# MEASURING OPEN SPACE QUANTITATIVELY IN ONE-UP-ONE-BACK FORMATION DURING SOFT-TENNIS DOUBLES GAME

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The purpose of this study was to quantitatively define and measure the area of open space in one-up-one-back formation adopted in soft-tennis doubles game. Using the film images of real games, the variables of forehand ground strokes and ball bounces for 153 shots were analyzed with the direct linear transformation procedure. Further taking types of stroke technique and game situations into considerations, horizontal distance between contact point and landing point of shots were predicted by multiple regression analysis. As the result, four scales (two for stroke characteristics, stroke technique, and game situation) were selected as significant predictors. Then on the basis of these data, we predicted the horizontal distance of shots and defined the potential areas on court as "open space" in which shots could be landed, and actually computed the area of open space on one case in the game.

**KEY WORDS:** open space, soft-tennis, one-up-one-back formation, multiple regression analysis.

**INTRODUCTION:** In many ball games, open space (OPS) has a significant importance, because making shots or passes into OPS yields some advantages, and OPS itself must be indispensable information to make shots effective. The doubles game of soft-tennis is often played in the one-up-one-back formation. In this formation, the baseliner is faced with an opponent volleyer for the most part of the match, thus the importance of the information on OPS will increase because the baseliner has to decide quickly in which direction to make a shot. On the contrary, if the baseliner knows the information on OPS, she or he can easily plan the game strategies to have advantages, and this will facilitate the performance of the baseliner. However, OPS appearing on the court during the soft-tennis doubles game is not known quantitatively. Further OPS will be affected by the characteristics of the stroke, because the spin direction of the ball, that affects ball flight, is determined by the techniques of ground strokes (Groppel, 1984). Thus we have to take the techniques of ground strokes into account when considering OPS.
The purpose of this study was to quantitatively define and measure open space in one-up-one-back formation in the soft-tennis doubles game.

**METHODS:**
**Filming environment and procedures:** Women's and men's finals of the All Japan Soft-Tennis Championships in 1997 were videotaped by five cameras operating at 60Hz. Figure 1 shows the arrangements of cameras and location of the reference frame for further analysis. C1-C2 and C3-C4 systems were assigned to videotape both court and its surrounding of the north and south sides, respectively. Events of racket-ball contact and ball bounce were used as identical time-codes to synchronize five cameras. We could confirm the game situations by the image of C5. After the finals, 198 control points were videotaped using 2.5m-high reference frame to compute 3D coordinates of players, ball and racket-head.

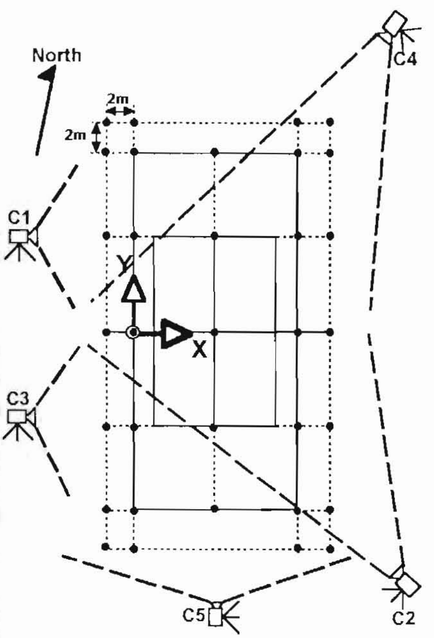


Figure 1: A schematic diagram of filming environment, global coordinate system for analysis, and locations of the reference frame (solid circle).

**Data Analysis:** The film images of four cameras (C1-C2 and C3-C4 systems) were digitized, and 153 successful forehand ground strokes by baseliners were analyzed with the direct linear transformation procedure. Then the following variables were obtained; the horizontal ball distance of forehand ground strokes (HD); the horizontal distance between racket-ball contact point and net (DN); the height of contact point (H); the racket-head velocity near impact (RV); and the angle between racket-head trajectory and ground near impact (RA). RV and RA were computed from displacement data collected over 2 frames prior to and after impact. RA was the angle between the vector of racket-head trajectory during the period above and its orthogonal projection to the court. Raw coordinate data of the racket-head were smoothed by cubic spline function. Average standard errors of x, y and z values in C1-C2 and C3-C4 systems were (4.20, 3.79, 2.94 cm), (5.80, 3.65, 2.82 cm), respectively. Digitizing reliability was ensured by the z value of ball bounce points, whose mean was 0.12 (SE=0.28) cm. Then using forward stepwise procedure of multiple regression analysis, HD was examined to ascertain if it could be predicted by other independent variables. Considering this prediction, technique types of ground stroke and difference of game situations were taken into account. Namely, we discriminated both between lobs and drives, and between returns (both for the 1st and 2nd serve) and baseline-plays, and these categories were treated as nominal scales. Further dummy variables (1 or -1) were assigned to these categories and subcategory. Subcategory meant return for the 1st or 2nd serve. Ground stroke (lob or drive), game situation (return or baseline-play), and return (for the 1st or 2nd serve) categories were named as LOD, ROB and RET, respectively.

**RESULTS AND DISCUSSION:** Table 1 shows the correlation matrix among continuous variables and muliticollinearity was not found, thus all these continuous variables were pooled for the stepwise procedures. Table 2 shows the results of forward stepwise procedure of multiple regression analysis. Four scales (DN, RA, LOD and ROB) were selected as significant predictors for HD, and the equation for predicting HD fitted to measured HD significantly ($p < .001$; Figure 2). Thus the equation obtained was as follow;

$$HD = 11.986 + 0.928 \times DN - 3.647 \times RA - 0.963 \times D_{LOD} - 0.228 \times D_{ROB} \quad (1)$$

where $D_{LOD}$ (1 in case of drive or -1 of lob) and DROB (1 in case of return or -1 of baseline-play) were dummy variables.

**Table 1 Correlation matrix among continuous variables.**

| Continuous scale | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1.Horizontal distance between racket-ball contact point and net (DN); | — | .045 | .130 | .048 |
| 2.Angle between racket-head trajectory and ground near impact (RA) | | — | -.424 | -.366 |
| 3.Height of contact point (H) | | | — | .377 |
| 4.Racket-head velocity near impact (RV) | | | | — |

**Table 2 Results of stepwise procedure of multiple regression analysis for predicting the horizontal distance of forehand shot.**

| Scale | Regression coefficient | *F*-value | *p*-value |
|---|---|---|---|
| Horizontal distance between racket-ball contact point and net (DN); | .928 | 78.89 | $<1.00 \times 10^{-4}$ |
| Angle between racket-head trajectory and ground near impact (RA) | -3.647 | 10.90 | $1.20 \times 10^{-3}$ |
| Height of contact point (H) | 0 | .46 | .50 |
| Racket-head velocity near impact (RV) | 0 | $2.00 \times 10^{-3}$ | .96 |
| Ground stroke (LOD) | -.963 | 14.96 | $2.00 \times 10^{-4}$ |
| Game situation (ROB) | -.228 | 1.36 | .25 |
| Return (RET) | 0 | .02 | .88 |

It was a very logical result that DN was selected as a predictor. However, it was unexpected that RV was not selected as a predictor. Possible explanation for RV is that soft-tennis ball is made with rubber, thus it changes its shape very easily after impact and during the flight, thus ball cannot be treated approximately as a rigid sphere, and this means that ball flight will be influenced aerodynamically.

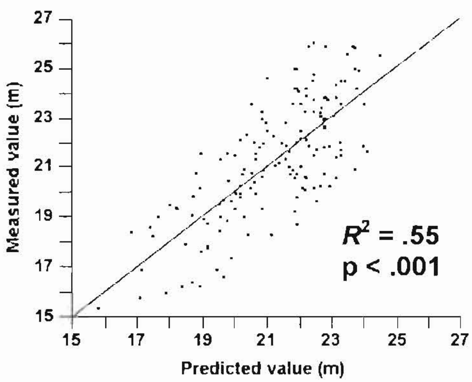


Figure 2: Scatter plot of measured and predicted value of the horizontal distance of forehand strokes.

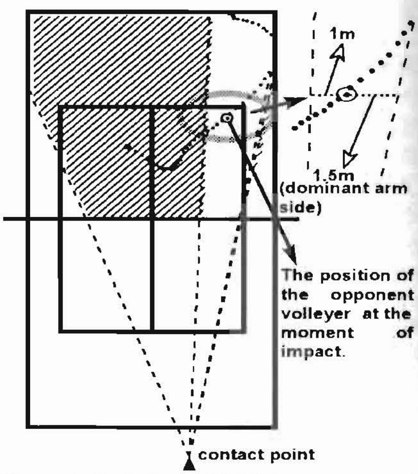


Figure 3: Definition of OPS (areas covered with oblique lines) and the trace of opponent volleyer (solid circle).

According to the equation (1), we defined OPS as shown in Figure 3. Using RA as a variable we considered the case in which HD become shortest when applying the baseliner's individual result to the equation (1). Namely, value of (Mean - SD) was used. Further we assumed the limited length (1.5 m in the side direction (x) of the dominant arm from the center of the trunk, 1 m in the opposite direction, respectively) of the opponent volleyer to reach a ball flying by racket without movement in any direction, and OPS was defined as the areas covered with oblique lines in Figure 3. In the case of Figure 3, the area of OPS was 85.6 m2, and OPS was spreading towards the left direction widely for the baseliner, because the opponent volleyer stood to the right direction after returning 1st serve.
If this method to determine OPS is valid, it is possible to know when the area of OPS become minimum, optimal position for volleyer, and useful information to win the game.

**CONCLUSION:** 153 forehand ground strokes were analyzed, and HD was examined with multiple regression analysis. As the results, HD could be predicted with the scales of DN, RA, LOD, and ROB significantly. Further OPS could be determined by predicting HD.

**REFERENCES:**

Groppel, J. L. (1984). Tennis for advanced players and those who would like to be. Champaign: Human Kinetics Publishers.