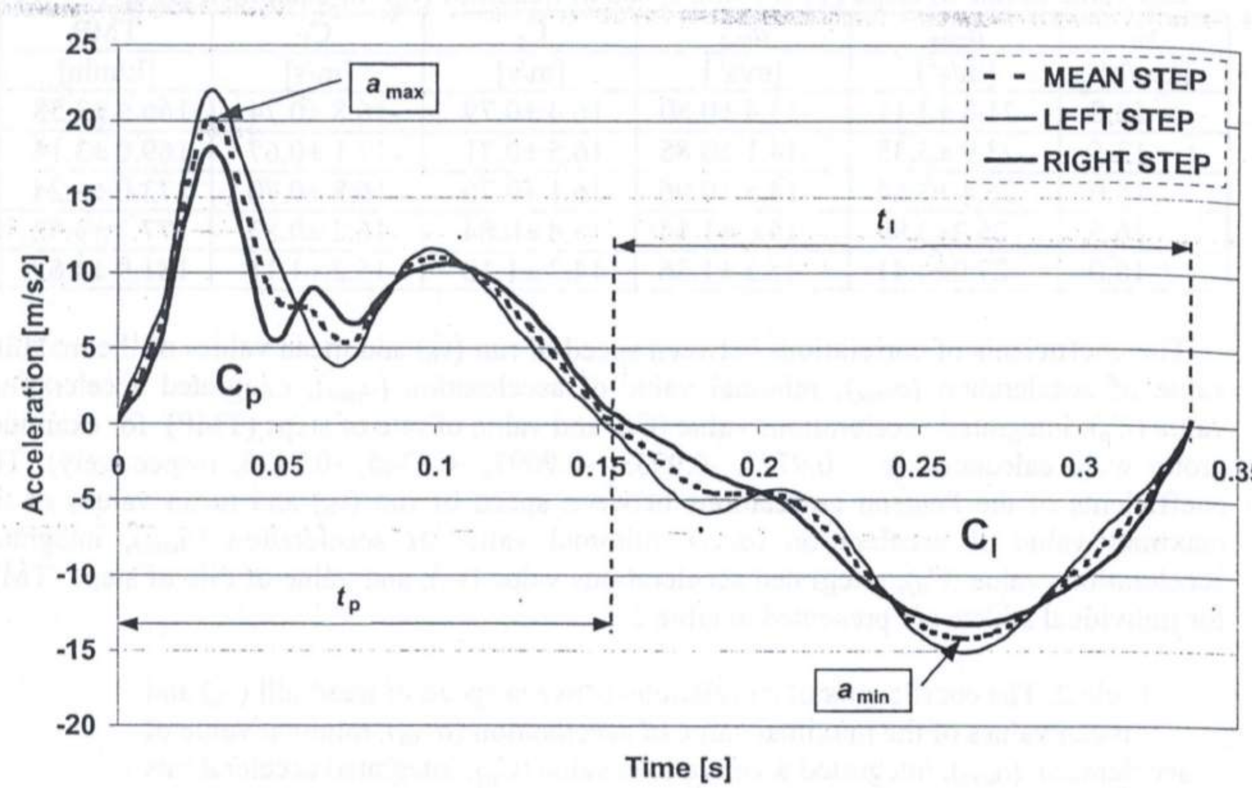

Fig. 2. Example of VACM characteristic for left leg, right leg and mean step with marked analyzed values

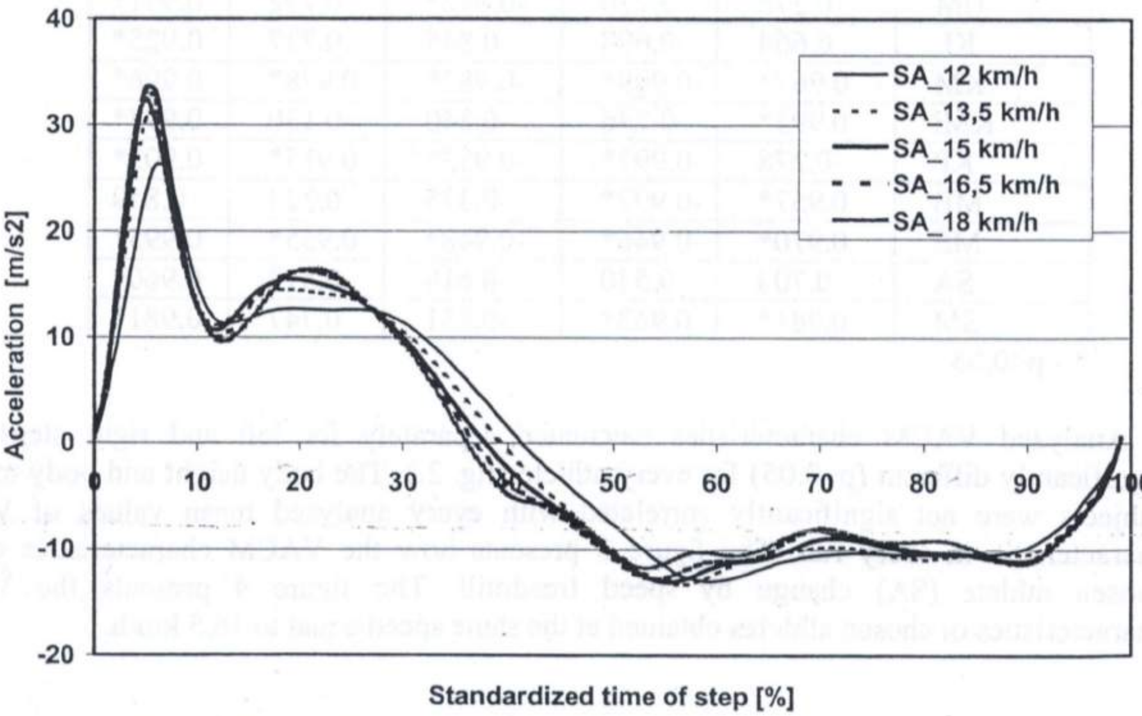

Fig. 3. The VACM characteristics obtained by chosen athlete (SA) by different treadmill speed

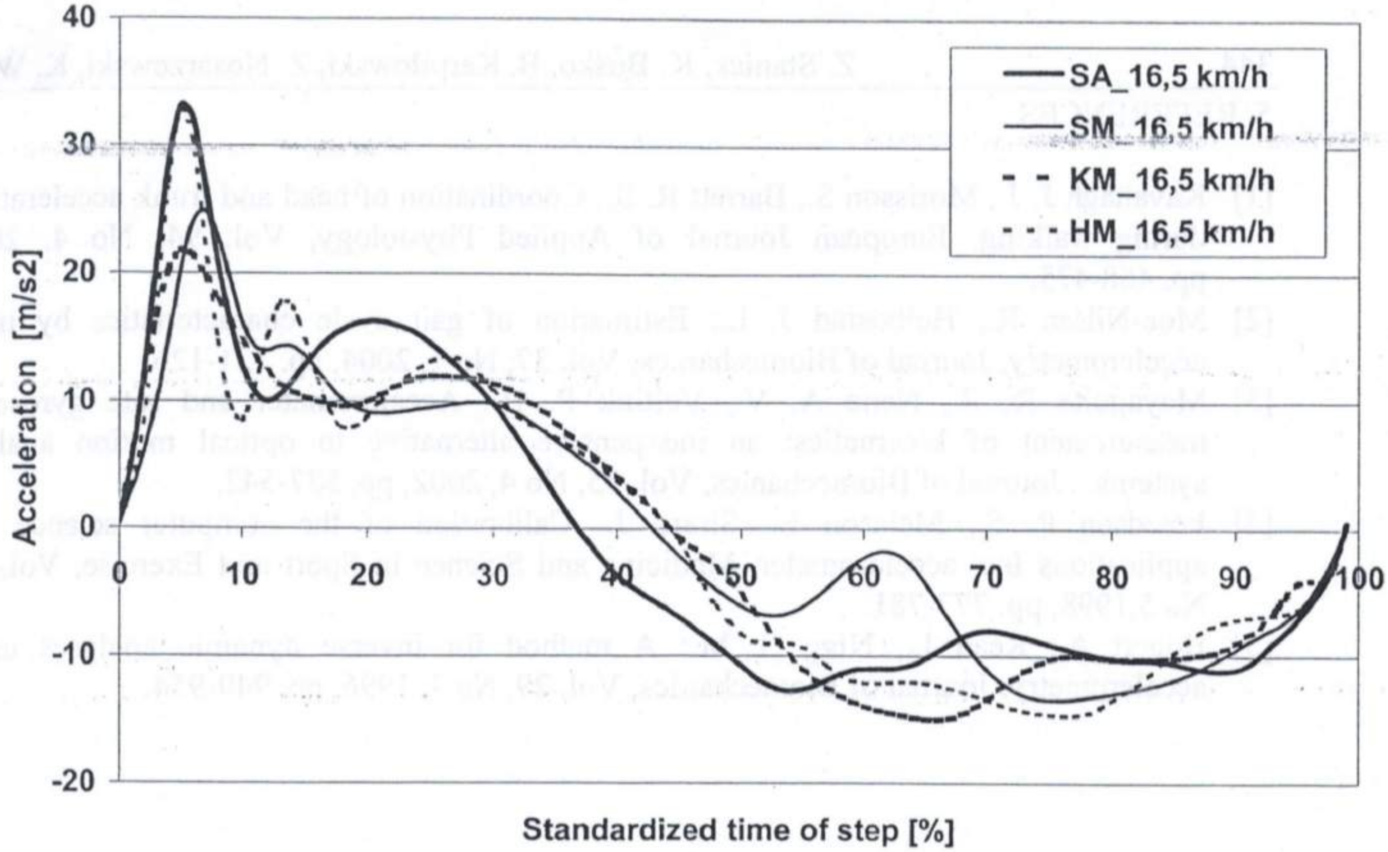

Fig. 4. The VACM characteristic obtained by chosen athletes at the same treadmill speed

4. DISCUSSION

For examined group the height and body mass of athlete are not significant influences on VACM characteristic. According to references results of our study confirm that the speed of running has significant influence on analyzed value and shape of VACM characteristic. The VACM characteristic well illustrates changes of dynamic of foot contact with ground (treadmill) at the landing, impact, and fly period as an effect of speed changes. Fly is presented by the curve of acceleration on the -10 m/s^2 (1 g) level. It can wave depending on position and way transfer of limb. Statistical analyzes of results and shape of VACM characteristic points that other athlete's characteristics are significantly different for the same speed of treadmill. For this reasons the VACM characteristic can be interpret as characteristic of personal technique of running. Significant differences between analyzed values of VACM characteristic of left and right step obtained from generally fit athletes hints that the VACM characteristic may be very useful during rehabilitation for analyze of typical injury and posture defects.

In summary, obtained results hints, that analyze of characteristic of vertical acceleration curve of body mass center of runner may be useful for qualitative and quantitative assessment of individual technique of running in sport training or rehabilitation of postural defects or after injures of movement apparatus of human.

5. REFERENCES

[1] Kavanagh J. J., Morisson S., Barrett R. S.: Coordination of head and trunk accelerations during walking. European Journal of Applied Physiology, Vol. 94, No 4, 2005, pp. 468-475.

[2] Moe-Nilsen R., Helbostad J. L.: Estimation of gait cycle characteristics by trunk accelerometry. Journal of Biomechanics, Vol. 37, No 1, 2004, pp. 121-126.

[3] Mayagoita R. E., Nene A. V., Veltink P. H.: Accelerometer and rate gyroscope measurement of kinematics: an inexpensive alternative to optical motion analysis systems. . Journal of Biomechanics, Vol. 35, No 4, 2002, pp. 537-542.

[4] Freedson P. S., Melason E., Sirard J.: Calibration of the computer science and applications Inc. accelerometer. Medicine and Science in Sport and Exercise, Vol. 30, No 5,1998, pp. 777-781.

[5] Bogert A., Read L., Nigg B. M.: A method for inverse dynamic analyses using accelerometry. Journal of Biomechanics, Vol. 29, No 7, 1996, pp. 949-954.