INFLUENCE OF THE LABORATORY CONTEXT AND THE SIZE OF THE MARKERS SET ON THE TENNIS SERVE EVALUATION

François Tubez [1,2], Bénédicte Forthomme [1], Jean-Louis Croisier [1], Vincent Denoël [1,3], Olivier Brüls [1,4], Julien Paulus [1] and Cédric Schwartz [1]

Laboratory of Human Motion Analysis, University of Liège, Liège, Belgium [1]
Physiotherapy Department, HERS of Libramont, Libramont, Belgium [2]
Department ArGEnCo, University of Liège, Liège, Belgium[3]
Department of Mechanical Engineering, University of Liège, Liège, Belgium[4]

The purpose of this study was to identify the influence on the tennis serve evaluation of 1/ the test environment and 2/ the number of the markers placed of the player. Two different studies were performed. The first compared a 4 vs. 28 marker set in a laboratory the same day. The second compared a 4 markers test in a laboratory with a 4 markers test on an official tennis court one week apart. We observed similar results between the different tests of both studies.

KEY WORDS: kinematic, protocol, overarm throwing, performance

INTRODUCTION: The research studies performed in real match situations are rare because of the influence of various extrinsic variables (e.g. influence of the opponent). However, standardized tests with highly controlled variables (e.g. test duration, ball effect, direction of the serve) may differ from practice in competition. Moreover, the markers placed on the skin to measure the player's kinematics may alter his natural motion. Standardized tests are achieved either in a laboratory (Seeley and al., 2008) or on a tennis court (Reid, Whiteside and Elliott, 2010). The latter solution have the advantage of measuring the serve in a more "natural" environment. However, advantage of the laboratory is to integrate tools such as 3D kinematic, force platforms or electromyography.
The present research describe the influence of performing kinematic evaluation of the tennis serve (i) on a tennis court vs. in a laboratory and (ii) with a limited (4 markers) vs. an extended markers set (28 markers). The aim is to observe the influence of these two variables on performance parameters in a tennis serve analysis. For that, we compare the racket velocity, the racket height and the ball accuracy. We know that racket velocity is linked with ball speed (Tanabe and Ito, 2007, Gordon and Dapena, 2006) which is a contributor to overall service performance (Girard and al, 2007). We also know that impact height is important to serve an "ace" (Whiteside, 2017). We consider these measures because they partly determine the final performance of the serve.

METHODS: Tennis players were asked to hit 15 flat first serves in a 1 m² area placed on the "T" zone of the deuce diagonal of the tennis court.

Two different studies were performed:

i. Fourteen players, righties, International Tennis Number (ITN) 6 to 2, 16 ± 6 years. A test using a 28 markers set in a laboratory is compared the same day with a test using a 4 markers set in a laboratory (Figure 1A). The passing of the tests were randomized.
ii. Thirteen players, righties, International Tennis Number (ITN) 3, 24 ± 3 years. A 4 markers test in a laboratory is compared one week apart with a 4 marker tests on an official tennis court (Figure 1B). The passing of the tests were randomized.

We used a three-dimensional optoelectronic system (Codamotion™, Charnwood Dynamics, Rothley, UK) to track the markers positions. The markers were placed on the player's racket (3), dominant wrist (3), dominant forearm (4), dominant arm (4), trunk (3), pelvis (3) and legs (2x4) with the 28 markers set (Figure 2) and on the racket (3) and pelvis (1) with the 4 markers set. To measure our parameters, we did not use all the 28 markers but we propose this markers set to better represent the situation encountered in other studies (Tubez, 2015).The markers were placed in accordance with the recommendations of the International Biomechanical Society (ISB) (Wu and al. 2002; Wu and al. 2005). The acquisition rate was equal to 200 Hz.

Figure 1: A. Laboratory; B. Official tennis court

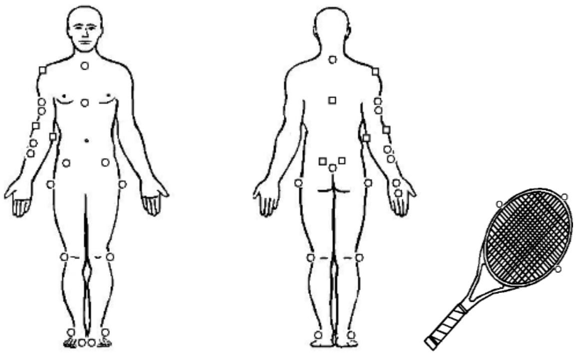

Figure 2: Representation of body and racket marker (circle) and additional anatomical points (square) placement (Tubez, 2015).

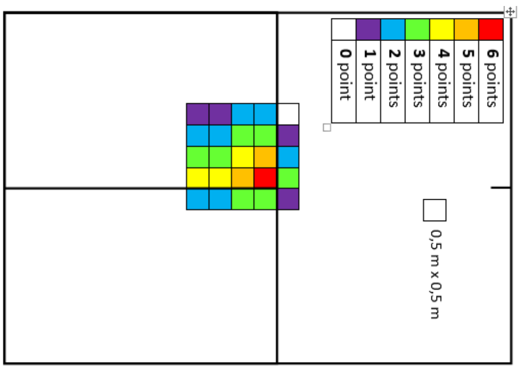

Figure 3: Scoring system

We observed three parameters: racket velocity at impact, racket height at impact and ball landing accuracy. We measured the racket velocity and height with the centroid of the three racket markers (one on the top and two on both lateral sides) to better align the racket speed with ball impact location. The accuracy of the serve was evaluated using a personal point system based on the landing location of the ball relatively to the 1 m^2 area (Figure 3). Serves landing within the target area are ranked according to a 0 to 6 scoring system and similarly to the Fernandez-Fernandez (2014) scoring system. The final score was the mean of the 15 individual scores (maximum = 6). The velocity and the height at impact were based only on the three best serves (Reid, Whiteside and Elliott, 2010; Tubez and al., 2015), which were selected based on ball velocity and landing accuracy Fernandez-Fernandez (2014). In both studies, groups were compared using a Wilcoxon test ($P < .05$). We also calculate the correlation coefficient to determine the relation between the marker sets.

RESULTS AND DISCUSSION: In the first study, we did not observe any significant differences between the 28-maker set and the 4-marker set for the three parameters (Table 1). Different placement of markers can be a source of error in the measurements. In this study, the markers placement were strictly the same between the two protocols (the markers were not removed between the tests). It is reassuring to observe a high correlation (r) for racket variables. The potential observed differences are therefore not attributable to the placement of the markers. For the ball accuracy parameter, we do not observe differences between the tests but we observe a correlation near zero, meaning a lack of relationship between the two tests. The players who have accurate serves for the 28-marker test are not obviously the more accurate for the 4-marker test. This parameter is potentially more difficult to reproduce for the players.

Table 1.
Comparison between the 28-marker set (28-Lab) and the 4-marker set (4-Lab) in a laboratory. N= 14.

	Mean ± SD		**P-Value**	**r**
	28-Lab	4-Lab		
Racket velocity ($m.s^{-1}$)	30,8 ± 5,3	31,0 ± 5,5	0,54	0,99
Racket height (m)	2,40 ± 0,25	2,39 ± 0,25	0,36	0,99
Ball accuracy (points)	1,5 ± 0,5	1,5 ± 0,6	1,00	-0,14

The order of passing these two tests were randomized. If we compare the first test and the second test without taking account of the marker set, we do not observe any difference for the three parameters (results not showed).

In the second study, we did not observe any significant differences between the tests in the laboratory and on the tennis court for the three parameters (Table 2). Once again, racket parameters (velocity and height) seems to be more linked (r) between the two tests in comparison to the ball accuracy parameter. These results show that the laboratory situation has no influence on the observed parameters. The setting up of our laboratory and our protocol seems therefore to be relatively close the official field situation.

Table 2.
Comparison between the 4-marker test in a laboratory (4-Lab) and the 4-marker test on the official tennis court (4-Court) (C). N= 13.

	Mean ± SD		**P-Value**	**r**
	4-Lab	4-Court		
Racket velocity ($m.s^{-1}$)	39,3 ± 4,4	38,5 ± 3,4	0,45	0,70
Racket height (m)	2,69 ± 0,10	2,72 ± 0,11	0,09	0,94
Ball accuracy (points)	1,9 ± 0,7	2,1 ± 0,7	0,45	-0,05

We measure the racket velocity and height with the centroid of the three racket markers. Taking into consideration this specific method, if we compare our results to the recent literature, we observe similar racket height (2,83 m in adult group) (Whiteside and Reid, 2017) and similar racket velocity (31 to 48 $m.s^{-1}$) (Whiteside and al. 2013a). We measure the speed of the racket at impact instead of the ball velocity to avoid influence of the stringbed. Because our system to measure the ball accuracy is original, it is not possible to have comparison with other studies for this parameter.
The differences of racket velocity, racket height and ball accuracy observed between the table 1 and the table 2 is attributable to the population studied. In the table 1, the age, height and level population average are inferior to the population encountered for the second study (table

2). The mean age in the first study corresponds to the age of a teenager, while in the second study the mean correspond to an adult. Therefore, it is normal to observe a higher racket speed for the second study because velocity is higher for adult players (Whiteside and al. 2013b). For the same reasons, it makes sense to note a lower impact height for the first study group. Concerning the ball landing accuracy, the second study group seems to be more accurate and this would be explained by the higher ITN in this group. In our study, it would have been interesting to compare the three test situations with a single homogeneous group.

CONCLUSION: In our work, we have observed that serve performance is not affected by the size of the makers set placed on the body and also not affected by the laboratory context. We observe similar results between the different tests. We observe no influence of the first test on the second test concerning the observed parameters and a familiarization test does not seem necessary. Although there was no observed difference between the groups, the accuracy seem less reproducible than racket parameters. Our scoring system is maybe perfectible and an electronic line-calling systems would probably be a better solution for the analysis.
We evaluated the player in a laboratory with a 28-marker set. The laboratory context allow to standardize the protocol and the 28-marker set bring more data for the kinematic analysis of the tennis serve. In the future, it would be interesting to compare our results and a situation without any markers. In this situation, only the ball accuracy and the ball speed (with radar) could be measured.

REFERENCES:

Fernandez-Fernandez, J., Ulbricht, A., Ferrauti, A. (2014). Fitness testing of tennis players: How valuable is it? *Br J Sports Med.*, 48; 22-31.

Girard, O., Micallef, J.P. and Millet, G.P. (2007). Influence of restricted knee motion during the flat first serve in tennis. *Journal of Strength and Conditioning Research* 21, 950-957.

Gordon, B. & Dapena, J. (2006). Contributions of joint rotations to racquet speed in the tennis serve. *J Sports Sci,* 24, 31-49.

Reid, M., Whiteside, D., Elliott, B. (2010). Serving to different locations: set-up, toss, and racket kinematics of the professional tennis serve. *Sport. Biomech.,* 10(4), 407-414.

Seeley, M.K., Uhl, T.L., McCrory, J., McGinn, P., Kibler, W.B., Shapiro, R. (2008). A comparison of muscle activations during traditional and abbreviated tennis serves. *Sport. Biomech*., 7(2), 248-259.

Tanabe, S. & Ito, A. (2007). A three-dimensional analysis of the contributions of upper limb joint movements to horizontal racket head velocity at ball impact during tennis serving. *Sports Biomech*, 6, 418-33.

Tubez, F., Forthomme, B., Croisier, J.L., Cordonnier, C., Brüls, O., Denoël, V., Berwart, G., Joris, M., Grosdent, S., Schwartz, C. (2015). Biomechanical analysis of abdominal injury in tennis serves. A case report. *J Sports Sci Med.* 8;14(2):402-12

Whiteside, D., Reid, M. (2017). Spatial characteristics of professional tennis serves with implications for serving aces: A machine learning approach. Journal of Sports Sciences. 35(7):648-654.

Whiteside, D., Elliott, B., Lay, B., Reid, M. (2013a). A kinematic comparison of successful and unsuccessful tennis serves across the elite development pathway. *Human Movement Science.* 32, 822-835.

Whiteside, D., Elliott, B., Lay, B., Reid, M. (2013b). The Effect of Age on Discrete Kinematics of the Elite Female Tennis Serve. *Journal of Applied Biomechanics,* 29, 573-582

Wu, G., Siegler, S., Allard, P., Kirtley, C., Leardini, A., Rosenbaum D, Whittle M, D'Lima DD, Cristofolini, L., Witte, H., Schmid, O., Stokes, I., (2002) ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion--part I: ankle, hip, and spine. International Society of Biomechanics. *Journal of Biomechanics* 35, 543-548.

Wu, G., Van Der Helm, F.C.T., Veeger, H.E.J., Makhsous, M., Van Roy, P., Anglin, C., Nagels, J., Karduna, A.R., McQuade, K., Wang, X., Werner, F.W. and Buccholz, B. (2005) ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand. *Journal of Biomechanics* 38, 981-992.

Acknowledgement
The authors wish to thank the Wallonia-Brussels Federation for their assistance in this study.