The Effect of New Balls in Tennis: Four Years at Wimbledon

Jan R. Magnus; Franc J. G. M. Klaassen

The Statistician, Vol. 48, No. 2 (1999), 239-246.

Stable URL:
http://links.jstor.org/sici?sici=0039-0526%281999%2948%3A2%3C239%3ATEONBI%3E2.0.CO%3B2-H

The Statistician is currently published by Royal Statistical Society.

The Statistician (1999)
48, *Part* 2, *pp.* 239–246

Focus on Sport

The effect of new balls in tennis: four years at Wimbledon

Jan R. Magnus and Franc J. G. M. Klaassen

Tilburg University, the Netherlands

[Received April 1998. Revised October 1998]

Summary. We analyse two often-heard hypotheses concerning tennis-balls. The first is: are new balls an advantage to the server? They are not (at least not at Wimbledon). However, they do affect the way that points are played. With new balls, more services are missed but this negative effect is compensated by winning more points if the second service is in. The second hypothesis is: did the softer balls in the 1995 Wimbledon championships result in lower dominance of service? The answer, again, is no. The dominance of service appears to have decreased over time even without special measures; the use of softer balls has had hardly any extra effect, at least not the balls used in 1995. If a faster decrease in the dominance of the service is deemed necessary, then stronger measures are called for. An obvious and easy-to-implement measure is to abolish the second service, which has the additional benefit of making matches more even and thus more attractive for spectators.

Keywords: Logistic regression; Tennis; Wimbledon

1. Introduction

Tennis as a game has a long history which goes back to the Greeks and Romans. But it was not until 1870 that it became technically possible to produce rubber balls which bounce well on grass. When the All England Lawn Tennis Club decided to hold their first championships in 1877, a three-man subcommittee drew up a set of laws. Rule II stated that

> 'the balls shall be hollow, made of India-rubber, and covered with white cloth. They shall not be less than 2 1/4 inches, nor more than 2 5/8 inches in diameter; and not less than 1 1/4 ounces, nor more than 1 1/2 ounces in weight.'

See Little (1995), p. 284. The quality of the tennis-balls has gradually improved. From 1881 to 1901 the balls were supplied by Ayres; thereafter by Slazinger and Sons. Yellow balls were introduced at the 100th championships meeting in 1986. During the 1877 championships 180 balls were used; now more than 30 000 are used in one year.

During a tennis-match new balls are provided after the first seven games (to allow for the preliminary warm-up) and then after each subsequent nine games. (Before 1955 new balls were provided at the beginning of each set.) Most commentators and many spectators believe that new

Address for correspondence: Jan R. Magnus, CentER for Economic Research, Tilburg University, PO Box 90153, 5000 LE Tilburg, the Netherlands.
E-mail: magnus@kub.nl

 0039–0526/99/48239

balls are an advantage to the server. But is this true? This is the first of two questions which we wish to investigate in this paper. The second question relates to the Wimbledon experiment in 1995, when the organization decided to use softer balls in an attempt to lower the dominance of service. The service is considered to be too dominating, especially in the men's game, and this would have a negative effect on the attraction of tennis for spectators. The second question is therefore: did the softer balls used in 1995 have the desired effect?

The simplest model in analysing tennis-matches is based on the assumption that two fixed probabilities govern a match: the probability of winning a service point for both players. Then, one can calculate the probability of winning a game, set, tie-break or match; see Hsi and Burych (1971), Kemeny and Snell (1976) (in particular pages 161–167) and Pollard (1983). Klaassen and Magnus (1998) analyse whether the assumption of fixed probabilities of winning a point on service is realistic. Another series of papers deals with the tennis scoring system and its effect on the probability of winning a match; see Maisel (1966), Miles (1984), Riddle (1988, 1989) and the comments by Jackson (1989). Finally, the service and the first–second service strategy have been analysed by George (1973) and Gillman (1985). Gillman concluded that 'missing more serves may win more points'.

Many papers on the statistical analysis of tennis are theoretical and contain no data. If data are used, then these are often point-to-point data for one match or based on end-of-match results (6–4, 6–3, 6–3, say). The current paper is an exception: we use point-to-point data on 481 Wimbledon matches. This means a total of 88 883 observations.

In Section 2 we describe the Wimbledon data and discuss the question of weighting. Section 3 addresses the effects of new balls, whereas Section 4 concerns the softer balls in 1995.

2. The data and two selection problems

We shall investigate the two questions by using data from 481 matches played in the men's singles and women's singles championships at Wimbledon from 1992 to 1995. Since all matches in our data set are played on one of the five 'show courts'—the centre court and courts 1, 2, 13 and 14—we have data on almost half of all singles matches played during these four years. For each of these matches we know the exact sequence of points. We also know at each point whether the first or the second service was in and whether the point was decided through an ace or a double fault. We have slightly more matches for men than for women, but of course many more sets, games and points for the men's singles than for the women's singles, because the men play for three sets won and the women for two. The men play fewer points per game than the women, because the dominance of their service is greater, as shown by Magnus and Klaassen (1999a). But the women play fewer games per set on average (scores like 6–0 and 6–1 are more common in the women's singles than in the men's singles), because the difference between seeded and non-seeded players is much greater. (See Magnus and Klaassen (1999b) for empirical evidence. At Wimbledon 16 players out of 128 are seeded.) This also leads to fewer tie-breaks in non-final sets for women. (At Wimbledon there is no tie-break in the final set, i.e. the fifth set in the men's singles and the third set in the women's singles.) Both men and women play about 60 points per set. The men play on average 230.5 points per match; the women 131.9. See Magnus and Klaassen (1999a) for further details on the data.

As noted, all matches in our data set are played on one of the five show courts. Usually matches involving top players are scheduled on these courts. This causes an under-representation in the data set of matches with non-seeded players. This is, however, not the only selection problem in our data set. If two non-seeded players play against each other in the quarter-final, this match is likely to be scheduled on a show court. But, if they play in the first round, their match is

considered to be of less importance and is likely to be played on another court. After all, there are 16 first-round matches involving a seeded player and such matches often take precedence. Therefore, the under-representation of matches between two non-seeded players is most serious in early rounds. This dependence on round in the selection of matches is also present in other matches, although it is less serious, as Table 1 shows. We distinguish between round (1, first round; 7, final) and type of match (Sd–Sd for two seeded players, Sd–NSd for a seeded against a non-seeded player and NSd–NSd for two non-seeded players). The column labelled 'Sample' in each part contains the number of matches in our sample, the column labelled 'Population' the number of matches actually played and the third column the number of matches in our sample as a percentage of matches actually played.

We see that the percentage of matches of non-seeded against non-seeded (NSd–NSd) players in our data set is 24.9 for the men and 14.8 for the women. Both are lower than the percentages for Sd–NSd matches, which are themselves lower than those for Sd–Sd matches. This illustrates the first selection problem, namely the under-representation of matches involving non-seeded players. (Note that in the first round of the women's singles there are 63 rather than 64 matches between a seeded and a non-seeded player. The reason is that Mary Pierce, seeded 13, withdrew in 1993 at the last moment. She was replaced by Louise Field, an unseeded player.)

The second selection problem, caused by the round dependence, appears from the increasing pattern in the sampling percentages over the rounds. For example, only 32.0% of all first-round matches in the men's singles and 26.2% in the women's singles are in the data set, whereas all finals have been sampled.

Since we wish to make statements about Wimbledon (and not just about the matches in our sample), we account for both selection problems by weighting the matches when computing the statistics below. The weights are the inverses of the sampling percentages in Table 1. This procedure involves an assumption, namely that within each cell the decision by Wimbledon's

Table 1. Number of matches in the sample and in the population

Round	*Sd–Sd*			*Sd–NSd*			*NSd–NSd*			*Total*		
	Sample	*Population*	*%*	*Sample*	*Population*	*%*	*Sample*	*Population*	*%*	*Sample*	*Population*	*%*
Men's singles												
1	—	—	—	48	64	75.0	34	192	17.7	82	256	32.0
2	—	—	—	46	54	85.2	16	74	21.6	62	128	48.4
3	—	—	—	39	41	95.1	16	23	69.6	55	64	85.9
4	8	9	88.9	15	15	100.0	8	8	100.0	31	32	96.9
5	7	7	100.0	9	9	100.0	0	0	—	16	16	100.0
6	7	7	100.0	1	1	100.0	0	0	—	8	8	100.0
7	4	4	100.0	0	0	—	0	0	—	4	4	100.0
Total	26	27	96.3	158	184	85.9	74	297	24.9	258	508	50.8
Women's singles												
1	—	—	—	43	63	68.3	24	193	12.4	67	256	26.2
2	—	—	—	43	58	74.1	3	70	4.3	46	128	35.9
3	—	—	—	42	48	87.5	12	16	75.0	54	64	84.4
4	8	8	100.0	20	21	95.2	2	3	66.7	30	32	93.8
5	11	12	91.7	3	3	100.0	1	1	100.0	15	16	93.8
6	6	6	100.0	1	2	50.0	0	0	—	7	8	87.5
7	4	4	100.0	0	0	—	0	0	—	4	4	100.0
Total	29	30	96.7	152	195	77.9	42	283	14.8	223	508	43.9

organizers whether a match is on a show court or not is random, so that the matches on the show courts (which are the matches that we observe) are representative. One could argue that, if the sample is very small compared with the population, this method would make the few observed matches too important. Most notably, in the women's singles we observe only three of the 70 matches played between two non-seeded players in the second round. If these three matches were selected by the organizers to include, for example, players just outside the top 16, then our method would be seriously biased for this cell. As it happens, the three matches concern players with Women's Tennis Association rankings 27–41, 131–143 and 22–113 and hence there is no reason to believe that these matches are not representative.

3. Is serving with new balls an advantage?

To determine whether serving with new balls is an advantage, let us consider Table 2. (In Tables 2–5 our summary statistics for service characteristics are based on all points played, thus including points played during tie-breaks.) The age of the balls in games is indicated from 1 (new balls) to 9 (old balls). During the five minutes of warming up before the match begins, the same balls are used as in the first seven games. Thus it makes sense to set the age of the balls in the first game of the match at 3. If the hypothesis that new balls provide an advantage were true, the dominance of service, measured by the probability of winning a point on service, would decrease with the age of the balls. (Magnus and Klaassen (1999a) showed that the probability of winning a point on service is the best statistic to measure service quality or dominance.) Table 2 does not support this hypothesis, at least in the men's singles. For the women the probability of winning a point on service with balls of age 9 is significantly lower than with balls of age 1, but overall there is no evidence for the hypothesis either. (In this paper 'significant' means that the estimate is more than two standard errors away from its target. The standard errors are presented in parentheses.)

Although serving with new balls appears to provide no advantage in terms of the number of

Table 2. Service characteristics depending on the age of the balls

Characteristic	*Percentage of the characteristics for the following ages of balls:*									*Total (%)*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	
Men's singles										
Aces	8.7	7.9	8.6	7.7	8.2	8.3	8.5	8.4	7.2	8.2
	(0.4)	(0.4)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.4)	(0.3)	(0.1)
Double faults	5.8	5.3	5.8	6.6	5.4	5.6	4.9	5.1	5.1	5.5
	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.1)
Points won on service	64.7	63.4	64.2	64.8	64.0	64.1	65.8	64.3	64.3	64.4
	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.2)
1st services in	58.9	60.2	58.4	58.6	59.1	59.1	59.7	60.3	61.0	59.4
	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.6)	(0.2)
Women's singles										
Aces	2.4	2.5	3.4	3.2	3.8	2.7	3.7	3.7	2.1	3.1
	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	(0.1)
Double faults	6.7	5.4	5.8	5.2	5.6	4.0	5.2	5.4	6.4	5.5
	(0.5)	(0.5)	(0.4)	(0.4)	(0.4)	(0.3)	(0.4)	(0.4)	(0.4)	(0.1)
Points won on service	56.2	56.3	55.9	54.8	58.4	56.2	57.7	55.9	53.3	56.1
	(0.9)	(1.0)	(0.8)	(0.8)	(0.8)	(0.8)	(0.9)	(0.9)	(0.9)	(0.3)
1st services in	58.3	61.0	61.3	56.9	61.1	61.9	61.9	63.9	61.4	60.8
	(0.9)	(1.0)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)	(0.9)	(0.9)	(0.3)

points won, Table 2 shows that new balls may affect the way that points are won. For example, the probability of '1st service in' seems to increase when the balls become older, and the probability of a double fault seems to decrease, which is, of course, partly due to the increasing trend in the probability of '1st service in'. The reason for this, perhaps, is that older balls are softer and fluffier (hence have more grip) than newer balls. The service is therefore easier to control, resulting in a higher percentage of '1st service in' and fewer double faults.

Both effects would result in a greater dominance of service as balls become older. To show why, nevertheless, the dominance of service appears to be independent of the age of the balls, we split the probability of winning a point on service as follows:

$$\begin{aligned}\Pr(\text{point won on service}) &= \Pr(\text{point won on 1st service}) \\ &\quad + \Pr(\text{1st service fault})\Pr(\text{point won on 2nd service}) \\ &= \Pr(\text{point won if 1st service in})\Pr(\text{1st service in}) \\ &\quad + \{1 - \Pr(\text{1st service in})\}\Pr(\text{point won if 2nd service in}) \\ &\quad \times \Pr(\text{2nd service in}). \qquad (1)\end{aligned}$$

To analyse how these probabilities depend on the age of the balls, we specify a simple logit model with a linear function of the age of the balls as the systematic part; see McFadden (1984). For example, the probability of winning a point on service is specified as

$$\Pr(\text{point won on service}) = \Lambda(\beta_0 + \beta_1 \text{ age of balls}), \qquad (2)$$

where Λ is the logistic distribution function, $\Lambda(x) = \exp(x)/\{1 + \exp(x)\}$. Table 3 presents the maximum likelihood estimation results for all probabilities in equation (1).

As already suggested by Table 2, the probability of '1st service in' increases when balls become older. One might argue that this positive effect on the probability of winning a point on the first service is counteracted by a benefit for the receiver when balls become older and thus softer and fluffier. The first service would be slower and hence easier to return. We find no

Table 3. Service characteristics depending on the age of the balls: logit estimation results

Probability	*Estimates for the men's singles*		*Estimates for the women's singles*	
	constant	*age of balls*	*constant*	*age of balls*
Point won on service	0.580	0.003	0.269	−0.005
	(0.019)	(0.003)	(0.027)	(0.005)
Point won on 1st service	−0.293	0.007†	−0.593	0.019†
	(0.018)	(0.003)	(0.027)	(0.005)
Point won if 1st service in	1.001	0.002	0.443	0.011
	(0.027)	(0.005)	(0.035)	(0.006)
1st service in	0.341	0.008†	0.340	0.020†
	(0.019)	(0.003)	(0.027)	(0.005)
Point won on 2nd service	0.057	−0.001	0.041	−0.036†
	(0.029)	(0.005)	(0.042)	(0.008)
Point won if 2nd service in	0.414	−0.006	0.378	−0.043†
	(0.031)	(0.006)	(0.046)	(0.008)
2nd service in	1.766	0.017†	1.820	−0.001
	(0.041)	(0.008)	(0.061)	(0.011)

†Estimate 'significantly' different from 0.

evidence for this, as age has no effect on the probability of winning a point if the first service is in. Therefore, in total, players win more points on their first service as balls become older.

The second service is different. The men miss fewer second services when using old balls, which is in line with the decreasing double-fault statistics in Table 2. However, if the second service is in, they win fewer points, but not significantly so. On balance, the quality of the second service, measured by the probability of winning a point on the second service, is independent of the age of the balls.

For the women the quality of the second service does depend on the age of the balls. The second service is easier to return with older balls, which makes the quality of the second service depend negatively on the age of the balls.

Formula (1) can now be used to show that, on balance, the age of the balls does not affect the dominance of service. It is true that older balls lead to more points won on the first service. However, both men and women have fewer opportunities to score points on their second service, as the probability of missing a first service decreases. Moreover, the women score fewer points on their second service. On balance, the effects on the first and second service offset each other, so the age of the balls does not affect the quality of service.

A second interpretation of the question whether serving with new balls provides an advantage is that newer balls may benefit the server only in the first game that they are used (age 1). It may be the transition from old, soft and fluffy balls to new, hard balls that is difficult to cope with for the receiver and/or server. To analyse this we add a dummy variable for balls of age 1 to the logit models used above. However, there is no evidence for an effect of this dummy on the probabilities in Table 3. Only for the probability of '2nd service in' for the women's singles does the dummy have a significantly negative effect. This is in line with the high percentage of double faults with new balls in Table 2. Including the dummy does not change the effect of the age variable essentially.

4. Softer balls

We now turn to another aspect of tennis-balls. A major discussion in tennis concerns the dominance of service and the effect that it has on the attraction of tennis as a spectator sport. This is particularly true on fast grass courts such as at Wimbledon. Many proposals have been made to reduce the dominance of the service: making the net higher or the service court smaller; abolishing the second service; the use of softer balls. The last proposal was put into effect at the 1995 Wimbledon championships. Has this resulted in less dominance of service?

Before we can address this question, we need to know something about the weather, since this also affects a match. If the weather had been very different in 1995 from that in the three previous years, then it would have been difficult to make proper comparisons. The weather at Wimbledon has been documented by Little (1995)—the weather has not been very different in the four years of our observations.

In Table 4 the four years are compared through some service characteristics. The dominance of service in 1995 did not differ significantly from that for the years before. In 1995, 64.0% (0.4%) of the points in the men's singles were won on service, compared with 64.5% (0.2%) in the three years before. For the women the conclusion is the same. Hence, the softer balls used in 1995 did not have the desired effect. Note that this is in line with the absence of any effect of older, and thus softer and slower, balls on the dominance of service, which we showed in the previous section.

Table 4 also shows that the softer balls in 1995 seem to have had some effect. The men hit significantly more aces and double faults in 1995 and both men and women missed more first

Table 4. Service characteristics depending on the year of tournament

Characteristic	*Percentages of the characteristics for the following years, men's singles:*					*Percentages of the characteristics for the following years, women's singles:*				
	1992	*1993*	*1994*	*1995*	*1992–1994*	*1992*	*1993*	*1994*	*1995*	*1992–1994*
Aces	7.7	8.1	8.1	8.9	8.0	3.2	3.6	2.4	3.3	3.0
	(0.2)	(0.2)	(0.2)	(0.3)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.1)
Double faults	4.6	5.2	6.2	6.2	5.3	5.2	5.7	5.3	5.8	5.4
	(0.2)	(0.2)	(0.2)	(0.2)	(0.1)	(0.3)	(0.3)	(0.3)	(0.3)	(0.2)
Points won on service	64.9	64.9	63.9	64.0	64.5	57.0	56.6	55.4	55.4	56.3
	(0.4)	(0.4)	(0.4)	(0.4)	(0.2)	(0.6)	(0.6)	(0.6)	(0.5)	(0.4)
1st services in	61.6	60.4	58.5	56.9	60.1	61.1	60.5	62.2	59.6	61.3
	(0.4)	(0.4)	(0.4)	(0.4)	(0.2)	(0.6)	(0.6)	(0.6)	(0.5)	(0.3)

services. The low percentages of '1st service in' and '2nd service in' for 1995 are, however, peculiar, since the analysis of the new-balls hypothesis showed that older (and thus softer and slower) balls lead to more instead of fewer services in. A more careful investigation of Table 4 shows that the deviations have little to do with the softer balls. Over the whole period of four years the percentage of aces and double faults has gradually increased for the men, and the percentage of '1st service in' has gradually decreased for both men and women.

To obtain a clear distinction between the trend and any additional effect of the softer balls, we use a logit model similar to that used before. The trend variable is the year of tournament (92, 93, 94 or 95) and a dummy for year 95 is used to capture any additional effect of the softer balls in 1995. Hence, we write all probabilities in equation (1) as logistic distribution functions of $\beta_0 + \beta_1$ year $+ \beta_2$ dummy95. For example,

$$\Pr(\text{point won on service}) = \Lambda(\beta_0 + \beta_1 \text{ year} + \beta_2 \text{ dummy95}). \tag{3}$$

Table 5 shows the maximum likelihood estimation results. In only two cases is the year 1995 different after correction for the time trend. However, only for the men's '2nd service in' does the

Table 5. Service characteristics depending on the year of the tournament: logit estimation results

Probability	*Estimates for the men's singles*			*Estimates for the women's singles*		
	constant	*year*	*dummy95*	*constant*	*year*	*dummy95*
Point won on service	2.643	−0.022	0.022	3.333	−0.033†	0.030
	(1.088)	(0.012)	(0.031)	(1.527)	(0.016)	(0.042)
Point won on 1st service	2.809	−0.033†	0.000	1.084	−0.017	−0.043
	(1.049)	(0.011)	(0.030)	(1.557)	(0.017)	(0.043)
Point won if 1st service in	−1.667	0.029	0.013	5.105	−0.049†	0.048
	(1.513)	(0.016)	(0.045)	(1.982)	(0.021)	(0.054)
1st service in	6.506	−0.066†	−0.004	−1.529	0.021	−0.117†
	(1.064)	(0.011)	(0.030)	(1.555)	(0.017)	(0.043)
Point won on 2nd service	4.792	−0.051†	0.045	1.637	−0.019	0.049
	(1.652)	(0.018)	(0.046)	(2.472)	(0.027)	(0.068)
Point won if 2nd service in	2.224	−0.020	0.003	1.657	−0.016	0.053
	(1.805)	(0.019)	(0.051)	(2.647)	(0.029)	(0.073)
2nd service in	13.479	−0.125†	0.154†	3.702	−0.020	0.013
	(2.440)	(0.026)	(0.067)	(3.565)	(0.038)	(0.097)

†Estimate 'significantly' different from 0.

1995 dummy have an effect that might be attributed to the softer balls. The negative effect for the women's '1st service in' cannot be due to the softer balls, as we showed in the previous section that softer balls have a positive effect on this service characteristic. Our conclusion is thus that the softer balls in 1995 had hardly any effect on the service characteristics.

Table 5 can also be used to analyse whether and how the game of tennis at Wimbledon has evolved from 1992 to 1994, particularly the way that servers win their points. We observe a gradual decrease in the dominance of service, i.e. the probability of winning a point on service, both for the men and for the women. For the women this can be attributed solely to a decrease in the probability of winning a point on the first service. (Removing the insignificant 1995 dummy leads to a significantly negative effect of the year on this probability.) More specifically, it has become more difficult to win a point on service if the first service is in. This may be due to an improvement in the return of service by professional players, as is sometimes claimed.

This claim is also supported by the results for the men in Table 5. The men apparently take more risk on their first and second services, leading to more aces (see Table 4), a lower percentage of '1st service in' and more double faults. Are they pushed to hit more difficult services, because of the better returns? Apparently the services are still not sufficiently difficult to increase the probability of winning a point on service if the service (first or second) is in. This is again in line with the improvement-of-return hypothesis. We see this as the main cause behind the gradual decrease in the dominance of service.

So, the dominance of service has decreased over time without special measures. The use of softer balls has hardly any effect, at least not the balls used in 1995 at Wimbledon. If a faster decrease in the dominance of the service is deemed necessary, then stronger measures are called for. Magnus and Klaassen (1999a) have argued that abolishing the second service, which is an obvious and easy-to-implement measure, has the additional benefit of making matches more even and thus more attractive for spectators.

Acknowledgements

We thank IBM UK and the All England Club at Wimbledon for their kindness in providing the data. We also thank the two referees for their constructive comments.

References

George, S. L. (1973) Optimal strategy in tennis: a simple probabilistic model. *Appl. Statist.*, **22**, 97–104.
Gillman, L. (1985) Missing more serves may win more points. *Math. Mag.*, **58**, 222–224.
Hsi, B. P. and Burych, D. M. (1971) Games of two players. *Appl. Statist.*, **20**, 86–92.
Jackson, D. A. (1989) Letter to the Editors. *Appl. Statist.*, **38**, 377–378.
Kemeny, J. G. and Snell, J. L. (1976) *Finite Markov Chains*. New York: Springer.
Klaassen, F. J. G. M. and Magnus, J. R. (1998) On the independence and identical distribution of points in tennis. *Mimeo*. CentER for Economic Research, Tilburg University, Tilburg.
Little, A. (1995) *Wimbledon Compendium 1995*. London: All England Lawn Tennis and Croquet Club.
Magnus, J. R. and Klaassen, F. J. G. M. (1999a) On the advantage of serving first in a tennis set: four years at Wimbledon. *Statistician*, **48**, 247–256.
———(1999b) The final set in a tennis match: four years at Wimbledon. *J. Appl. Statist.*, to be published.
Maisel, H. (1966) Best k of $2k - 1$ comparisons. *J. Am. Statist. Ass.*, **61**, 329–344.
McFadden, D. (1984) Econometric analysis of qualitative choice models. In *Handbook of Econometrics* (eds Z. Griliches and M. D. Intriligator), vol. II, ch. 24. Amsterdam: North-Holland.
Miles, R. E. (1984) Symmetric sequential analysis: the efficiencies of sports scoring systems (with particular reference to those of tennis). *J. R. Statist. Soc.* B, **46**, 93–108.
Pollard, G. H. (1983) An analysis of classical and tie-breaker tennis. *Aust. J. Statist.*, **25**, 496–505.
Riddle, L. H. (1988) Probability models for tennis scoring systems. *Appl. Statist.*, **37**, 63–75; corrigendum, 490.
———(1989) Author's reply. *Appl. Statist.*, **38**, 378–379.