Bulletin of the *Transilvania* University of Braşov • Vol. 9 (58) No. 2 - Special Issue – 2016
Series I: Engineering Sciences

STATISTICAL PROCEDURE FOR EVALUATION OF STABILITY EVOLUTION FOR TENNIS PLAYERS

B. BRAUN[1]

Abstract: *There is described a new proposed procedure for statistical analysis in terms of body stability, based on the data recording in case of two young players, one female, the other male. The developed procedure invoked some algorithms for comparing the body stability parameters, evaluated in the same time and conditions, but for different tasks specific game. The procedure refers also to compare the stability parameters between both players, evaluated for the same play tasks, conditions and time intervals. It was found that the evaluating procedure was very efficient to establish the compatibility between two players that could play together. It could successfully be used in the future to establish the double tennis player teams.*

Key words: *COM, fore-hand, back-hand, stability, recording*

1. Introduction

The body equilibrium and stability play an important role for any persons in daily activities. It can influence the life style and especially it could preserve from domestic accidents.

In case of persons who practice sportive activities, especially for those who are involved in performance sports like tennis, athletics, skiing, skating etc. the body equilibrium is indispensable.

For this reason, in the last years many researches were increasingly focused on body balance, to find the causes and to find any efficient solutions to improve the body stability in different situations [1], [2]. The actual researches in domain address different kind of tests on human subjects to evaluate the body stability and balance, for instance to accomplish different types of tasks while the stability is registered, for different foot position [3], [4]. To improve the body equilibrium more solutions were established, depending on the problem causes: specific physical exercises, rehabilitation gymnastics or surgery interventions [5], [6], [7].

For sportive activities, one of the most efficient methods in terms of body stability is the direct observation evaluation of the concerned person. This method invokes a trainer who observes and evaluates the athlete's evolution, giving some instructions to improve the movement coordination [8]. Other evaluation methods refer to the human body biomechanical evaluation, by contact or without contact. In the last situation, the athlete operates while he is supervised by video equipments and intelligent software and hardware interfaces, in different

[1] Centre "Advanced Research on Mechatronics", *Transilvania* University of Braşov.

environment conditions [9], [10], [11].

2. Used equipment and procedure

Our research concerns behaviour assessment viewpoint of stability for tennis players. In the paper is presented a criterion of evaluation, referring to the body center of mass (COM) displacing amplitudes while playing.

The proposed analysis method was developed due to a casuistic study, concerning two persons, one female and the other male. Both persons were chosen from a large sample of tested persons (about 50 persons), on the basis of some anthropometric measurements (height, weight, length of different parts of the limbs etc.) [12]. Chosen persons fit in the extreme limits of 50 percentiles of the entire sample of tested subjects, the female having 44 kg weight and 1.63 cm height and the male having 63.5 kg and 1.75 cm. The reason for which the two persons were established in the extreme limits of the 50 percentiles of the sample was to find out if they could form a double-mix team in tennis matches. It was known that each one plays tennis as amateur.

Both subjects were thoroughly tested, by the point of view of body balance, forces, plantar mark etc., being registered and recorded.

A very important aspect of the research, described in the paper refers to the body stability and equilibrium. For this reason, the parameters of interest being the COM displacement amplitudes during different movements specific to tennis game (in case of service, fore-hand or back - hand). For this evaluation, a Kistler force plate was used to test the COM displacement amplitudes evolution during simulating different tennis sequences for both persons. Its technical characteristics are presented in the table below:

Table 1. *Technical and functional characteristics of the used force plate*

Dimensions (L x l x h) [m]	**Forces and displacements directions**	**Signal acquisition via hardware interfaces**	**Software environment**
0.5 x 0.4 x 0.04	along all axes (X / Y / Z)	- PC CARD DAS 16/16 acquisition board for analog input/output data; - PC CARD D24/CTR3 acquisition board for digital input/output data	- Bioware

The testing referred to evaluate the body COM displacement amplitudes evolution in two orthogonal directions, in lateral plane (DA_x) and in sagittal plane (DA_y), meaning along the force plate axes.

3. The data processing algorithm

To process the data, it proceeded to a set of 4 recordings on the force plate, for each tested person, each recording representing a simulation of game sequence: 1 – initial state; 2 – in service; 3 – fore-hand and 4 – back-hand.

To evaluate the body behaviour during the match, several aspect of interest were addressed. The first one refers to the differences in the averaged amplitudes, for equal time intervals of the entire sequence duration. Testing and registration were performed in the same condition for each sequence, for both subjects (temperature, timing, data acquisition frequency). Each registration lasted 11 seconds, meaning the mean timing of a tennis game sequence. In these condition, the data were centralised and processed for each second, meaning for 11 equal time intervals. To have a proper and complete data measuring, each game sequence simulation invoked three measurements on the force plate.

It was known that the plate was set to register N = 100 values each second. Thus means that for each second the parameter of interest was to determine the variation of the COM displacement amplitude in both planes, using the following relationship:

$$\Delta A_{x/y\_i} = \left| Max(A_{x/y\_1} \div A_{x/y\_N}) - Min(A_{x/y\_1} \div A_{x/y\_N}) \right| \tag{1}$$

where: $\Delta A_{x/y\_i}$ means the amplitudes variation (in lateral and sagittal planes) determined for each second of the data recording (i = 1 ÷11); $Max(A_{x/y\_1} \div A_{x/y\_N})$ represents the maximum value in terms of COM amplitude (both lateral and sagittal planes) of the registered data in each second. The same algorithm was applied to determine the COM displacement amplitudes variation for each of the three recordings, meaning to determine the amplitudes variations for the first measuring ($\Delta A_{x/y\_i\_I}$), for the second ($\Delta A_{x/y\_i\_II}$) and for the third measuring ($\Delta A_{x/y\_i\_III}$). As a result, a difference between the maximum and minimum amplitudes variation and considered for the three recordings (equation 2) was an issue of concern. Table presents an example of the processed data.

$$\delta\Delta A_{x/y\_i} = \left| Max(\Delta A_{x/y\_i\_I} \div \Delta A_{x/y\_i\_III}) - Min(\Delta A_{x/y\_i\_I} \div \Delta A_{x/y\_i\_III}) \right| \tag{2}$$

Table 2. *Example of processed data providing form the recording in case of male subject while simulating the sequence of fore-hand*

Time [s]	**ΔAx - Fore-hand (1st recording) [mm]**	**ΔAx - Fore-hand (2nd recording) [mm]**	**ΔAx - Fore-hand (3rd recording) [mm]**	**Amplitudes variation difference [mm]**
1	11.85	37.69	25.32	**25.84**
2	178.22	170.98	21.83	**156.39**
3	163.01	188.24	195.82	**32.81**
4	198.04	205.78	169.06	**36.72**
5	251.33	73.61	174.18	**177.72**
6	207.83	192.58	184.61	**23.22**
7	176.31	185.36	227.45	**51.14**
8	174.25	158.32	181.61	**23.29**
9	191.77	180.43	147.52	**44.25**
10	158.16	155.74	167.55	**11.81**
11	163.36	171.67	168.95	**8.31**

The established calculus algorithms were applied into EXCEL calculus sheets, obtaining a data statistics for each of the two invoked persons, for each game sequence simulation recording. Based on the data generated by spreadsheet in EXCEL, the COM amplitudes variation during a sequence (for all type of sequence simulation) could be represented as COM evolution diagrams. Figures 1 present the evolution diagram in terms of amplitudes variation in sagittal plane, in case of fore-hand sequence for the male person:

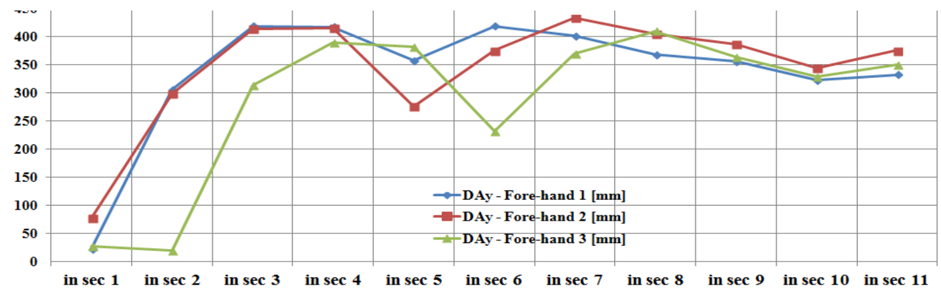

Fig. 1. *Evolution of COM displacement amplitude variation in sagittal plane during the for-hand sequence simulation in case of the male person*

Such of data statistics and diagrams were obtained for all types of sequences simulations (initial phase, in service, fore-hand and back-hand) for both tested subjects.

Another aspect of interest was to determine the differences between the COM averaged amplitudes (calculated for the same time intervals (each second)) for simulation of different game sequences (e.g. to compare the amplitudes in the second 5 when for-hand simulation with the amplitudes in the second 5 when back-hand simulation). The aim is to find which game sequence more risks should behave. Centralizing the data, via similar tabular spreadsheets, it was possible to determine the comparative values for different game sequences. The procedure was applied both for COM displacement amplitudes variation in lateral and sagittal planes, for both evaluated persons. Table 3 presents an example referring to the data on comparative COM amplitudes in lateral plane evolution between all simulated game sequences, for the female.

Table 3. *Example of comparative statistics between different game sequences referring to the COM amplitudes evolution in lateral plane for the female person*

Time [s]	Initially sequence Difference between total amplitudes (ΔAx) [mm]	In service sequence Difference between total amplitudes (ΔAx) [mm]	Fore-hand sequence Difference between total amplitudes (ΔAx) [mm]	Back-hand Difference between total amplitudes (ΔAx) [mm]
1	3.64	20.98	19.11	3.08
2	4.59	50.34	0.97	25.1
3	4.11	24.6	5.95	6.76
4	3.07	47.86	20.19	5.43
5	1.95	66.91	30.27	35.25
6	6.3	7.35	47.44	28.34
7	3.39	82.88	19.53	13.29
8	6.12	68.07	8.45	15.34
9	2.18	26	3.79	23.2
10	2.19	17.24	17.19	15.38

Based on the determined tabular values the comparative COM amplitudes evolution diagrams have been obtained. In the figure 4 there is presented an example related to the table 3:

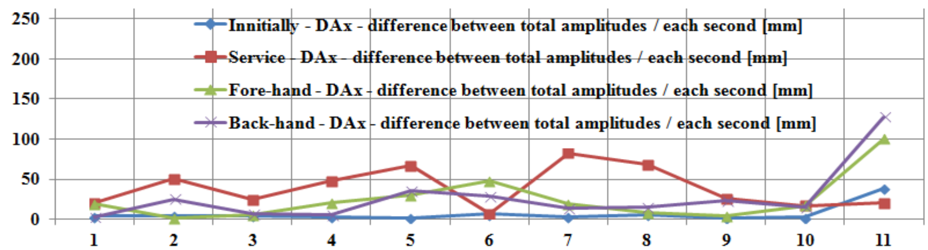

Fig. 2. *Diagram of comparative COM displacements amplitudes in lateral plane for all game sequences for the female person*

Another important aspect of the data processing referred to compare the evolution in stability, for all sequences between both persons. Table 4 presents an example referring to the COM displacement amplitudes comparative evolution, referring to the lateral plane, for back-hand sequence:

Table 4. *Example of comparative statistics between the two tested persons, for back-hand sequence, in terms of in lateral plane COM displacement amplitudes*

Time [s]	**ΔAy - back-hand – male person [mm]**	**ΔAy - back-hand – female person [mm]**	**Comparative results for back-hand sequence [mm]**
1	193.99	45.34	**148.65**
2	214.62	246.58	**31.96**
3	333.22	361.96	**28.74**
4	428.90	316.62	**112.28**
5	445.02	232.97	**212.05**
6	472.75	227.80	**244.95**
7	482.48	311.12	**171.36**
8	482.64	327.76	**154.88**
9	403.02	315.71	**87.31**
10	473.72	239.42	**234.30**

4. Results and discussion

Based on the obtained results it was found that for ñinitiallyò sequence the COM displacement amplitudes in lateral and sagittal planes were the lowest. By contrast, for ñback-handò sequence the same stability parameters were the highest, meaning the most risky game sequence. Comparing the results between the two subjects, it was found that the female person proved a much better stability in lateral plane (COM amplitudes about 4 times lower). Besides, it was found that female subject has also o better stability in sagittal plane (with 20.17%).

As a result it was found that the man (being higher and with a greater force in coup), could be successfully completed into a double-mix by the women having a better stability. Thus means that one could be more dynamic, chasing balls to the back of the field and the other could retrieve and return the ball in the net area.

The proposed evaluation method proved to be successfully applied in the future to select the player team for tennis games, especially in double or double-mix couples.

Acknowledgement

The researches have been accomplished in the Research and Development Institute of Transylvania University of Brasov, with abroad and contribution from students at Medical Engineering study program, in achieving their diploma projects.

References

1. Baritz, M., I.: *Correlated and interconnected analyses for human walking and standing biomechanical behavior.* In: ISPRA '10: Proceedings of the 9th Wseas International Conference on Signal Processing, Robotics and Automation Book Series: Mathematics and Computers in Science and Engineering, p: 236-243, 2010.
2. Jose, M., Gomez, T.**:** *Evaluation of Idiopathic Scoliosis based on Alignment, Equilibrium and Stability: Gomez Orthotic Spine System*. In: Torres, J Spine, 2:5, Vol. 2, 2013.
3. Panjan, A., Sarabon, N.: *Methods for the Evaluation of Human Balance Body*. In: Sport Science Review, vol. XIX, no. 5-6, p. 131-133, 2010.
4. Baritz, M. I., Cotoros, L, D.: *Oscillatory Movements Analysis at Knee Level.* In: Applied Mechanics and Materials,vol. 436, p. 271-276, 2013.
5. Schleer, R.: *Improvement of Body Balance and Gait Stability by Means of the Hallufix Foot Splint*. In: Summary of a scientific study, p. 1-4, 2014.
6. Mckillip, T. Q.: *How to Increase Body Balance*, http://www.ehow.com/, 2014).
7. OrtoProfil: *Reabilitation.* In: http://www.ortoprofil.ro/reabilitare, accessed in 2013.
8. Info storage: *Direct observation*, In: http://storage0.dms.mpinteractiv.ro/media/1/186/3941/10745973/1/dsc-0251.jpg?width=630, accessed in 2015.
9. Surveillance methods: *Advantage-tennis*. In: http://www.advantage-tennis.co.uk/images/camera.JPG, accessed in 2016.
10. Motion Analysis: SIMM. In: http://www.motionanalysis.com/html/movement/simm.html, accessed in 2016.
11. Barbu, D.M., Baritz, M.I.: *Evaluation of the Human Body Equilibrium in a Vibration Environment*, In: Applied Mechanics and Materials, Vol. 801, p. 295-299, 2015.
12. Parkinson, M.: *The use of humanoid glyphs in graphs for representing human variability in the spatial design of products*. In: Proceedings of the 2nd International Digital Human Modeling Symposium, 2013.